Amateur Plant Breeder's Handbook (2004)

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This guide is intended for amateur plant breeders, usually members of a plant breeding club, who need a quick reference to terms that they may encounter in the course of conversation or reading. For readers who enjoy browsing, the guide should also be a source of information for anyone wanting to get away from the modern prejudices that favour single-genes, genetic engineering, and crop protection chemicals. It is also a guide for organic farmers, and for those interested in sustainable agriculture, pure food, and a healthy lifestyle.

Although hard copy of this book is easily printed, the electronic version is recommended for its links. Clicking on any link will take you immediately to its main reference, and the 'back' button will take you back to your original reading. Hypertext makes browsing both easy and interesting.

Readers requiring more technical detail are referred to *Self-Organising Agro-Ecosystems*, available as shareware at ***www.sharebooks.ca***. Readers contemplating a plant breeding club are referred to *Return to Resistance*, also available at this site, and to the author's website, ***www.sentex.net/~raoulrob***. Other books are listed in the ***Recommended Reading*** at the end of the present work.

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A

Abaca

See: Musa textilis.

Abelmoschus esculentus

Okra, previously called *Hibiscus esculentus*. This is an annual crop grown for its fruits that are cooked and eaten as a green vegetable. There has been considerable hybridisation with wild species and there is much genetic variation. Scope for amateur breeders working with horizontal resistance.

Abscission

The discarding of plant organs, such as leaves of deciduous trees in the autumn.

Acaricide

See: Miticide.

Acidity

See: pH.

Acre

A measure of land area. One acre is 4840 square yards, or 0.405 hectare.

Acropetal

Growing upwards so that the oldest parts are at the base and the youngest at the tip.

Adlay

See: Coix lachryma-jobi.

Adult plant resistance

Horizontal resistance in many crops, particularly the cereals, is often expressed more in mature plants, and less in young seedlings. This is to be expected because the epidemic intensifies as the growing season progresses. For this reason, horizontal resistance is often called adult plant resistance and, by implication, it is more difficult to observe it, measure it, or screen for it, in young plants.

Aerobic

Living conditions in which there is a plentiful supply of oxygen. Organisms which require oxygen are labelled as aerobic organisms, or aerobes. The converse, meaning without oxygen, is anaerobic.

Aestivation

An organism's survival of a hot dry summer.

Aflatoxin

Toxins produced by *Aspergillus flavus* and related fungi. Mouldy feedstuffs contaminated with aflatoxins have caused severe disease and mortalities in livestock, particularly poultry.

African millet

See: Eleusine coracana.

Agaric

Any member of the *Agaricaceae*, a fungus family in which the fruiting bodies are mushroom shaped.

Agave sisalana

Sisal. Once an important bast fibre crop in its centre of origin in Mexico, and also in East Africa (Kenya and Tanzania), sisal has been largely supplanted by synthetic fibres. Seed set in sisal is extremely rare and breeding this crop is far too difficult for amateur breeders.

Agriculture

Agriculture was independently discovered and developed by many different groups of people in various parts of the world, the main centres being based on the crops wheat (Europe), maize (Central and South America), and rice (Southeast Asia). Agriculture consists of the propagation and nurturing of domesticated animals and plants. The cultivation of crop plants is now divided into agricultural and horticultural crops. The latter involve a wide array of fruit and vegetables and offer great scope for amateur breeders. Commercial agriculture is undertaken for financial gain, while subsistence agriculture, mainly in the tropics, is undertaken to feed the farmer and his family, possibly with the sale of some subsistence surpluses. Most subsistence crops also offer great scope for amateur breeders. Forestry involves the cultivation of trees for timber and it too offers scope for amateur breeders.

Agrobacterium

Agrobacteriium tumefaciens is the bacterium that causes a disease called crown gall on many different species of host, most particularly on temperate fruit trees. The galls can grow to the size of a football if left untreated. Amateur breeders working with rootstocks of fruit trees may care to take resistance to this bacterium into consideration in their breeding. Genetic engineers use this bacterium as a means of introducing foreign DNA into a plant, but this is not a technique for amateurs.

Agro-ecosystem

The ecosystem of a cultivated crop. It differs from the surrounding, natural ecosystem because of the various artificial components of agriculture.

Agro-ecotype

The local landrace of an outbreeding crop is often called an agro-ecotype because, like a wild ecotype, it has responded to selection pressures within its own locality in the agro-ecosystem, and it is well adapted to that locality. In systems terminology, this adaptation is called local optimisation. In a wide sense, any domesticated variety of plant or animal is an agro-ecotype. Amateur plant breeders may regard their work as improving the domestication of existing agro-ecotypes.

Agronomic suitability

The agronomic suitability of a cultivar is one of the four objectives of plant breeding (the others being yield, quality of crop product, and resistance to pests and diseases). It is governed by a variety of traits such as plant shape and size (often called crop architecture), time of maturity, suitability for mechanical cultivation and harvesting, frost and/or drought resistance, yield potential, suitability to market requirements, and so on. This is a factor that amateur breeders must always take into account.

Agronomy

That component of agriculture which is concerned with the theory and practice of growing crops, and with the management of soils.

Aguacate

See: Persea americana.

Air-borne parasites

Plant parasites can be air-borne, soil-borne, water-borne (mainly in irrigation water), and seed-borne. The air-borne parasites include fungi and flying insects, which can sometimes travel for hundreds of miles on prevailing winds.

Akee

See: Blighia sapida.

Aldrin

One of the dirty dozen chemicals called POPS. Aldrin is an insecticide, now banned by international treaty.

Aleurites spp.

Tung, an ancient crop in China, it is now grown in several warm countries. The seeds of *A. fordii* and *A. montana* yield a paint oil of exceptional quality. The market has declined from competition with cheaper paints, particularly plastics. Considerable scope for local amateur breeders who are not ambitious about their new cultivars.

Alfalfa

See Medicago sativa.

Alga

(Plural: algae). Primitive plants that have chlorophyll and can photosynthesise. They range in size from single-celled and microscopic, or many-celled and many feet long. They occur mainly in water, which may be either fresh or marine.

Alkaloid

An organic compound containing nitrogen, and with conspicuous physiological properties. Well-known alkaloids include nicotine, caffeine, quinine, morphine, cocaine, and strychnine.

Allele

The alternate copies of a single gene. Each gene normally consists of two alleles. Each allele occurs on one of the two matching chromosomes, one of which comes from the male parent, and the other from the female parent. In one individual, the two alleles may be both dominant (AA), both recessive (aa), or one of each (Aa). The first two of these combinations are described as homozygous; the third is heterozygous.

Allelopathy

A mechanism that reduces or eliminates competition from other species by the production of toxins. The best known example is that of antibiotics produced by fungi to suppress the growth of bacteria. Equally familiar is the effect of a carpet of pine needles in suppressing the germination of other plants.

Alliaceae

The botanical family that includes the onions and their relatives. However, some taxonomists prefer to classify *Allium* spp., within either the Liliaceae or the *Amaryllidaceae*.

Allium ampeloprasum

Leeks and ‘elephant’ garlic. Leeks are tetraploids and set seed freely, while ‘elephant’ garlic is a hexaploid (*6x*) and is sterile. Plant breeding clubs should certainly consider the possibility of breeding

leeks for horizontal resistance, but they should steer clear of ‘elephant’ garlic. The breeding procedures are those of open-pollinated crops.

Allium cepa

The common onion, including the shallot. This vegetable is an excellent subject for breeding by amateurs. There are many different types of onion, ranging from sweet to pungent, and from deep red to white. And there are many parasite problems of onions, all of which can be either solved or greatly ameliorated by breeding for horizontal resistance. Onions are open-pollinated but flower only in their second season. The parasite screening should be undertaken in the first season and it should be based on both yield and appearance after exposure to major infestations of parasites. The best selections are stored, and this constitutes a second screening for resistance to storage rots and pests. The storage survivors are planted out and allowed to flower, but a negative screening decapitates the worst plants, and only the best individuals can form pollen and seed. New varieties can consist of either improved populations (synthetic varieties) or hybrid varieties. The latter procedure requires more work but has the advantages of higher yields and complete protection of seed production.

The wild progenitors of onion are extinct.

Allium sativum

Garlic. This crop cannot be recommended for amateur breeders as it never sets seed, and it can be propagated vegetatively only. The flowers sometimes produce small bulbils, which can be used for propagation, but these are also vegetative and are not the result of pollination. The formation of flowers and seeds is a major physiological sink that severely reduces the yield of vegetative parts of the plant. Ancient cultivators; probably had a gut-feeling about this, and preferred clones that did not produce flowers or seed. Garlic provides an excellent example of the durability of horizontal resistance because all the varieties are ancient clones that have been cultivated for centuries without crop protection chemicals, and without serious loss from parasites. Any modern problems with parasites are the result of an environmental erosion of horizontal resistance.

Allium schoenoprasum

Chives. The leaves are used as a garnish. This species is an outbreeder and is easy to breed. Chives can be propagated either vegetatively or from true seed. Chives do not have well-formed bulbs but they do form tillers to produce dense clumps of plant. Easy to breed.

Allogamy

Greek; *allo* = other, or different; *gamy* = marriage. The term means cross-pollination. An allogamous plant or species is one in which cross-pollination is normal or even obligatory. Cultivated allogamous species include maize, sorghum, millets, and rye; members of the onion family, members of the cucumber family; and various pulses and vegetables. The converse term, meaning self-pollination, is autogamy.

Allo-infection

Infection is the contact made by one parasite individual with one host individual for the purposes of parasitism. Allo-infection (Greek: allo = other or different) means that the parasite has arrived from somewhere else; it had to travel to its host. The first infection of any host individual must be an allo-infection. The gene-for-gene relationship provides a system of locking which ensures that most allo-infections are non-matching infections. This is the sole function of vertical resistance in a wild pathosystem. (See also: Auto-infection, Allogamy).

Allopatric

Species, ecotypes, or pathotypes that come from another part of the world.

Allopolyploid

A polyploid has more than two sets of chromosomes (e.g., triploid, tetraploid). In an allopolyploid, the chromosomes are derived from two or more different species. In an autopolyploid, all the chromosomes are derived from the same species.

Allotetraploid

An allotetraploid has four sets of chromosomes derived from two different diploid species. For example, *Coffea arabica* is believed to be an allotetraploid derived from a cross of the two diploid species *Coffea canephora* and *Coffea eugenioides*. An interspecific cross is usually sterile, but the cross can be made fertile by doubling its chromosome number, and making it an allotetraploid. However specialists should be consulted before such a breeding approach is attempted by amateur breeders in other crops.

Allspice

See: Pimenta dioica.

Alocasia macrorrhiza

One of the aroids, of minor significance, cultivated in S.E. Asia.

Almond

See: Prunus amygdalus.

Alternaria

This genus is an imperfect fungus (i.e., it has no sexual stage) with an extremely wide host range. Various species of Alternaria cause leaf and fruit spots on citrus, brassicas, flax, potatoes, tomatoes, leeks, onions, and other crops. The spots form concentric rings of colonisation and the disease is often called 'ring-spot' or 'target spot'. It is easy to accumulate horizontal resistance to this fungus and plant breeding clubs should take it into account when breeding many species of vegetables.

Amaranth

See: Amaranthus.

Amaranthus

Amaranth is an ancient crop of the Americas cultivated either as a grain crop or as a pot herb. It is also a popular ornamental. The Spanish tended to prohibit its cultivation as they believed it was associated with cannibalism, but its full potential is now being recognised. The grain amaranths consist of three species, *A. hypochondriacus* and *A. cruentas* that originated in Mexico and Guatemala, and *A. caudatus*, which is native to Andean countries such as Peru. Vegetable amaranths are boiled as greens and include *A. tricolor*, *A. dubius*, and *A. cruentus*. Most amaranths are have high levels of horizontal resistance to all their pests and diseases but there is considerable scope for improvements in yield, quality, and agronomic suitability, including possible day-length changes. The amaranths are wind-pollinated and should be subjected to open-pollinated breeding techniques. An attractive crop for plant breeding clubs.

Amateur plant breeding

Plant breeding that is undertaken by people who are not professional plant breeders, and who have no formal training in plant breeding. Amateur plant breeders will often prefer to be members of a plant breeding club.

Ammonium nitrate

An artificial fertiliser that is exceptionally rich in nitrogen. Ammonium nitrate must be handled with care, as it is powerfully explosive when mixed with a combustible such as oil.

Amphidiploid

An alternative term for allotetraploid.

Amphimictic

The adjectival form of amphimixis.

Amphimixis

The converse of apomixis, and meaning reproduction by seed which has been produced by a normal sexual fusion.

Anacardiaceae

Family of tropical trees that includes mango and cashew.

Anacardium occidentale

Cashew nut. Although it is frost-susceptible, cashew is one of the hardiest of trees and, in warm countries, will grow on poor soils that are unsuitable for other crops. The nuts fetch a high price and the crop is about as valuable as arabica coffee. However, a factory is necessary for the specialised task of shelling the nuts. Each nut is borne externally on the end of a fairly large fruit. The fruit is edible, but very astringent, and it can be utilised for the manufacture of alcohol. There is a correlation between total yield and quality, the highest yielding trees producing small nuts of low commercial quality. But there is great variation among trees, and there is scope for selection within existing orchards, by amateur breeders, with a view to vegetative propagation of selected clones.

Anaerobic

Living conditions in which there is an absence of oxygen. Organisms which do not require oxygen are labelled as anaerobic organisms. The converse, meaning with oxygen, is aerobic.

Analogous evolution

Evolution in which similar features have different origins (e.g., the wings of birds, insects, and bats represent analogous evolution). This is the converse of homologous evolution, in which similar features have a common origin (e.g., all the plants in one family have a common ancestor).

Ananas comosus

Pineapple. This is a very difficult crop to breed and it is definitely not recommended for amateur plant breeders.

Anastomsis

Natural grafting that can occur in either stems or roots. For example, mango seeds contain both a nucellar embryo and a normal embryo that is the result of open-pollination. Trees growing from casually discarded seeds often consist of two trunks joined at the base by anastomosis. One trunk is the nucellar seedling and is identical to the maternal parent, while the other is an open-pollinated

variant and is visibly different in many characteristics, including fruit quality and resistance to parasites.

Ancient clones

The importance of ancient clones is that they provide proof of the durability of horizontal resistance. Such clones may date from centuries, even millennia, ago. They are common in figs (*Ficus*), olives *Olea*), date palms (*Phoenix*), citrus (*Citrus*), horseradish (*Armoracea*), garlic (*Allium*), ginger (*Zingiber*), turmeric (*Curcuma*), saffron (*Crocus*), rhubarb (*Rheum*), etc.

Andromonoecious

Having both male and hermaphrodite flowers on the same plant.

See: Cucumis melo.

Anethum graveolens

Dill. See also: curry powders.

Angiosperm

Seed-forming plants whose seeds are protected by a seed-coat. This group includes the flowering plants, both monocotyledons and dicotyledons, and it provides virtually all human food, either directly as vegetable matter, or indirectly, as meat. A few Angiosperms are parasitic on other plants. They lack chlorophyll and they include dodder (*Cuscuta* spp.), broomrape (*Orobanche* spp.) and witchweed (*Striga* spp.). It is possible to breed crops for horizontal resistance to these parasitic Angiosperms. See also: Gymnosperm.

Annual plant

A plant which flowers, fruits, and dies in one season.

Anther

The male reproductive part of a flower that produces pollen.

Anthesis

The time of pollen production.

Anthracnose

A plant disease caused by a species of the fungus called *Colletotrichum* (pronounced Coll-ee-TOT-tree-coom). The symptoms are sunken lesions, several millimetres in diameter, with small, black, sporulating, fungal bodies on the sunken surface.

Antibiotic

A substance that inhibits the growth of micro-organisms, e.g., penicillin. It seems that all antibiotics provide an unstable protection when used singly, and that a cocktail of different antibiotics is much more stable.

Aphids

Plant parasitic insects of the Order Homoptera which are among the most common, and serious, of insect pests of crops. Also known as greenfly or green bugs, aphids have several different forms, including winged females for allo-infection; wingless, asexual, viviparous females for Auto-infection; and winged males and females for sexual reproduction. Many species of aphid are heteroecious. Many are vectors of virus diseases.

Apical dominance

The suppression of lateral branches by the apical shoot, or apex, of the plant.

Apical meristem

The meristem at the main growing point, or apex, of a plant.

Apis

The genus to which honey bees belong. These are stinging, social, hymenopterous insects, useful in the production of honey, and in the pollinating of many species of crop. Amateur breeders can often make use of them to produce a random polycross.

Apium graveolens

Celery and celeriac. An ancient domestication known to the classical Greeks. Celery is used for its green stems, mainly as a flavouring in soups and salads. Celeriac (var. *rapaceum*) is grown for its swollen, edible roots.

Apomictic

The adjectival form of apomixis.

Apomixis

Greek: *apo* = without; *mixis* = mixing. Asexual reproduction by seeds produced from the maternal tissue of a flower. Apomictic seeds occur mainly in grasses, and they have the advantage of being the equivalent of vegetative propagation, being free of most vegetatively transmitted diseases (particularly viruses). The so-called 'apomictic gene' is a topic of interest among molecular biologists because it could very easily preserve agricultural characteristics, including hybrid vigour, in ***heterozygous*** seeds of ***open-pollinated*** crops.

Apothecium

An open fruiting body shaped like a ‘dry martini’ glass, produced by some Ascomycetes**,** with asci on the open, upper surface. Sometimes called ‘cup fungi’.

Apple

See Malus.

Apple scab

See Venturia inaequalis.

Apricot

See Prunus armeniaca.

Araceae

The family to which the aroids belong; see Alocasia, Colocasia, Cyrtosperma, and Xanthosoma

Arachis hypogea

The peanut, also known as ‘monkey nut’, and groundnut, because the plant thrusts its pods underground as a method of self-sowing. Originating in South America, ancient domestication produced non-fragile pods and shorter pod-bearing stems. Like the non-shattering character in cereals, these changes made harvesting much easier. Most groundnut varieties are inbreeders and cross-pollination is rather difficult. They are also allotetraploids and crossing with wild diploids is not easy. However, many interspecific crosses have been made and these offer considerable scope for development. A serious challenge for amateur breeders but one with great potential for the courageous.

Arachnid

A member of the *Arachnida*, the class of arthropods that includes spiders, mites, scorpions, and ticks.

Archetype

The wild ancestor of a modern cultivar.

Areca catechu

This palm is the source of the betel nut, which is chewed as a narcotic by more people than use chewing gum. It is chewed as a ‘quid’ of betel pepper leaves with a dash of slaked lime. This ‘quid’ turns the saliva red and this colours walls and sidewalks from spitting. The young palm is also a popular house-plant. There is some scope for amateur breeders to select superior palms within existing populations in areca-producing countries.

Areca palm

See: Areca catechu.

Armillaria

Armillaria mellea is known as the honey fungus, and it can cause a serous disease of many species of tree. It produces long black rhizomorphs that look like boot-laces, and that can grow through the soil and spread the disease from tree to tree. *Armillaria* often produces toadstools on dead tree stumps. In the tropics, it occurs only at high altitudes. It has even been postulated that a large network of rhizomorphs constitutes the largest living organism. Foresters often ring-bark trees about a year before felling them, and this denudes the roots of nutrients. The fungus is the unable to invade them. Another defence is to dig trenches that the rhizomorphs cannot cross. However, many pathologists think that *Armillaria* will only attack trees that are weakened from some other cause such as water-logging or shallow soil. It is not feasible for amateurs to breed for horizontal resistance to this disease.

Armoracia rusticana

Horse radish. The roots are used to make a peppery condiment, but this species does not flower or set seed. It is definitely not recommended for amateur plant breeders. There are many clones with widely varying degrees of pungency. These ancient clones have few pests or disease and they are a good example of both the effectiveness and the durability of horizontal resistance.

Aroids

Aroids are a group of tropical root crops belonging to the family Araceae. See: Alocasia, Colocasia, Cyrtiosperma and Xanthosoma.

Arrowroot

See: Maranta arundunacea.

Arrowroot, Queensland

See: Canna edulis.

Arsenic

Compounds of this well-known poison were frequently used as an insecticide before the days of the much less hazardous modern synthetic insecticides.

Arthropod

An invertebrate animal belonging to the Phylum *Arthropoda*, which includes insects, spiders, crustaceans, centipedes, and millipedes. This is the largest phylum and it contains more than one

million known species. Arthropods are characterised by an exoskeleton with a segmented body and jointed limbs.

Artichoke, globe

See: Cynara scolymus.

Artichoke, Jerusalem

See: Helianthus tuberosus.

Artificial fertilisers

The term 'fertilisation' has two meanings in agriculture. It can mean sexual fertilisation of either plants or animals, or it can mean manuring of crops. Fertilisers used for manure are divided into the two categories of organic and artificial. Organic manures are either the excrement of farm animals, usually known as farmyard manure (F.Y.M.) or stable dung, bone meal, or quarried deposits of fish-eating bird excrement, known as guano. Artificial fertilisers are produced in factories, usually by a simple modification of natural products, such as atmospheric nitrogen, rock phosphate, or potash. Their constituents are known as N, P, and K, the symbols standing for nitrogen, phosphorus, and potassium. Other constituents may include calcium and magnesium, as well as various minor nutrients and trace elements. Artificial fertilisers are allowed in sustainable agriculture, but not in organic farming.

Artificial selection

Genetic selection which is controlled by people, within a genetically diverse population. Artificial selection is the basis of both domestication, and modern plant and animal breeding. See also: natural selection, agro-ecotype.

Artocarpus altilis

Breadfruit, which is an ancient domestication and is the staple food in a number of Pacific Islands.

Ascomycete

Fungi whose sexual reproduction is by means of an ascus. Many plant pathogen are Ascomycetes, such as the powdery mildews, and apple scab (Venturia inaequalis).

Ascospore

A spore produced within an ascus. Ascospores are haploid, being the result of the reduction division (meiosis) of a newly fertilised diploid cell, which is the only diploid component in the life cycle of an Ascomycete. Being the result of meiosis, an ascus usually contains eight ascospores but, in some species, the ascus contains only four, or two ascospores.

Ascus

The microscopic reproductive organ of an Ascomycete fungus. The ascus consists of a tube containing eight, four, or two haploid ascospores that are the result of meiosis. When the ascospores are mature, the tube bursts at its tip, from internal pressure, and the ascospores are projected into the atmosphere like microscopic bullets.

Asexual reproduction

Reproduction without sex. Asexual reproduction prevents variation and it produces clones. Many microscopic organisms, such as viruses, bacteria, and imperfect fungi, have asexual reproduction only. Many r-strategists plant parasites, such as fungi and aphids have both sexual and asexual reproduction. This has the advantage of speed and economy for the parasite, and it permits a population explosion. If continued for too long, asexual reproduction in the higher organisms is a survival disadvantage in a wild population, but it can be very useful in agriculture. The asexual propagation of plants by cuttings, grafts, etc., is called vegetative propagation. Some Angiosperms have asexual reproduction by apomictic or nucellar seeds. See also: r-strategists.

Asparagus officinalis

A dioecious vegetable that is perennial cultivated for its young succulent shoots. Difficult to breed and not recommended for plant breeding clubs.

Asparagus pea

See: Psophocarpus tetragonobolus.

Asynchronous flowering

The production of flowers at different times within one season. Asynchronous flowering assists cross-pollination. It also assists survival, if there is bad weather that hinders pollination.

Attention deficit hyperactivity disorder

The syndrome in children which, as its name implies, exhibits hyper-activity and a very short attention span. It has been reported that about two million children suffer from this syndrome in the United States. And it is thought that that cause of the syndrome may be exposure to hormone mimics during foetal development and/or childhood. See also: Dirty dozen, POPS.

Aubergine

See: Solanum melongena.

Austronesian family of languages

Also known as the Malayo-Polynesian family of languages, these are the languages of remote islands extending from Madagascar, in the West, to Easter Island, in the East, and from Hawaii, in the North, to New Zealand, in the South. The Austronesian people spread these languages by their ability to make long ocean voyages long before either the Chinese or the Europeans developed ocean-going ships.

Autocratic plant breeding

The converse of the democratic plant breeding produced by self-organising crop improvement. Autocratic plant breeding is justified by the expense of breeding for vertical resistance, and by the relatively few cultivars produced by such breeding. These cultivars, however, have a very wide ecological adaptation and their widespread use justifies their cost. But the farmer is given little or no choice of cultivar, and the breakdown of a vertical resistance can lead to widespread damage.

Autoecious

The converse of heteroecious, which means that a rust or an aphid is obliged to change its species of host in order to complete its life cycle. An autoecious rust is one that completes its entire life cycle on one species of host. However, entomologists use the term 'monoecious' in place of autoecious when describing aphids. Unfortunately, in botany, monoecious means that separate male or female flowers occur on a single plant (See also dioecious, hermaphodite).

Autogamy

(Greek: auto = self; gamy = marriage). Self-fertilisation, or self-pollination. An autogamous species is one in which individual flowers, or plants, are fertilised with their own pollen. However, some cross-pollination always occurs in an autogamous species and variability is always maintained. (See also: allogamy).

Auto-infection

Infection is the contact made by one parasite individual with one host individual for the purposes of parasitism. Auto-infection (Greek: auto = self) means that the parasite was born on (or in) the host that it infects; it had no need to travel to its host. Auto-infection is possible only after a matching allo-infection has occurred. The parasite then reproduces asexually to produce a clone in which all individuals are identical. It follows that, in terms of the gene-for-gene relationship, all auto-infection is matching infection. Consequently, vertical resistance cannot control auto-infection, which can be controlled only by horizontal resistance. Because all parasitism involves auto-infection, it must be

concluded that horizontal resistance occurs in every host, against every parasite of that host. (See also: allo-infection, autogamy).

Autoployploid

A polyploid has more than two sets of chromosomes (e.g., triploid, tetraploid). In an autopolyploid, all the chromosomes are derived from the same species. In an allopolyploid, the chromosomes are derived from two or more different species.

Auxin

Auxins are plant hormones.

Avena fatua

Wild oats. This species can be a serious weed as it is difficult to control in cereal crops.

Avena sativa

Cultivated oats. This species is a hexaploid and the first controlled crosses were made by a Scottish farmer, one Patrick Sheriff, in 1860. Subsequently, most professional work has used pedigree breeding and back-crossing with a view to introducing vertical resistances. However amateur breeding for horizontal resistance is entirely feasible and a male gametocide, as used with wheat, will probably be effective.

Average

The mean. A figure obtained by dividing the total of given amounts by the number of amounts in the set.

Avocado

See: Persea americana.

Axil

The upper angle between a leaf and the stem.

Axillary bud

A bud that is located in an axil. Many axillary buds are suppressed by ***auxins*** emanating from the ***apical meristem***, and they develop only if the apical meristem is damaged or removed.

B

Back-crossing

A Mendelian breeding technique designed to transfer a single gene, usually a resistance gene, from a wild plant into a cultivar. The cultivar and the wild plant are cross-pollinated to produce a hybrid progeny. A hybrid individual that carries the resistance gene is then back-crossed with the cultivar parent to produce a second breeding cycle. This process of back-crossing is repeated for several breeding cycles until the hybrid is indistinguishable from the cultivar parent, except that it carries the resistance gene from the wild parent. Note that back-crossing is an excellent technique when breeding for vertical resistance, but that it dilutes polygenically inherited characters, and it should not be used when breeding for horizontal resistance. See also: Pedigree breeding.

Bacteriocide

A pesticide that kills bacteria.

Bacteriophage

A virus that attacks bacteria.

Bacterium

A bacterium (pl. bacteria) is the most primitive of the cellular organisms. About 1,600 species of bacteria are known to science and some of these are parasitic on plants. Bacteria are prokaryotes. That is, although their cells do contain DNA, they do not contain a nucleus.

Bajra

See: Pennisetum typhoides.

Balanced science

Balanced science means two things. First, all systems levels are treated equally. Second, factual science and theoretical science are treated equally. One of the reasons that twentieth century crop science has become unbalanced is because both the higher systems levels and theoretical aspects have been seriously neglected. See also: Suboptimisation.

Bambara groundnut

See: Voandzeia subterranean.

Bamboo

See: Gramineae.

Banana

See: Musa.

Barley

See: Hordeum vulgare.

Barberry

See: Berberis.

Basidiomycete

A group of fungi whose microscopic spores, called basidiospores, are produced on microscopic structures called basidia. The basidium is the result of sexual recombination, and it usually produces four haploid spores by reduction division. This group includes all toadstools and mushrooms as well as a number of plant pathogen.

Basidiospore

A microscopic spore produced at the end of a basidium by a Basidiomycete. These spores are usually produced in groups of four, and they are the result of sexual recombination followed by reduction division.

Basidium

A microscopic, club-shaped structure on which basidiospores are produced.

Bast fibre

Any coarse plant fibre used for making ropes, sacking, or mats (e.g., hemp, jute, sisal).

Batatas

See: Ipomea batatas.

Beans

See: Glycine (soybean), Phaseolus (haricot and other beans), Vicia (broad bean, or faba bean).

Bed bugs

A wingless hemipterous bug, belonging to the genus *Cimex*, which sucks human blood, and infests beds and dirty houses. It is of interest because centuries of use of dried flowers of Chrysanthemum cineriifolium in Dalmatia have proved that natural pyrethrins are a stable insecticide.

Beech

See: Fagus sylvatica.

Beehives

Amateur breeders wishing to obtain a massive random polycross in an outbreeding species that is pollinated by bees, will usually benefit from placing a beehive close to their field plots. If they do not wish to handle bees themselves, a friendly bee-keeping neighbour can probably be found to assist.

Bees will also achieve a significant amount of cross-pollination in an autogamous species such as beans, but the use of a marker gene is recommended.

Bees

See: Apis.

Beet

See: Beta vulgaris

Beet, sugar

See: Beta vulgaris.

Beetles

Insects of the Order *Coleoptera* characterised by hard fore-wings which meet in a straight line down the back, and cover the hind wings. Many beetles are serious crop parasites, and others are serious parasites of stored food products. Some beetles, such as ladybirds, are beneficial in that they eat other crop parasites. There are some 300,000 species of beetles in the world, and this is by far the largest order of living organisms.

Bell-shaped curve

The graph that is produced when various levels of a quantitative character that has a normal distribution (e.g., horizontal resistance) are plotted against their frequency.

Benincasa hispida

The white, or wax, gourd, which is a member of the Cucurbitaceae.

Berberis spp.

The wild barberry that is the alternate host of the heteroecious wheat stem rust (Puccinia graminis). Barberry is the winter host in which sexual recombination occurs, and new vertical pathotypes are produced. See also: Saturation technique.

Bergamot oil

This essential oil is extracted from the rind of the Bergamot variety of Citrus aurantium, and is used to scent Earl Grey tea. The name derives from the town of Bergano in northern Italy. An inferior bergamot oil is obtained from the labiate herb Mentha citrata.

Berry

A fruit containing no hard parts except the seed, e.g., tomato, banana, grape, date, gooseberry.

Berry fruits

See: Rubus spp.

Bertholletia excelsa

Brazil nut. A young seedling of this tree takes at least twenty years to bear its first fruit, and may take as long as eighty years. The fruits take a year to ripen. Definitely not a crop for amateur plant breeders.

Beta vulgaris

This species, which belongs to the family *Chenopodiacea*, has been domesticated into sugar beet, garden beets (beetroots), fodder beet, mangolds, and chards. It is open-pollinated and breeding is based on recurrent mass selection.

The German chemist Marggraf first observed sugar in fodder beets and his pupil Achard started improving the crop and developing extraction techniques. Napoleon encouraged beet sugar production during the British naval blockade, which prevented the import of cane sugar from the West Indies. Subsequent tariff protection of various European and North American beet sugar industries did much to stimulate production. Beet sugar now makes up about half of the world supply of crystalline sugar. The accumulation of resistance to 'curly top' virus in North America was a good example of very rare twentieth century breeding for horizontal resistance. Recent breeding has produced 'monogerm' varieties which have only one seed in each fruit. These are important as they eliminate the need for hand-thinning, and they allow the total mechanisation of the crop. However, this degree of technicality has taken the crop out of the hands of amateur breeders.

Beetroots, fodder beet, mangolds, and chards offer scope to the amateur breeder working with horizontal resistance.

Betula spp.

Birch trees, used in plantation forests to produce hardwood. Not recommended for amateur breeders.

Biennial

A plant which requires two seasons to flower, fruit, and die.

Biffin, R.H.

The scientist in Cambridge who first discovered single-gene resistance and initiated the long and misguided history of professional plant breeding for vertical resistance.

Billion

The term billion should be used in the more logical American sense to mean one thousand million (10^9), rather than the somewhat idiosyncratic British sense of one million million (10^{12}) which is called one trillion in North America.

Bimli jute

See: Hibiscus cannabis.

Bimodal rainfall

A tropical pattern of seasons in which there are two rainy seasons, and two dry seasons each year.

Binomial coefficients

The numbers that make up the lines in Pascal's triangle. The largest binomial coefficient for a given number of pairs of genes in the gene-for-gene relationship, is the number of biochemical locks and keys obtained in the n/2 model.

Bioassay

The testing or measuring of a substance with living organisms. For example, the toxicity of an insecticide can be determined by measuring its effects on living insects.

Biochemical key

A term sometimes used to describe the vertical parasitism genes in an individual parasite. Its biochemical key either does or does not fit the biochemical lock of the host that it is allo-infecting. This is the operation of the system of locking of the gene-for-gene relationship in a wild plant pathosystem, according to the n/2 model. Its function is to reduce the frequency of allo-infections that are matching infections, thus reducing the population explosion of an *r-strategists* parasite.

Biochemical lock

A term sometimes used to describe the vertical resistance genes in an individual host. Its biochemical lock either does or does not match the biochemical key of the parasite that is allo-infecting it. This is the operation of the system of locking of the gene-for-gene relationship in a wild plant pathosystem, according to the n/2 model. Its function is to reduce the frequency of allo-infections that are matching infections, thus reducing the population explosion of an *r-strategists* parasite.

Biochemistry

The chemistry of living processes.

Biodiversity

Any aspect of biological diversity, including ecosystems, and their diversity of species, ecotypes, etc. The term is relevant to the ecological principle that diversity provides stability.

Biological anarchy

The loss of biological control that occurs when pesticides kill the hyper-parasites, predators, competitors, antagonistic organisms, or other biological control agents of a crop parasite. Biological

anarchy is probably a phenomenon of much greater importance than has been realised in the past. When the effects of biological anarchy are considerable, a restoration of biological controls causes a major reduction in parasite damage, and this is the basis of integrated pest management (IPM). Because the use horizontal resistance restores biological controls, the phenomenon of biological anarchy suggests that we may need considerably less horizontal resistance than we may think in order to obtain a complete control of various crop parasites.

Biological control

The control of crop parasites that is exerted by predators, hyper-parasites, competitors, antagonistic organisms, and other agents. The effects of this control can be diminished or lost entirely by the use of crop pesticides. This loss of biological control that occurs with pesticide use is called biological anarchy. The proponents of integrated pest management (IPM) rely very heavily on restoring lost biological controls by reducing pesticide use. These losses may be more important than many people realise. They also suggest that we may need rather less horizontal resistance than we may think in order to obtain a complete control of crop parasites, because the biological controls will be restored once pesticide use stops. The best means of restoring biological control is by the use of horizontal resistance; and the best means of enhancing horizontal resistance is by restoring biological control. The two effects are mutually reinforcing.

Biological order

A term from modern complexity theory. It means that the self-organisation is fully functional and operating. The n/2 model is the result of self-organisation and, when functioning, is an example of biological order. Parasitism is not competition between host and parasite. Nor is it cooperation. It is biological order.

Biology

The study of living organisms.

Biomagnification

The phenomenon in which a toxin, such as DDT, accumulates as it moves up the food chain. This happens because an individual eats small amounts of the toxin with each meal but does not excrete it. The levels of toxin thus increase from minute traces in, say, lake water, to very high levels in fish-eating birds that are at the top of the food chain. It is a sobering thought that humans are at the top of their own food chain.

Biomass

The total weight of one or more named organisms within a particular area.

Biometrician

(Greek: bio = life; metrics = measurements). A member of the biometrical school of genetics, in contrast to the Mendelian school. Biometricians study the inheritance of quantitatively variable characters controlled by polygenes. This school developed population breeding methods using recurrent mass selection, and it employs horizontal resistance. In more general terms, biometry is any quantitative analysis of biological phenomena.

Biosphere

A term coined by the Viennese geologist Eduard Seuss (1831-1914) in 1875 to describe that part of the Earth's surface where life occurs. The term was used in 1926 by Vladimir Vernadsky (1863-1945) as the title of his book on this subject. This work was an early example of the holistic approach but, because of political problems and the Cold War, it remained largely unknown in the West until recently. See also: Gaia hypothesis.

Biotechnology

The use of micro-organisms, which are often genetically engineered, for industrial and pharmaceutical purposes.

Biotrophic

A biotrophic parasite is one that obtains nutrients from the living tissues of its host, as opposed to a necrotrophic parasite, which kills those tissues with toxins before consuming them.

Biotype

A subdivision of a species in which all individuals are morphologically identical but physiologically (or parasitologically) dissimilar. Entomologists tend to refer to vertical pathotypes of insects as 'biotypes', but the term is imprecise.

Birch

See: Betula spp.

Birth rate

The rate at which a population is gaining individuals. This rate is an important factor in the development of ***epidemics*** and ***infestations*** in crops. See also: death rate, population growth.

Bisexual

In botany, this term means that both sexes are present and functional in one flower.

Bixa orellana

Annatto, a tropical American shrub which is cultivated as a food colouring.

Blackberry

See: Rubus spp.

Black currant

See: Ribes.

Black gram

See: Phaseolus mungo.

Black pepper

See: Piper nigrum.

Blast

Possibly the most important disease of rice, caused by the fungus *Pyricularia oryzae*

Blastofaga psenes

The fig wasp. See: Ficus carica.

Blemishes

Blemishes on fruit and vegetables are often caused by crop parasites. Since the development of synthetic crop protection chemicals, it has become fashionable to see only blemish-free produce on sale. However, blemishes are an indication of freedom from pesticides and are valued for this reason by lovers of organic food.

Blighia sapida

Akee, a West African tree with poisonous fruits. However, the white arils from naturally matured fruits are edible. Now common in the West Indies.

Blight

The common name of many plant diseases, usually caused by the downy mildews (Peronopsorales). The symptoms of most blight diseases are a burning and necrosis of the leaves. Potato blight (*Phytophthora infestans*), which caused the Irish famine during the 'hungry forties' of the nineteenth century, is the most famous of the blight diseases and, possibly, the most famous plant disease of all.

Blood

See: Dried blood.

Blueberry

See: *Vaccinium spp*.

Boehmeria nivea

Ramie, a perennial grass with strong stem fibres extracted as a bast fibre.

Boll worms

There are several different insects that attack cotton bolls, and are known as boll worms.

Bonavist bean

See: Dolichos lablab.

Bone meal

An organic phosphate fertiliser produced by roasting animal bones that are usually obtained from an abbatoir.

Books

See: Recommended reading.

Boom and bust cycle

A term applied to the apparently endless repetition of success and failure in the use of vertical resistance in professional plant breeding. The term has also been applied to the manufacture of unstable pesticides that fail on the appearance of a resistant strain of the pest.

Bootlace fungus

Common name for Armillaria mellea.

Bordeaux mixture

The first, and also the most spectacularly successful, of all man-made fungicides, discovered in Bordeaux, France, by Millardet, in 1882. The mixture is prepared by mixing a solution of copper sulphate with freshly slaked lime. This fungicide saved the French wine industry from ruin by the newly introduced downy mildew (Peronospora viticola), and it also controlled potato blight, caused by Phytophthora infestans.

Borlaug, Norman

Breeder of the miracle wheats and winner of the 1970 Nobel Peace Prize.

Boron

Boron is an important plant nutrient although its physiological function is poorly understood. Boron deficiency causes many growth distortions. If boron deficiency is suspected, a specialist should be consulted.

Botanical insecticides

There are five natural insecticides derived from plants. These are nicotine, pyrethrins, rotenone, ryania, and sabadilla.

Botrytis

A microscopic fungus which is a facultative parasite on many species of crops, particularly on fruit and vegetables, and especially during very humid weather. It usually causes a disease called grey mould, and it is mostly a necrotrophic pathogen (i.e., it kills host tissue with toxins before invading and obtaining nutrients from them). The fungus often produces sclerotia from which apothecia bearing asci sometimes develop. It is consequently considered an Ascomycete, even though asci have never been observed in some species.

Bougainville

Antoine de Bougainville (1729-1811) was the first Frenchman to circumnavigate the world. The island of Bougainville, largest of the Solomon Islands in the South Pacific, is named after him. So is the ornamental plant Bougainvillea.

Bougainvillea

A tropical genus native to South America and much used throughout the tropics and subtropics as an ornamental. The plant is a woody, climbing shrub with many prominent 'flowers' that are really bracts concealing the very small true flowers. These bracts vary in colour from bright red, through orange and yellow, to white. Not difficult to breed and a fun project for amateur breeders in suitable climates.

Bouillie bordelaise

See: Bordeaux mixture.

Brassica alba

(Syn. Sinapis alba) White mustard. This is a 'hot' mustard, as opposed to the three species (B. juncea, B. nigra, & B.carinata) which are 'pungent' mustards. An open-pollinated species requiring recurrent mass selection for breeding.

Brassica campestris

Turnip and Canola. A complex, outbreeding species suitable for amateur breeders working with horizontal resistance.

Brassica carinata

Ethiopian mustard. This crop is confined to the highlands of northeast Africa where it is grown for oil, which is locally known as Noug oil. There is probably scope for amateur breeders to select within existing landraces.

Brassica juncea

Brown mustard, also known as Indian mustard. This crop originated in India and it has secondary centres of origin in China and southern Russia. This species has the advantage that it can be combine-harvested and, for this reason, has become a major crop in Canada and parts of the northern U.S.A. This area now produces the bulk of the world's mustard. *B. juncea* is self-pollinating and is cultivated as pure lines. While much amateur breeding has occurred in India in the past, mainly for the production of oil, there is little scope for amateur breeders in the cultivars of commercial mustard cultivation.

Brassica napus

Swedes, rutabuga, and rape seed. This species is an allotetraploid derived from a cross of the diploid B.campestris and B.oleracea. Swedes, which are visually similar to turnips, are a relatively recent crop first recorded in Sweden in 1620. Rape seed is a somewhat older, European domestication. (Note that the rape seed, known as Canola, is a cultivar of B. campestris). Suitable for breeding by amateur breeders with special interests, given some assistance from experts.

Brassica nigra

Black mustard. This was the traditional, hand-harvested, European mustard until the mid-twentieth century, when it was largely replaced by B. juncea, which is suitable for mechanical harvesting.

Brassica oleracea

Cabbages, Brussels sprouts, kohl rabi, cauliflower, broccoli, and kales. This is an ancient domestication, and many of these crops were known to the ancient Romans. It is a complex species probably derived from three wild species with a presumed doubling of chromosome number, followed by the loss of some chromosomes. The species is open-pollinated and requires recurrent mass selection, although some self-pollination occurs with sprouts, cauliflowers, and kohl rabi. Most of the crops are biennials and breeding by amateurs is feasible although some specialist help will probably be needed. Calabrese, a sprouting broccoli, is *B. olearacea* var. *italica*, and it has recently become popular in North America.

Brassica oleracea var. gemmifera

Brussels sprouts. See under: Brassica oleracea.

Brassicas

Members of the Brassica genus of the *Crucifereae* family, includes broccoli, cabbages, canola, cauliflower, kale, kohl rabi, rape seed, sprouts, turnip, and various mustards. The taxonomy of the various species is confused, and the names given here may not coincide with other accounts.

Brazil nut

See: Bertholletia excelsa.

Breadfruit

See: Artocarpus altilis.

Bread wheat

See: Triticum aestivum.

Breakdown of vertical resistance

A total, qualitative failure of vertical resistance resulting from a matching allo-infection. Being matched, the vertical resistance stops functioning, and it is said to have broken down. In a wild pathosystem, which has genetic diversity, breakdowns occur only in individual host plants. In a crop pathosystem, which has genetic uniformity, the breakdown involves the entire cultivar, because every allo-infection, from plant to plant within that crop, is a matching infection. Because some matching always occurs, vertical resistance is temporary resistance. Because horizontal resistance operates against matching pathotypes of the parasite, it does not break down in this way; it is durable resistance. See also: discontinuous pathosystem.

Breeders' rights

The plant breeders' equivalent of authors' copyrights. These rights earn royalties on the sale of seed of registered cultivars. The breeders' rights legislation in most countries has a further clause that entitles a breeder to use a registered cultivar in his breeding program. However the regulations under the plant patent legislation of the USA is considerably different in this respect.

Breeding club

An association of amateur plant breeders who are motivated primarily by the desire for pure food that is free from pesticides . Because it is durable resistance, and is the easiest resistance to work with, most breeding clubs will work with horizontal resistance, using

recurrent mass selection in order to increase the levels of quantitative horizontal resistance sufficiently to control all locally important parasites of the crop in question. On-site selection is important if the new cultivar are to be in balance with the local ***agro-ecosystem***.

Breeding clubs, royalties

In most countries, a breeding club that has produced and registered a new cultivar is entitled to royalties on the sale of propagating material of that cultivar. The club should establish well in advance how possible royalties are to be used, either to support the club activities, or to be shared among members, or to be used for charitable purposes such as supporting new clubs. Some clubs may choose to put a cultivar in the public domain, but it should still be registered to prevent anyone else from exploiting it.

Breeding clubs; neighbour's complaints

One of the oldest of agricultural disputes is caused by the farmer who allows weed seeds to blow on to his neighbours land. The pollen blowing across farm boundaries from open-pollinated plants, that have been geneticall engineered, has also become a matter of dispute. Similar disputes can arise from breeders clubs that deliberately encourage pests and diseases, which can then spread on to their neighbours' crops.

The best means of avoiding this kind of dispute is for a club officer to visit neighbours and explain exactly what the club is doing, and why. The basic explanations are as follows: (i) Soil-borne parasites will not normally spread to the neighbours' land. (ii) Water-borne parasites may spread in surface drainage water, or in a stream or river that is supplying irrigation water, but this is a relatively rare occurrence, and can usually be controlled or avoided. (iii) Minor wind-borne parasites do not matter. (iv) Major wind-borne parasites are around anyway, regardless of anything the club might do and, if the farmer is using pesticide controls, these should not matter. If the neighbour's spray schedule is not working this is either because he is using inappropriate techniques, or because a new pesticide-resistant strain of the parasite had appeared. In neither event can the club be blamed. (v) If the farmer is using a cultivar with a vertical resistance that breaks down during the club activities, it should be explained that the designated pathotypes used by the club are all common races that have been around for some time. The club cannot be blamed for a normal failure of vertical resistance on someone else's land.

Breeding clubs; publication

Publication, probably on the Internet, serves two possible purposes. One is for purposes of exchange, either of breeding material, or of information on techniques. The other is to advertise the merits of a new cultivar.

Breeding cycle

The complete cycle of events that constitutes one generation of plant breeding. A breeding cycle usually begins with the cross-pollination of selected parents, and ends just before the next cross-pollination is due. There may be several intervening generations which may include a multiplication generation, single seed descent for several generations, and, perhaps, late selection to produce the new parents of the next breeding cycle in an autogamous species.

Brinjal

See: Solanum melongena.

Broad bean

See: Vicia faba.

Broccoli

See: Brassica oleracea.

Bromeliaceae

The botanical family of monocotyledons that includes pineapple.

Bromus inermis

A cultivated fodder grass called ‘Smooth Brome’.

Broom corn

See: Sorghum bicolor.

Broomrape

See: Orobanche spp.

Brussels sprouts

See: Brassica oleracea.

Buckwheat

See: Fagopyrum spp.

Bud

A young shoot, usually protected by scales or bracts, often for over-wintering purposes. Vegetative buds can be used for bud-grafting and meristem culture, but flower buds cannot.

Bud graft

The type of graft in which a vegetative bud is removed from its parent plant and used as a scion to be grafted onto a stock. The bud is normally removed with a portion of green bark, which is then inserted under the green bark of the stock. This technique is widely used with fruit trees, such as stone and pome fruits, and citrus, as well as other trees such as rubber, in order to grow a susceptible scion on a resistant rootstock. Inter-specific and inter-generic grafts are often possible.

Budding

The process of making a bud-graft. The term can also be applied to the vegetative reproduction of micro-organisms (e.g., yeasts) which multiply by budding.

Bug

In a colloquial sense, a bug is any small organism that is a nuisance. It is also an irritating fault in a computer program. In an entomological sense, however, a bug is an insect that is a member of the Order Hemiptera, characterised by sucking mouth parts. Many bugs are serious crop parasites.

Bulb

An underground storage organ of a monocotyledon in which a shortened stem bears fleshy leaf bases that enclose the next season's bud. Not to be confused with a corm.

Bulk screening

A technique for obtaining a fair degree of homozygosity for the purposes of late selection. A heterozygous population of an inbreeding species is multiplied for several generations in the field with minimal or zero selection in the early stages. Such early selection as does occur involves only single gene characters such as marker genes. However, single seed descent in a greenhouse is usually preferable, because it is faster.

Bullo

See: Elusine corocana.

Bullrush millet

Also known as pearl millet, spiked millet, cat-tail millet and bajra. See: Pennisetum typhoides.

Butterfly

Adult insects of the Order Lepidoptera, which have large membranous wings. The wings are covered in scales, which usually confer bright colours on the upper surface of the wings, and these serve as sex attractants. The scales on the lower surface of the wings usually confer camouflage colours. At rest, the upper surfaces of the wings are displayed to attract a mate. Alternatively, they are pressed

together in a plane vertical to the body for purposes of concealment. The fore-wings are normally larger than the hind wings. The long, slender antennae invariably have a clubbed end. The juvenile stages are known as caterpillars or grubs, and many are serious parasites of crops. The sucking mouthpart (proboscis) of the adult is usually a coiled tube, used for extracting nectar from flowers. See also: moths.

C

C_3, C_4 photosynthesis

There are two different chemical pathways in photosynthesis, known as C_3 and C_4. The former is common while the latter, which occurs mainly in a few tropical plants is rather rare. However, C_4 photosynthesis is much more efficient and is responsible for the high yields of crops such as sugarcane, cassava, and maize.

Cabbage

See: Brassica oleracea.

Cabernet Sauvignon

The principal grape cultivar of Bordeaux, France, producing the red wine known as claret in England. See Vitis vinifera.

CABI

Commonwealth Agricultural Bureaux International. For a fee, the following institutes, which are part of CABI, will identify crop diseases, insects, and nematodes, respectively: (1) International Mycological Institute, Bakeham Lane, Egham, Surrey, TW20 9TY, England; (2) International Institute of Entomology, 56 Queen's Gate, London, SW& 5JR, England; (3) International Institute of Parasitology, 395A, Hatfield Road, St. Albans, Herts, AL4 0XU, England.

Cacao

See: Theobroma cacao.

Cadang-cadang of coconuts

A lethal disease of coconuts in the Philippines, caused by a viroid. This disease should be considered a grave phytosanitary risk in all other coconut areas.

Cajanus cajan

This tropical pulse, a member of the family Leguminoseae, is called the pigeon pea, also known as red gram, Congo pea, and no-eye pea, and it is a native of Africa This crop is self-pollinating with about 20% of out-crossing, usually by bees and other insects. For controlled hybridisation, the flowers must be emasculated before 9.00 a.m., on the day before the flower opens. They may be hand-pollinated at the time of emasculation. Pigeon peas have a wide ecological adaptability but they do poorly in the wet tropics and they cannot tolerate frost. Most cultivars are short-day plants. This is a suitable crop for amateur breeders who should usually begin by selecting within local landraces.

Calabash

See: Crescentia cujete.

Calabrese

See: Brassica oleracea var. italica.

Calcium

Calcium is an essential nutrient of plants, and it ranks in importance after nitrogen, phosphate, and potash. Using lime (calcium carbonate) as a fertiliser both adds calcium and lowers the acidity (see pH) of the soil.

Calyx

The outermost covering of a flower, made up of sepals, which may be either united or separate.

Cambium

A layer of active cells that separates the xylem and the phloem. These cells produce new xylem and phloem that are represented by the annual rings of trees.

Camellia spp.

See: *Thea* spp.

Camote

See: Ipomea batatas.

Canker

A necrotic, sunken lesion on a thick part of a plant, such as a stem. Cankers are usually caused by fungi.

Canna edulis

Known as ‘achira’ in South America, where it originated, this crop is usually called Queensland arrowroot, or purple arrowroot, in English. It is grown commercially in Australia for extraction of

starch from the rhizomes. Hybrids of wild species of *Canna* are a popular ornamental known as the Canna Lily. Rather too specialised for amateur breeders .

Cannabis sativa

1. Hemp. Tall varieties grown especially for the stem fibres. The stems are retted either wet or dry in order to extract the bast fibres, which make up about 25% of the stem tissues. The cultivation of hemp has often been legally restricted because of its close similarity to the drug varieties that produce marijuana (see below). However, the crop is becoming popular and offers scope for amateur breeders in areas where it has not been previously cultivated. The fibres, gathered from wild plants, have been used since Neolithic times, and the plant has probably been cultivated in China and Central Asia, for fibre production, for more than six thousand years. It is still cultivated in many countries for its fibres, although competition from synthetic fibres has greatly reduced its importance.

2. Marijuana. Short varieties grown for drug purposes. Known as 'ganja' in India, 'marijuana' in the Americas, and 'bhang' elsewhere, this is a relatively harmless drug plant. This crop, which is illegal in many countries, provides an excellent example of what can be achieved by amateur breeders. A great number of breeders working independently have increased the strength of the plant's psychoactive component, tetrahydrocannabinol (THC) by about 100 times the naturally-occurring concentration. But the general advice to plant breeding clubs is to remain legal.

Canola

See: Brassica campestris.

Cantaloup

See: Cucumis melo.

Capsicum spp.

When Columbus reached the Americas, he believed he had arrived in India, and he caused more confusion in European languages than any other person by introducing terms such as 'Indians', 'West Indies', 'India rubber', 'Indian corn' (maize), and 'red pepper'. He was looking for black pepper (Piper nigrum) but all he found were chilli peppers, otherwise known as red, green, sweet, and hot peppers, cayenne, Tabasco, and paprika, which are all members of the genus *Capsicum*. Chilli peppers are now so common in countries such as India and China that the people of these countries believe them to be indigenous.

The taxonomy of this genus is very confused and, as most types interbreed freely, the one species *Capsicum annuum* covers all but a few perennial types known as *Capsicum frutescens*. The whole of

C. annuum should be regarded as a single hybrid swarm showing immense variation. The plants are mostly self-pollinated with about 15-20% of cross-pollination. Pure lines are thus possible and both emasculation and crossing are easy. Combined with the very wide variation, this ease of working makes it an excellent crop for amateur breeders working in warm climates. There are some quite serious virus and anthracnose disease, as well as several insect pests, that merit breeding for horizontal resistance.

Chillies are another example of a crop with extinct wild progenitors.

Capsid

Leaf or plant bugs of the family *Miridae*, of the order *Hemiptera*. Some species are serious pests of cultivated plants.

Carbohydrate

Organic chemicals made up of carbon, hydrogen, and oxygen, such as starch and sugars. Most carbohydrates are produced by plants as a result of photosynthesis, a process that uses chlorophyll and solar energy to combine water and carbon dioxide into carbohydrates, often in the proportion of one carbon atom to two hydrogen atoms and one oxygen atom. Carbohydrates are a major source of dietary energy.

Cardamom

See: Elettaria cardomomum.

Carica papaya

Papaw (often misspelled 'pawpaw'). The plants are tropical, soft-wooded trees with a relatively short lifespan, cultivated for their fruit and for the extraction of papain, which is an enzyme able to break down protein, and it is used as a meat tenderiser, and as a medical aid to digestion. The best eating fruit is produced in a very hot climate. The plants are dioecious but hermaphrodite lines exist. Being open-pollinated, recurrent mass selection is easy, and this is an excellent crop for amateur breeders. There should be a rigorous negative screening of male trees before anthesis. The only problem is that the plants are rather big, and considerable space is required if a large population is to be screened in each breeding cycle. There are a number of virus diseases, and breeding for horizontal resistance should be both rapid and easy. Selection within commercial crops might be the most convenient technique, selecting plants with minor symptoms rather than those with no symptoms, as these might be escapes from infection. If feasible, inoculation of all plants in the screening population is advised.

This is one of the crops that has never been found wild, possibly because hunter-gatherers exploited it to extinction while early farmers ensured the survival of domesticated forms. The crop is believed to have originated in Central America, in the area Mexico-Costa Rica. See also: Extinct wild progenitors.

Carya pecan

Pecans, a native of Mexico and the southern USA. Nuts are still harvested from wild trees but the majority are cultivated as clones. Some scope for amateur breeders selecting among wild trees. The pecan is also the source of hickory wood, in demand for smoking various foods.

Carnivore

An eater of animal tissues; meat-eater. See also: herbivore, omnivore.

Carpocapsa pomonella

The codling moth which attacks apples, producing a grub in the core of the fruit.

Carrot

See: Daucus carota.

Carrying capacity of the environment

There is an absolute limit to the carrying capacity of any natural environment for any wild species. However, the carrying capacity of an artificial agro-ecosystem can be increased considerably above the natural limit by the use of artificially selected (domesticated) species, and artificial cultivation practices, such as weeding, and the use of artificial fertilisers and irrigation.

Carthamus tinctoris

Safflower. A member of the *Compositae* family, this is a minor oil seed crop, with potential as an ornamental, grown chiefly in India, USA, and Mexico. Suitable for amateur breeders.

Cash crops

A subsistence farmer usually has two categories of crop. His subsistence crops are for the feeding of himself and his family; they may also include fodder crops for his farm animals. His cash crops are grown for sale. As a general rule, a subsistence farmer is poor, and he is unwilling to spend cash on his subsistence crops, because that cash gets eaten. But cash spent on cash crops is likely to be returned with a profit. One of the many advantages of increasing the yield of his subsistence crops is that he will have more land available for cash crops.

Cashews

See: Anacardium occidentale.

Cassava

See: Manihot esculenta.

Castanea spp.

Chestnut. The sweet chestnut (*C. sativa*) is cultivated as selected clones. The American chestnut (*C. dentata*) has been largely destroyed by the introduced chestnut blight (*Endothia parasitica*). Various species are prized for their timber. Not recommended for amateur breeders .

Castor

See: Ricinus communis.

Catalyst

A substance that increases the rate of a chemical reaction without being changed itself.

Caterpillar

The juvenile instars of a butterfly or moth.

Cauliflower

See: Brassica oleracea.

Cayenne pepper

See: Capsicum spp.

Ceiba pentandra

Kapoc. A tropical tree that produces seed fibres with a superficial resemblance to cotton. The cotton-like hairs are water-resistant and very buoyant, and they are used mainly as filling for life-jackets. Kapoc is also used for sound and heat insulation. Unfortunately, the hairs cannot be spun to produce yarn and cloth; if they could, this tree would be a crop of major importance as it far out-yields cotton.

Celeriac

See: Apium graveolens.

Celery

See: Apium graveolens.

Cell

The fundamental unit of plant and animal bodies. Unlike animal cells, plant cells are protected by a cellulose wall. But all cells consist of a membrane enclosing cytoplasm and nuclear material.

Cell wall

In plants, most of the microscopic cells are encased in a protective covering called the cell wall. This covering is usually made of cellulose. See also: Lignin.

Cellulose

The organic chemical that constitutes cell walls. Cotton, for example, is pure cellulose. When it is dissolved in a suitable solvent, such as amyl acetate, which is then evaporated off, cellulose is converted into celluloid, which was a widely used film for photography, and for wrapping food and cigarettes, before the days of synthetic plastics.

Cenchrus ciliare

A subtropical fodder grass native to South Africa.

Centre of diversification

The geographic area in which a crop species shows the greatest diversification. The centre of diversification is often different from the centre of origin, particularly with tetraploids.

Centre of origin

The geographic area in which a crop species was domesticated from its wild progenitors.

Cereals

Cereals are grasses (members of the botanical family Gramineae) that are cultivated for their edible seeds. The most important cereals are wheat, rice, and maize. Other cereals include millets, sorghum, teff, rye, oats, and barley. See also: pseudo-cereals.

Certified seed

Seed can be certified in a number of ways. True seeds can be certified with respect to their identity, purity, trueness to type, freedom from diseases, and germination percentage. Plant parts used for vegetative propagation (e.g., tubers, setts, rooted cuttings) are often certified in the same way. Note that cultivar that require seed that is certified free from disease are usually very susceptible, otherwise such certification, which is expensive, would not be necessary. One of the many objectives of amateur plant breeding is to develop horizontal resistance to the point that certification for freedom from disease is no longer required.

CGIAR

See: Consultative Group on International Agricultural Research.

Chance escape

For a variety of reasons, some individuals in a screening population may remain free of pests or diseases. Also known as disease escape, this phenomenon can be very misleading because it is so easily confused with resistance. See also: inoculation, patchy distribution.

Chard

See: Beta vulgaris.

Chateau Beaucaillon

It was at the Chateau Beaucaillon, in the Bordeaux district of France, that Millardet, in 1882, discovered Bordeaux mixture, the highly effective fungicide for downy mildews and potato blight.

Chenopodium quinoa

Quinoa, the most important of the grain amaranths, is an extremely variable crop that was domesticated in Central America long before the Spanish conquest. The three main aspects of its domestication are seeds that are twice as large as the wild progenitors, the elimination of seed dormancy, and the retention of the seeds in the head. This pseudo-cereal is an interesting example of parallel domestication that is closely similar to that of the Old World true cereals. This is a minor crop but one which offers great scope for amateur breeders .

Cherry

See: Prunus avium.

Chestnut

See: Castanea spp.

Chestnut blight

See: Endothia parasitica.

Chickory

See: Cichorium spp.

Chickpeas

See: Cicer arietinum.

Chiclé

See: Manilkara zapota.

Chicory

See: Cichorium spp.

Chillies

See: Capsicum spp.

Chives

See: Allium schoenoprasum.

Chloris gayana

Rhodes grass; this is the dominant, wild grass in extensive savannas in East and Southern Africa. Selection has produced a number of pasture cultivars both perennial and annual. Some cultivars are turf grasses and make attractive lawns. This species can be grown over a wide range of habitats and it has been introduced to many areas. It has reasonably high yields of hay, fodder, and grazing. It is palatable to stock. A suitable species for amateur breeders in ecologically appropriate areas.

Chlorophyll

The pigment that makes plants green, and which is the catalyst for converting carbon dioxide and water into carbohydrates, using solar energy, in the process known as photosynthesis. The term is derived from the Greek words for 'green' and 'leaf'.

Chlorotic

A loss or reduction in the green colour of leaves, due either to the destruction of chlorophyll, or to the prevention of its synthesis, usually by the action of a parasite, particularly a virus, or by a mineral deficiency.

Cholam

See: Sorghum bicolor.

Cholera

An intestinal diseases of humans caused by the bacterium *Vibrio chlorae*. This disease, and typhoid, caused by the bacterium *Salmonella typhi*, are spread by houseflies, and the Allied forces dusted the whole of Naples with DDT during World War II, in order to prevent major epidemics of insect-borne diseases, including malaria. DDT-resistant houseflies soon appeared and this was the first known example of the breakdown of an unstable, synthetic pesticide to new strains of the pests. It was this failure of DDT that initiated the 'boom and bust cycle' of pesticide production.

Chromosome

Microscopic, threadlike bodies that occur in the nuclei of plant and animal cells. Each chromosome consists of strands of DNA, which is the protein that encodes all genetic information. This information is made up of units called genes. Chromosomes occur in pairs, with one of each pair coming from the male parent, and one from the female parent. Each gene normally consists of two alleles, with one on each of the pair of chromosomes. During the process of cell division, the pairs of chromosomes replicate in a process called mitosis. When gametes are produced, the pairs of chromosome separate, without replication, to form two haploid gametes. A chromosome is the most

concentrated known system of storing information. Bacteria and viruses do not store their genetic information in chromosomes. See also: diploid , doubled monoploid, tetraploid, etc.

Chrysanthemum cineriifolium

The species of daisy, called pyrethrum, from which natural pyrethrins are extracted. Pyrethrum originated in Dalmatia (the area that used to be called Yugoslavia) where people still put dried pyrethrum flowers in their bedding to kill fleas and bed bugs. They have apparently been doing this for centuries, without any resistant fleas or bed bugs appearing, demonstrating that natural pyrethrins are a stable insecticide. But this insecticide is currently too expensive for use in crop protection.

Pyrethrum is open-pollinated and is an excellent crop for amateur breeders . The breeding objectives should be both a high yield of flowers, and a high pyrethrin content in those flowers. The latter can be professionally assessed in a commercial or university laboratory, or an amateur bioassay can be obtained by adding a minimal amount of powdered, dried, flower to a jam jar containing an insect such as a housefly or a bee. Some agricultural engineering will also be required in order to produce a mechanical harvester. If the price of pyrethrins could be reduced significantly, the crop protection market would be virtually unlimited. This is thus a crop of great potential. See pyrethrins for a description of the insecticide itself.

CIAT

Centro Internacional de Agricultura Tropical. This is the international research centre for tropical agriculture located in Cali, Colombia. It is one of the CGIAR research stations.

Cicadulina spp.

Species of leaf hopper insects. Some species are vectors of virus diseases of plants, the most notable being maize streak virus in Africa.

Cicer arietinum

Known as chick pea, or gram, this is the most important pulse in India, particularly in the semi-arid areas, as it is very resistant to drought. This plant is self-pollinating and, because the pods contain only one or two seeds, cross-pollination by hand is a laborious business. Apart from this, it is a suitable crop for amateur breeders , especially in India where many local landraces offer scope for screening. There is need for improved horizontal resistance to a number of diseases, and to the gram caterpillar, *Heliothis armigera*. Storage pests are a serious problem and the possibility of developing horizontal resistance to them merits investigation.

This is a crop that has extinct wild progenitors.

Cichorium spp.

C. intybus is chickory, whose dried and roasted roots are used for blending with coffee. The young shoots of *C. endiva* are endives, and are used as a vegetable, mainly in salads.

Cimex lectularius

A flat, wingless, reddish-brown, hemipterous bug, known as the bed bug, of interest in that the natural pyrethins in Chrysanthemum cineriifolium have remained a stable insecticide after centuries of use in Dalmatia.

CIMMYT

Centro Internacional de Mejoramiento de Maiz y Trigo. Located near Texcoco, in Mexico, this is the home of the miracle wheats, and it is a bastion of pedigree breeding and single-gene resistances. With IRRI, these are perhaps the best examples of autocratic plant breeding, as opposed to the democratic plant breeding of plant breeding clubs.

This is one of the CGIAR research stations.

Cinchona spp.

Several species of this South American genus of trees are cultivated for the extraction of quinine and other drugs.

Cinnamomum zeylanicum

The spice cinnamon, consists of the dried green bark (called quills) of an open-pollinated, evergreen tree, which is indigenous to Sri Lanka (Ceylon), and is propagated by seed. Selection within existing crops should lead to improved clones and vegetative propagation . There is thus scope for amateur breeders . There are no serious pests or diseases, but these might develop if a single clones is cultivated excessively.

Cinnamon is a very ancient crop and was being shipped by Austronesian people to Madagascar, and from there it was taken to Africa and, eventually, to ancient Rome. The Portuguese conquered Ceylon in 1536 and gained a monopoly in the cinnamon trade. The Dutch conquered them, and the monopoly, in 1656. Then the British conquered the Dutch, and won the monopoly, in 1796. In the nineteenth century, commercial production commenced in various parts of the world, and the monopoly was broken, but the Sri Lanka cinnamon remains the best.

Distillation of the wood of *C. camphora* produces camphor.

Cinnamon

See: Cinnamomum zeylanicum.

CIP

Centro Internacional de la Papa. Located in Lima, Peru, this is the international research centre for potatoes. This is one of the CGIAR research stations.

Circadian rhythm

Most living organisms have a twenty-four hour rhythm in various of their metabolic processes. This 'circa-diem' rhythm is apparently controlled by an internal biological clock which continues to function under artificial conditions of continuous day or night. However, the mechanism of this clock is not understood.

Citrullus lanatus

Water melon. This is a member of the Cucurbitaceae family, and is a native of Africa. Like all cucurbits, water melons are open-pollinated and there is great variation in all the quality characteristics. There are a number of pests and diseases and amateur breeding for horizontal resistance is likely to be productive.

Citrus (generally)

"Oranges and lemons, the bells of St Clements". Citrus fruits are among the oldest, originating mainly in S.E. Asia, and having spread throughout the Old World in antiquity. They are some of the most popular fruits, usually eaten fresh, but also made into special jams known as marmalade. They are a major source of Vitamin C. *Citrus* spp., are members of the botanical family *Rutaceae*. Most citrus trees are grafted on to stocks that are resistant to various root rots, but graft incompatibilities can lead to secondary problems, such as stem-pitting due to the tristeza virus. Citrus fruits become orange or yellow when ripe but, in the tropics, they may remain green. Many citrus species produce nucellar (i.e., parthenocarpic) seeds. The rind of most citrus fruits contains essential oils that are used in a wide range of perfumes, soaps, and foods.

Most citrus varieties are so popular, and so well entrenched, that there is little scope for amateur breeders to produce improved quality. There is scope for improved horizontal resistance, but amateur breeders should regard this as one of the more challenging crops.

Citrus aurantifolia

Lime. In the late eighteenth century, the British admiral Nelson insisted on his sailors drinking lime juice, in order to prevent scurvy, which is due to a deficiency of Vitamin C. This earned the British the nickname of 'limeys'. Lime fruits do not travel well and are little used in temperate countries.

However, they are immensely popular in tropical and subtropical countries where the fresh juice is routinely squeezed over food and into alcoholic drinks.

Citrus aurantium

The sour or Seville orange. Not suitable for eating as fresh fruit, these oranges are used mainly for making marmalade. Sour orange is also widely used as a rootstock for other species of citrus, but these graft combinations are often susceptible to the Tristeza virus. This species includes the Bergamot variety that yields Bergamot oil, which provides the characteristic flavour of Earl Grey tea.

Citrus limon

Lemon. This is the origin of the term 'lemonade' and this yellow fruit has always been popular in temperate countries where limes were unavailable. It is usually too sour to be eaten as a fruit, but it is widely used as a flavouring and garnish in many foods and drinks. The freshly grated peel, known as zest, is also widely used as a flavouring.

Citrus paradisi

Grapefruit. Now popular as a breakfast dish, this mildly bitter, acidic fruit is one of the largest citrus fruits. It is of relatively recent origin and is thought to be a chance hybrid between two other *Citrus* spp. The name 'grapefruit' was apparently used for the first time in Jamaica in 1814, but its etymology is obscure.

Citrus reticulata

Mandarin, or tangerine. Often known as the 'loose-skinned' oranges because of their easy peeling, these fruits are used mainly as a dessert. They probably originated in Vietnam and are of ancient cultivation in China and Japan.

Citrus sinensis

Sweet orange. This is the most important of the citrus fruits, in terms of acreage, and it is now used mainly as a fresh juice at breakfast in order to provide a daily dose of Vitamin C. There are three main types of cultivar. Navel oranges have a second row of carpels opening at the apex with the appearance of a 'belly button' or navel. Blood oranges have a red, or streaky red pulp. Thirdly, there are cultivars with normal fruits.

'Valencia' is the most important commercial cultivar, followed by 'Washington Navel' and 'Jaffa'.

Claviceps purpurea

The fungus that causes ergots and ergotism. The fungus infects the stigma of an open-pollinated cereal, such as rye, or various species of open-pollinated fodder grasses. The seed is then

transformed into a black fungal body that is the ergot and is poisonous. Ergotism used to be a serious problem in the rye districts of eastern Germany, Poland, and western Russia, where wheat is difficult to grow. This problem was largely solved by the introduction of potatoes.

Clay

1. Clay minerals are kaolin, mica, talc, and similar groups. 2. Clay is a component of soils, with a particle size of less than two microns. 3. Clay soils contain at least 20% clay particles and are described as heavy soils.

Cleaning crop

A crop, such as potatoes, that is used in the rotation to help suppress weeds. It does this by shading out the young weeds, which can be finally destroyed by cultivation.

Cleistothecium

(Plural: cleistothecia). The entirely enclosed body containing one or more asci, typical of the Erysiphales. The cleistothecium is ruptured by the developing ascus which can then eject its ascospores.

Cline

A large population covering a wide geographic area and exhibiting genetic change from one end to the other. For example, wild cocoa occurs as a cline covering the length of the Amazon River, with totally allogamous types at the river source, in the West, and a gradual change to autogamous types at the river mouth, in the East.

Clone

A population in which all the individuals are descended by asexual reproduction from one parent individual. Consequently, all the individuals within a clone are genetically identical. However, some clones may contain asexually produced variants called 'sports' or mutants. vegetative propagation of plants includes the use of grafts, cuttings, suckers, tuber, bulbs, corms, setts, and rhizomes. Typical clonal crops are potatoes, sweet potatoes, yams, cassava, strawberries, hops, apples, olives, citrus, dates, sugarcane, bananas, and pineapples.

Clove

See: Eugenia caryophyllus.

Clovers

See: Trifolium spp.

Cluster bean

See: Cyamopsis tetragonolobus.

Cobnut

See: Corylus avellana.

Coca

See: Erythroxylon coca.

Cochliobolus

See: Helminthosporium.

Cocoa

See: Theobroma cacao.

Coconut

See: Cocos nucifera.

Cocos nucifera

The coconut palm. An extraordinarily useful palm that provides food, drink, fibre, timber, thatch, mats, fuel, and drinking cups. This palm is also the source of copra, the dried endosperm, which was the major source of vegetable oil until the mid-twentieth century, and the major cash crop on innumerable tropical islands. This oil was used mainly for the manufacture of soap, and the market declined with the development of soapless detergents and other oil crops, such as soya, canola, and oil palm.

The species is usually divided into tall palms and dwarf palms. It is thought that the former represent the wild type, and the latter are the result of very ancient domestication that brought more numerous nuts closer to the ground and easier to open. There is scope for amateur breeders to cross-pollinate the two types to produce hybrid palms with an increased yield and, in the Caribbean, resistance to lethal yellowing disease.

The coconut is of considerable anthropological interest because it provided a source of both drinking water and Vitamin C on long ocean voyages. Austronesian people were sailing across oceans several millennnia before the Chinese developed ocean-going ships in the fourteenth century, or the Europeans, in the fifteenth century. This ocean travel permitted the colonisation of uninhabited ocean islands, and the spread of the Austronesian family of languages to Madagascar in the West, Easter Island in the East, Hawaii in the North, and New Zealand in the South.

Coconuts spread naturally, by floating on sea water, to the east coast of Africa, and the islands of the Western Pacific. However, they were unable to reach the west coasts of America, or the Atlantic. They were taken to both areas by European sailors in the sixteenth century. The Portuguese took them from East Africa to West Africa and the Caribbean. The Spanish too them across the Pacific to the New World. The palms of the west Pacific were in epidemiological contact with the centre of origin, and were resistant to various coconut diseases. The palms of East Africa, however, had been separated epidemiologically from the centre of origin for millennia, and they are susceptible to diseases such as Cadang-Cadang in the Philippines, and Lethal Yellowing in the Caribbean. Both diseases can be controlled by planting hybrids that are crosses between the Pacific Tall and the dwarf palms.

Coco-yam

See: Xanthosoma sagittifolium and Colocasia esculenta.

Codling moth

See: Carpocapsa pomonella.

Coffea arabica

Arabica coffee. This is the main coffee of commerce. It is an autogamous allotetraploid, (2n = 44) believed to have been derived from an infertile cross between the two wild diploid, Coffea canephora and Coffea eugenioides (2n = 22), which subsequently doubled its chromosome number to become a fertile tetraploid. First cultivated in Ethiopia, it was taken to *Arabia Felix* (Southern Yemen) where the famous Mocha variety was grown. The Dutch then took it to Ceylon (Sri Lanka) and Indonesia. Seed was then taken to Amsterdam, and one tree was given to the King of France who sent seed to Martinique. All the coffee of the New World was derived from this seed and was a pure lines. All the pests and diseases had been left behind in the Old World, and Latin America soon became the principle coffee producing area, with Brazil in the lead.

Ethiopia now has coffee cultivar with sufficient horizontal resistance to control all the major pests and diseases, including coffee berry disease, and it is the only country that can produce this resistant coffee that does not need any crop protection chemicals.

In countries where the ripe berries are picked by hand, the ‘wet method’ of processing is used. The coffee is pulped, graded, and fermented to produce so-called parchment coffee, which is then dried in the sun. It is then hulled to remove the parchment and silver skin. This produces a mild

coffee that will tolerate a light roast. With the 'dry method', whole cherries are dried in the sun and then milled. This produces a hard coffee which must be given a dark roast.

There is a detailed account in *Return to Resistance*.

Possibly the most promising approach to coffee breeding is to re-create the allotetraploid from the two wild diploids. But this is not recommended for amateur breeders . See also: Hemileia vastatrix.

Coffea canephora

Robusta coffee. Less desirable than C. arabica, it is suited to a much wetter climate, and is in demand for the manufacture of instant coffee. Believed to be one of the diploid parents of the allotetraploid *Coffea arabica*.

Coffea eugenioides

A wild diploid coffee of eastern Africa, of no commercial value, but it is believed to be a parent of the allotetraploid Coffea arabica. If an attempt were made to re-create Coffea arabica, this species would become scientifically important.

Coffee

See: Coffea arabica, Coffea canephora, and Coffea eugenioides.

Coffee berry disease (CBD)

See: Colletotrichum coffeanum.

Coffee leaf rust

See: Hemileia vastatrix.

Coix lachryma-jobi

Adlay, or Job's tears. Coix is a genus of monoecious grasses. Several species are of ancient cultivation as cereals in S.E. Asia, China, and Japan. A crop of considerable potential for amateur breeders .

Cola

See: Cola spp.

Cola spp.

Several species of this West African genus provide kola nuts that are rich in caffeine and are chewed as a stimulant. In ancient times, the kola trade defined the camel caravan routes through Sokatoo and Timbuctoo. There is now no international trade in kola nuts, and modern cola drinks contain no true kola.

Colchicine

A drug extracted from meadow saffron and used to induce polyploidy in plants.

Colletotrichum coffeanum

This is quite the most serious disease of coffee, and it is caused by the fungus *Colletotrichum coffeanum*. At present it is confined to eastern Africa. The fungus resides in the bark and parasitises the berries only. In a susceptible tree, there is a total loss of all berries several months before harvest, and this represents the minimum level of horizontal resistance. In resistant trees selected recently in Ethiopia, there is no loss of berries, and this represents the maximum level of horizontal resistance. In other countries where the disease occurs, it is controlled with fungicides.

Colocasia esculenta

This vegetatively propagated root crop is known variously as taro, dasheen, or coco yam. It is one of the aroids, and was the basis of the agriculture in Papua New Guinea, which is amongst the oldest in the world, dating from about 7000BC. However, it is a labour-intensive crop, and it became only a minor staple, which lacked the potential of a major staple, capable of supporting the growth of cities and the development of a sophisticated civilisation. There is some room for improvement by amateur breeders , mainly by selection within existing cultivar.

Colorado potato beetle

See: Leptinotarsa decemlineata.

Combine harvesting

Harvesting grain with a self-propelled machine that both cuts and threshes the crop. Combine harvesters usually have a storage bin that can be discharged into a truck moving alongside, while the harvesting continues without a break. Many machines also have a system of chopping the straw and discharging it on to the ground, often in windrows suitable for burning to control pests and diseases. Combine harvesters are used on most temperate cereals, some pulses, and crops such as mustard and canola.

Complexity theory

Modern complexity theory divides all systems into the two categories of linear and non-linear systems. The so-called ‘hard’ sciences, such as chemistry, physics, and astronomy, are based on linear systems, in which the parameters are fixed, are easily measured, and the outcomes easily predicted. The so-called ‘soft’ sciences, such as all the life sciences, are based on non-linear systems, in which the parameters are liable to change, are difficult to measure, and the outcomes difficult to

predict. For example, the solar system is linear, and we can predict the phases of the moon, and the tides, with great accuracy for centuries ahead. But the weather is a non-linear system and even short-term weather forecasts are notoriously unreliable.

A snooker table is a good example of a linear system. A skilled player can make shots that obey Newton's laws, and that are predictable. But put that snooker table on a moving ship and the game becomes a non-linear system, which is entirely unpredictable.

An essential feature of non-linear systems is the property of self-organisation and this is the basis of the concept of self-organising crop improvement.

See also: General systems theory.

Compositae

The botanical family that includes lettuce, sunflower, Jerusalem artichoke, pyrethrum, safflower, chrysanthemums, and daisies. It is characterised by an inflorescence of many small florets in a single disk, usually surrounded by the petals of the outermost florets.

Comprehensive horizontal resistance

See: horizontal resistance.

Congo pea

See: Cajanus cajan.

Conidia

The asexual produced, microscopic spores of a fungus that permit both vegetative propagation and a rapid and widespread dissemination. Conidia are usually produced in very large numbers, and these fungi are *r*-strategists capable of a rapid and large population explosion.

Conidiophore

The microscopic stalk of a fungus that bears asexual spores called conidia.

Conifer

Any tree of the order *Coniferales*, usually bearing cones and having needle-like leaves. Known as the Gymnosperms, they include pines, cedars, yew, and redwood.

Conservation

See: Genetic conservation.

Consultative Group for International Agricultural Research

The Consultative Group on International Agricultural Research, is located in Washington, DC. This is the body that allocates funds, amounting to several hundred million dollars annually, to the International Research Centres.

Consumers

1. A term in economics: purchasers of market produce. Consumers are a significant factor in the self-organising food production system because they determine which items sell best. For this reason, they are also a significant factor in self-organising crop improvement.

2. A term in evolution: one of the three primary groups of living organism, the others being producers and reducers. Consumers obtain their nutrients from other living organisms, and they include all herbivores, carnivores, omnivores, and parasites.

Contamination

From the point of view of plant breeders, contamination refers to unwanted foreign pollen that can accidentally enter the recurrent mass selection from outside, and introduce undesirable characteristics such as susceptibility. Contamination can also occur in cultures of plant pathogens. A distinction is also made between contaminated seed and infected seed. The former has parasites on the outside and can be decontaminated with surface seed dressings. The latter has internal parasites, which can be eliminated only by hot water treatment, or by systemic chemicals.

Continuity

See: Continuous epidemic.

Continuous distribution

Quantitative data that reveal a continuous spectrum of values between a minimum and a maximum.

See also: Normal distribution.

Continuous epidemic

In epidemiology, a continuous epidemic is one in which the parasitism never stops. This is sometimes called endemic disease. The epidemiological significance of continuity is that the parasite does not need to find a means of survival in the absence of a host. (See also: discontinuity).

Continuous pathosystem

A pathosystem in which host tissue is continuously available, and the parasitism continues indefinitely, without a break. Continuous pathosystems occur typically in evergreen, perennial hosts. Auto-infection is of primary importance in continuous pathosystems. vertical resistance has no

survival value in continuous pathosystems, and it will not be found in a crop species that is derived from a continuous wild pathosystem. See also: discontinuous pathosystem.

Continuous variation

A term sometimes used for quantitative variation, in which there is every degree of difference between two extremes. Thus, horizontal resistance shows continuous variation between its minimum and maximum levels. See also: discontinuous variation.

Contour ploughing

A system of ploughing in which the furrows follow the land contours in order to minimise soil erosion.

Copper

Copper is an important plant nutrient. It is an immobile element. Deficiency symptoms show first in the young leaves and shoots and result in general growth failure. Various copper compounds are used as fungicides.

Copper sulphate

Copper sulphate is obtained by dissolving metallic copper in sulphuric acid to produce a blue solution that crystallises into blue crystals known as 'blue stone'. It is a constituent of Bordeaux mixture, which is made by adding newly slaked lime to a solution of copper sulphate.

Copra

See: Cocos nucifera.

Copyright

The legal protection of intellectual property. Most countries now have a system of granting copyrights to plant breeders for new cultivar. The breeders are then entitled to royalties on all seed sales of their cultivars. This system of reward is of special interest to amateur plant breeders, and to plant breeding clubs. New cultivars with high levels of horizontal resistance can be accurately identified with DNA 'finger printing'.

Coriandrum sativum

An annual herb called coriander, and widely used since ancient times as a seasoning.

Corchorus spp.

Jute. This fibre crop is cultivated mainly in India. It provides considerable scope for amateur breeders , who should remember, however, that plastic fibres have largely replaced the natural plant bast fibres.

Corm

An underground storage organ of a monocotyledon consisting of a solid swollen stem. The next season's corm usually forms on top of the old one. Not to be confused with a bulb. Crocuses have corms, and tulips and onions have bulbs.

Corn

Technically, any small cereal grain. However, the use of this term is usually confined to the most important cereal within a region. Thus, in the corn belt of the USA, the term refers to maize. Corn in Britain is wheat. In Scotland, it is oats.

Corolla

A whorl, or whorls, of petals that forms the inner envelope of a flower. The petals may be either free or joined, and they are often brightly coloured to attract pollinating insects.

Corporate plant breeding

Plant breeding undertaken by large corporations, usually chemical manufacturers. Their motives are suspect, as they naturally have a preference for chemical pesticides rather than horizontal resistance. Consequently, they can be expected to produce new cultivar that have excellent yield, quality, and agronomic suitability, but that also have low levels of resistance. Corporate plant breeding is also involved in genetic engineering and the production of cultivars that have special properties, such as resistance to herbicides.

Corylus avelana

The hazel nut, cobnut, or filbert. This species shows considerable diversity and some taxonomists have suggested additional specific names. Not much scope for amateur breeders .

Corynebacterium

A genus of plant pathogenic, gram-positive bacteria that cause disease in tomato, potato, and various ornamentals.

Cosmopolitan cultivars

cultivar that have a wide geographical and environmental range.

Cotton

See: Gossypium spp.

Cotyledon

The first leaves produced by germinating seeds are called cotyledons. All flowering plants (Angiosperms) are divided in those that produce either one or two cotyledons at the time of seed

germination. Monocotyledons are plants that produce a single cotyledon, and they are often called the narrow-leaved plants. Among cultivated plants, they include all the grasses, cereals, and sugarcane, crops of the onion family, bananas, pineapples, palms, and ginger. Dicotyledons are plants that produce two cotyledons, and they are often called the broad-leaved plants. Seeds of dicotyledons can be split into two halves (e.g., split peas). Among cultivated plants, they include all the peas and beans, most of the temperate fruits and nuts, crops of the cabbage, cucumber, and potato families, cotton, rubber, tea, coffee, cocoa, cassava, sweet potato, and many vegetables, and herbs.

Covered smuts

The smut fungi are a group within the Basidiomycetes which cause diseases mainly in cereals and grasses. The covered smuts (c.f., loose smuts) are so-called because they form a black spore mass inside the seed, and these spores are released when the seed coat breaks. In cereal crops, this produces contaminated seed, as opposed to infected seed, and the disease can be easily controlled with a fungicidal seed dressing.

There is a covered smut of barley (Ustilago hordei), oats (Ustilago kolleri), and sorghum (Sphaceolotheca sorghi). The covered smuts of wheat are usually called bunt, or stinking smut, and are caused by (Tilletia caries, T. foetida, and T. contraversa).

Cowpea

See: Vigna unguiculata.

Cranberry

See: Vaccinium spp.

Crescentia cujete

The calabash, which is native to tropical America. The hard fruits are used as containers and musical instruments (maracas).

Cress

See: Lepidium sativum.

Crinipellis perniciosa

The fungus which causes ‘witches’ broom’ disease of cocoa.

Crocus sativa

Saffron. A much prized spice and yellow colouring obtained from the stigmas of this *Crocus*. Saffron is the basis of French bouillabaisse, Spanish paella, English saffron buns, Jewish gilderne, Russian

challah, Indian zaffrani chawal, and Persian sholezard. Saffron is also the most expensive spice of them all, because the anthers of a crocus flower are the most labour-intensive of all crops to harvest.

The wild progenitors of the saffron crocus are extinct, and this is an indication of its antiquity. Like garlic, the cultivated crocus does not set seed, and, it can be propagated only by corms. Multiplication of the crop is a very slow process because only two or three new corms are formed each year at the base of the old corm. It is not known how many clones exist but it is quite clear that all of them are ancient, and that they have been cultivated for millennia without any use of crop protection chemicals. Not recommended for amateur breeders .

Cronartium ribicola

White pine blister rust. This is a heteroecious rust of five-needled pines (Pinus spp.), and its summer host is Ribes spp. It was apparently introduced to North America at the turn of the nineteenth century, where it largely destroyed the white pine forests. It is thought (but not proved) that this introduction was an allopatric pathotype native to Eurasia, and that a local, North American pathotype had been present all the time. The two pathotypes would have become isolated from each other some sixty five million years ago with the separation of the continents. This would explain why an apparently functioning gene-for-gene relationship exists in the North American pathosystem of the Eurasian pathotype. Apparently, the same gene-for-gene relationship exists in both geographical areas and, if confirmed, this would provide a useful indication of the evolutionary age of gene-for-gene relationships. The North American white pines would have had adequate horizontal resistance to their own Horizontal pathotype, but not to the allopatric pathotype.

Surviving white pines are likely to be resistant, and their selection and propagation would form an excellent project for a plant breeding clubs in the forestry department of a university.

Crop

Any population of plants that is cultivated by a farmer. Crops are often defined by their ultimate purpose. Thus, cash crop, subsistence crop, food crop, fodder crop, etc.

Crop architecture

The shape of crop plants and, hence, the nature of the crop itself. For example, the bean varieties of one species may have either the determinate habit, or they may be climbing vines. The latter are useful for climbing up maize plants in mixed cropping, while the former are more suitable as a pure stand, and for mechanical cultivation and harvesting. The miracle wheats and rices of the Green Revolution are dwarf varieties that can tolerate high rates of nitrogenous fertiliser without lodging.

Soybeans became an important commercial crop only after types suitable for combine harvesting had been developed. Some crops, such as potatoes, can be densely planted in order to cover the ground completely, in order to control weeds.

Crop husbandry

The practice and science of the cultivation of crops.

Crop loss due to parasites

The crop losses caused by parasites are usually subdivided into pre-harvest and post-harvest losses, also known as field losses and store losses, respectively. Pre-harvest losses are controlled primarily by breeding the host for resistance, and by the use of crop protection chemicals. Other methods include rotation, to reduce the incidence of soil-borne parasites, and the burning of crop residues. Post-harvest losses are controlled mainly by keeping the product dry, and by depriving the parasites of oxygen.

Crop parasites

Any organism in which an individual spends a major proportion of its life cycle inhabiting and obtaining nutrients from one host individual. The term includes parasitic Angiosperms, insects, mites, nematodes, fungi, bacteria, phytoplasmas, viruses, and viroids. Entomologists normally handle the insects and mites, while plant pathologists usually handle all the other categories.

Crop pathosystem

An agricultural plant pathosystem in which people have interfered with the natural mechanisms of self-organisation. The host, the parasite, and the environment have all been altered by the multifarious activities of agriculture. It is normally characterised by genetic uniformity, and genetic inflexibility. If it is derived from a continuous wild pathosystem, it will not have any vertical resistances; if derived from a discontinuous wild pathosystem, it may have vertical resistances.

Crop protection

The combined disciplines of entomology, plant pathology, and plant breeding, aimed at jointly and cooperatively reducing crop losses resulting from both parasites and weeds. Modern crop protection depends very heavily on crop protection chemicals, and the chief aim of amateur plant breeders is to reduce this dependence on chemicals by breeding crops for horizontal resistance.

Crop protection chemicals

In the wide sense, this term means any chemical used to control crop parasites or weeds. The former are mainly insecticides and fungicides, while the latter are herbicides. In any discussion of crop parasites, however, the term is usually used to exclude herbicides.

Crop rotation

The cultivation of a succession of different species of crop on the same land. The main purpose of rotation is to reduce or prevent the build up of large populations of parasites, particularly soil-borne parasites. Other functions include the most efficient use of fertiliser residues.

Crop science

The combined disciplines of agronomy, horticulture, plant pathology, entomology, plant breeding, and plant physiology. Agricultural engineering and agricultural economics are sometimes included in this term.

Crop vulnerability

A crop is vulnerable if it is susceptible to a foreign parasite which is absent from the area in question. If the foreign parasite arrives in that area, the susceptibility is revealed, and the vulnerability is manifested. Potential damage then becomes actual damage. Some crop vulnerabilties are slight and unimportant. Others can be extreme, and the resulting damage can have major social and economic consequences. Thus the potato crops of Europe before 1845 were highly vulnerable to the ***blight*** fungus *Phytophthora infestans*. Note that a crop is vulnerable only if the parasite in question has epidemiological competence in the area concerned.

Cross

Short for cross-pollination.

Crossing generation

In recurrent mass selection , a plant breeding cycle may involve several generations. The crossing generation is the one in which cross-pollination occurs. See also: single seed descent; late selection; family selection.

Cross-pollination

Fertilisation with pollen coming from a different plant. When cross-pollination involves two genetically different plants, it leads to heterozygosity. See also: allogamy, outbreeder, self-pollination.

Crotalaria juncea

Sunn hemp, which is cultivated throughout the tropics as a fast-growing green manure. It is also widely used in India as a fibre for sacking and cords, but it is inferior to true hemp (Cannabis).

Cryptic error

The term originally used by Vanderplank to describe inter-plot interference or parasite interference.

Cucumber

See: Cucumis sativus.

Cucumis anguria

The West Indian gherkin. These fruits are used mainly in pickles, but they should not be mistaken for the more common gherkin which is only a small cucumber.

Cucumis melo

Melon. This highly variable species consists of four basic types, which interbreed freely. The 'Cantaloupe' melon is the most commonly cultivated and is characterised by a think, rough rind. The 'Honey Dew' melon, with ivory skin and green flesh, is also widely grown, and is in the group known as the winter or 'Casaba' melons. 'Musk melon' is popular in the United States and has a smooth skin and shallow ribs. Melons are open-pollinated. Most musk melons are andromonoecious, while Cantaloupes are usually monoecious. A good crop for amateur breeders.

Cucumis sativus

Cucumbers and gherkins. This species originated in India. There is a wide range of cultivar. The so-called 'English' cucumber has long fruits that are used mainly in salads and sandwiches. Pickling cucumbers have small fruits and are pickled as gherkins. The 'Sikkim' cucumber of India has reddish-brown fruits. All members of this species are monoecious, annual herbs, and some are parthenocarpic. There is considerable scope for recurrent mass selection by amateur breeders.

Cucurbita maxima

The pumpkin, also known as the winter squash. This species has extremely large fruit that is widely used for making Jack-o'-lanterns at Hallowe'en. The fruit and seeds are edible. The species is monoecious and should be regarded as a fun crop for amateur breeders.

Cucurbita pepo

The vegetable marrow, or squash, which originated in Central America. This species formed one of the kingpins of ancient Aztec farming, in which maize, beans, and squash were grown in a system of mixed cropping that both supplied a remarkably complete diet, and has proved remarkably

sustainable. However, this system is labour-intensive and will not allow the use of selective herbicides.

This species is a very variable, monoecious, annual herb. Most modern breeding has involved pedigree breeding with transfers of vertical resistance genes, and the production of hybrid varieties. In Europe, the seed is used as a source of high quality oil, and a mutant, lacking the heavy seed coat, produces seed containing 45-50% oil. There is scope of recurrent mass selection by amateur breeders .

Cucurbita spp.

This genus originated in the area of Mexico-Guatemala and has twenty-six species , of which five are cultivated. The principle cultivated species is Cucurbita pepo, and is described separately. In addition *C. moschata*, *C. maxima, C. ficifolia*, and *C. mixta*, provide winter squash in Central America and parts of South America. They provide scope for recurrent mass selection by local plant breeding clubs.

Cucurbitaceae

The botanical family that includes cucumbers, pumpkins, melons, etc. Most species are open-pollinated, and many are monoecious, and provide scope for amateur plant breeders. The main cultivated species are the wax or white gourd (Benincasa hispida) used as a vegetable in S.E. Asia; the water melon (Citrullus lanatus); the west Indian gherkin (Cucumis anguria); the melon (Cucumis melo); the cucumbers and gherkins (Cucumis sativus); the pumpkin (Cucurbita spp.); the marrow (Cucurbita pepo); the bottle gourd (Lagenaria siceraria); the loofah (Luffa spp.); the bitter gourd (Momordica charantia); and the choyote or christophine (Sechium edule).

Cucurbits

Members of the botanical family Cucurbitaceae.

Cultigen

A plant species or variety that is known only in cultivation. See also: cultivar; extinct wild progenitors.

Cultivar

A **culti**vated **var**iety, which has originated and persisted under cultivation, as opposed to a botanical variety, which is a component of a wild species . Cultivar names should be written with capital letters and enclosed in single quotation marks (e.g., ‘Russet Burbank’), but some authors prefer to use italics without quotation marks. A cultivar is usually a pure lines, a clones, or a hybrid variety, and it is

genetically uniform, and genetically inflexible. A cultivar consequently cannot respond to selection pressures during cultivation. See also: ecotype, agro-ecotype, landrace, micro-evolution.

Cultivation

The various processes of growing a crop.

Culture

In an agricultural context, this word means the growing of either a crop, or a micro-organism.

Cuminum cyminum

Cumin. A member of the botanical family Umbelliferae, cultivated in S.E. Europe, North Africa, India, and China. The seeds are used for flavouring curry powder and other mixed spices.

Curcuma domestica

Turmeric. This genus is native to S.E. Asia and is a member of the ginger family, Zingiberaceae. The rhizomes provide a yellow dye, and a flavouring essential to all curry powders. It is one of those crops in which true seeds are not produced, and its ancient clones are a useful example of the durability of horizontal resistance. The wild progenitors are extinct. Various clones exist in India, usually named after their home district, and varying in their suitability as a spice or a dye.

Currants

In a horticultural sense, currants are species of Ribes, and are known as red, white, and black currants. The black currant is a useful source of Vitamin C. However, the currants used in currant buns, and other cooking, are a special variety of dried grape called 'Corinth', and the term 'currant' is a corruption of this name.

Curry powder

In India, any good cook makes her own curry powders, and there are as many recipes as there are good cooks. Most curry powders contain about 25% turmeric (*Cucurma domestica*), 25% coriander (*Coriandrum sativum*) seeds, and various amounts of cumin (*Cuminum cyminum*) seeds, cardamoms (*Elettaria cardomomum*), fenugreek (*Trigonella foenum-graecum*) seeds, chillies (*Capsicum annum*), ginger (*Zingerber officinale*), black pepper (*Piper nigrum*), and dill (*Anethum graveolens*) seeds.

Cuscuta spp.

Dodder, also known as strangle-weed, hellbind, hailweed, and devil's hair. These species belong to a mono-generic family, the *Cuscutaceae*, in which all members are parasitic on other plants. Dodder consists mainly of yellow-red, slender, vine-like stems with vestigial leaves, and the plants lack chlorophyll entirely. Dodder can occasionally be an agricultural nuisance.

Dodder is used in research to transmit viruses from one host plant to another.

Cuticle

The outermost layer of the epidermis. A thick cuticle is often a mechanism of resistance.

Cuttings

Pieces of stem that are planted so that they may form roots and, eventually, new plants by vegetative propagation . All the cuttings originating from a single parent constitute a clones. The best method of rooting cuttings is in a mist-propagator.

Cyamopsis tetragonolobus

The cluster bean, or guar, is a member of the Leguminosae. Its wild progenitors are extinct but it is thought to have been a native of Africa, taken at an early date to S.E. Asia, where it now has many uses. It is also grown as a cash crop in Texas and Oklahoma. Some scope for amateur breeders in S.E. Asia.

Cyanide

Any of the highly poisonous salts of hydrocyanic acid, particularly potassium cyanide. It was used as an insecticide before the discovery of DDT and later synthetic insecticides.

Cyano-bacteria

Also called the blue-green algae, these prokaryote organisms contain photosynthesising pigments. They were apparently the first producers to appear on the evolutionary scene, and they have survived until the present.

Cyclone separator

Equipment for separating dust or other fine particles from air. The dusty air is spun as a cyclone inside a hollow cone. Being heavy, the solid particles are thrown against the sides of the cone by centrifugal force, and they sink to the calm air at the bottom of the cone. The clean air escapes through the top of the separator. This is equipment is usually quite large, and handles big quantities of dusty air being extracted from a factory or mill. However, miniature versions are made for collecting relatively large quantities of microscopic pollen grains, rust spores, etc.

Cynara scolymus

The globe artichoke. This Mediterranean crop is a perennial thistle and is vegetatively propagated, because true seedlings are very variable.

Cynodon dactylon

Star grass, also known as Bermuda grass or Bahama grass. One of the most widely dispersed grasses in the tropics and subtropics, extending even to S.W. England. While it can be a serious weed, with fast-growing rhizomes and runners, it can be useful as both a pasture grass and a turf grass. It is usually propagated vegetatively, but some forms can be sown by seed. Non-rhizomatous, high-yielding strains are known and are very useful. There is scope for amateur breeders .

Cyphomndra betacea

The tree tomato. This tree is not a true tomato but it belongs to the same family (Solanacea) and it has fruits that taste like tomatoes.

Cyrtosperma chamissonis

Giant taro. This plant is a huge herb growing up to four metres in height, grown for its tubers that take several years to mature, with a record of a sixty kilogram tuber in a plant ten years old. It is propagated vegetatively and it is usually grown in swamps.

Cytoplasm

The contents of a cell that are enclosed by the membrane, but excluding the nucleus.

D

Dactylis glomerata

A pasture grass grown mainly in the temperate regions of the Old World.

Daktulosphaira vitifoliae

The new scientific name for Phylloxera vitifoliae of grapes.

Damping-off

A disease of very young seedlings, which rots the stem at the soil surface. Affected seedlings then fall over like miniature, felled trees. The disease is caused by fungi such as *Phytophthora*, Pythium, and Rhizoctonia, and it is greatly aggravated by over-watering, which should be avoided. Otherwise, the best methods of controlling the disease are to use soils that have either been pasteurised with steam heat, or treated with a fungicidal soil drench.

Dandelion

See: Taraxacum.

Darwin, Charles

The English discoverer of evolution, Charles Robert Darwin (1809-82) was appointed to the post of naturalist on the scientific expedition of HMS Beagle (1831-6). In 1842, he bought Down House, in Kent, where he lived for the rest of his life, suffering from Chagas disease, which he had contracted in South America. Having a private income, he could investigate as he pleased and at his own slow pace. By 1844 he had developed his theory of evolution but he delayed publication until a note from Alfred Wallace revealed his independent discovery of the same idea. In 1858, their joint paper was read to the Linnaean Society and, in 1859, Darwin published his famous book *On the Origin of Species by Means of Natural Selection*. The book was widely and quickly recognised, but opposition came from religious groups who preferred a literal interpretation of the Bible.

Dasheen

See: Colocasia esculenta.

Date palm

See: Phoenix dactylifera.

Daucus carota

The carrot. This is an open-pollinated member of the family Umbelliferae and the production of uniform lines is difficult. Some work has been done on hybrid varieties but there are technical problems with this approach. There is plenty of scope for the accumulation of horizontal resistance, but amateur breeders should be a little wary of tackling this crop.

Day-length

A parameter that governs the initiation of flowering and other developments in plants. Tropical plants are often short-day plants (e.g., potatoes that will not form tubers until the September equinox when grown in temperate regions) and temperate plants are often long-day plants (e.g., hops and olives which will not flower in the tropics).

Day-neutral

A day-neutral plant is one that is not affected by day-length (e.g., temperate cultivar of potato). See also: photoperiod-sensitive.

DDT (Dichloro-diphenyl-trichlor-ethane)

One of the dirty dozen chemicals called POPS (persistent organic pollutants). The first, most famous, most successful, and most notorious of the synthetic insecticides. It was first synthesised chemically in 1873 but its insecticidal properties were not discovered until 1939, by the Swiss entomologist Paul Müller, who was awarded the 1948 Nobel Prize in Medicine. DDT proved to be of enormous value in the control of insect vectors of human diseases, such as malaria, typhoid, and cholera. Scientists still speculate whether DDT or penicillin has saved the most human lives. DDT also controlled the vectors of many animal diseases, as well as numerous crop pests. The latter included major pests such as Colorado beetle of potato, boll worms of cotton, and codling moth of apples. It should be remembered that these pests had previously been treated with compounds of lead, arsenic, mercury, and cyanide. DDT was both cheap and persistent. The peak production in the USA was in 1961 when 175 million pounds were produced. However, its widespread abuse led to serious environmental damage and fears for human health. Because DDT is water-insoluble, but fat-soluble, it accumulates in body fat, and a phenomenon called biomagnification leads to increasing concentrations of DDT up the food chain. Humans, as well as many carnivorous birds are at the top of their food chains and accumulate the highest levels. A further problem was the development of DDT-resistance in target insects. This was the first example of an unstable insecticide. Another problem concerned the killing of non-target and beneficial insects, such as pollinating bees, and the agents of biological control. In 1973, its use in the USA was banned, and many other countries followed this example. It is now banned by international treaty except in areas where its use is essential for the control of malaria.

Death

In systems terminology, death is a loss of behaviour, while decay is a loss of structure. Life is an emergent property, and death is the irrevocable loss of that emergent.

Death rate

The rate at which a population is losing individuals. When the death rate is constant, and equal to the birth rate, the population size does not change. When the death rate exceeds the birth rate, the population growth is negative, and the population size declines. But when the birth rate exceeds the death rate, the population growth is positive, and the population size increases. When the positive population growth is very rapid, and it is called a population explosion. This rapid rate is typical of *r*-strategists.

deBary

The German botanist Heinrich Anton deBary (1831-88) is considered the founder of modern mycology.

Deccan hemp

See: Hibiscus cannabis.

Deciduous

The habit of some trees and shrubs of shedding their leaves, by abscission, at the end of each growing season. The function of this habit is usually to escape an adverse season, such as a winter, or a tropical dry season. However, the deciduous habit also has advantages in the control of leaf parasites by providing a discontinuous pathosystem in which a gene-for-gene relationship can operate as a system of biochemical locking. Most deciduous trees are Angiosperms. See also: n/2 model Seasonal tissue.

Deficiency diseases

Deficiency diseases are among the non-parasitic physiological disorders, which are due mainly to nutritional deficiencies or toxicities. Each nutritional element produces its own deficiency symptoms. Within one plant, mobile elements can be taken from old tissues to feed the young tissues, and the symptoms then appear mainly in the older tissues. Conversely, immobile elements cannot be re-allocated in this way, and the main deficiency symptoms then appear in the youngest tissues. Deficiency symptoms are easily confused with herbicide injury, and a specialist should usually be consulted. For the symptoms of each mineral deficiency, see Nitrogen, Phosphorus, Potassium, Magnesium, Calcium, Boron, Sulphur, Iron, Zinc, Copper, and Manganese.

Defoliation

Loss of leaf. Defoliation can be (1) natural, as with leaf-fall in a deciduous tree or shrub; (2) pathologically induced by the activities of parasites; (3) induced by the misuse of herbicides; or (4) from abnormal environmental conditions, such as severe drought.

Dehiscent

This term means that a seed capsule, anther, etc, opens spontaneously when mature.

Democratic plant breeding

The converse of autocratic plant breeding. With democratic plant breeding, as many breeders as possible are producing as many cultivar as possible so that the farmer has a wide choice of cultivars. This approach is possible with the use of horizontal resistance because breeding for this kind of

resistance is so easy. In many instances, the farmers themselves will do their own plant breeding. Once there are enough amateur plant breeders, the whole system of crop improvement will become self-organising.

Density-dependent selection

The limiting of the size of a population (e.g., a vertical pathotype) by mechanisms that are themselves controlled by the size of that population. This is a probable genetic mechanism for controlling the system of locking of the n/2 model, ensuring that all the n/2 biochemical locks and keys occur with an equal frequency. The rarity of a vertical pathotype or pathodeme is a reproductive advantage that leads to commonness. And commonness is a reproductive disadvantage that leads to rarity.

Derris elliptica

The powdered dried root of this Leguminous plant contains rotenone and other toxic compounds that are used as an insecticide and a fish poison in S.E. Asia. The insecticide is used mainly as a hair wash to control lice. This derris insecticide is stable, as no derris-resistant strains of insects have appeared during centuries of use. Derris dust can also be used as an insecticide on crops. The pounded roots are soaked in water to produce a fish poison, and the poisoned fish can be eaten without risk. Selected clones of the crop are propagated vegetatively by cuttings of mature stems. But seed set is common and improvement by amateurs is feasible. However, there are no serious parasite of derris, and breeding for horizontal resistance appears to be unnecessary. Derris is a short-day plant that needs a tropical forest ecology, and there appears to be no possibility of producing temperate cultivar.

Desert locust

See: Schistocerca gregaria.

Designated host

A genetically stable host (i.e., a clones or pure lines) which has been chosen for use in the one-pathotype technique in a horizontal resistance breeding program. The designated host has a resistance that is matched by the designated pathotype, which is cultured on that host for the entire duration of the breeding program. All the original parents of the breeding population are chosen on the basis of their susceptibility to the designated pathotype, which is used to inoculate every screening population. This will ensure that all vertical resistances are matched during the screening for horizontal resistance, regardless of how the vertical resistance genes may have recombined during the crossing process. Only one designated pathotype may be chosen for each species of parasite. The one-pathotype technique is necessary only when vertical resistances occur in the host species.

However, its use is not always necessary, even then, and alternative techniques exist. Consult a specialist or see Self-Organising Crop Improvement (a sharebook at this website) for further information).

Designated pathotype

A pathotype (i.e., strain, or race) of a parasite which has been chosen for use in the one-pathotype technique in a horizontal resistance breeding program. The designated pathotype is cultured on the designated host for the entire duration of the breeding program. All the original parents of the breeding population are chosen on the basis of their susceptibility to the designated pathotype, which is used to inoculate every screening population. This will ensure that all vertical resistances are matched during the screening for horizontal resistance, regardless of how the vertical resistance genes may have recombined during the breeding process. Only one designated pathotype may be chosen for each species of parasite. The one pathotype technique is necessary only when vertical resistances occur in the host species. However, its use is not always necessary, even then, and alternative techniques exist. Consult a specialist or see Self-Organising Crop Improvement (shareware at this website) for further information).

Designation

See: Designated host; Designated pathotype.

Dessicator

A glass jar with a air-tight lid that is used for drying out small quantities of plant tissue, such as seeds or root nodules. Dry calcium chloride is a powerful desiccating chemical, but it is toxic and must be kept well separated from living tissues. Alternatively, silica gel is harmless, but it is less powerful in its drying action.

Determinate habit

The converse of the climbing habit in plants. A determinate plant remains relatively small and close to the ground, like dwarf beans or potatoes. The determinate habit results from the terminal flower of an inflorescence opening first, and the further lengthening of the stem is then arrested.

Dew

See: Guttation.

Diallel cross

A polycross in which each parent is mated with every other parent. In a full diallel cross, each parent is represented twice, once as a male and once as a female. More commonly, a half diallel cross is

used, in which each parent is represented only once, either as a male or a female, but not both. A half diallel cross is usually used at the start of recurrent mass selection . The alternative is to use a random polycross.

Dichotomous

A dichotomous stem is one that forks regularly into two branches.

Dicotyledon

Any Angiosperm that has two cotyledons. They are often called the broad-leaved plants. Seeds of dicotyledons can be split into two halves (e.g., split peas) and they include all the peas and beans, most of the temperate fruits and nuts, crops of the cabbage, cucumber, and potato families, cotton, tobacco, rubber, tea, coffee, cocoa, cassava, sweet potato, and many vegetables, herbs and spices.

Dieback

A plant disease symptom in which stems die backwards from the tip. Diebacks are usually caused either by a pathogen attacking the young tissue of the stem tip, or by a disease in another part of the plant producing toxins that kill the growing point. They can also have a physiological cause, such as a nutrient deficiency.

Differential interaction

A table of host and parasite interactions (i.e., responses of resistances to parasitic abilities and vice versa) in which several different pathodemes are necessary to identify a pathotype , and several different pathotypes are necessary to identify one pathodeme. A differential interaction is also known as a variable ranking, as opposed to the constant ranking that is typical of horizontal resistance and horizontal parasitic ability. The Person-Habgood differential interaction is the definitive interaction of vertical resistance and vertical parasitic ability.

Digitaria decumbens

A subtropical fodder grass native to Southeast Africa.

Dikaryon

A fungus in which each cell has two haploid nuclei, which are usually genetically distinct. Dikaryotic mycelium is thus equivalent to diploid mycelium. It occurs mainly in the rust fungi.

Dimorphous branching

Some crop species (e.g., arabica coffee, cotton, black pepper) have two kinds of branches. The orthotropic branch is the branch that grows vertically, and it produces side branches, called plagiotropic branches, that tend to grow horizontally. It is usually the plagiotropic branches that bear

the flowers and seed. cuttings must be taken from the orthotropic branch, and this severely limits vegetative propagation .

Dioecious

Greek = two houses (pronounced dye-ee-shous). A plant species in which the male and female sexes are separated in different plants. See also: Hermaphrodite.

Dioscorea alata

This is the Asian yam, also known as the white yam, the greater yam, the winged yam, and the water yam. See Dioscorea spp., for a description of the genus . This yam was of major importance to the seafaring Polynesians who took it to most of the tropical islands of the Old World. It is propagated vegetatively, because most cultivar never produce fertile seed, and some are completely sterile. Not recommended for amateur breeders .

This is a crop with extinct wild progenitors.

Dioscorea bulbifera

This is the aerial yam, also known as the potato yam. It is of minor importance as a food crop but was probably important in ancient times. It is the only species that occurs wild in both Africa and Asia. See Dioscorea spp., for a description of the genus . Not recommended for amateur breeders .

Dioscorea cayenensis

This is the yellow yam, also known as the twelve-month yam, and the yellow guinea yam. In spite of its name, this is a West African species that still occurs wild. It was taken to the New World with the slave trade. It is widely grown in West Africa but it is not as important as Dioscorea rotundata**.** Not recommended for amateur breeders . See Dioscorea spp., for a description of the genus .

Dioscorea rotundata

This is the white yam, also known as the Guinea yam, and the eight-months yam. It originated in West Africa and is the most important species agriculturally. Many clones exist but most of them set fertile seed so rarely that breeding is all but impossible. Not recommended for amateur breeders . See Dioscorea spp., for a description of the genus .

Dioscorea spp.

These are the true yams, not to be confused with sweet potatoes, which are called yams in the southern USA. Although generally considered a Monocotyledons , this genus has many features of Dicotyledons , including reticulate veining in the leaves and occasional seeds with two cotyledons, in which only one cotyledon develops. The genus is very old geologically, and it occurs, and has been

domesticated, in both the Old and the New Worlds. The principle species are described under their specific names.

The true yams are monoecious. Most cultivar are propagated vegetatively because they produce fertile seed rarely or not at all. This makes breeding extremely difficult, and these crops are not recommended for amateur breeders. There are few pests and diseases of yams and, because all the cultivated clones are ancient, they are a useful demonstration of both the durability and the efficacy of horizontal resistance.

Wild yams were recently in danger of extinction due to the demand for natural diosgenin in the manufacture of oral contraceptives. However, the development of synthetic diosgenins has eliminated this threat.

Dioscorea trifida

The cush-cush yam is the only cultivated yam that is indigenous to the New World. Not recommended for amateur breeders. See Dioscorea spp., for a description of the genus.

Dioscorides

Pedanus Dioscorides was a first century Greek physician who wrote a standard work called *De Materia Medica* that concerned plants and minerals of medical significance.

Diploid

A cell or a plant with two sets of chromosomes. One set comes from each parent. Diploidy is the normal state in most plants and animals. See also: Doubled monoploid, Haploid, Tetraploid, Triploid, Dikaryon.

Diptera

The Order of insects called flies, characterised by having only one pair of wings. This is one of the largest orders of insects. The Order includes biting insects such as black flies, mosquitoes, and sand flies. Houseflies are carriers of human diseases such as typhoid and cholera, and this was the first insect to develop resistance to DDT.

Dirty Dozen

The list of the twelve most persistent organic pollutants (POPs) banned at a United Nations convention in May 2001. Nine of the chemicals in this list are crop protection chemicals and, of these, eight are insecticides.

Discontinuity

See: Discontinuous pathosystem.

Discontinuous epidemic

See: Discontinuous pathosystem.

Discontinuous pathosystem

A pathosystem in which the parasitism is intermittent because there is a complete absence of host tissue at periodic intervals, such as during a tropical dry season, or a temperate winter. Discontinuous pathosystems involve seasonal host tissue, and they occur typically with annual plants, and the leaf parasites of deciduous trees and shrubs. Discontinuity confronts the parasite with three difficult problems, because it must survive the absence of host tissue, it must find a new host individual when tissue is again available and, if vertical resistance***s*** occur, it must match the host that it does find. Allo-infection is of primary importance in discontinuous pathosystems, and vertical resistance has a high survival value. See also: Continuous pathosystem.

Discontinuous variation

In genetic terms, variation among individuals may be continuous or discontinuous. Continuous variation means that there is every degree of difference between two extremes. Discontinuous variation means that a character is either present or absent, and there are no intermediates. Continuous variation results from quantitative inheritance, while discontinuous variation results from qualitative inheritance.

Disease

Plant diseases usually have the most colourful names, such as blight, downy mildew, powdery mildew, blast, rust, smut, smudge, wart, streak, blister, and scorch. Plant diseases are caused by parasitic organisms called pathogen, that are usually microscopic, and which include fungi, bacteria, phytoplasmas, viruses, and viroids. The development of a disease within a host population is called an epidemic.

Deficiency diseases are due to nutritional inadequacies and are best described as physiological disorders.

Disease cycle

See: Epidemic cycle.

Disease escape

For a variety of reasons, some individuals in a screening population may remain free of pests or disease. Also known as chance escape, this phenomenon can be very misleading because it is so easily confused with resistance. See also: inoculation, patchy distribution.

Disinfection

In a plant protection context, this term means destroying the initial inoculum in order to control the epidemic. Disinfection is undertaken most commonly with contaminated seed and infected seed. But it can also refer to storage containers, with a view to reducing post-harvest losses.

Disinfestation

This term means the same as disinfection except that it normally refers to insects.

Dissecting microscope

A low power, stereoscopic microscope with two optical systems that provide a three-dimensional view.

Dissemination

The geographical spread of pests or disease. The natural dissemination of fungi is usually by wind-borne spores, while insects usually travel by flight, often assisted by wind. However, dissemination can also occur with irrigation water, contaminated or infected seed, muddy boots or tractor wheels, international trade, travellers, etc.

Distal

That part of a plant organ that is most distant from its point of attachment. See also: Proximal.

Distribution, normal

See: Normal distribution.

Dithiocarbamates

Synthetic fungicides that are stable.

Diurnal

During daylight hours, as opposed to nocturnal.

Diversity

See: genetic diversity.

Dizygotic

Dizygotic twins develop as two separate embryos produced by two separate ova fertilised by two separate sperm. Also known as fraternal twins. See also: Monozygotic.

DNA

Di-ribo-nucleic acid. The protein which encodes genetic information, and controls all things inherited. In plants and animals, the DNA is located in the chromosomes.

Dodder

See: Cuscuta spp.

Dolichos lablab

See: Lablab niger.

Domestication

The process by which ancient cultivators changed wild plants into crop plants by artificial selection. Usually, domestication was a very gradual process in which cultivators tended to use their best plants as parents for the next crop, producing quantitative improvements. Occasionally, however, domestication would progress in sudden and dramatic developments, with qualitative changes, as when both the non-shattering and free-threshing forms of wheat were discovered. These changes occurred thousands of years ago, and the descendants of those forms have been in continuous cultivation ever since. Ancient domesticators often achieved results that modern plant breeding cannot improve as, for example, with pineapples, bananas, olives, and the classic wine grapes.

A few plant species were domesticated quite recently. These include rubber (Hevea brasiliensis) and oil palm (Elaeis guineensis).

Dominant character

A genetic character is described as dominant when its controlling allele eclipses the recessive allele.

Dormancy

Inactive as in sleep. Many seeds exhibit dormancy, which is a valuable ecological and evolutionary survival mechanism that ensures survival of the species in the event of some disaster that destroys all non-dormant individuals. Dormancy can be a nuisance in agriculture, and in plant breeding. It can often be broken by mechanical or chemical reduction of the seed coat, or by temperature treatment of the seed.

Dottato

An ancient Roman cultivar of fig that was mentioned by Pliny the Elder (23-79 AD) and which is still being cultivated in Italy. This is an example of an ancient clone demonstrating the durability and efficacy of horizontal resistance.

Doubled monoploid

A monoploid (i.e., haploid) cell or plant that has undergone a doubling of its chromosomes to produce a functional diploid. Doubled monoploids are produced artificially, usually by culturing a pollen mother cell, or a pollen cell, into a haploid plantlet, which is then stimulated chemically to

double its chromosome number. Alternatively, an unfertilised ovule can sometimes be made to grow into a haploid plantlet by pollination with pollen from a different species . Doubled monoploids are completely homozygous, and this can be very useful in various plant breeding procedures. (See also: Haploid, diploid , Tetraploid, Triploid).

Douglas fir

See: Pseudostuga menziesii.

Downy mildews

Plant parasitic fungi of the Order Peronosporales, so called because they produce a very light, white mildew on the external surfaces of the plant lesions, usually on the lower leaf surfaces. The best known members are potato blight (Phytophthora infestans) and downy mildew of grapes (Plasmopora viticola). Downy mildews were originally controlled by Bordeaux mixture.

Dried blood

Obtained from slaughter houses, dried blood is often used as an organic fertiliser. However, the supply is strictly limited.

Drought resistance

The ability of a plant to withstand drought. This property can be very valuable in areas of uncertain rainfall. For example, sorghum has greater drought resistance than maize, and is grown in many semi-arid areas for this reason.

Duram wheat

See: Triticum durum.

Durra

See: Sorghum bicolor.

Dwarf varieties

See: Wheat, and Rice.

Dysmicoccus brevipes

The mealy-bug that causes wilt of pineapples. There is great need for horizontal resistance to this pests but this is not a task for amateur breeders .

E

Early selection

Selection during an early generation after cross-pollination when the selected individuals are heterozygous. Early selection is usually acceptable in allogamous species but not in autogamous species. Its advantage is a considerable shortening of the breeding cycle. Its disadvantage is that heterosis may give a false impression of resistance and yield, and that recessive polygenes will remain unexpressed. These disadvantages are eliminated with late selection.

Echinochloa frumentacea

Japanese barnyard millet. This millet is the fastest growing of any cereal, and can produce a harvest in little more than forty days. It is grown as a minor cereal in the Orient and India, and as a fodder crop in North America where it can produce up to eight crops a year. A fun-project for amateur breeders .

Ecology

The study of the interactions of species , or populations, with each other, and with their environment. Ecology makes considerable use of systems theory, and the concept of the ecosystem. It also tends to emphasise the higher systems levels, and the holistic approach. See also: Pathosystem.

Economics, agricultural

One of the disciplines that make up crop science. Like general economics, agricultural economics can be divided into macro- and micro-economics. See also: Self-organising crop improvement.

Ecosystem

A biological system that occupies a specified area, and which involves the interactions of all the living organisms in that area, both with each other, and with their environment. A subsystem of the biosphere, defined by either geographical or biological boundaries.

Ecotype

A local variant that has been produced by selection pressures peculiar to its own locality within the ecosystem. Ecotypes are the result of micro-evolution and natural selection. See also: cultivar, Landrace, Agro-ecotype.

Edaphic

Pertaining to soils.

Eddoe

See: Colocasia esculenta.

Eelworm

The colloquial term for a nematode, or round worm.

Eggplant

See: Solanum melongena.

Elaeis guineensis

The oil palm, which is native to West Africa. This palm has the highest yield of vegetable oil of any crop. The oil is obtained from the fruit which contains two distinct types of oil. Palm oil is extracted from the soft fruit flesh, which contains 45-55% of oil. Palm kernel oil comes from the seed, which contains about 50% of oil. This is not a crop for amateur breeders .

Electron microscope

A microscope that uses electrons instead of light. It has the advantage of a far higher resolution that can show virus particles. But it is a very technical and expensive instrument.

Elephant garlic

See: Allium ampeloprasum.

Elephant grass

See: Pennisetum purpureum.

Elletaria cardomomum

Cardamom. This genus is native to S.E. Asia and is a member of the ginger family, Zingiberaceae. The fruits are widely used as a spice, and are particularly prized in Arab countries for adding to coffee. The plants are open-pollinated and offer scope for amateur breeders located in areas suitable for cultivation.

Elusine coracana

Finger millet, also known as African millet, as well as wimbi, bullo, telebun, and other vernacular names. It is an important crop in the drier areas of Africa and India, although sorghum and bulrush millet are more drought-resistant. It has a wide range of uses as flour, as an additive to various dishes, and for brewing. In a dry climate, it stores well for up to ten years. Finger millet is self-pollinated and

there are innumerable cultivar in both Africa and India. A suitable crop for amateur breeders , who should start by selecting within local landraces that are mixtures of inbreeding lines.

Emasculation

The physical removal of the anthers from a hermaphrodite flower, or the male flowers from a monoecious plant, in order to prevent self-pollination, and to compel cross-pollination. Alternative methods involve the use of a male-sterility gene, or a male gametocide.

Embryo

An unborn, unhatched, or ungerminated offspring. An embryo normally results from the fusion of a male gamete with a female gamete. However, in plants, nucellar embryos and apomictic seeds are also possible. See also: Metaxenia.

Emergent property

This concept was first defined by C.D. Broad some eighty years ago. An emergent property is one that emerges at a particular level of complexity, a particular systems level, but which cannot occur at a lower systems level. Thus, the system of locking of the gene-for-gene relationship is an emergent that is possible only at the systems level of the two interacting populations of the pathosystem. There must be a population of many different locks, and many different keys, if a system of locking is to function. At the lower systems levels of an individual lock, or an individual tumbler within a lock, a system of locking is impossible. The danger of doing research at too low a systems level is that an emergent may not be apparent. This is a major cause of suboptimisation.

Possibly the best example of emergent properties in biology is the schooling of fish, and the flocking of birds. A scientist studying a single fish in an aquarium, or a single bird in an aviary, cannot possibly observe the phenomenon of schooling or flocking because this property emerges only at the systems level of the population.

Empirical science

Science that emphasises facts, as opposed to concepts and theories. Its converse is rationalism. Either extreme constitutes bad science, and good science must be a blend of both facts and theories.

Endemic

1. An endemic species is one that is uniquely present in a locality. 2. An endemic disease is one that is continuously present, as opposed to an epidemic disease, which is intermittently present.

Endive

See: Cichorium.

Endosperm

The nutritive material, usually oil or starch, stored in some seeds.

Endothia parasitica

The fungus that was accidentally introduced to America from Europe early in the twentieth century. It causes 'chestnut blight' and it destroyed the wild chestnut forests of North America.

Engineering, agricultural

One of the many disciplines that makes up crop science. It is concerned primarily with agricultural machinery.

Ensete

See: Ensete ventricosa.

Ensete ventricosa

This member of the banana family is grown for food in Ethiopia. *Ensete edule* is also cultivated for food in this area. These crops are not recommended for amateur breeders .

Entomologists

Scientists who study the science of insects, or entomology.

Entomology

The scientific discipline concerned with the study of insects. Crop entomology is concerned with the study and control of insects that are crop parasites, crop pollinators, or agents of biological control and integrated pest management.

Entropy

The degree of disorder or randomness of the constituents of a system. In a closed system, entropy increases. That is, all energy gradients disappear, and complexity of pattern is reduced to total simplicity of pattern. Its converse is negative entropy (negentropy). In an open system, negentropy can increase. All living systems are open systems.

Environment

Approximately synonymous with habitat, the environment can be defined as all the external conditions that affect the survival and growth of an organism.

Enzyme

An organic catalyst, which can both promote and control a specific biochemical reaction.

Ephemeral

Short-lived, temporary.

Epidemic

Parasitism at the systems level of the population. An epidemic may be continuous or discontinuous, and this determines the relative importance of the two kinds of resistance, and the two kinds of infection. A continuous epidemic is sometimes called an endemic but this usage is best avoided. See also: Epiphytotic, Epizootic.

Epidemic cycle

An epidemic cycle occurs with a discontinuous epidemic, and it concerns the overall development of an individual epidemic, from the initial inoculum of the parasite to its population extinction. An epidemic cycle normally coincides with a growing season, such as a summer in temperate regions, or a rainy season in the tropics. However, the epidemic cycle of rubber in the Amazon Valley is defined by the deciduous nature of the rubber tree, whose leaf-fall is independent of season in this continuously warm and wet environment.

Epidemiological competence

A parasite can cause an epidemic only if it has epidemiological competence in the area in question. The level of epidemiological competence can vary from one area to another, and from one season to another, and it is controlled mainly by climatic factors such as temperature and humidity. For example, the maize disease called 'tropical rust' (Puccinia polysora) lacks epidemiological competence outside the lowland tropics. Maize cultivar in Europe are highly susceptible to this disease, but they are not vulnerable to it, because of its inability to cause an epidemic in a temperate climate. The susceptibility of these European maize cultivars becomes apparent only if they are cultivated in the lowland tropics. Variation in epidemiological competence explains the need for On-site selection when breeding for horizontal resistance.

Epidemiology

The study of epidemics, which requires both a holistic and a mathematical approach.

Epidermis

The outermost tissue of leaves and herbaceous stems. The epidermis usually consists of a single layer of cells, often protected by a layer of wax. The pattern of cells, similar to that of a jigsaw puzzle, is often characteristic of a particular species, and can be used during research for plant identification in animal feces, and in certain forensic situations. Stomata are a component of the epidermis.

Epiphyte

A plant that lives on another plant without being parasitic. For example, moss and lichen growing on a branch of a tree are epiphytes.

Epiphytotic

A somewhat pedantic term, sometimes used to describe an epidemic in plants, on the grounds that the Greek root *demos* refers to people. But the term 'epidemic' is an English word, and common usage allows it to be applied to plants and animals. Note that epiphytology is the study of epiphytes, and that the study of epiphytotics is epiphytotiology. These usages are not recommended. See Also: Epizootic.

Epizootic

A somewhat pedantic term (pronounced epi-**zoh**-otic), sometimes used to describe an epidemic in animals. The study of epizootics is epizootilogy. These usages are not recommended. See also: Epiphytotic.

Eradication

Eradication, like the word 'unique', is a word that must be qualified with caution. Eradication is an absolute, which either does or does not succeed. In the present context, it means the total and complete elimination of a pest or disease, within a stated area. For example, eradication of the accidental introduction of Colorado beetle of potatoes in Germany was successful, but attempts to eradicate a later introduction in France failed, and this pest then became firmly established in Europe. Occasional appearances of the beetle in Britain have been successfully eradicated.

Eragrostis curvula

A subtropical fodder grass native to Southeast Africa.

Eragrostis tef

This cereal is unique to Ethiopia where it is used for the production of the staple dish 'njera'. It is also an excellent fodder crop. The self-pollinated flowers are very small and this makes cross-pollination extremely difficult. Not recommended for amateur breeders .

Ergotism

The human disease caused by the ingestion of poisonous ergots. The symptoms of ergotism are a constricting of the blood vessels which can lead to gangrene, abortion in pregnant women, and death. Before the discovery of the cause of this disease, ergots were common in rye produced in a wet summer, and ergotism was a powerful incentive for the cultivation of potatoes in the rye districts of

Europe, particularly in eastern Germany, Poland, and western Russia. Today, ergots are recognised and easily separated from rye before milling. They have a market value in the pharmaceutical industry as an aid to childbirth.

Ergots

Toxic black bodies produced in rye by the fungus Claviceps purpurea. Toxic ergots are also produced by Claviceps penniseti in bulrush millet. When ingested, ergots are the cause of the human disease ergotism.

Erosion of horizontal resistance

A quantitative loss of horizontal resistance. There are four categories of erosion. (1) A host erosion results from genetic changes in the host. This can occur during the cultivation of a genetically flexible crop, but not during the cultivation of a genetically inflexible crop. It can also occur during the breeding of any crop in the absence of a parasite, particularly if the screening population is protected by a functioning vertical resistance or by a pesticide. It is then known as the vertifolia effect. (2) An environment erosion results when a cultivar is taken from an area of low epidemiological competence, and is cultivated in an area of high epidemiological competence. (3) A parasite erosion results from genetic changes in the parasite. This is important only occasionally, and only with facultative parasites. (4) A false erosion results from sloppy experimental work, when a cultivar thought to be resistant is later found to be susceptible.

Erysiphales

The plant-pathogenic powdery mildews, characterised by growing on the external surfaces of plants. This Order contains six genera defined by the cleistothecia, which may have one or several asci, and various types of appendage: Erysiphe (several asci, simple appendages), Sphaerotheca (one ascus, simple appendages), Microsphaera (several asci, dichotomous appendages), Podosphaera (one ascus, dichotomous appendages), Phyllactinia (several asci, rigid appendages), and Uncinula (several asci and curled appendages). The imperfect stage, consisting of hyphae and conidia only, is called Oidium.

Erysiphe

A genus of the Erysiphales, or powdery mildews. The most important species are Erysiphe graminis, which attacks wheat, barley, rye, oats, and many fodder grasses; Erysiphe polygoni, which attacks peas, clovers, and swedes; and Erysiphe cichoracearum, which has a wide host range that includes

various cucurbits, tobacco, and many ornamentals. vertical resistance are common and there is considerable scope for breeding for horizontal resistance by amateurs.

Erythroxylon coca

Coca, the source of cocaine, native to tropical and subtropical South America.

Escapes from parasitism

See: Chance escape.

Essential oils

This term means 'essence' rather than indispensable. Essential oils are obtained from a wide variety of plants, and the oil is extracted either by distillation or by solvents, which are then evaporated off and re-used. Most essential oils are used in the perfume industry but a few have medicinal uses. Many of them offer scope for amateur breeders who, however, should be aware of the very limited markets that are easily saturated.

Ethrel

The trade name for ethephon, which is 2-(chloro-ethyl)-phosphonic acid. It is an ethylene (ethene) generator when applied to plant surfaces. Ethylene has numerous physiological effects, such as inducing synchronous flowering and fruit ripening, which assists mechanical harvesting, etc. Ethrel is also used as male gametocide to induce random cross-pollination for recurrent mass selection in inbreeding cereals such as wheat.

Eucalyptus spp.

A genus of trees, known as gum trees, originating in Australia. These fast-growing trees are an excellent source of fire-wood in areas that are short of fuel for cooking. They are now widespread throughout the tropics and subtropics. There is considerable scope for amateur breeders to select within existing populations for fast growth.

Eucaryote

All organisms, other than bacteria and cyano-bacteria, are eucaryotes, and they are characterised by consisting of cells that contain a distinct nucleus enclosed in a membrane and containing chromosomes, as well as other specialised organelles. See also: Procaryote.

Eugenia carophyllus

The clove tree, which originated in the spice islands of the Moluccas, in eastern Indonesia. The cloves of commerce are the dried, unopened buds, and they became a monopoly of the Portuguese in the early sixteenth century. The Dutch gained the monopoly in 1605, and kept it for two centuries.

Later, cloves were taken to many areas, but they flourished best in Zanzibar, which became the main producer. Cloves are now grown increasingly in Indonesia, where they are in great demand for clove cigarettes.

Evergreen

Evergreen trees and shrubs have persistent leaves and continuous pathosystems and, consequently, a gene-for-gene relationship and vertical resistance will not evolve in them. A gene-for-gene relationship can evolve only in a discontinuous pathosystem. See also: Deciduous.

Evolution

The results of natural selection, often described as the survival of the fittest. Macro-evolution (or Darwinian evolution) occurs during periods of geological time, and involves genetic changes that are both new, and irreversible. New species are formed by macro-evolution. Macro-evolution also produces an increase in complexity, and new genetic code. micro-evolution occurs during periods of historical time, and it involves genetic changes that are not new, and that are reversible. It does not increase complexity, but merely re-organises existing complexity. Nor does it produce new genetic code; it merely re-arranges existing code. The formation of ecotypes is micro-evolution by natural selection, and the production of cultivar or agro-ecotypes, by plant breeding is micro-evolution by artificial selection.

The mechanism of evolution has long been disputed and is now thought to be the result of natural selection operating on ***emergents*** at all systems levels.

Examples of horizontal resistance

See: horizontal resistance, examples.

Exobasidium vexans

The fungus that causes blister blight of tea. There is great scope for selection for horizontal resistance within existing crops grown from true seed, as these crops constitute a vast hybrid swarm.

Exoskeleton

The hard external surface of all arthropods, including the insects. Because the exoskeleton cannot expand or grow, it must be shed or moulted at several stages during the growth of the individual arthropod. See also: Instar.

Extension service

The service that provides technical and specialised information to farmers. In the USA, the extension officers are known as county agents.

Extensive crop

A crop that has low production costs and profit margins. Soybeans, maize, and wheat are typical extensive crops in North America. See also: intensive crop.

Extinct wild progenitors

Crops whose wild progenitors have been harvested by ancient hunter-gatherers to extinction. The domesticated forms survived because farmers are always careful to preserve propagating material of their crops. But food gatherers are often careless about wild plants and, in the course of a few human generations, they would never notice the decline in numbers that was occurring because of their activities. Among ancient clones, this loss of wild progenitors has occurred with black pepper, garlic, ginger, olive, saffron, and turmeric. Among other crops, a loss of wild progenitors also occurred with apple, broad bean, cassava, chillies, green peas, onions, peanuts, soybean, sweet potato, tea, turmeric and yams .

Extinction

The total loss of a species resulting from either natural competition, or the activities of humankind.

F

f.sp.

See: forma specialis.

F_1, F_2, etc.

The letter 'F' stands for 'filial' and refers to the generation. Thus F_1 is the first generation (sons), F2 is the second generation (grandsons), and so on, following the cross of two parents, that are labelled P. This nomenclature is used mainly with autogamous crops and refers to the self-pollinating generations that follow cross-pollination.

Facultative parasite

A parasite that is able to extract nutrients from both a living plant host, and from dead plant material. See also: Obligate parasite.

Fagopyrum spp.

Buckwheat. This one of the pseudo-cereals. Three species are cultivated. Fagopyrum esculentum is the common buckwheat, F. cymosum is the perennial buckwheat, and F. tataricum is the Tartary

buckwheat. The buckwheats are a very ancient crop originating in China. They are not very important commercially but they have persisted agriculturally for many millennia. They are open-pollinated and amenable to general improvement by amateur breeders using recurrent mass selection. There is room for improvement in horizontal resistance to both pests and disease.

Fagus sylvatica

The beech. A hardwood tree used in plantation forests. Not recommended for amateur breeders.

Family

A taxonomic group of closely related genera.

Family selection

When working with pure lines crops, the technique of family selection, or 'head to row' selection, can lead to a more rapid genetic advance. Family selection means that all the seeds derived from one 'head' or 'ear', or from one plant, constitute a 'family'. All the members of one family are planted together, in one row, or in one small plot. The selection is in two stages. The first stage selects the best families. The second stage selects the best individual plants within those best families. Only the best individuals, from the best families, are kept. Note: This term has nothing to do with the taxonomic group called a family.

FAO

See: Food & Agriculture Organisation of the United Nations.

Farm animal breeding

The breeding of farm animals deserves cursory mention in a guide to plant breeding for one simple reason. There are no single-gene characteristics of any economic significance in farm animals. The total domination, by Mendelian breeders, that occurred in professional plant breeding, has been avoided in animal breeding. The improvement of farm animals has invariably involved population breeding, often conducted by individual farmers. However, a feature common to both kinds of breeding is that heterosis has been exploited in poultry breeding.

Farmer participation schemes

The term 'farmer participation' in plant breeding is a somewhat belated attempt to allow farmers some influence in the production of new cultivar. The participation can vary from the one extreme of a farmer-survey to determine farmer preferences, to the other extreme of the farmers doing the actual breeding, usually as members of a breeding club, possibly under the guidance of a professional breeder.

Farmer selection

This is an aspect of some plant breeding programs in which the farmers make the final selection of cultivar. Each farmer is given a different group of new clones or pure lines of a crop, emerging from a breeding program. He is asked to grow them and choose those he likes best. His favourites become his own property, with the sole provision that the breeder may have some of them for the purpose of further breeding. The farmer may then grow that material for his own use, and give or sell propagating material to his neighbours. The participation of farmers' wives is important in this process, particularly in the non-industrial countries. This farmer selection represents one of the first steps in self-organising crop improvement.

Farmer's privilege

This is a clause in most the plant breeders' rights legislation of most countries that permits a farmer to use some of his own crop of a registered cultivar for seed on his own farm only. He may not sell any of that crop for seed unless licensed to do so. However, some seed companies deny this right, particularly with respect to GMOs, by a special clause in the sale contract. See also: Breeders' rights.

Farmyard manure (FYM)

The rotted excrement of farm animals, mostly cattle, pigs, and horses, but also poultry, and usually mixed with straw, used as a fertiliser for crops. Organic farmers insist on the use of natural (i.e., non-synthetic) fertilisers and FYM is the most important of these. Unfortunately, there is never enough FYM to supply the total farming need. Imagine, for example, trying to find enough FYM to fertilise the entire corn belt of the USA.

Feed grains

Grains, mostly cereals, used for feeding farm animals. Maize is the most important of the feed grains.

Feedback

The modification or control of a process or system by its own results. Feedback can be either positive or negative. Positive feedback leads to increase and is destabilising. For example, population growth depends on the number of reproducing individuals. As the population increases, the rate of growth also increases, and there can be a population explosion. Negative feedback leads to stability. For example, an excess of individuals limits the available food, and leads to a loss of breeding individuals. The population size is then stable. See also: Homeostasis.

Female sterility

Some crops (e.g., banana) do not produce true seed because of a female sterility. However, male sterility is much more common, and is more useful in plant breeding.

Fermentation

Fermentation is the alteration of biological substances by either microbiological or chemical means. Microbiological fermentation may be constructive (e.g., the production of penicillin) or destructive (e.g., the breakdown of sugars into carbon dioxide and alcohol, in beer, wine, and bread). Chemical fermentation occurs without the participation of micro-organisms and it occurs, for example, in the fermentation of green tea into black tea, and in the production of silage.

Fertile Crescent

An archaeological term used to describe the fertile area of ancient agriculture that extends from modern Israel in a wide arc to the valley of the Tigris and Euphrates rivers.

Fertilisation

This term, which is derived from 'fertile', has two meanings in crop science. It can refer to the feeding of crops with farmyard manure, or artificial fertilisers; and it can also refer to the sexual fertilisation of a female ovule by a male pollen cell.

Festuca arundinacea

Fescue is a grass used widely for sown pastures. There are technical problems in its breeding.

Feterita

See: Sorghum bicolor.

Fibre

Plant fibres give strength to stems. Some of them can be retted to provide bast fibres for the manufacture of coarse materials such as sacking, sails, and tarpaulins. The most important of these are flax (Linum usitatissimum), hemp (Cannabis sativa), Manila hemp, or abaca (Musa textilis), Sunn hemp (Crotalaria juncea), jute (Corchorus spp.), and sisal (Agave sisalana).

With the development of plastic fibres, the demand for natural bast fibres has decreased dramatically. These crops are now relatively unimportant. Flax, hemp, and sunn hemp are easy to breed, but Manila hemp and sisal are not recommended for amateur breeders . Note that cotton is a plant fibre, but it is not a bast fibre and it remains a very important crop.

Ficus carica

The edible fig. This is a vegetatively propagated crop of very ancient domestication, which originated in southern Arabia. It has been cultivated in the Mediterranean basin since antiquity and, more recently, it has been taken to all suitable areas of the world. Several Mediterranean countries produce large amounts of dried figs, and fig paste, for export. The so-called fruit is a complex organ containing numerous minute flowers on its inner surface, and these are pollinated by the fig wasp (Blastofaga psenes), which enters through a very small pore at the distal end. About 600 distinct clones have been recognised. Dottato is an ancient Roman cultivar of fig that was mentioned by Pliny the Elder (23-79 AD) and which is still being cultivated in Italy. These figs are of interest because of their ancient clones, which demonstrate both the utility and the durability of horizontal resistance. Fig breeding is technically complicated, and is not recommended for amateur breeders .

Field resistance

Resistance that is apparent in the field but not in the laboratory. This vague term has been widely misused and is best avoided. It is sometimes used, incorrectly, as a synonym for horizontal resistance. See also: Tolerance.

Field screening

A screening operation that is conducted in the field, as opposed to the greenhouse, or the laboratory. Because of the necessity for on-site selection, amateur breeders working with horizontal resistance should always employ field screening, except for a final laboratory screening for certain aspects of quality, which cannot be determined in the field.

Field trials

Typically, these are statistical trials carried out under field conditions. The statistics involved used to be the bane of agricultural students' lives but these days they are handled entirely by computer. Note that statistical trials are very valuable when comparing cultivar, spacing, or fertiliser use for variables such as yield and crop quality. But they can be very misleading when comparing treatments for the control of crop pests and diseases, because of parasite interference. Note also that statistical trials measure the probability of small differences being real differences. Big increases in yield or ***horizontal resistance*** do not need statistical trials and, for this reason, they are not usually necessary for amateur breeders .

Fig

See: Ficus carica.

Filbert

See: Corylus avellana.

Finger millet

See: Eleusine coracana.

Fir, Douglas

See: Pseudostuga menziesii.

Fire-blight

A disease of trees in the Rosaceae family (e.g., apple, pear, hawthorn) caused by a bacterium called Erwinia amylovora. Diseased trees appear to have been scorched by fire.

Flatulence

Most grain legumes cause flatulence because they contain proteins that are indigestible, and which ferment in the lower bowel to produce carbon dioxide and other gasses. Some reduction of the flatulence factors is possible by breeding, and this could be a breeding objective of amateur breeders .

Flax

See: Linum usitatissimum.

Flecks, hypersensitive

See: Hypersensitive.

Flexibility

See: Genetic flexibility.

Flocking of birds

The phenomenon in which birds in flight behave as a single entity. This behaviour is thought to provide protection against predators. It is an excellent example of an emergent property that is observable only at the systems level of the population. A scientist studying a single bird (e.g., a pigeon) in an aviary could not observe or analyse the flocking habit. This failure to work at the higher systems levels constitutes suboptimisation. See also: Schooling, n/2 model.

Floret

A single flower in an inflorescence that is made up of many flowers grouped together.

Flower

The reproductive structure of seed-bearing plants, containing either specialized male or female organs (dioecious, monoecious), or both male and female organs (hermaphrodite), such as stamens and a pistil, enclosed in an outer envelope of petals and sepals.

Fodder beet

See: Beta vulgaris.

Fodder crop

Any crop that is grown for feeding farm animals, such as hay, turnips, mangolds, fodder beet, fodder legumes, and fodder grasses.

Fodder grasses

Members of the botanical family Gramineae cultivated for feeding farm animals, as hay, silage, or pasture. See also: Tropical grasses, Pasture grasses.

Fodder legumes

Members of the botanical family Leguminoseae cultivated for feeding farm animals. This tem includes alfalfa, clovers, and vetches, but the pulses are not generally used as fodder.

Foliage

See: Leaf.

Fomes spp.

Basidiomycete bracket fungi that attack various species of forest trees, including rubber in the Amazon Valley. The brackets grow out of the base of the tree and have spore-bearing tissues in the form of pores (as opposed to gills) on the lower surface.

Food & Agriculture Organisation of the United Nations (FAO)

FAO has its headquarters in Rome, Italy, and was one of the first agricultural institutions to promote the use of horizontal resistance in its International Program for Horizontal Resistance (FAO/IPHR).

Food chain

The food chain is an ecological concept, and it is a form of eating hierarchy, with the smallest and most numerous animals at the bottom of the hierarchy. These animals may eat plants or each other. With increasing rank, the numbers get smaller, and the animals get larger. As a general rule, the animals of one rank eat animals in a lower rank (except for parasite which may inhabit animals much larger than themselves). Each rank may be thought of as a link in a chain that stretches from the lowest to the highest level. Animals in any rank may also eat plants.

A low concentration of toxins, particularly fat-soluble and water-insoluble toxins such as DDT, in the environment tends to increase as it travels up the ranks of the food chain (see biomagnification), and it may reach dangerous levels at the top of the chain, in birds of prey, and large mammals, including people.

Foreign parasites

species of plant parasites that are absent from an area, but which could become serious if accidentally introduced. Foreign parasites are the main cause of crop vulnerability.

Forestry

The cultivation of trees for timber. This term also includes the exploitation of natural forests for timber. Many forest tree species offer scope for amateur breeders, mainly by selection within existing populations. However, because most forest species are open-pollinated, a good parent tree will be only a half-sib.

forma specialis

Usually abbreviated to 'f.sp.' (singular) and 'f.spp.' (= *formae speciales,* plural) this taxonomic term means 'special form' and is a subdivision of a species of a parasitic fungus that is defined by its host. Thus Fusarium oxysporum has various *formae speciales* defined by hosts as widely different as banana, flax, tomato, and date palm. A *forma specialis* can parasitise only its own host genus, and there are usually wide differences in the levels of horizontal resistance within that genus.

Foundation stock

The original source of seed from which all other grades of seed are produced.

Four-angled bean

See: Psophocarpus tetragonobolus

Foxtail millet

See: Setaria italica.

Fragaria ananassa

The cultivated strawberry, which is one of the most popular and widely cultivated of the soft fruits. It is an open-pollinated, dioecious, octoploid (2n = 8x = 56) and is a member of the botanical family Rosaceae. Each cultivar is a clones that is propagated vegetatively by runners. The species exhibits very wide variation and there is scope for amateur breeders. The main breeding objectives, other than yield and fruit quality, are horizontal resistance to various pests and diseases. Suitability for mechanical harvesting also has a high priority, and amateur breeders should know something of the machines available.

Frankincense

Known as olibanum in its centre of production in eastern Africa, frankincense (Old French = *franc encens* = pure incense) is an aromatic gum obtained from trees of the genus *Bowellia* and, when thrown on to glowing charcoal, it produces an aromatic smoke. Little scope for amateur breeders.

Free enterprise in plant breeding

For most of the twentieth century, plant breeding was considered an esoteric subject that could be handled only by highly trained geneticists. This was largely because of the many difficulties encountered by pedigree breeding for single-gene, vertical resistance. With the very different approach to breeding for horizontal resistance, using population breeding and recurrent mass selection, plant breeding is so easy that it can be undertaken by amateurs, particularly when they organise themselves into a plant breeding clubs. When there are many such clubs in the world, there will be widespread free enterprise in plant breeding.

Free trade

Free trade was the key to Adam Smith's (1723-90) economic theories, which he published in *The Wealth of Nations* in 1776. His ideas were closely similar to those of modern complexity theory, which recognises the importance of self-organisation in a non-linear system.

Frequency of parasitism

The frequency of parasitism is the proportion of host individuals that are parasitised. The injury from parasitism is the actual amount of damage done to an individual host, or the average amount done to a host population, by the parasite. In a wild plant pathosystem, the injury from parasitism is inversely proportional to the frequency of parasitism. That is, the higher the frequency, the lower the injury, and, conversely, the higher the injury, the lower the frequency. In this way, the total damage from parasitism never exceeds a tolerable level that does not impair the host's ability to compete ecologically and evolutionarily. vertical resistance, with its system of locking, reduces the frequency of parasitism. horizontal resistance, as a second line of defence, reduces the injury from parasitism. Continuous plant pathosystems, that have horizontal resistance only, usually have a high frequency of parasitism, and a low injury from parasitism.

Frost

Frost damage to frost-sensitive plants can easily be mistaken for an infectious disease. See: Physiologic disorder.

Fruit

In its wide botanical sense, a fruit is any ripened ovary, or group of ovaries, and the associated tissues. More generally, the term is restricted to those fruits, which offer a reward, in the form of sweetness and food, to animals that eat the fruit and unconsciously spread the seed, often in feces, which are deposited far from the parent plant. The production of true seed in fruit, often as a result of cross-pollination, is an essential aspect of plant breeding. In a culinary context, savoury fruits (e.g., tomato, cucumber, peppers, egg plant) are called vegetables, and sweet vegetables (e.g. rhubarb) are called fruits.

Fu-fu

A traditional West African dish originally made from yams (***Dioscorea***) but more recently from Xanthosoma sagittifoilium.

Fuggle hops

See: Humulus lupulus.

Fumigation

Fumigation is aimed at killing pests with a gas or smoke. The most frequent use is in greenhouses and warehouses. A specialised use is in the treatment of imported produce to keep out foreign pests. One of the most effective fumigants was methyl chloride, but this substance is now banned because of the damage it does to the ozone layer.

Fungi

Originally classified as non-flowering plants that lacked chlorophyll, fungi are now put in a separate kingdom. Most fungi are microscopic and haploid, producing a short-lived diploid form only as a result of sexual fusion. The fungi are divided into the Ascomycetes (having ascospores), the Basidiomycetes (having basidiospores), the Phycomycetes (having sexual reproduction that does involve either ascospores or basidiospores), and the imperfect fungi, that have no known sexual reproduction. Many of the fruiting bodies are macroscopic, and are known as mushrooms, toadstools, puff balls, etc. Most fungi are very valuable reducers, but a few are parasitic on plants and the cause of plant diseases.

Fungicide

A pesticide that kills a fungus. Most fungicides are synthetic and are proprietary compounds that are used to control plant diseases, but a few have medicinal, veterinary, and domestic uses. The most famous, and spectacularly successful fungicide was Bordeaux mixture, discovered by Millardet in

France in 1882. A protective fungicide is one that is entirely external and which prevents infection. It thus protects the host plant from disease. A systemic fungicide is one that is absorbed by the plant and can kill an internal fungus. It thus cures a disease.

Fusarium oxysporum

This fungus causes wilt diseases in many different hosts. The pathologically induced wilt is usually caused by a combination of xylem vessels that are blocked by the presence of the fungus, and by toxins produced by the fungus.

This fungus has a very wide host range and its various formae speciales are usually named after their hosts, or the area of their first discovery. Thus f.sp. *cubense* causes Panama disease of banana, f.sp. *albedinis* causes Bayoud disease of date palms, f.sp. *lycopersici* causes tomato wilt, f.sp. *apii* causes celery wilt, f.sp. *conglutinans* causes cabbage yellows, f.sp. *dianthi* causes carnation wilt, f.sp.*lini* cause flax wilt, f.sp. *pisi* cause pea wilt, f.sp. *vasinfectum* causes cotton wilt, and so on. amateur breeders can accumulate horizontal resistance in the annual hosts but crops such as banana and date palm are definitely not recommended for them.

Note that the various f.spp., of this fungus exhibit a differential interaction with their host species, but that this differential interaction is not due to vertical resistance. See also: Verticillium.

FYM

See: Farmyard manure.

G

Gaia hypothesis

The hypothesis developed by James Lovelock that postulates that the entire biosphere is a single, self-organising, non-linear system.

Gall

An abnormal plant growth, usually more or less spherical, and usually induced by a plant parasite.

Gamete

A sexual haploid cell that may be male of female, and which unites with another gamete of the opposite sex to produce sexual recombination in a zygote, which is diploid . In plants, the male gametes are called pollen, and the female gametes are ovules.

Gametic sterility

Sterility that results from the fact that either the male or the female gametes are infertile.

Garcinia mangostana

The mangosteen. A delicious fruit native to S.E. Asia. The plant is a dioecious tree, and the seeds are parthenogenetic. Not recommended for amateur breeders .

Garlic

See: Allium sativum.

Gaümannomyces graminis

Previously called Ophiobolus graminis, this fungus causes 'Take-all' disease of wheat and other cereals.

Gaussian curve

The bell-shaped curve of a normal distribution.

Gene

The unit of inheritance which is carried on a chromosome. An inherited character may be controlled by a single gene (i.e., a Mendelian gene), or it may be controlled by many genes (polygenes). See also: Allele.

Gene banks

The popular term for collections of plants made for purposes of genetic conservation. A gene bank may consist of collection of seeds, which have to be re-grown periodically, or of an arboretum of tree crops.

Gene frequencies

Mendelian breeding emphasises single genes, and gene-transfers by pedigree breeding. Biometricians' breeding emphasises polygenes, and changes in their gene frequencies by population breeding, recurrent mass selection and transgressive segregation. For example, horizontal resistance is a polygenic character, and its level can be increased by increasing the frequency of its polygenes in a single individual.

Gene pool

The totality of genes possessed by a population of sexually reproducing organisms.

Gene-for-gene relationship

A gene-for-gene relationship exists when each gene for resistance in the host has a corresponding (or matching) gene for parasitic ability in the parasite. This phenomenon is the definitive characteristic of

the term vertical, and the concept of the vertical subsystem. The gene-for-gene relationship was discovered by H.H. Flor in 1940. When the host and parasite genes match, the vertical resistance does not operate, the infection is successful, and parasitism occurs. When the genes do not match, the vertical resistance functions, the infection is unsuccessful, and parasitism does not occur.

The sole function of the gene-for-gene relationship is to control the population explosion of an r-strategists parasite, which usually has an asexual reproduction that leads to a particularly rapid multiplication. This control is commonly achieved by reducing the proportion of allo-infections that are matching infections. But it can also function by reducing the growth, and hence the reproduction, of a non-matching parasite (see quantitative vertical resistance). A gene-for-gene relationship will evolve only in a discontinuous pathosystem, and in seasonal host tissue (i.e., annual plants, or the leaves and fruit of deciduous trees or shrubs).

For mathematical reasons, it is thought that all individuals of both host and parasite in a wild plant pathosystem have half of the total genes available. This provides the maximum ***heterogeneity***, and the maximum effectiveness, for a given number of pairs of genes in a system of biochemical locks and keys (see n/2 model).

General systems theory

The general systems theory concerns the properties that systems have in common. It is often helpful to study a system in terms of this theory, and in terms of other systems. There are many different kinds of system, such as solar systems, political systems, ecological systems (ecosystems), mechanical systems, legal systems, electrical systems, and so on. The concept of the pathosystem is based on the general systems theory.

Systems theory is now divided into the general systems theory and complexity theory, which developed out of it. Systems theory is based on the concept of a pattern, and of systems levels, which are patterns of patterns. Thus a book is a pattern of chapters, each of which is a pattern of paragraphs, and so on down to words and letters. In biology, a population is almost synonymous with 'systems level'. Thus a forest is a population of trees, a tree is a population of leaves, a leaf is a population of cells, and so on.

Key aspects of systems theory involve the concepts of suboptimisation, emergent properties, and the holistic approach.

See also: Complexity theory, Linear systems, Non-linear systems.

Generation

A plant generation is generally considered to be the life span starting from seed and extending to the next production of seed. Some annual plants produce up to five generations per year. At the other extreme, some trees require many decades to complete a single generation. In plant breeding, one breeding cycle may embrace several plant generations, such as a multiplication generation, and selfing generations for single seed descent and late selection.

Genetic advance

The increase in the level of a quantitative variable that results from recurrent mass selection . For example, after one screening generation, there might be a 5% increase in the yield, or in the level of horizontal resistance to a particular species of parasite.

Genetic base

The totality of polygenes at the start of a population breeding program. Consider a simplified model. Ten parents each possess 10% of the polygenes controlling horizontal resistance. Each parent is thus very susceptible, and the parent population is also very susceptible. But each parent possesses polygenes that no other parent possesses. This means that the genetic base contains 100% of the polygenes controlling horizontal resistance. The purpose of the population breeding is to bring all these polygenes together in one individual by recurrent mass selection and transgressive segregation.

In practice, some 10-20 different parents, consisting of modern cultivar, preferably originating from independent breeding programs, will normally provide an adequate genetic base for a horizontal resistance breeding program. If the base proves to be inadequate, it can always be widened at a later stage by adding new parents to it.

Genetic code

The system of genetic information storage in DNA and RNA molecules in living organisms. The genetic code is analogous to writing, as a method of storing information.

Genetic conservation

The preservation of genetically controlled characters in gene banks, which consist either of stored seeds, or of living museums in botanic gardens and arboretums. The concept of genetic conservation was first developed by Mendelians with respect to vertical resistance genes. It is of relatively minor importance for biometricians, and polygenically inherited characters such as horizontal resistance. However, the conservation of old cultivar is of considerable importance to organic farmers, at least until such time as superior, new, horizontally resistant cultivars become available.

Genetic diversity

Genetic diversity means that the individuals within a population differ in their inherited attributes. Wild plant populations are typically diverse. Most subsistence crops in tropical countries are also diverse. But modern commercial crops usually have genetic uniformity. A genetically diverse population has genetic flexibility. A fundamental ecological principle states that diversity leads to stability.

Genetic engineering

A technique that makes it possible to change the genetic make-up of an individual or species , by introducing a gene from a different species. Of necessity, this technique can work only with single-gene characters, and its scientific popularity is responsible for much of the regrettable neglect of the far more important many-gene (polygenic) characters.

Genetic flexibility

A genetically diverse population has genetic flexibility in the sense that it can respond to selection pressures. For example, if a host population has too little horizontal resistance, it will gain resistance. This happens because resistant individuals, being less parasitised, have a reproductive advantage over susceptible individuals that are more heavily parasitised. Both the proportion of resistant individuals, and the levels of resistance (see transgressive segregation), will be increased accordingly in the next generation. See also: Genetic inflexibility.

Genetic homeostasis

The tendency of a population to maintain a genetic composition that provides an optimum balance with its environment. See also: Homeostasis.

Genetic inflexibility

Most modern cultivars are either pure lines or clones, and they are genetically inflexible in the sense that they do not respond to selection pressures during cultivation. This is a valuable characteristic because it ensures that useful agricultural properties are not lost. See also: Genetic flexibility.

Genetic line

A line of descent in which each generation is descended from, and related to, the previous generation.

Genetic male sterility

See: Male sterility.

Genetic modification

A term used by molecular biologists to describe the results of genetic engineering. It is an unfortunate choice of words, which is best avoided, because any form of breeding constitutes genetic modification.

Genetic source of resistance

Mendelian breeders working with single-gene resistances must first find a genetic source of resistance, usually in a wild progenitor. This concept is now so pervasive that many believe the only way to breed for horizontal resistance is to first find a source of resistance. This is incorrect, as polygenic characters cannot be transferred in the way that single-gene characters are transferred, either by back-crossing or by genetic engineering. Breeding for horizontal resistance involves changing gene frequencies, and this can be achieved with susceptible parents using recurrent mass selection , provided that the genetic base is wide enough.

Genetic uniformity

A genetically uniform population in which all the individuals are identical. Such a population lacks genetic flexibility in the sense that it cannot respond to selection pressures. For example, if a genetically uniform host population has too little horizontal resistance, it cannot gain more resistance, because all the individuals have an equal level of resistance, and are equally parasitised. No individual has a reproductive advantage over any other individual and, consequently, there will be no change in the level of resistance in the next generation. See also: Genetic flexibility.

Genetic uniformity means that all the individuals within a population are identical in one or more of their inherited attributes. Modern crops are typically uniform because they are cultivated as pure lines, hybrid varieties, or clones. A genetically uniform population has genetic inflexibility and this is desirable in agriculture because it ensures that valuable characteristics will not be lost. See also: genetic diversity.

Genetically modified organism (GMO)

Any organism that had been modified by genetic engineering. The organisms involved range from micro-organisms modified to produce complex pharmaceuticals, to herbicide-resistant and parasite-resistant crops, and pigs intended to provide transplant organs for humans.

Genetically modified pharmaceuticals

Some rare pharmaceutical products can be produced in quantity by genetically modified micro-organisms, and this is a more acceptable application of genetic engineering that the use of GMOs in

agriculture. This is because no alternatives to these often essential drugs exist, and the patient either takes them or does without. Even if these drugs did have long-term adverse effects, this is usually considered less damaging to the patient than having no drugs at all. In comparison, there is much less justification for the use of genetically modified crops in agriculture.

Geneticist

A scientist who studies genetics. Plant and animal breeders are often called applied geneticists.

Genetics

The study of biological inheritance. There are two branches of genetics called the Mendelian and the biometrical. Mendelians study single-gene characters, which are either present or absent with no intermediates. Biometricians study many-gene (polygenic) characters, which are continuously variable between a minimum and a maximum. Some scientists recognise a third branch called population genetics, which studies the changing frequencies of Mendelian genes within a natural population. However, this term should not be confused with the very different population breeding. Obviously, a good geneticist studies all aspects of genetics equally. Plant and animal breeding are sometimes described as applied genetics.

Gene-transfer breeding

See: Pedigree breeding.

Genome

The monoploid set of chromosomes which, in a homozygous plant, occurs in a gamete, and consists of all the genes. A term often used loosely to mean the complete set of genes in a plant.

Genotype

The genetic constitution of an organism, as opposed to its actual appearance, which is called the phenotype. The distinction allows for recessive genes and polygenes, which may be present but not expressed because of heterozygosity.

Genus

In the taxonomic hierarchy, a genus is a subdivision of a botanical family, and it normally constitutes a number of species . A genus is group of closely related species, which have clearly defined characteristics in common. All plants have two Latin names; the first is the generic name, and the second is the specific name. The adjectival form is ‘generic’, as in inter-generic hybrid.

Geometric series

The series 2^0, 2^1, 2^2, 2^3, etc., with arithmetic values 1, 2, 4, 8, etc., is a geometric series. This series is relevant to the Habgood nomenclature, and the Person-Habgood differential interaction.

Geotropism

The response of a plant to gravity. A tap root exhibits positive geotropism, and grows downwards. An apical shoot exhibits negative geotropism, and grows upwards.

Germ tube

The microscopic tube, extruded by either a pollen grain or a fungal spore, that penetrates the stigma or the host tissues, as the case may be.

Germination

The first step in the growth of either a seed or a spore.

Germination percentage

A seed testing term which defines the viability of a seed lot.

Gherkins

See: Cucumis sativus.

Gibberellic acid

Also known as gibberellin, this compound was originally isolated from a fungus (*Gibberella fujikuroi*.) but is now known to occur in all plants. Many different gibberellins, called GA_1, GA_2, etc., have been identified. Gibberellins are plant growth substances that tend to affect the entire plant. They stimulate growth and have many commercial applications such as breaking potato seed tuber dormancy, increasing celery stalk length, suppressing seed formation in grapes, increasing the size of ornamental flowers, and delaying fruit maturity.

Ginger

See: Zingerber officinale.

Globodera rostochiensis

A cyst-forming nematode, known as the 'golden nematode', that is a serious pest of potatoes and tomatoes.

Glomerella spp.

A poorly defined genus of fungi, which are often the perfect (i.e., sexual) stages of Colletotrichum.

Gluten

The main protein in wheat flour. Gluten allows wheat dough to stretch and this makes the production of bread possible, by allowing gas bubbles to develop in the dough from fermentation by yeast.

Glycine max

The soybean, now the most important grain legume in the world, with Brazil, USA, and China being the largest producers. Soybean was domesticated in China about one millennium BC. However, the modern expansion in cultivation came only after breeding in the USA had produced types suitable for mechanical harvesting and with appropriate day-length responses, because photoperiod sensitivity limits a cultivar to a narrow belt of latitude. Modern production is as an industrial crop for edible oil extraction (20-23% of the seed) and a high protein meal used mainly for animal feed, but with increasing prospects for human food. In the Far East, soybeans are utilised as soy sauce, soya milk, bean curd or tofu, and green beans. Soybeans can also be used as a pasture crop, and for hay and silage.

Soybean is self-pollinated. About 1% of natural cross-pollination occurs and can be utilised in a recurrent mass selection program if a suitable marker gene can be found. amateur breeders should aim primarily at horizontal resistance, with a view to producing cultivars for organic farmers.

Glycyrrhiza glabra

Liquorice. A pernnial herb of the family *Leguminosae*, which is of ancient cultivation in Central Asia and Southern Europe. It has sweet rhizomes and roots. The sweetness comes from glycyrrhizin.

GMO and GM

See: Genetically modified organism.

Golden gram

See: Phaseolus aureus.

Golden nematode

See: Globodera rostokiensis.

Gooseberry

See: Ribes grossularia.

Gossypium spp.

Cotton. This genus has about thirty species that are divided into linted and non-linted species. The four linted species in cultivation are divided into Old World and New World cottons. The two Old World cottons are diploid and are *Gossypium arboreum* and *G. herbaceum*. The two New World

cottons are tetraploid and are *G. barbadense* and *G. hirsutum*. The last of these is Upland cotton and is responsible for about 95% of world production. The long staple Sea Island and Egyptian cottons are *G. barbadese* and account for about 5% of world production.

Cotton is naturally cross-pollinated, but it is tolerant of inbreeding and inbred cultivar can be maintained. population breeding presents no difficulties.

Since the first use of DDT, cotton has suffered a major vertifolia effect with respect to its insect pests. The increased susceptibility has been aggravated by the boom and bust cycle of insecticide production, and the tendency for politicians and bankers to interfere in the cultivation of the crop. Population breeding for horizontal resistance in cotton is likely to produce unexpectedly promising results. However, cotton breeding is somewhat technical, particularly in assessing fibre yield and quality, and it should perhaps be undertaken by university breeding clubs.

Gourds

See: Cucurbitaceae.

Gradient

See: Parasite gradient.

Grafting

The technique in which a scion is biologically joined to a stock. The stock is usually a horizontally resistant rootstock, and this provides a means of controlling root and trunk diseases. The scion is usually a high quality but susceptible cultivar. The classic example of this control method was the grafting of classic wine grapes on to American rootstocks in order to control Phylloxera. Occasionally, a double graft is used, as with a susceptible rubber trunk being grafted to both resistant rootstocks and leaf blight-resistant crowns Other uses of grafting include the grafting of potato parents on to tomatoes to produce a vine with many inflorescences for use in true seed production.

There are two general techniques of grafting. A bud graft involves inserting a bud of the scion under the bark of the stock, and is the usual method for tree crops. A wedge graft involves inserting a wedge of the scion into a V-slit cut into the stem of a decapitated stock, and is the usual method for herbaceous plants. A third technique is the ‘approach’ graft in which the cut surfaces of the stems of two separately rooted plants are bound together, but it is rarely used.

Grain crops

This term covers all crops in which the harvestable product is a small seed. It includes all the cereals, the grain legumes, the pseudo-cereals, and mustard. However, oil seed crops, such as sunflower, flax, and canola, are not normally considered to be grains.

Grain Legumes

See: Leguminoseae.

Gram

See: Phaseolus.

Gramineae

The grass family. Cultivated members of this Monocotyledonous family include the cereals, fodder grasses, and sugarcane. There are about 8,000 species of grass in some 700 genera. From the human point of view, this is quite the most important family of plants as it provides most of our food, either directly or indirectly (all beef is grass). According to some taxonomists, the bamboos are also members of this family.

Gram-positive

A staining test used in the identification of bacteria. The bacteria are stained with crystal violet and then iodine. They are then washed in a solvent such as acetone or alcohol. Gram-positive bacteria retain the stain, while gram-negative bacteria lose it. All plant pathogenic bacteria are gram-negative, except Corynebacterium spp.

Granadilla

See: Passiflora edulis.

Grapes

See: Vitis vinifera.

Grapefruit

See: Citrus paradisi.

Grassland

Most grasslands are natural, and sown grassland (pasture) is a relative new concept in agriculture. Natural grasslands are known variously as savannah, prairie, pampas, scrub, veldt, chaparral, and steppes.

Grass

Any member of the botanical family Gramineae. This family includes the cereals, the fodder grasses, sugarcane, and, according to some taxonomists, the bamboos.

Green manure

A crop grown specifically for improving the soil by being ploughed into the soil while still green. Green manures often consist of legumes which fix nitrogen.

Green pea

See: Pisum sativum.

Green Revolution

The Green Revolution resulted from the development of dwarf wheats and rices that could tolerate heavy applications of nitrogenous fertiliser without lodging. This led to major increases in the world production of food and earned Norman Borlaug a richly deserved Nobel Peace Prize in 1970.

There is a more detailed account in *Return to Resistance* (available as a sharebook at this website).

Greenhouse

Both glass and plastic sheet are transparent to light but opaque to radiant heat. A greenhouse absorbs sunlight which is re-radiated internally as heat. Temperate greenhouses have the problem of inadequate sunlight during winter and at night, and they have to be artificially heated. Tropical greenhouses have the problem of excessive heat, and they have to be cooled. Refrigeration is prohibitively expensive, and the best cooling is by good ventilation that evaporates large amounts of water. Greenhouses also protect plants from rain and hail, and they can be fumigated.

Commercial greenhouses are used for producing crops out of season. In plant breeding, research greenhouses are used mainly to reduce the length of the breeding cycle by increasing the number of plant generations in one year.

Greenhouse cooling

The cooling of a plant breeding greenhouse in the tropics can be difficult. The external surface of the glass or plastic can be sprayed with a heavily diluted white plastic emulsion paint in order to reduce the light absorption. Rapid changes of air, by extraction fan if possible, and the evaporation of large amounts of water, offer the most efficient and the most economical cooling. Refrigeration is far too expensive and should not be contemplated.

Greenhouse effect

This is a geophysical effect, in which the so-called greenhouse gasses (i.e., carbon dioxide, methane, etc.) in the atmosphere are transparent to sunlight but opaque to radiant heat. This phenomenon is believed to lead to global warming.

Greenhouse gasses

See: Greenhouse effect.

Greenhouse screening

Screening a breeding population inside a greenhouse. Because of the requirements of on-site selection, greenhouse screening is inadvisable, except when breeding a crop that is to be cultivated in a commercial greenhouse. However, other components of the breeding cycle (e.g., multiplication, single seed descent, pollination) may be undertaken out of season in a greenhouse in order to reduce the total breeding time.

Grid screening

Grid screening is a technique for overcoming parasite gradients and patchy distributions of parasites, in field screening. The entire screening population is divided into a grid of suitably-sized squares, and relative measurements are used to select the best individual in each square. Squares that are totally free of a parasite should be eliminated from the screening process.

Gros Michel

The most popular cultivar of banana during the first half of the twentieth century. It eventually went out of production because of Panama disease. Nevertheless, the continuous monoculture of a single clone, for half a century, over a huge area in the tropics, where there is no closed season, was a remarkable achievement.

Groundnut

See: Arachis hypogea.

Groundnut, Bambara

See: Voandzeia subterranean.

Growth chamber

A special chamber with controlled light, heat, humidity, and atmosphere, for conducting research into plant growth. These chambers are often useful when studying crop parasites, but they are expensive, and are not normally necessary for amateur breeders .

Grub

The larval stage of many insects, including many crop parasites.

Guano

Semi-fossilised excrement of fish-eating birds. Guano was much prized as a source of natural phosphate but is now in short supply.

Guar

See: Cyamopsis tetragonolobus.

Guava

See: Psidium guajava.

Guignardia bidwelli

An Ascomycete fungus that causes black rot of grapes.

Guinea corn

See: Sorghum.

Gumbo

The West African name for okra, Abelmoschus esculentus.

Gum trees

See: Eucalyptus spp.

Guttation

The excretion of water by plants, usually at night, when atmospheric humidity is high, and transpiration is restricted. Typically, this makes lawns wet in the early morning. This wetness is often mistakenly called dew. A true dew is caused by condensation of water from a saturated atmosphere.

Gymnosperm

Seed forming plants whose seeds are not protected by a seed coat. This group includes the conifers, cycads, yews, and *Ginkgo*. *Gymno-* is Greek for naked, and the name Gymnosperm has the same root as gymnasium.

Gymnosporangium

A genus of rust fungi, in which most species are heteroecious, with the summer stage mainly on Cupressus spp., and the winter (sexual) stage on pome fruits.

H

Habgood nomenclature

This nomenclature uses the numbers of the binomial expansion (i.e., 2^0, 2^1, 2^2, 2^3, etc., with arithmetic values of 1, 2, 4, 8, etc.). Each binomial number has an arithmetic value that is double that of its predecessor. The sum of any combination of binomial numbers is unique. For example, the sum 21 can be obtained only by adding 16 + 4 + 1, and no other combination of binomial numbers can add up to this sum.

The nomenclature can be applied to matching pairs of vertical genes. Each pair of matching genes is then labelled with the binomial numbers 1, 2, 4, 8, etc., in order of discovery. The name of each pair of genes is the primary Habgood name, and it is a single binomial number. Any combination of genes is named with the sum of their binomial numbers, and this is a secondary Habgood name. It will be seen that any combination of genes, in either the host or the parasite, is named with a single number, and that exactly matching vertical resistances and vertical parasitic abilities have the same name.

The composition of a secondary Habgood name is easily determined. Suppose the secondary name was 29. The largest possible binomial number is subtracted from it. In this case, this would be binomial 16. This means that gene 16 is present. The remainder is 13, from which 8 can be subtracted, indicating that gene 8 is present. The remainder is now 5, showing that genes 4 and 1 are also present. These gene names 16 + 8 + 4 + 1 add up to 29, and no other combination of binomial numbers can add up to this sum.

Habitat

The natural home of an organism, usually with living conditions that are closely similar to those of its original environment.

Hand-pollination

The artificial pollination of a flower, usually involving cross-pollination in order to obtain a sexual recombination of two chosen parents. See also: Emasculation.

Haploid

A cell or plant that has only one set of chromosomes. A sex cell (i.e., pollen and ovules in plants, sperm and ova in animals) is normally haploid, and the fusion of two sex cells produces a normal

diploid with two sets of chromosomes. Haploid plants can be produced artificially, and their single set of chromosomes can be doubled to produce a doubled monoploid. The terms haploid and monoploid are synonymous. See also: tetraploid, triploid.

Hardy-Weinberg law

The law that states that gene frequencies will remain constant from generation to generation, provided that no other factors, such as selection or mutation, are operating.

Hardwoods

Timber trees that are Dicotyledons . The timber of these trees is suitable for fine furniture and cabinet making. See also: Softwoods.

Haricot bean

See: Phaseolus vulgaris.

Harvesting

The process of gathering in a crop. Commercial harvesting of grain crops is usually undertaken with a combine harvester. Many horticultural crops, and all subsistence crops are harvested by hand. The harvesting of a plant breeder's screening population usually involves carefully selected individual plants.

Hashish

See: Cannabis sativa.

Hay

Pasture grasses and/or pasture legumes that have been cut and dried in the field for use as animal feed. "Making hay while the sun shines" is a traditional method of providing winter-feed for farm livestock.

Hazel nut

See: Corylus avellana.

Head to row selection

See: Family selection.

Hectare

A measure of land area. One hectare is 10,000 square metres, or 2.471 acres.

Helianthus annuus

The sunflower, which is now a valuable oil crop. The Church in Russia forbade the use of a long list of cooking oils on many fast days each year. Being an unknown New World plant, sunflower was not

on that list of proscriptions. It consequently became very popular in Russia where the first cultivars were developed. Dwarf varieties are now grown for combine harvesting in many countries. The species is open-pollinated and amenable to selection for horizontal resistance by amateur breeders Sunflowers, and the closely related Jerusalem artichoke, are the only crop species of any significance to originate in North America.

Helianthus tuberosus

The Jerusalem artichoke. A close relative of the sunflower, it is open-pollinated and amenable to recurrent mass selection for horizontal resistance by amateur breeders who might have a special interest in this rather unimportant crop.

Heliotropic

(= phototropic) A directional growth or movement towards light.

Helminthosporium

A genus of fungi which cause disease on a number of crops. While mostly imperfect fungi, a few species belong to the Ascomycete genera Pyrenophora, Ophiobolus, Gaeumannomyces, and Cochliobolus.

Hemileia vastatrix

Coffee leaf rust. This disease is of interest because, when arabica coffee was taken as one pure lines to the New World, all of its pests and diseases were left behind in the Old World. This gave Latin America a commercial advantage and it now produces about 80% of the world's coffee. When the rust was accidentally introduced into Brazil in 1970, there were fears of a major disruption of the world supply. Fortunately these fears proved groundless, as the disease was easily controlled.

Leaf rust is also interesting in that its spores can be either wind-borne or water-borne. The former method of dissemination is clearly for the process of allo-infections from tree to tree. The latter is for Auto-infection from one leaf to another within one tree.

This disease is an apparent exception to the rule that vertical resistance will evolve only in the seasonal tissue of a discontinuous pathosystem, because coffee is an evergreen perennial. However, infection can only occur if there is free water on the leaf surface. During the tropical dry season, all infected leaves are shed, and the fungus dies with them. Consequently, arabica coffee is functionally deciduous with respect to rusted leaves only.

Hemiptera

An order of insects usually called ‘bugs’. Many leaf bugs are important crop pests. The order also includes the bed bug, which is of interest in demonstrating the stability of natural pyrethrins.

Hemp

See: Cannabis sativa.

Hemp, Deccan

See: Hibiscus cannabis.

Hemp, Manila

See: Musa textilis.

Hemp, sunn

See: Crotalaria juncea.

Herb

Any flowering plant that lacks woody tissues.

Herbicide

Any chemical that kills weeds. Modern herbicides are often selective in the sense that they will kill some types of plant but not others. Typically, 2,4-D kills Dicotyledons and may be used safely on Monocotyledons crops such as cereals. Further selectivity has been obtained by the use genetically modified crops that are resistant to a specific herbicide.

Herbicide injury

Traces of herbicide in sprayers or other equipment can cause injuries to crop plants. The symptoms can be very confusing and, if suspected, a specialist should be consulted.

Herbivores

An animal that lives on plants, mostly grasses that can withstand grazing because their leaves grow from the base, and not the tip. The appearance of grasses, some 25 million years ago, led to an explosive evolution of herbivores. The evolution of humans, as hunter-gatherers, depended on the fact that the African savannah carries up to 20,000 kilograms of herbivores per square kilometre. At the other extreme, tropical rain forest carries only 5-10 kg/sq.km. It is no accident that rain forests have the fewest archaeological remains of hunter-gatherers, or that our hominid ancestors favoured open grasslands.

Herders

Nomadic people who had domesticated a social (i.e., herding) species of animal. Surviving herder societies include the Laplanders who herd reindeer, and the Masai, who herd cattle. The earliest known herders date from 20,000 years ago, and they herded Barbary sheep in North Africa.

Heritability

The percentage of a plant's quantitative variable that is due to genetics, the remaining percentage being due to environment. For example, a plant may have a zero level of parasitism because the parasite is absent from the area in question. It appears to have 100% resistance. However, if the parasite were present with maximum epidemiological competence, the plant might have a 50% level of parasitism. The heritability of that apparent 100% resistance would then be only 50% (i.e., half of the original apparent resistance is inherited and can be inherited by the progeny, while the other half is an environmental effect that cannot be transmitted to the progeny).

Hermaphrodite

Having both sexes in one individual. In plants, this means having both sexes in one flower. If both sexes occur in separate male and female flowers on one plant, this arrangement is termed monoecious. See also: dioecious.

Hessian fly

See: Mayetiola destructor.

Heteroecious

Greek = different houses. A heteroecious plant parasite is one that is compelled to parasitise two different species of host, often called the winter host, during which sexual recombination occurs, and the summer host, which involves asexual reproduction only, in order to complete its life cycle. A heteroecious pathosystem has two species of host. In practice, the only heteroecious parasites of plants are species of aphids and rusts, but some of them are major pests and disease of crops. During the summer phase, these parasites are r-strategists and a system of biochemical locks and keys, derived from the vertical subsystem and the gene-for-gene relationship, can be shown to have a remarkable evolutionary survival advantage. (See *Self-OrganisingAgro-Eosystems,* available as a sharebook on this website, for a more detailed discussion).

Heterogeneous

Of different descent (c.f., heterogenous = of different composition). Pronounce it heterogeneous (c.f., heterogenous). See also: homogeneous, homogenous.

Heterogenous

Of different composition (c.f., heterogeneous = different descent). Pronounce it hete**ro**genous (c.f., hetero**gen**eous). See also: homogeneous, homogenous.

Heterosis

The hybrid vigour that is exhibited by the progeny of two inbred (i.e., homozygous) but different parents. This vigour persists for only one generation, and it is the basis of hybrid varieties.

Heterozygous

This term refers to a plant whose two parents were genetically different. In plants, the term may refer to a single gene, or to the entire genetic make-up of the individual plant. Heterozygous plants do not 'breed true to type'. See also: homozygous.

Hevea brasiliensis

Para rubber. Note that the name comes from the State of Para in Brazil, and that each 'a' is pronounced long, as in 'art'. The name should not be pronounced with each 'a' short, as in 'parachute'.

Para rubber is a deciduous tree native to the Amazon Valley. It was taken to the Far East by the British, and this area became the main producer because it was free of the native pests and diseases. The Brazilian complaint that rubber was stolen from them is not justified in view of their enormous use of Old World crops such as coffee, sugarcane, and soybean. In any event, plantation rubber does not thrive in Brazil, but old plantations, laid out by the Ford Motor Company in the early part of the twentieth century, have resistant survivors and merit screening for vegetative propagation .

Hexaploid

A cell or a plant with six sets of chromosomes. Diploid is the normal state in most plants and animals. See also: doubled monoploid, haploid, tetraploid, triploid.

Hibiscus cannabis

Kenaf, bimli jute, or Deccan hemp. A jute substitute that probably originated in Africa.

Hibiscus esculentis

See: Abelmoschus esculentus.

Hippomane manchinella

This is the plant from which arrowhead poisons are extracted in South America. It is of interest in that arrowroot got its name from being a supposed antidote to these poisons.

Holistic approach

A systems term meaning that systems analysis, or systems management, is being conducted at the highest feasible systems level. The converse, in which the system is studied at the lower systems levels, is called the merological approach. The holistic approach is essential if suboptimisation is to be avoided.

Homeostasis

The ability of a system to maintain an optimum in all its variables, and to recover from swings away from this optimum, at any systems level. The recovery is the result of negative feedback. For example, if a man gets too hot, he sweats, and the evaporation of the sweat cools him down. Conversely, if he gets too cold, he shivers, and this unconscious exercise warms him up. See also: Genetic homeostasis.

Homogeneous

Of the same descent (c.f., homogenous = of different composition). Pronounce it homo**gen**eous c.f., ho**mo**genous, as in ho**mo**genised milk). See also: heterogeneous, heterogenous.

Homogenous

Of the same composition (c.f., homogeneous = different descent). Pronounce it ho**mo**genous, as in ho**mo**genised milk, (c.f., homo**gen**eous). See also: heterogeneous, heterogenous.

Homologous evolution

Evolution in which similar features have a common origin (e.g., all the plants in one family have a common ancestor). This is in contrast to analgous evolution, in which similar features have different origins (e.g., the wings of birds, insects, and bats represent analogous evolution).

Homozygous

In plants, this term may refer to the alleles of a single gene, or to the entire genetic make-up of an individual plant. In the former situation, the two parents each had the same allele of that gene. In the latter situation, the two parents were genetically identical in all respects. A population of plants that are homozygous in their entire genetic make-up is called a pure line, and these plants ‘breed true to type’. (See also: heterozygous).

Hops

See: Humulus lupulus

Hordeum vulgare

Barley. A crop that is as old as wheat, dating from about nine thousand years ago. It is salt-tolerant, and it often substituted for wheat, in ancient times, in soils that had become salty from inappropriate irrigation. However, it is little used in human nutrition today. The main use is for animal feed, and for malting to make beer. There is plenty of scope for developing horizontal resistance, and the crop is probably amenable to the use of male gametocides.

Horizontal

In a plant epidemiological context, this term is entirely abstract, and it means that a gene-for-gene relationship is absent. Horizontal resistance and horizontal parasitic ability are both defined by the absence of a gene-for-gene relationship. A horizontal subsystem of a pathosystem is also defined by the absence of a gene-for-gene relationship.

See also: Horizontal parasitic ability, horizontal resistance, Horizontal pathotype, and Horizontal pathodeme.

Horizontal parasitic ability

Parasitic ability that does not result from a gene-for-gene relationship. Horizontal parasitic ability is the parasitic ability of the Biometricians, and its inheritance is usually controlled by many polygenes. Although it has been very little studied, it seems always to vary quantitatively. It is the parasitic ability that enables a parasite to obtain nutrients from its host after the vertical resistance has been matched, and in spite of the horizontal resistance. (See also: vertical parasitic ability).

Horizontal pathodeme

A population of a host in which all individuals have the same horizontal resistance. Many different cultivar with the same horizontal resistance, but with differing agronomic characteristics, all belong to the same horizontal pathodeme.

Horizontal pathotype

A population of a parasite in which all individuals have the same horizontal parasitic ability. The various members of a horizontal pathotype may differ in other respects, such as pesticide resistance.

Horizontal resistance

Resistance that does not result from a gene-for-gene relationship. Horizontal resistance is the resistance of the Biometricians; its inheritance is normally controlled by polygenes. It results from many different resistance mechanisms; it is quantitative in both its inheritance and its effects; it controls all the consequences of a matching infection including Auto-infection; it also controls allo-

infections in a continuous pathosystem that lacks a gene-for-gene relationship; and it is durable resistance.

The level of horizontal resistance can be at any degree of difference between the minimum and the maximum. The minimum level of horizontal resistance usually means that there is a total loss of crop in the absence of crop protection chemicals. Conversely, the maximum level of horizontal resistance usually means that there is a negligible loss of crop in the absence of crop protection chemicals.

In plants that lack a gene-for-gene relationship, horizontal resistance is the sole protection, and the only resistance. In plants that have a gene-for-gene relationship, the function of horizontal resistance is to control all the consequences of a matching allo-infection, including all Auto-infection. Horizontal resistance thus occurs in every plant against every parasite of that plant.

Horizontal resistance requires population breeding and recurrent mass selection . For this reason, Mendelian breeders do not like it, and it has been seriously neglected during the twentieth century. However, these population breeding techniques are so easy to use in most crops that amateur breeders can undertake the breeding for horizontal resistance, usually when organised into a plant breeding clubs, or a university breeding club.

Once adequate horizontal resistance is accumulated, the environmental and human hazards, as well as the labour and costs of applying crop protection chemicals are eliminated. Because a good horizontally resistant cultivar need never be replaced, except with a better cultivar, breeding for horizontal resistance is cumulative and progressive.

As horizontal resistance is accumulated, the crop losses from pests and diseases decline, and the biological anarchy that was induced by the use of crop protection chemicals also declines, as biological control agents return and increase in numbers. The improved biological control enhances the effects of the horizontal resistance. The two phenomena are mutually reinforcing.

See also: Horizontal parasitic ability, vertical resistance, Comprehensive horizontal resistance, Laboratory measurements, Relative measurements, Partial resistance, Field resistance, Race-non-specific resistance.

Horizontal resistance, comprehensive

The horizontal resistance to one species of parasite does not normally function against any other species of parasite. Comprehensive horizontal resistance means that a cultivar has high levels of

horizontal resistance to all the locally important species of parasite. This is achieved during breeding by selecting for the one character of 'good health' (i.e., the holistic approach).

Because the epidemiological competence of parasites varies considerably between agro-ecosystems, the horizontal resistances that are comprehensive in one agro-ecosystem may be too high, or too low, in another agro-ecosystem. This is why On-site selection is important.

Horizontal resistance, examples

There are numerous examples of deliberate and successful breeding for horizontal resistance. The best summary is by N.W. Simmonds, entitled *Genetics of Horizontal Resistance to Diseases in Crops*, and published in *Biol. Rev*. **66**: 189-241. See also: Phaseolus vulgaris.

Horizontal resistance, laboratory measurements

horizontal resistance can be measured in the laboratory using plant growth chambers. But these measurements are expensive and difficult, and they do not necessarily correspond to field performance. They are not recommended for amateur breeders .

Horizontal resistance, opposition to

The scientific opposition to horizontal resistance during the twentieth century was apparently due to the fact that plant breeding was dominated by Mendelian breeders who (1) disliked working with polygenes and population breeding methods, and (2) favoured work with single-gene resistances, in spite of the ephemeral nature of vertical resistance. This attitude, which still endures, has led to a serious vertifolia effect in many crops, and it does much to explain why we now use crop protection chemicals in such enormous quantities. See also: Mindset.

Horizontal resistance, relative measurements

horizontal resistance is difficult to measure and it has no exact scale of measurement comparable, say, to the Celsius scale of temperature measurement. In practice, the only feasible measurements of horizontal resistance are field measurements that are also relative measurements. That is, a cultivar is described as being either more or less resistant to a specified parasite, than another cultivar of known performance.

Horizontal subsystem

The subsystem of a pathosystem that is controlled by horizontal resistance and horizontal parasitic ability.

Hormone

A substance that regulates the behaviour of specific cells or tissues. Hormones can be natural or synthetic.

Hormone mimic

Some synthetic chemicals, such as insecticides, can mimic hormones and, at extremely low concentrations, they can damage an unborn human foetus, or an actively growing young child. The safest course for an expecting mother, or for young children, is to eat only organic foods.

Horse bean

See: Vicia faba.

Horseradish

See: Armoracia rusticana

Horticulture

That branch of crop husbandry that involves fruits, vegetables, and ornamentals.

Host

A species , or an individual organism, that harbours parasites, and supplies those parasites with nutrients.

Host range

The range of different species of host that a parasite is able to exploit.

Host-parasite relationship

The category of parasitism in which there is a high frequency of parasitism, but a low injury from parasitism. For example, fleas parasitise zebras. They parasitise every zebra in the herd, so the frequency of parasitism is maximal. But they do very little harm to each individual zebra, so the injury from parasitism is minimal. See also: Predator-prey relationship.

Hot water treatment

A treatment for seeds that are infected. With careful control of the temperature, it is possible to kill the pathogen without killing the seed. Loose smuts of cereals can be controlled in this way.

Houseflies

These flies were the first known insects to develop resistance to a synthetic insecticide, which was DDT in Naples, during World War II, thus demonstrating the previously unknown possibility of unstable insecticides.

Humulus lupulus

Hops, which are now used almost exclusively for brewing beer. The plant is a perennial vine which dies back to ground level each fall. The above-ground parts thus have a discontinuous pathosystem and they have vertical resistance. It is a long-day plant and it is dioecious. It is propagated vegetatively, and only about eight clones dominated world production until quite recently. These include 'Fuggle' and 'Golding' in Britain, 'Hallertaur' in Bavaria, and 'Saaz' in Czechoslovakia. These clones are mostly ancient, and they demonstrate the utility and durability of horizontal resistance. A breeding program started in Germany in 1922 accumulated polygenic resistance to downy mildew by breeding within the European population. This was one of the earliest examples of horizontal resistance being chosen over vertical resistance. This is not a crop for amateur breeders .

Humus

The decomposed organic matter in soils. Humus is a source of plant nutrients, and it is necessary for microbiological activity. It also contributes to soil structure and drainage.

Hundred seed weight

This measurement indicates the average seed weight in a crop such as wheat. Breeders who aim exclusively at total yield may end up with very many, very small grains; while breeders who aim exclusively at a high weight of individual seeds may end up with low yields. amateur breeders should be aware of this laboratory measurement when selecting parents in a program of recurrent mass selection .

Hungry Forties

The period during the 1840s when blight was destroying the potato crops of Europe. The famine was at its worst in Ireland where one million people died of starvation, and one and a half million emigrated, mainly to North America. This reduced the population of Ireland by about one third. Eastern Germany, Poland, and western Russia suffered similar famines.

Hunter-gatherers

People who are pre-herders and pre-agriculturalists. Hunter-gatherers still exist in areas where herding and agriculture are not possible (e.g., Kalahari desert). The early vegetarian hominids became tool-*users*, employing naturally shaped stones to break open large bones abandoned by carnivores. Later they became tool-*makers*, and this initiated a period of about two million years of hunter-gathering. Herding started only twenty thousand years ago, and agriculture began a mere nine thousand years ago.

Hyacinth bean

See: Lablab niger.

Hyaline

A mycological term that means a tissue which is lacking pigments and is almost transparent.

Hybrid

The offspring of a cross between two different genera, species , or varieties. Note the specialised meaning of hybrid variety.

Hybrid seed

See: Hybrid variety.

Hybrid swarm

A population, usually of an open-pollinated plant, that shows very great genetic diversity because it is derived from a cross between two or more different species . The tea crop is a typical example. See also: cline.

Hybrid variety

A cultivar of an open-pollinated species (e.g., maize, cucumber, onion) which has been produced by crossing two inbred lines. The resulting seed then produces plants that exhibit hybrid vigour, or heterosis. A hybrid variety can be used only once, because the hybrid vigour is largely lost in the second generation. This means that the seed of hybrid varieties is expensive, but the expense is more than justified by the increased yields. Hybrid varieties do not normally need the protection of breeders' rights because the breeder has complete control of the inbred lines.

Hybrid vigour

Also known as heterosis, this is the increased vigour that is exhibited by an interspecific cross (e.g., mules, which are sterile hybrids of a horse and donkey), or by a cross between two inbred lines of a single species , particularly an open-pollinated species of plant. See also: Hybrid varieties.

Hybridisation

In plants, the cross-pollination that produces a hybrid.

Hydroponics

The cultivation of plants in a nutrient solution instead of in soil. This technique is used mainly in greenhouses, and it is particularly useful for single seed descent. The plant roots can be suspended directly in the solution, or in inert gravel wetted with the solution, or inside flattened, plastic, tubular, film that is lying on the ground. In the last case, the plant grows through a small hole in the film, and

nutrient solution is pumped continuously through the tube. The advantages of hydroponics are (i) a high density of plants using less greenhouse space, (ii) rapid growth and maturation leading to a shortened breeding cycle, (iii) general freedom from pests and diseases, and (iv) labour-saving.

Hymenoptera

The Order of insects that includes bees, wasps, ants, and Ichneumons.

Hyperparasite

A parasite of a parasite. One of the principle agents of biological control. For example, rust is a parasite of coffee leaves, and it has a hyper-parasitic grub that eats its spores. There is also a hyper-hyper-parasite, a wasp that parasitises this grub. If coffee trees are sprayed with insecticides, the effects of this hyper-parasitism are lost. See also: Predator.

Hypersensitive fleck

A small necrotic speck, just visible to the naked eye, which indicates a hypersensitive reaction of a gene-for-gene relationship to a non-matching allo-infection.

Hypersensitivity

The process in which a group of cells surrounding an infection site dies very rapidly, and the infecting parasite dies with them. The infection then fails. This is a common mechanism of vertical resistance against allo-infections in leaves, but note that not all vertical resistance is due to hypersensitivity (e.g., Fusarium and Verticillium wilts), and not all hypersensitivity is due to vertical resistance. See also: Hypersensitive fleck.

Hypha

A single strand of microscopic fungal mycelium.

Hypocotyl

The stem of a germinating seedling that is below the cotyledons.

I

IBPGR

The International Board for Plant Genetic Resources, located in Rome, Italy.

ICARDA

The International Centre for Agricultural Research in the Dry Areas, located at Aleppo, Syria. This is one of the CGIAR research stations.

Ichneumon flies

Small wasps belonging to the Hymenoptera, that parasitise other insects by laying eggs in them, in their early instars. These are useful biological control agents.

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics, located in Hyderabad, India. This is one of the CGIAR research stations.

IITA

The International Institute for Tropical Agriculture, located at Ibadan, Nigeria. This is one of the CGIAR research stations.

Ilex paraguariensis

Yerba maté. An infusion of the leaves is similar to tea, which is popular in the southern areas of South America.

Immobile nutrients

Immobile nutrients cannot move around in the plant and, consequently, their deficiency symptoms appear first in the young leaves. Immobile nutrients include: Calcium, Boron, Sulphur, Iron, and Copper.

Immunity

Immunity means that a host cannot be parasitised by a particular species of parasite. Thus, coffee is immune to wheat rust, and wheat is immune to coffee rust. Immunity is a non-variable. The maximum level of horizontal resistance may be an apparent immunity, but it is not true immunity because it is variable, and it can be eroded. Vertical resistance has often been called immunity, but it too is an apparent immunity because it operates only against non-matching strains of the parasite.

Impartial resistance

See: Partial resistance.

Imperfect fungus

A fungus that has never been known to produce ascospores, basidiospores, or oospores, and which consequently cannot be classified among the Ascomycetes, Basidiomycetes, or Phycomycetes

respectively. The imperfect fungi are also known as fungi imperfecti, the Deuteromycetes, or the asexual fungi, and their reproduction is apparently entirely asexual.

Inbred line

A genetic line of plants that has been self-pollinated for a sufficient number of generations (usually a minimum of six) to produce individuals that are more or less homozygous, and which 'breed true'. See also: pure lines.

Inbreeder

A species of plant that is autogamous (i.e., self-pollinating). See also: Outbreeder.

Inbreeding cereals

Cereals, such as wheat, rice, barley, and oats that are self-pollinating and are usually cultivated as pure lines.

Inbreeding crops

Many of the cereals and grain legumes are inbreeding and they require hand-pollination during the breeding process. See individual crops for details. Most tree crops are out-breeding, with the notable exceptions of arabica coffee and peach.

Traditionally, during the twentieth century, inbreeding crops have been subjected to Pedigree breeding and the gene-transfer techniques suitable for single-gene characters, rather than the recurrent mass selection that promotes many-gene characters. Consequently, many of them exhibit a marked vertifolia effect, and they are mostly good candidates for breeding for horizontal resistance by amateur breeders.

Inbreeding depression

The converse of hybrid vigour, or heterosis. When an outbreeder is repeatedly selfed there is a steady loss of vigour. When two of these inbred lines are crossed, they exhibit heterosis.

Inbreeding grain legumes:

The following grain legumes are inbreeders:

All cultivated species of Phaseolus, Arachis, Cicer, **Glycine**, Lablab, Lens, Pisum, Psophscarpus, and Voandzeia. See also: Outbreeding legumes.

Incompatibility

When both self- and cross-pollination are unable to fertilise, the pollination is described as incompatible. See also: Self-incompatibility.

Incubation period

See: Latent period.

Indeterminate

Some crops, such as haricot beans, can have either the determinate or the indeterminate habit. With the former, they are self-supporting, bushy plants. And with the latter, they grow as vines. Potatoes are determinate plants but, when grafted on to tomatoes, they become indeterminate, and this is a very useful technique when many flowers are needed for the production of true seed for breeding purposes.

Indigenous

This term means that a species is native to the area in question. The converse words are exotic and foreign.

Indigo

See: Indigofera spp.

Indigofera spp.

Several species of this genus of the Leguminoseae are cultivated for a natural blue dye called indigo, or anil. This dye has been used for at least 4000 years, and it is superior to the European woad (Isatis tinctora). However, with the development of analine dyes, the world market for natural dyes collapsed.

Induced deficiencies

Occasionally, a nutrient deficiency can be induced, in spite of the fact that there is an adequate amount of that nutrient available. For example, water softeners replace calcium salts with sodium salts. An excess of sodium salts can induce a potassium deficiency. For this reason, house plants should never be watered with softened water.

Industrial country

The politically correct term for the rich countries of the world. The poor countries used to be called 'Third World' countries but are now referred to as non-industrial countries.

Industrial melanism

In Britain, during the industrial revolution, a species of moth, which had superb camouflage colouring when resting on the bark of a tree, became very visible to insect-eating birds when the tree bark turned black from soot pollution. It was shown by breeding experiments that light-coloured

moths could easily be changed to black, and *vice versa*. This is an example of the ability of reversible micro-evolution to change ecotypes.

Infected seed

Infected seed has internal parasites that cannot be reached by surface chemicals which would control contaminated seed. Typically, covered smuts of cereals produce contaminated seed, while loose smuts of cereals produce infected seed.

Infection

In a plant pathological context, this term is defined quite strictly. It is the contact made by one parasite individual with one host individual for the purposes of parasitism. See also: allo-infections, Auto-infection.

Infectious

This term is normally taken to mean that a disease is caused by a parasitic organism, and that it can be transmitted from one host individual to another. But, in common usage, a laugh or a yawn can also be described as infectious.

Infestation

This term is usually used in relation to insects but, in a wide epidemiological context, the terms infection and epidemic can be applied to all categories of parasite, including the insects.

Inflexibility

See: Genetic inflexibility.

Inflorescence

A flowering structure that has more than one flower. For example, the Umbellifereae are so called because each inflorescence is made up of many florets in an arrangement that is reminiscent of an umbrella.

Inheritance

Inheritance is described as monogenic when the character in question is controlled by a single gene. Monogenic inheritance is qualitative in its effects and it leads to discontinuous variation in which a character is either present or absent, without any intermediates. Inheritance is described as polygenic if the character in question is controlled by many genes, called polygenes. Polygenic inheritance is quantitative in its effects, and it exhibits continuous variation with all degrees of difference between a minimum and a maximum. All polygenic resistance is horizontal resistance, but not all horizontal resistance is inherited polygenically.

Initial inoculum

The size of the parasite population at the beginning of the epidemic. Other things being equal, a high initial inoculum leads to a more rapid development of the epidemic, while a low initial inoculum leads to a slower or later development of the epidemic.

Injury

The injury from parasitism is the actual amount of damage done to an individual host, or the average amount done to a host population, by the parasite. The frequency of parasitism is the proportion of host individuals that are parasitised. In a wild plant pathosystem, the injury from parasitism is inversely proportional to the frequency of parasitism. That is, the higher the frequency, the lower the injury, and, conversely, the higher the injury, the lower the frequency. In this way, the total damage from parasitism never exceeds a tolerable level that does not impair the host's ability to compete ecologically and evolutionarily. Vertical resistance, with its system of locking, reduces the frequency of parasitism. horizontal resistance, as a second line of defence, reduces the injury from parasitism. Continuous plant pathosystems, that have horizontal resistance only, usually have a high frequency of parasitism, and a low injury from parasitism.

Inoculation

In a crop science context, this terms means to introduce a parasite to a plant individual or population. Thus a screening population may be inoculated (or artificially infested) with one or more species of parasite in order to exert selection pressure for resistance. See also: Designated pathotype.

Inoculum

The living culture of a parasite that is used to inoculate a host individual or population.

Inorganic chemicals

Any chemical compound that does not contain one or more carbon atoms. It is noteworthy that plants absorb all their nutrients as inorganic chemicals (e.g., nitrates, phosphates, potash) while the higher animals, and people, absorb all their nutrients as organic chemicals. The exception is iron; plants absorb it in organic form while animals absorb it in inorganic form. Animals also absorb water, oxygen, and common salt as inorganic chemicals.

Insect cages

Small cages, usually constructed of stiff wire covered in muslin or mosquito netting, and used to cover an individual plant in order to confine insects to that plant. The main use for insect cages in plant breeding is to multiply insects for purposes of inoculating a screening population. Alternatively,

insect cages may be used to protect research plants from natural infestation, or to measure the population growth rate of an insect, as an indication of host resistance to that insect.

Insect culture

The multiplication of insects, usually in insect cages, for purposes of inoculating a screening population. This inoculation might involve screening for horizontal resistance to the insect in question, or for horizontal resistance to a virus disease of which the insect in question is a virus vector.

Insecticide

A pesticide that kills insects. An insecticide may provide a stable protection (e.g., natural pyrethrins, rotenone, nicotine, soap, oils, etc.) in which case it does not break down to new insecticide-resistant strains of the insect. Or it may provide an unstable protection (e.g., DDT, and most modern synthetic insecticides) and lead to a boom and bust cycle of insecticide production.

Insects

Insects are a Class of Arthropods that have three pairs of legs, and three body regions (head, thorax, and abdomen). In addition, they nearly always have a pair of antennae, and the adults often have one or two pairs of wings. Insects usually reproduce with eggs, but live birth also occurs (e.g., aphids). Insect growth involves a series of 4-8 moults, and the stages between moults are called instars. There is often a metamorphosis, usually at the time of the last instar (e.g., caterpillars turning into butterflies or moths). Most insect parasites of crops cause damage during the early instars, and the function of the final adult instar is often one of reproduction only, without any feeding. See also: Aphid, Beetle, Ladybird, Stem borer, Thrips, Whitefly.

Instar

A stage of growth of an insect that is concluded by the moulting or shedding of the exoskeleton, which is incapable of growth or expansion. Most insect species have 4-8 instars, often concluding with a metamorphosis.

Institutional plant breeding

Plant breeding conducted by a large institute. This kind of breeding is usually expensive and, consequently, it favours cultivar with a wide climatic adaptability. In practice, this means the use of vertical resistance if at all possible. Institutional breeding does not normally allow for farmer-participation schemes and it tends to be autocratic. see also: Corporate plant breeding, Democratic plant breeding, and Self-organising crop improvement.

Integrated pest management (IPM)

A system of pest management in which every important parasite in a crop is monitored and crop protection chemicals are used only when absolutely necessary. The idea is to minimise the use of crop protection chemicals in order to reduce biological anarchy and to stimulate biological control. IPM is used mainly against the insect parasites of crops, and it is greatly assisted by horizontal resistance.

Intellectual property protection

Legislation that provides the equivalent of a copyright on a breeder's registered cultivar. The sale of all propagating material of that cultivar is then controlled, and the breeder earns royalties on those sales.

Intensive crop

A crop that has high profit margins and which consequently justifies considerable expense in its production. Horticultural crops are intensive crops, while cereals are usually extensive crops.

Inter-generic cross or hybrid

A hybrid between two different genera. Inter-generic hybrids are rare, and are usually difficult to make. Not recommended for amateur breeders.

International Agricultural Bureaux

See: CABI

International Research Centres

Agricultural research centres located in non-industrial countries, and financed by industrial countries through CGIAR. The principle centres working with crops are: Maize and wheat (CIMMYT) in Mexico; rice (IRRI), in the Philippines; potatoes (CIP), in Peru; wet tropical crops (IITA), in Nigernia; dry tropical crops (CIAT), in Colombia; semi-arid areas (ICRISAT), in India; and in arid areas (ICARDA).

Internode

The part of a stem that separates two nodes.

Interplot interference

See: Parasite interference.

Interspecific cross or hybrid

A hybrid between two species within the same genus. This type of plant breeding is not generally recommended for amateur breeders who are hoping to develop new cultivar with high levels of horizontal resistance. But attempts at inter-specific crossing can be fun.

IPC

See: CIP.

IPM

See: Integrated Pest Management.

Ipomea batatas

The sweet potato. This crop originated in tropical South America. It was taken by Polynesians to Fiji and New Zealand, where it is known by its Peruvian name 'kumara'. The Portuguese took it to Africa and the Far East where it is known by its Caribbean name of 'batatas', which is the origin of the English word 'potato'. And the Spanish took it from Acapulco to the Philippines where it is known by its Mexican name of 'camote'. It is now one of the more important tropical food crops. Although it is cultivated as clones, the crop sets true seed freely, and farmers often keep self-sown seedlings as new cultivar. The harvestable product is a tuber which, in the USA, is incorrectly called a yam. This is an excellent crop for farmer-participation schemes, and for amateur breeders.

The progenitors of sweet potato are extinct. Ipomea purpurea is the morning glory.

Irish famine

See: Hungry forties.

Iron

Iron is an important plant nutrient. It is a component of many enzymes. Iron is also an immobile nutrient and iron deficiency shows first in the young leaves which become pale green and then yellow, even necrotic, but the veins tend to remain green.

IRRI

The International Rice Research Institute, located at Los Baños, Philippines. This is one of the CGIAR research stations.

Irrigation

The process of supplying a crop with water. Irrigation may be overhead irrigation with sprinklers, or furrow irrigation with water poured between the rows. Flood irrigation is used with rice paddies, and

with the annual floods of a river such as the Nile. In areas where water is scarce, drip irrigation and subsurface irrigation are now used.

Isatis tinctora

This plant provides a natural blue dye called woad, which is inferior to indigo.

Isolate

This word can be either a noun or a verb. The noun usually refers to a micro-organism that has been obtained as a pure culture from a mixture of organisms. The verb refers to the process of making an isolate.

Isolation from foreign pollen

When subjecting an open-pollinated crop to recurrent mass selection , it must be isolated from other compatible crops to ensure that no unwanted pollen from outside introduces unwanted characteristics, such as susceptibility, in the population breeding.

Isolation to protect neighbours

A plant breeding clubs may choose to isolate its work, in either time or space, or both, in order to protect neighbours from crop parasites. For example, the screening plots might be located in the middle of a large field or farm growing a different species of crop. In general, however, the requirements of on-site screening restrict the possibilities of isolation in both time and space.

J

Jargon

Esoteric words of an unnecessary obscurity, intended to exclude the uninitiated.

Jawa

See: Sorghum bicolor.

Jerusalem artichokes

See: Helianthus tuberosus.

Job's tears

See: Coix lachryma-jobi.

Jola

See: Sorghum bicolor.

Juglans regia

Walnut. Cultivars are propagated vegetatively as clones and it is advisable to grow a mixture of clones to improve pollination.

Jute

See: Corchorus spp.

Jute, bimli

See: Hibiscus cannabis.

K

Kafir corn

See: Sorghum bicolor.

Kale

See: Brassica oleracea.

Kaoliang

See: Sorghum bicolor.

Kapoc

See: Ceiba pentandra.

Kenaf

See: Hibiscus cannabis.

Koch's postulates

Three postulates for demonstrating the pathogenic nature of a micro-organism, which must (1) be isolated from the diseased tissue and cultured, (2) be inoculated into a healthy host and shown to cause the same disease, and (3) be isolated from the inoculated host and shown to be the same organism. These postulates were very important in the late nineteenth century when the pathogenic nature of micro-organisms was still being disputed. But they are not necessary for amateur breeders .

Kohlrabi

See: Brassica oleracea.

Kola

See: Cola spp.

Koracan

See: Eleusine coracana.

K-strategist

For any species , the carrying capacity of the environment is a constant, and it is represented by the letter 'K'. K-strategists are species in which the population size is more or less constant, and is limited by the carrying capacity of the environment. K-strategists tend to have large individuals that live for a long time, and which replace themselves by reproducing relatively infrequently with large and biologically expensive offspring (i.e., low birth rates and high survival rates). Elephants and Californian redwoods are K-strategist species. Note that there is a spectrum of continuous variation between the extreme K-strategist and its converse, the extreme *r*-strategist.

Kumara

See: Ipomea batatas.

L

Labelling

A feature of Pedigree breeding is that every cross-pollination must be labelled, and this is very labour-intensive. With population breeding, labelling is unnecessary and this labour-saving can be devoted to more useful activities, such as the screening of larger numbers of crosses.

Labiate

A member of the botanical family *Labiateae*.

Lablab bean

See: Lablab niger.

Lablab niger

The bovanist bean, Egyptian bean, Indian bean, etc. This is a suitable crop for amateur breeders in warm countries working with recurrent mass selection and horizontal resistance.

Laboratory screening

When conducting recurrent mass selection, a laboratory screening can often enhance a field screening by determining aspects of quality that are not discernible in the field.

Labour-saving

Any plant breeding has a limit to the number of person-hours that can be devoted to it. Consequently, any labour-saving device will permit an increase in the number of crosses, and the number of plants in the screening population. When doing recurrent mass selection, there is no need to label crosses, or individual plants, or to keep detailed records of parasitism, etc. The only thing that matters is that the final selections must be the best plants of that generation and, the larger the screening population, the greater the genetic advance. Labour-saving is not laziness. It is increased productivity.

Lactuca sativa

Lettuce. This crop is a member of the Compositae family, and it is the main component of salads. There are four basic types known as 'crisphead', 'butterhead', 'romaine', and 'leaf'. All types show great variation and there is considerable scope for increased horizontal resistance. The chief disease is downy mildew caused by the fungus *Bremia lactucae*. Past resistance breeding has involved vertical resistance, and there is scope for horizontal resistance breeding by amateurs.

Ladybirds

Beetles of the family *Coccinellidae*. These beetles are distinctively oval, almost spherical, with a flat under-surface, and they are coloured red or orange, with conspicuous black spots. Both the adults and the larvae of many species of ladybird feed on other insects, particularly aphids, which are crop parasites, and the ladybirds are valuable agents of biological control.

Lagenaria siceraria

The bottle gourd. A monoecious member of the Cucurbitaceae, this is a very ancient crop that pre-dates pottery in many tropical areas. It is apparently the only crop that was common to both the Old World and New World before the development of trans-oceanic travel. Gourds are believed to have originated in Africa, and to have floated across the Atlantic Ocean to Brazil at a very early date. They also spread to India and China, and all parts of S.E. Asia. The dried hard shells of the fruit have a

wide range of uses including bottles, bowls, spoons, ladles, tobacco pipes, musical instruments, and floats for fishing nets. The crop has a limited scope for local amateur breeders .

Landrace

A cultivated plant population which is genetically diverse and genetically flexible. A landrace can respond to selection pressures during cultivation. The maize crops of tropical Africa, which were so vulnerable to tropical rust, were landraces, and they responded to the selection pressure for resistance. Prior to the discovery of Johansen's pure lines in 1905, most crop varieties in the industrial world were landraces, and most subsistence crops in the non-industrial world are still landraces. See also: cultivar, Ecotype, Micro-evolution.

Larch

See: *Larix* spp.

Larix spp.

Larch, which is used as a plantation forest species of softwood. Not recommended for amateur breeders .

Larvae

The early instars of an insect are generally called larvae (singular, larva), particularly in insects that exhibit metamorphosis. Thus caterpillars are the larvae of butterflies and moths. It is often these juvenile stages that are voracious feeders, and that constitute some of the most serious insect parasites of crops. This term should not be confused with the molten rock that comes out of volcanoes, and is spelled lava. See also: Grub.

Late selection

Traditionally, selection is conducted on highly heterozygous individuals which then become the parents of the next screening generation. This is now called early selection. Late selection involves self-pollinating the variable progeny of a ***cross*** for 3-4 generations, using either the bulk breeding method or single seed descent, and producing a mixed population of relatively homozygous individuals. The late selection is made among these homozygous individuals. Late selection is efficient because it produces plants with a reduced hybrid vigour, which can be misleading during the screening process, and it also produces a greater expression of recessive alleles, which are exhibited only in the homozygous state. The features of late selected plants thus have a higher heritability than those of early selected plants. However, this advantage must be equated with the longer breeding cycle required by late selection.

Latent period

In plant pathology, the period between infection and the start of pathogen reproduction. One of the many mechanisms of horizontal resistance is to increase the latent period, thus reducing the reproductive rate of the pathogen.

Lead

Before the days of DDT and synthetic insecticides, highly dangerous compounds of lead were often used to kill crop pests.

Leaf

The main site of photosynthesis, leaves are thin laminae of green tissue, and are typically carried by a stem-like petiole that emerges from a node of the stem. There is usually a leaf bud in the axil of each leaf.

Leaf hopper

Insects of the family *Cicadellidae*. Many are serious pests of crop plants.

Leaf miner

A plant parasitic insect that mines a tunnel between the upper and lower surfaces of a leaf. The tunnel has a white, translucent appearance, and it starts quite narrow but broadens as the insect larva increases in size.

Leaf spot

A spot, usually irregularly circular, and usually necrotic, caused by a pathogen.

Leek

See: Allium ampeloprasum.

Legume

A cultivated member of the botanical family Leguminoseae.

Leguminoseae

Legumes which are cultivated for their seeds, such as peas, beans, lentils, peanuts, soybeans, and grams, are known as grain legumes or pulses. Those that are cultivated for grazing, or hay, in order to feed farm animals are known as fodder legumes, and include clovers, alfalfa (lucerne), vetches, sainfoin, etc. Most of the pulses are self-pollinating, while the fodder legumes are mainly cross-pollinating.

Lemon

See: Citrus limon.

Lens esculenta

The lentil. A self-pollinated member of the family Leguminoseae, this is one of the oldest pulses and it has been cultivated in the wheat and barley lands of the Old World since the beginnings of agriculture. Most cultivars are pure lines and there is room for recurrent mass selection by amateur breeders. In addition to improved horizontal resistance, there is a need for higher yields, suitability for mechanical harvesting, and a reduction of flatulence factors.

Lentil

See: Lens esculenta.

Lepidium sativum

Garden cress, cultivated as a salad plant, and served as young seedlings.

Lepidoptera

The insect order that contains the butterflies and moths and is characterised by four large wings that are covered in scales. In the butterflies, the upper surfaces of the unfolded wings are usually brightly coloured sex attractants, while the lower surfaces of the wings have camouflage colours, which appear when the wings are folded together vertically. The moths fold their wings horizontally, and they then exhibit camouflage colours. Many of the early instars, known as caterpillars, or grubs, are serious crop pests. Most Lepidoptera are now rare because of the widespread use of insecticides.

Leptinotarsa decemlineata

The Colorado beetle of potatoes. Originally a parasite of the wild Solanum rostratum (buffalo burr, or prickly potato) in Colorado, USA, this beetle moved on to cultivated potatoes as a new encounter parasite, and became one of the worst insect pests in the whole of agriculture. It is a yellow and black striped beetle, the same shape as a ladybird, but much larger, being half an inch long. The larvae and beetles are voracious eaters of potato leaves and, if not controlled, they can destroy a potato crop. Originally controlled with compounds of lead and arsenic, the beetles are now controlled with synthetic insecticides. Little breeding for resistance has been attempted, probably because no single-gene resistances could be found. An attractive project for amateur breeders working with horizontal resistance.

Lesion

Any visible damage or injury to a plant, usually caused by a parasite.

Lettuce

See: Lactuca sativa.

Lice

Plural of louse; the human louse is of interest in that it has never developed resistance to natural pyrethrins.

Life cycle

The complete cycle of events undergone by a living organism between birth (or hatching) and reproduction followed by death.

Lignin

The substance that is deposited in plant cell walls to make them woody. Lignin is thus the main constituent of timber.

Liliaceae

The lily family, which includes onions, leeks, garlic, shallots, etc. which are members of the genus Allium. Some taxonomists prefer to put this genus in a separate family called the Alliaceae.

Lima bean

See: Phaseolus lunatus.

Lime

This word has three quite distinct meaning in English. It can mean calcium oxide, as in quicklime; or the linden tree ***(****Tilia europaea)*; or the citrus fruit.

Lime fruit

See: Citrus aurantifolia.

Lime tree

Tilia europaea. The lime tree, or linden tree.

Linden

See: Lime.

Line

In genetics, a line of descent. The term is used most frequently in the concept of a pure lines.

Linear system

The general systems theory originally concerned rather simple systems such as the solar system, and mechanical systems, such as clockwork. These are now called 'linear' systems, and they obey Newton's laws. Modern complexity theory concerns more complex systems, which are non-linear. Linear systems have parameters that are easy to measure, and outcomes that are easy to predict. Non-linear systems have parameters that are difficult to measure, and outcomes that are impossible to

predict. The solar system is a linear system. It obeys Newton's laws of motion. Indeed, Newton formulated these laws to explain the behaviour of the solar system. We can predict the phases of the moon, and the tides, with great accuracy, for centuries ahead. Weather systems, on the other hand, are non-linear. They are also notoriously unpredictable. Weather forecasts of even a week ahead are famously unreliable.

In the context of complexity theory, 'linear' means that the parameters are fixed, while 'non-linear' means that the system parameters are likely to change. For example, a game of snooker is a linear system. But if the snooker table is on a ship in a rough sea, the game becomes a non-linear system. The mathematics of non-linear systems is a very new, incomplete, and complex sub-discipline, and it originated in fluid dynamics.

In the context of complexity theory, linear also means that the output is proportional to the input, and the whole is equal to the sum of the parts. Non-linear means that the output is greater than the input, and the whole is greater than the sum of the parts. This 'something extra' consists of emergent properties.

All living systems are non-linear. Life itself is an emergent. So too are all the attributes of life, that used to be called 'vital forces'.

See also: Self-organisation.

Linkage

Genetic linkage means that two genes are closely associated on one chromosome, and they tend to be inherited jointly. For example, a sex-linked gene will be expressed in one sex but not both.

Linnaeus

Carolus Linnaeus (1707-1778) was the father of taxonomy who introduced the binomial system of nomenclature.

Linseed

See: Linum usitatissimum.

Linum usitatissimum

Flax and linseed. This species is a self-pollinating annual. There are three categories of cultivar in this crop. Flax cultivars tend to be tall, with few branches and flowers. The stems are retted to produce linen. Linseed cultivars are relatively short, many-branched, and many-flowered, they produce seed used for the production of linseed oil. This oil was originally in great demand for the manufacture of paint, but it has now been almost totally supplanted by plastic latex paints. The dual

cultivars can be used for both linen and oil production. A very new development comes from the discovery that newly ground flax seed is an excellent dietary source of Omega-3 polyunsaturated oils.

Flax is historically interesting in that H.H. Flor, in 1940, discovered the gene-for-gene relationship while working on flax rust (*Melampsora lini*) in Illinois, USA.

This crop is suitable for amateur breeders working with horizontal resistance and recurrent mass selection .

Liquorice

See: Glycyrrhiza glabra.

LISA

See: Low input sustainable agriculture.

Litchi

See: Nephelium litchi.

Local optimisation

A term from systems theory that concerns responses to variation within a system. In ecology, local optimisation is illustrated by the formation of ecotypes, which vary as a result of different selection pressures in various localities within the ecosystem. Each ecotype is locally optimised to its own locality. Similarly, genetically flexible landraces, or agro-ecotypes, are locally optimised to their own local agro-ecosystem, and they will invariably perform less well in a different agro-ecosystem. In plant breeding, the purpose of On-site selection is to achieve local optimisation of many quantitative variables such as horizontal resistance***s***.

Locking

The system of locking that functions in the vertical subsystem of a wild plant pathosystem, controlled by the gene-for-gene relationship, apparently in accordance with the n/2 model, depends on a heterogenous mixture of locks and keys. A system of locking is ruined by uniformity ("What happens when every door in the town has the same lock, and every householder has the same key, which fits every lock?"). However, our use of vertical resistance genes in agriculture is based on uniformity, and this is why vertical resistance is temporary resistance in our crops.

Locks and keys

Every vertically resistant plant has one or more vertical resistance genes that collectively constitute a biochemical lock. And every vertically parasitic parasite has one or more vertical parasitism genes that collectively constitute a biochemical key. When a parasite is allo-infections a host, its key either

does or does not fit the lock of the host. The allo-infection succeeds only if the key fits (i.e., a matching infection).

Lodging

Long-stemmed cereal plants are liable to be blown over when they are wet and heavy in a storm. This is called lodging. The basis of the Green Revolution was the development of short-strawed (i.e., dwarf) varieties of wheat and rice. These could be given high applications of fertiliser without risk of lodging, and the yields were increased accordingly.

Lolium spp.

Ryegrass. Two species are used in sown grass for fodder. Perennial ryegrass (L. perenne) and Italian ryegrass (L. multiflorum) are very important. They hybridise freely and offer scope for amateur breeders.

Long-day

Many temperate plants are photoperiod-sensitive, and depend on a long day to initiate flower production. For this reason, crops such as olives and hops cannot be cultivated in the tropics. Equally many tropical plants depend on a short day to initiate flower production and, possibly, other processes, such as tuber formation. See also: potatoes.

Loofah

See: Luffa spp.

Loose smuts

See: Ustilago.

Low-input sustainable agriculture (LISA)

A system of sustainable agriculture designed for farmers in non-industrial countries, which has low cash inputs, and minimum risks of soil erosion and other forms of damage to the farm. The crops are fertilised with farmyard manure and night soil.

Lucerne

See: Medicago sativa.

Luffa spp.

monoecious vines cultivated for the production of the loofah-sponge which is prepared by retting. The fruit fibres were also used for a variety of filtering and shock absorbing functions. They have now been almost entirely replaced with plastics.

Lupin

See: Lupinus spp.

Lupinus spp.

Lupins have been cultivated since antiquity. They grow quickly on poor soil, they fix nitrogen, and they produce abundant seeds. However a perennial problem was the presence of toxic alkaloids. Modern breeding has eliminated these from a number of species , which show great promise as a source of protein for both humans and farm animals. Scope for amateur breeders .

Lycopersicon esculentum

The tomato. Although this is botanically a fruit, it is always considered to be a vegetable in culinary and horticultural terms. It is probably the second most important vegetable after potatoes. The cultivated tomato is a self-pollinating, annual plant. It is plagued with parasite, largely because of low levels of horizontal resistance resulting from a century of the vertifolia effect. Much breeding has taken place in the past, but there has tended to be a very rapid turnover of cultivars because of the use of vertical resistance.

With the spread of the A2 mating type of blight (*Phytophthora infestans)* in the northern hemisphere, tomatoes have become more difficult to cultivate. When there was only the A1 blight, functional oospores could not be produced, and the only way in which blight could survive the winter was in potato tubers. This meant that tomatoes could get blight only from potatoes, and only rather late in the season. However, with functional oospores in the soil, tomatoes now get blight much earlier, and much more severely.

Organic gardeners can avoid blight be putting a temporary, transparent, plastic sheet roof over the tomatoes to ensure that the leaves and stems never get wet. Blight spores need free water on the leaves in order to infect. The plants must then be given furrow irrigation.

Tomatoes are a very promising crop for amateur breeders working for improved horizontal resistances by using recurrent mass selection .

M

Macadamia nut

See: Macadamia *spp*.

Macadamia spp.

There are three cultivated species of macadamia nuts. They all originate in Northern Australia but are now cultivated in Hawaii and California also. The species are of doubtful taxonomic rank, and they interbreed freely to produce fertile hybrids. Some scope for local amateur breeders .

Mace

See: Myristica fragrans.

Macro-evolution

Evolution above the species level, as opposed to micro-evolution, which is evolution below the species level. Macro-evolution operates during periods of geological time, it produces changes that are new, it produces an increase in complexity, it is irreversible, it produces new species, and it produces new genetic code. Micro-evolution is the exact converse in all of these attributes.

It is now thought that the mechanism of macro-evolution is natural selection operating on emergent properties, at all systems levels.

Macroscopic

Visible to the naked eye, c.f. microscopic.

Magnesium

An essential plant nutrient. Magnesium is a mobile element and, consequently, the older leaves show symptoms first. Deficiency is easily recognised by a necrotic area between the main veins of the older leaves. It can be cured by an application magnesium sulphate (bath salts).

Maize

See: Zea mais.

Maize streak virus

This African virus is transmitted by leaf hoppers that are gregarious. As a consequence, the spread of the virus within a crop is limited and, only a low percentage of plants are diseased. This low frequency of disease exerts no selection pressure for horizontal resistance. The few diseased plants are so susceptible that they are usually killed, and the population as a whole remains susceptible. Occasionally, a much higher proportion of plants become infected, and the disease is then very destructive.

This disease has two important lessons for breeding for horizontal resistance. First, it is essential to select plants that have few symptoms but that are known to be infected, otherwise chance escapes will be chosen without any genetic advance in resistance. Second, inoculation is desirable to ensure as uniform a distribution of parasitism as possible. With this virus, disturbing the leaf hoppers every day, so that they eventually inhabit every plant, achieves such a uniformity.

Major staple

A major staple is a crop that has a high yield per man-hour, and per unit area; that is reliable from season to season; that produces a food that can be stored; and a food that is easily cooked. A major staple liberates a significant proportion of the population from food production, and they become available for other specialised activities, such as arts and crafts, medicine, architecture, and all those attributes of a sophisticated civilisation, which can be defined as the growth of cities. There are only three major staples in the world. These are wheat, rice, and maize. Every ancient and modern civilisation was based on one of these three crops, and any area or society that lacked them failed to produce a major civilisation. See also: Minor staple.

Malarial mosquitoes

These mosquitoes provide good examples of unstable insecticides, such as DDT.

Male gametocide

Any substance that kills the male reproductive cells (i.e., pollen, or pollen mother cells) of a plant, rendering it male-sterile. Male gametocides can be used to convert an inbreeder (e.g. wheat) into an outbreeder, for purposes of recurrent mass selection . Treated plants become the female parents, and untreated plants become the male parents.

There is also considerable interest in using male gametocides for the commercial production of seed of hybrid varieties but, so far, the available substances are not efficient enough.

Male sterility

A male sterile plant is one that has fertile ovules but sterile anthers and/or pollen. Male sterility can be induced with a male gametocide, or it may be genetically controlled. Male sterility can be useful in plant breeding by forcing inbreeding plants to cross-pollinate.

Malus pumila

The apple. Apples are members of the rose family (Rosaceae) and are of very ancient origin in Eurasia. The wild progenitors are either extinct or unknown. Pliny the Elder (23-79AD), listed twenty two varieties of apple known to the ancient Romans. Today, apples are probably the most popular

fruit, with oranges or, perhaps, bananas being second. The apple is self-incompatible and bees are necessary for pollination. Hand pollination is easy, but the main difficulty in breeding is the very large number of seedlings that have to be screened in order to produce one new ***cultivar***. Cultivated apples are normally grafted on to seedling rootstocks. An old apple orchard can be useful for testing promising scions in a breeding program, because an old tree can carry some fifty or more grafts.

The story of Johnny Appleseed suggests a technique for amateur plant breeders. His real name was John Chapman, and he travelled westward, in the early 1800s, into Ohio, Indiana, and Illinois. As he went, he planted hundreds of apple seeds that he had obtained from cider presses in Pennsylvania. Most of his seedlings would have produced aberrant types, but some were very useful. In any event, these early settlers wanted apples mainly for making applejack, as this was the only source of alcohol they had. His activities helped to make the Ohio Valley a major apple producing area, and North America soon had a greater variability in apples than Europe. He was ultimately responsible for the phrase "As American as apple pie".

In Canada (and elsewhere, no doubt) passengers eating an apple on a train would often throw the core out of the window. Many of these train tracks are now abandoned, and have been converted into hiking trails. Numerous apple trees grown from those unwanted apple cores line these tracks and they merit investigation as a possibly useful, and readily available, population for selection purposes. It should be remembered that each core would normally produce several trees that are genetically very different from each other, even though they seem to grow as one tree that is apparently branched near the ground.

Mammalian toxicity

Before being released to growers, new crop protection chemicals have to be tested for their mammalian toxicity. This is usually measured in milligrams of the chemical, per kilogram of mammalian body weight, required to kill 50% of the test population. This lethal dose is called the LD_{50}. These tests, of course, are made on laboratory animals, usually rats or mice.

Manchineel

See: Hippomane manchinella.

Mandarin orange

See: Citrus reticulata.

Manganese

A trace element nutrient of plants, manganese is a component of many enzymes. A specialist should be consulted if manganese deficiency is suspected.

Mangifera indica

The mango. The most popular of the tropical fruits, mangoes are to tropical region peoples what apples are to temperate region peoples. Mangoes vary widely in their fruit quality and the best are probably the finest fruit of all. Unfortunately, the best do not reach temperate markets, and most people in the industrial countries have not experienced a really good mango. Mango is a member of the family Anacardiaceae, which also includes the cashew nut (Anacardium occidentale).

Many mango fruits have two or more embryos, of which one or more is a zygote and does not 'breed true', while the other produces a nucellar seedling, that does 'breed true'. Many mango trees that are derived from a casually discarded seed have two or more trunks, joined at the base by anastomosis, but differing genetically because of the two types of seed. Pollination is usually by insects and is essential for fruit set, even when all the embryos are apomictic. Self-pollination is possible.

The best approach for amateur breeders is selection within local populations.

Mango

See: Mangifera indica.

Mangolds

See: Beta vulgaris.

Mangosteen

See: Garcinia mangostana.

Manioc

See: Manihot esculenta.

Manihot esculenta

Cassava, or manioc. This important tropical food crop originated in Central and South America and was taken to Africa by the Portuguese at an early date. The edible tubers are divided into sweet and bitter types, the latter containing toxic amounts of hydrocyanic acid, which is liberated when the enzyme linase acts on a glucoside called linamarin. These bitter types are cultivated in areas where wild pigs, baboons, and porcupines are serious pests. The hydrocyanic acid can be eliminated by washing, boiling, or roasting. Cassava is an important famine reserve in areas where desert locusts

are serious. The leaves are also used as a pot herb. High-yielding cassava, producing up to 70 tonnes/hectare, can be cultivated commercially for starch production. The crop is propagated vegetatively, and true seeds are very variable. Its wild progenitors are extinct.

Scientists at IITA, in Nigeria, launched an innovative program in which true seed of cassava was given to school children to grow in the school garden, with a view to doing their own selection work. This was both a valuable education, and a means of farmer-participation in breeding. This is an example that should be copied with many crops, in many schools, in many countries.

Manila bean

See: Psophocarpus tetragonobolus.

Manila hemp

See: Musa textilis.

Manilkara zapota

Chiclé, a tree native to Central America, with cultivar that are propagated vegetatively. The bark is tapped for latex which is boiled to produce chiclé gum, the basis of chewing gum. However, demand outstrips supply and synthetics are now used. There is need for cultivars suitable for plantations. A possible longterm project for amateur breeders in appropriate areas.

Manure

This word is usually taken to mean organic fertiliser, in the form of excrement of farm animals (farmyard manure), night soil, sewage solids, bone meal, dried blood from abbatoires, or guano.

Many-gene characters

See: polygenic characters.

Maranta arundinacea

Arrowroot. A South American crop grown primarily for its high quality starch used for invalid foods and face powder.

Marker gene

A Mendelian gene that is used to identify the progeny of cross-pollination in an inbreeding species of crop.

Marrow

See: Cucurbita pepo.

Mass selection

Often called population breeding, or recurrent mass selection this is the converse of Mendelian or Pedigree breeding. Mass selection requires a population, as large and as genetically diverse as possible, which is screened for the best individuals that are to become the parents of the next screening generation. It is the method of choice for many-gene characters, and for amateur breeders working with horizontal resistance. The selection criteria can include all aspects of yield, quality, agronomic suitability, and horizontal resistance to all locally important parasites. It is essential to screen for all the desirable characteristics in each breeding cycle. The assessment of each individual must be relative to the neighbouring individuals and the population as a whole. A holistic approach is recommended.

Matching

In terms of the gene-for-gene relationship, an allo-infection is described as matching when the vertical parasitism gene(s) of the parasite match the vertical resistance gene(s) of the host (i.e., the biochemical key of the parasite fits the biochemical lock of the host). The vertical resistance then fails to operate and the allo-infection is successful. See also: Non-matching.

Maté

See: Ilex paraguariensis.

Maximum

The highest possible value of a quantitative variable.

Mayetiola destructor

The Hessian fly. A stem borer of wheat. This parasite is interesting in that vertical resistance against it is quantitative. It is thought that the evolutionary function of this resistance is to reduce or even prevent reproduction of the parasite, rather than to reduce the frequency of matching allo-infections. In either event, it appears that the evolutionary function of the gene-for-gene relationship is to stabilise the population explosion of an *r*-strategist parasite.

Mean

An alternative term for average. See also: Gaussian curve, Normal distribution, Mode, Skewed distribution.

Mechanisms of resistance

The mechanisms of resistance in plants to their parasites are many and varied. As a general rule, they are of little interest to amateur breeders working with horizontal resistance, who should use the

holistic approach. It is a great mistake to breed plants for a single, prominent resistance mechanism, such as hairy leaves that resist certain insects.

Medicago sativa

Alfalfa, known as lucerne in Britain. This is probably the most important of the fodder legumes and it is used for grazing, hay, and silage. Its origins are ancient and are apparently linked to the domestication of the horse. The plant is pollinated by special bees, although some self-pollination does occur. This is one of the relatively rare examples of recurrent mass selection used by professional breeders to accumulate horizontal resistance during the twentieth century.

Meiosis

Reduction division. This is the process in which the two sets of chromosomes in a diploid nucleus separate to form two haploid nuclei that become gametes. See also: Mitosis.

Melampsora lini

Flax rust. This is the disease in which H.H. Flor discovered the gene-for-gene relationship.

Melinis minutiflora

A tropical fodder grass, called molasses grass, and native to Africa.

Meloidogyne spp.

A widespread genus of root feeding nematodes, that do not form cysts and which can be serious pests of crops.

Melon

See: Cucumis melo.

Melon, water

See: Citrullus lanatus.

Melongene

See: Solanum melongena.

Mendel, Gregor

Gregor Johann Mendel (1822-84) is often regarded as the father of genetics. More accurately, he is the originator of single-gene (or Mendelian) genetics, although his work was later used to explain the action of polygenes. This is an example of the time lag in science. Mendel's work was ignored for thirty-five years. After its recognition, in 1900, its importance was greatly over-emphasised in plant breeding for the next century. Today, single-gene genetics still dominate plant breeding and, of necessity, genetic engineering.

Mendelian

Pertaining to Mendel's laws of inheritance.

Mendel's laws of inheritance

Mendel's laws of inheritance were based on his work, but were formulated only after his death. They are not of great interest to amateur breeders working with many-gene characters. The first law states that when two homozygous individuals are crossed, the F_1 individuals are phenotypically identical. The second law states that recessive characters that are masked in the F_1 of a cross between two homozygous individuals, will reappear in a specific proportion in the F_2. The third law states that members of different allele pairs (i.e., Aa and Bb) will assort independently of each other when gametes are formed, provided that the genes are not linked.

Mentha spp.

Mint, peppermint, spearmint, and Japanese mint (menthol). These species hybridise freely and are very variable. There is scope for amateur breeders looking for both highly specialised crops of exceptional quality, and useful levels of horizontal resistance.

Mercury

Mercury compounds are mostly very toxic and their use as crop protection chemicals, particularly as fungicidal seed dressings, is now banned.

Meristem

The undifferentiated tissue of a plant growing point. Meristem cells are capable of dividing into various different tissues and organs. They are the equivalent of the human stem cells in medical terminology.

Meristem culture

A technique for freeing vegetative propagating material from virus and other diseases. The meristem is the part of the plant that is undergoing active cell division to produce new tissues. These new tissues remain free of all parasites for a short period. By removing the meristem, and culturing it with tissue culture techniques, it is possible to produce a new plant that is free of parasites. Not a suitable technique for amateurs.

Merological approach

A systems term meaning systems analysis, or systems management, that is being conducted at the lowest feasible systems level. The converse, in which the system is studied at the higher systems

levels, is called the holistic approach. The holistic approach is essential if suboptimisation is to be avoided.

Metabolism

The chemical processes that take place in any living organism. Anabolism is constructive metabolism, and is concerned with the synthesis of proteins, carbohydrates, and other substances. Catabolism is destructive metabolism, and is concerned with the breakdown of chemical substances to produce energy.

Metamorphosis

Metamorphosis in insects usually occurs in the final instar and it results in an organism that is markedly different from that of the earlier instars. For example, a caterpillar metamorphoses into a butterfly.

Metaxenia

The phenomenon in which plant tissues outside the embryo sac (i.e., edible fruit tissues) are influenced by the pollen. This phenomenon is seen, for example, with dates.

Metroxylon spp.

Sago palm. Several species are used in S.E. Asia and Polynesia for the production of sago, a starch extracted from the pith of a palm stem that is about fifteen years old.

Microcyclus ulei

This is the fungus that causes South American Leaf Blight (SALB) of Para rubber. It is of interest in that rubber grows in the Amazon valley, which is permanently warm and wet, and it has a gene-for-gene relationship in spite of apparently having a continuous pathosystem. In fact, the rubber tree is deciduous, in spite of its continuously warm and wet tropical environment, and this demonstrates the evolutionary value of the deciduous habit in producing a discontinuous pathosystem for the control of parasites.

Micro-evolution

Evolution within species . Unlike macro-evolution, micro-evolution operates during periods of historical time, it produces changes that are not intrinsically new, it produces no increase in complexity, it is reversible, it produces new ecotypes, and it does not produce new genetic code.

Micro-evolution in a wild ecosystem produces differing ecotypes as a result of different selection pressures in different parts of the ecosystem. It is the result of natural selection. Micro-evolution in an agro-ecosystem system produces differing agro-ecotypes as a result of different selection pressures in

parts of the agro-ecosystem. It is the result of an artificial selection called domestication, or plant or animal breeding.

The classic example of micro-evolution was industrial melanism.

Micro-organism

Any organism that is microscopic or ultra-microscopic (i.e., viruses, which are too small to be visible with a light microscope, and can be seen only with an electron microscope). Most plant pathogens are microscopic, but most plant pests are macroscopic.

Microscope

A magnifying instrument. A high power optical microscope will discern organisms as small as bacteria, but smaller organisms (e.g., viruses) require the considerably greater magnifying power of an electron microscope. See also: Dissecting microscope.

Microscopic

Too small to be seen with the naked eye.

Microsphaera

A genus of the Erysiphales (powdery mildews) characterised by cleistothecia that contain several asci, and appendages that dischotomise several times at the tip. The main species of economic importance are M. alphitoides (oak mildew), M. berberis, (barberry mildew) and M. grossulariae (Gooseberry mildew).

Mildew

Plant pathologists recognise two kinds of parasitic mildew. Powdery mildews occur on the external surface of a plant, and they belong to the Erysiphales. Downy mildews penetrate the internal tissues of the host, they belong to the *Peronosporales*, and they include potato blight (*Phytophthora infestans*) and grape downy mildew (*Peronospora viticola*).

Millardet

In 1882, Pierre Marie Alexis Millardet discovered the first fungicide, which he called Bouillie Bordelaise or Bordeaux mixture. See also: Plasmopora viticola.

Millet

Any of the cereals belonging to the genera Echinochloa, Eleusine, Panicum, Paspalum, Pennisetum, and Setaria.

Milo

See: Sorghum bicolor.

Mindset

A state of fixed belief that is largely impervious to conflicting evidence or argument. Scientists are supposedly open-minded but some curious examples of scientific mindset exist. When Joseph Lister first introduced his concept of anti-septic (now called aseptic) surgery, there was furious opposition from many of his medical colleagues. When Gregor Mendel discovered single-gene genetcs, he was ignored for over thirty years. When Alfred Wegener introduced his geological concept of continental drift in 1915, most geologists vigorously denied its very possibility for about half a century, until plate tectonics proved him right. For an even longer period, geologists also denied the possibility of catastrophic change, until Walter Alvarez showed that the extinction of the dinosaurs was due to a major extra-terrestrial impact. And when J.E. Vanderplank introduced his concept of horizontal resistance, in 1963, it was met with comparable hostility in a mindset which continues to this day.

See also: Vested interests.

Mineral oil

Mineral oil can be sprayed on to the surface of water where it makes an impervious film that prevents mosquito larvae from breathing. This is an example of a stable insecticide.

Minimum

The lowest possible value of a quantitative variable.

Minimum tillage

A cultivation technique that makes some use of herbicides in order to disturb the soil as little as possible. The main objective is one of soil conservation but other advantages accrue, such as a reduction in cultivation costs, etc.

Minor staple

A minor staple is the principle food crop of an agricultural people, but one that is not sufficiently productive to become a major staple. Minor staples permit the development of village societies only. They do not liberate a sufficient proportion of the people from agriculture to permit the growth of cities, and the development of a sophisticated civilisation. Examples of minor staples include yams in West Africa, sorghum and millets in East Africa, potatoes in the high Andes, and taro in Papua New Guinea.

Miracle rices

The dwarf rice cultivars of the Green Revolution. See also: IRRI.

Miracle wheats

The dwarf wheat cultivars of the Green Revolution. See also: CIMMYT.

Miridae

The plant bugs, many of which are serious pests of crops.

Mist propagator

A transparent chamber for rooting cuttings in a nutritionally and biologically inert rooting medium that discourages rotting. The cuttings are left with as much leaf as possible, in order to maximise photosynthesis, and water loss is prevented by keeping the leaves permanently wet with an automatically controlled, fine mist of water. High light intensities are recommended, even at the risk of relatively high temperatures in the chamber. Many crops, in which vegetative propagation was previously difficult or impossible on a commercial scale, can now be vegetatively propagated in mist propagators.

Mites

Small arthropods of the Order Acarina, and important parasites of both plants and animals. They differ from insects principally in that they have eight legs. The plant parasitic mites are often called spider mites, and are often coloured red. They can cause considerable damage to plants by feeding on the surface cells of stems and leaves, causing severe lesions resembling 'burn'.

Miticide

A pesticide that kills mites.

Mitosis

A dividing of a nucleus to produce two daughter nuclei that are genetically identical to each other. See also: Meiosis.

Mobile nutrients

Plant nutrients that can be moved internally from one part of a plant to another. When there is a deficiency of a mobile nutrient, the deficiency symptoms occur in the older leaves. Mobile nutrients include: Nitrogen, Phosphorus, Potassium, and Magnesium.

See also: Immobile nutrients.

Mode

The most frequent quantitative variable within a mixed population. For example, height in people ranges from the minimum to the maximum, and this character has a normal distribution. Very short people are rare. So are very tall people. The most frequent height is the mode. This distribution is

represented by the ‘bell-shaped’ or Gaussian curve, and it is typical of other quantitative variables such as horizontal resistance. With a normal distribution, the mode is also the mean, or the average. With a skewed distribution, the mode and the mean are different.

Moko disease

A wilt disease of banana caused by the bacterium Pseudomonas solanacearum.

Molasses

The sweet syrup of non-crystallising sugars left over from the refining of cane sugar. This syrup is utilised in cattle feed, and in the fermentation of rum. It is also refined into treacle for human consumption.

Mold

The American spelling of mould.

Molecular biology

A modern branch of biology in which biological phenomena are studied at the systems level of the molecule. It includes the study of single genes and genetic engineering.

Molecule

The smallest part of a chemical compound that can take part in a chemical reaction. A molecule consists of a group of atoms,.

Momordica charantia

The bitter gourd, bitter cucumber, or balsam pear. This monoecious vine originated in the Old World and is now common throughout the tropics. The young fruits are peeled and steeped in water to remove the bitterness before cooking. This crop is amenable to improvement by amateur breeders .

Monkey nut

See: Arachis hypogea.

Monocotyledon

Any Angiosperm that has only one cotyledon in each seed. They are often called the narrow-leaved plants, and the leaf veins are usually more or less parallel. The flower parts are in multiples of three. Seeds of monocotyledons cannot be split into two halves like split peas. Cultivated monocotyledons include all the cereals and other grasses (Gramineae), onion family (Alliaceae), palm family (Palmae), banana family (Musaceae), ginger family (Zingerberaceae), yam family (Dioscoreaceae), and pineapple family (Bromeliaceae).

Monoculture

The cultivation of a single crop, without any crop rotation. Monoculture greatly increases the chances of serious epidemics, particularly of soil-borne parasites. Monoculture is most dangerous when it is continued for a long period of time, when it involves very large acreages, and when the entire crop consists of a single, genetically uniform cultivar, and when that cultivar is protected by vertical resistance. Possibly the largest and longest monoculture consisted of the United Fruit Company banana plantations of the Gros Michel cultivar in various countries of the Caribbean. It was eventually ruined by the soil-born diseases called Panama disease and Moko disease.

Monocyclic parasites

Parasites that have only one life cycle in each season or crop cycle. See also: Oligocyclic, Polycylic.

Monoecious

Greek = one house. The occurrence of separate male and female flowers on one plant. See also: dioecious, hermaphrodite.

Monogenic characters

Characters whose inheritance is controlled by a single gene. For example, vertical resistances are monogenic characters.

Monogerm

Sugar beet in which each fruit contains only one seed. This is an important commercial advantage as it removes the necessity of thinning out the young seedlings in the field by hand.

Monolock

In the crop pathosystem, we have misused the gene-for-gene relationship by employing it on a basis of crop uniformity called monolock. For this reason, vertical resistance is temporary resistance in agriculture. Monolock is a host-parasite system of locking that has been ruined by uniformity. “What happens when every door in the town has the same lock, and every householder has the same key, which fits every door?” This kind of uniformity occurs in cultivars that are genetically uniform, and in which every plant has the same biochemical lock (i.e., vertical resistance). Such a cultivar is likely to be cultivated in crop populations that total millions, probably billions, and possibly even trillions, of plants, all with the same lock.

Monoploid

A plant possessing only one basic set of chromosomes. See also: Doubled monoploid.

Monozygotic

Monozygotic twins are produced from a single fertilised egg, which then divides into two separate but genetically identical embryos. See also: Dizygotic.

Monsoon

Seasonal winds in India and S.E. Asia. The wet monsoon blows from the southwest, from May to September, and brings rain from the Indian Ocean. The dry monsoon blows from the northeast from October to April, and brings dry conditions.

Morning glory

See: Ipomea.

Morus spp.

The mulberry. *Morus nigra* is the black mulberry, an ancient crop native to the Middle East and cultivated for its fruit for many centuries in the Mediterranean area. *Morus alba* is the white mulberry which originiated in China and is used for feeding silkworms.

Mosaic

In plant pathology, many virus diseases are called 'mosaic'. This term is also applied to the symptoms of these viruses, which produce a leaf mottling of normal and abnormal colouration. There is little difference between a mosaic and a mottle.

Mosquitoes

Flies of the family Culicidae, in the Order Diptera. These insects are vectors of several serious, tropical, human diseases, such as malaria, yellow fever, dengue fever, filariasis, and encephalitis. They are relevant here because of their resistance to unstable insecticides.

Moth

Adult insects of the Order Lepidoptera, which have large membranous wings, covered in scales that often confer colours that constitute a superb camouflage. At rest, the wings are folded over the body, with the upper surfaces outward, for purposes of concealment. Unlike butterflies, moths normally use scents (called pheromones), rather than wing colours, as sex attractants. The fore-wings are larger than the hind wings. The long, slender antennae, are often feather-like. The young stages are known as caterpillars or grubs, and many are serious parasites of crops. The sucking mouth part (proboscis) of the adult moth is usually a coiled tube, and is used for extracting nectar from flowers.

Mottle

In plant pathology, many virus diseases are called ‘mottle’. This term is also applied to the symptoms of these viruses, which produce a leaf mottling of normal and abnormal colouration. There is little difference between a mottle and a mosaic.

Mould

The term has three meanings in agriculture. First, in the sense of ‘mouldy’, meaning stored products damaged by fungi, usually resulting from too high a moisture content. Second, some fungal plant diseases are called ‘mould’, particularly when the fungus is visible as a furry growth on the diseased tissues. Third, soil that is high in organic matter is often called ‘mould’.

Mtata

See: Sorghum bicolor.

Muck

1. Muck soils, consisting entirely of highly decomposed plant material. 2. Farmyard manure.

Mulberry

See: Morus spp.

Mulch

A covering spread over soil with a view to conserving soil moisture, protecting crop roots, controlling weeds, encouraging beneficial soil organisms, and adding nutrients to the soil. Mulch usually consists of dead plant material such as straw, old leaves, bark, or cereal husks and chaff. An ornamental mulch of crushed stone is now fashionable for flower beds and potted plants. A plastic mulch, consisting of polyethylene film, can be useful for weed control, or as a means of heating the soil, with the greenhouse effect, in order to kill soil-borne parasites of crops. However, stone and plastic mulches do not add nutrients to the soil. Mulching can also help soil conservation.

Multiline

A crop population which consists of a mixture of several pure lines that are morphologically very similar, but each of which has a different vertical resistance. The idea of the multiline is to introduce a diversity of vertical resistances into an otherwise genetically uniform cultivar. In practice, a multiline is normally useful only if there is a single species of parasite to be controlled, because a multiplicity of different parasites cannot easily be controlled in this way.

Multi-locational testing

The testing of cultivar in a wide range of agro-ecosystems with a view to identifying those with a wide environmental adaptability. This approach is useful with vertical resistance, but is inappropriate with the concept of comprehensive horizontal resistance, which usually limits a cultivar to a single agro-ecosystem.

Mung bean

See: Phaseolus aureus.

Musa fehi

The Fe'i banana. A close but unimportant relative of the true banana, which occurs in the South Pacific. The fruiting bunch is erect, unlike the true banana in which the bunch is pendant. Not a crop for amateur breeders .

Musa sapientum

The Latin name usually given to the edible bananas and plantains (but not the Fe'i banana). Both the taxonomy and the common usage terms are confused. A banana is a sweet fruit that is eaten raw and ripe. A plantain is a starchy fruit that is usually eaten cooked and either ripe or unripe. As a fruit, bananas are second only to grapes in commercial importance.

The bananas are Old World, Monocotyledons and they are the largest of herbs. (It is incorrect to speak of the banana 'tree', as it has no woody tissues. The so-called 'trunk' is a pseudo-stem made up a fibrous true stem surrounded and supported by leaf sheaths.) The fruits are sterile because the plant is a triploid and usually has both male and female gametic sterility as well. Definitely not a crop for amateur breeders .

For the first half of the twentieth century, bananas were cultivated in such large acreages, mainly by the United Fruit Company, in the countries surrounding the Caribbean, that these countries were known as 'Banana Republics'. The cultivation of one perennial clones ('Gros Michel') in huge acreages, in climatic conditions permanently favourable to epidemics, was probably the largest and most enduring monoculture ever achieved. This monoculture was eventually ruined by a number of different parasites, and this indicates that the very serious pests and diseases are damaging mainly because we cultivate susceptible crops, and not because of any inherent savagery of the parasite.

The first of these destructive parasites was Panama disease *(Fusarium oxysporum* f.sp*., cubense)***.** Many incorrectly blame the disease, when it was undoubtedly the monoculture that was at fault. Another major disease was a bacterial wilt (Moko disease) caused by Pseudomonas solanacearum.

More recently, Sigatoka disease (*Mycosphaerella musicola*), and Black Sigatoka disease (*Mycosphaerella fijiensis*) have become important. The most important insect pest is the banana weevil (*Cosmopolites sordidus*). It seems that these are all new encounter parasites, as bananas are very ancient clones that have been cultivated for millennia without serious parasites in their centre of origin in S.E. Asia.

Musa textilis

Manila hemp, or abaca. This fibre was the finest of the plant fibres and was used extensively for the highest quality ropes in fishing and shipping. It has now been supplanted by plastic ropes, but it is still in demand for extra strong papers, such as tea bags. The fibres are retted out of the outer sheaths of the petioles that form the pseudo-stem.

Musaceae

The banana and ensete family.

Mushroom

The macroscopic sporing body of a fungus. Mushrooms usually have gills, while toadstools have pores. Both edible and poisonous mushrooms occur. The cultivation of edible mushrooms is economically important, but breeding of this crop by amateur breeders is not recommended.

Mustard

See: Brassica spp.

Mutagenic

Any substance or process (e.g., exposure to radio-activity) that induces mutations. Occasionally, induced mutations can be useful in crop plants, and the techniques of inducing them are usually considered to be plant breeding tools which, however, are not recommended for amateur breeders.

Mutant

An individual or clone that exhibits a mutation. Often called a sport.

Mutation

A mutation is a change that occurs in a single gene. A mutant is an individual, or a clone, that exhibits such a change. Mutants that occur within existing clones of cultivated plants are often called sports. Mutations are usually deleterious in wild plants, but crop mutations occasionally have agricultural value. The special features of many ornamental plants, such as variegated leaves, are often due to mutations.

Mycelium

The microscopic filaments of a fungus. When seen in the mass, macroscopic mycelium is often called mould.

Mycology

The study of fungi.

Mycoplasma

See: Phytoplasma.

Mycorrhiza

One of a group of fungi that form symbiotic associations with the roots of higher plants. The fungi are more effective than the root at extracting nutrients from the soil, which they provide to the plant in exchange for carbohydrates.

Mycosphaerella

An Ascomycete fungus that causes leaf spots and stem lesions on many crops, including banana (M. musicola), strawberry (M. fragariae), peas (M. pinoides), brassicas (M. brassicicola), flax (Pasmo disease, M. linorum) and cucurbits (M. citrullina).

Myristica fragrans

The nutmeg. This tree is a member of the family *Myristicaceae*, native to the Moluccas, and it produces two distinct spices. Nutmeg is the dried seed, and mace is the dried aril tissue that surrounds the seed. The former is normally used in sweet dishes, and the latter in savoury dishes. Like cloves and cinnamon, this spice was part of the incredibly valuable spice monopolies, first held by the Arabs and Venetians, then by the Portuguese, then by the Dutch, and finally by the British, before being broken by worldwide competition.

The tree is dioecious and this makes the establishment of an orchard very difficult as the two sexes occur in equal proportions but few males are required. The sex of a tree cannot be determined until flowering, some 5-8 years after planting, and the excess males must then be removed. Half of the replacements are also males, and must later be removed, and so on.

There is room for considerable improvement by selecting within existing populations and then by vegetative propagation . This is within the scope of amateur breeders .

Myzus persicae

The green peach aphid. This aphid is the vector of many virus diseases, and is particularly important in potatoes.

N

n/2 model

This is a model of the probable functioning of the vertical subsystem and the gene-for-gene relationship in a wild plant pathosystem. The fact that we have only conceptual models is an indication of how little research has been conducted on wild pathosystems. However, its mathematical basis is so convincing that we can use it with considerable confidence until such time as we have indisputable facts.

The model is based on the assumption that the gene-for-gene relationship acts as a system of locking. Its primary function is to reduce the population explosion of an *r*-strategist parasite. It normally achieves this by reducing the frequency of allo-infections that are matching infections. But, when the vertical resistance is quantitative, it functions by reducing the reproduction, and the population growth rate of the parasite. The system of locking is an emergent property that is observable only at the systems level of the pathosystem. That is, at the level of the two interacting populations of host and parasite.

If every individual in both the host and parasite populations has no vertical genes at all, every allo-infection will be a matching infection, and the vertical subsystem will not exist. Equally, if every individual has all the vertical genes, every allo-infection will be a matching infection, and the vertical subsystem will not function. The mid-point between these two extremes is when every individual has exactly half of the vertical genes of the vertical subsystem. This is the $n/2$ situation, where n = the number of pairs of matching genes in the system. For example, if there are twelve pairs of genes, $n/2 = 6$, and every individual will have a six-gene combination. That is, every host individual will have a six-gene vertical resistance, and every parasite individual will have a six-gene parasitic ability. Think of each vertical resistance as a biochemical lock with six tumblers. And think of each parasite ability as a biochemical key with six notches.

From Pascal's triangle, we can see that, when $n/2 = 6$, there are 924 different locks and keys. If every lock and key occurs with equal frequency, and with a random distribution, the probability of an allo-infection being a matching infection will be 1/924. And, when there are twenty pairs of genes,

n/2 = 184,756, and the probability of matching is 1/184,756. This is a remarkably economical effect produced from a few pairs of Mendelian genes. It is also a vastly different situation from the single-gene vertical resistances employed on a basis of uniformity in agriculture. This agricultural situation is a classic case of suboptimisation.

The *n*/2 model is a theoretical model. The great merit of theoretical science is that it can predict novelty. If the *n*/2 model proves to be correct, this will be yet another justification of theoretical science.

Native

A species that occurs naturally in an area, and has not been introduced, deliberately or accidentally, by people.

Natural cross-pollination

cross-pollination that occurs naturally, as opposed to artificial or hand-pollination.

Natural selection

The selection that occurs naturally within a wild population that is genetically diverse. The selection operates because the most fit individuals reproduce the most, while the least fit individuals reproduce the least. This is the mechanism of natural evolution by survival of the fittest. Note that complexity theory now suggests that the mechanism of evolution is natural selection operating on emergents at all systems levels, and that the systems level of the individual is much less important than was previously thought.

Navy bean

See: Phaseolus vulgaris.

Necrosis, necrotic

Diseased plant tissue that is brown and dry.

Necrotrophic

A necrotrophic parasite is one that kills its host tissue before obtaining nutrients from it. Necrotrophic parasites are rather uncommon in plant pathology. See also: Biotrophic.

Nectar

The sugary substance produced by plants, and made into honey by bees. The function of the nectar is to attract pollinating insects, as well as humming birds and other pollinating organisms.

Nectary

Any organ of a flower or plant that secretes nectar. The usual function is to attract insects for the purpose of pollination.

Negative feedback

See: Feedback.

Negative screening

A screening technique designed to identify and eliminate the least desirable plants, as opposed to positive screening, which involves identifying and preserving the most desirable plants. This technique is often used with recurrent mass selection , in which the undesirables are weeded out, and the best plants are left to cross-pollinate. It can also be used with genetically diverse populations of a tree crop in order to reduce parasite interference, and promote population immunity. See also: Cocoa.

Nematocide

A pesticide that kills nematodes, or round worms. These worms are often parasites of crops. They are usually soil-borne, and nematocides are usually applied as soil fumigants.

Nematode

A class of worms called round worms. Plant parasitic nematodes are often called eelworms. They are invariably microscopic, and are usually soil inhabitants, which attack plant roots, often causing considerable damage to crops. However, leaf-invading nematodes are also known.

Nematology

The scientific discipline concerned with the study of nematode worms, many of which are parasites of both plants and animals.

Neolithic

The new Stone Age. This was the last stage of the period when people depended solely on stone tools. It saw the start of agriculture, which depended on the domestication of plants. The period lasted 7000-4000BC and was followed by the Bronze Age.

Neo-tuberosum

The potatoes that resulted from an experimental breeding of *Solanum andigena* in order to confirm that it was the original parent of Solanum tuberosum. The change was complete after a mere five generations of recurrent mass selection , and the neo-tuberosum has provided a considerably widened genetic base for breeding purposes.

Nephelium litchi

The litchi fruit, which originated in China.An evergreen tree that is usually propagated vegetatively. Little scope for amateur breeders .

New encounter parasite

If a parasite and its host evolved independently, in different parts of the world, and were then brought together by people, the parasite is described as a new encounter parasite. The parasite would have evolved originally on a botanical relative of its new host. Potato blight (Phytophthora infestans) is a new encounter parasite, which evolved in Mexico, while its crop host evolved in South America. The new encounter occurred in Europe. See also: Old encounter, Re-encounter.

NGO

Non-governmental organisation.

Nicotiana spp.

N. tabacum produces commercial tobacco, used for smoking, chewing, and snuff. *N. rustica* has a much higher nicotine content than *N. tabacum*, and it is occasionally used for smoking, and for nicotine extraction for use as an insecticide. Horizontal resistance is particularly important in tobacco intended for smoking, as these leaves must obviously be entirely free of chemical pesticides. Tobacco is an easy crop to breed but the now widespread dislike of smoking means that this is a crop in decline. It is not recommended to amateur breeders for this reason. However, pyrethrum shows promise as an alternative for tobacco farmers, and this is a suitable crop for amateur breeders.

Nicotine

Nicotine is extracted from tobacco and can be used as an insecticide, often in the form of nicotine sulphate. It is apparently a stable insecticide. However, it is toxic to humans and is generally avoided for this reason.

Niederhauser, John S.

Working with potato blight (Phytophthora infestans) in Mexico, in the 1950s, John Niederhauser was the first scientist to deliberately avoid vertical resistance in favour of horizontal resistance. He was awarded the World Food Prize in 1991.

Night soil

Human excrement that is spread on crops as organic manure. As it can carry various intestinal parasites, it should be employed with caution.

Niloparvata lugens

The brown plant hopper of rice. This is one of the relatively few insect parasites of crops in which there is a vertical subsystem. Unfortunately, the miracle rices proved unusually susceptible, and vertical resistance proved unsuccessful in its control. In the Philippines, it is being controlled with insecticides, but also with IPM, and farmer-participatory schemes breeding for horizontal resistance.

Nitrates

Nitrates are one of the commonest plant nutrients, applied either as artificial fertilisers or organic manures.

Nitrogen

Nitrogen is an essential component of proteins and it is normally absorbed by plants as inorganic chemicals, usually as nitrates. Nitrogen deficiency shows as poor growth and a general light green colour. Nitrogen is mobile nutrient.

Nitrogen fixation

Although the atmosphere consists mainly of nitrogen, plants are unable to absorb it directly. Many micro-organisms fix atmospheric nitrogen in forms that plants can use, but the most important by far are the nitrogen-fixing nodules formed by Rhizobium on the roots of legumes.

Nitrogen-fixing root nodules

Nodules formed on the roots of plants of the botanical family Leguminoseae, by bacteria called Rhizobium. These nodules are able to convert atmospheric nitrogen into protein. This is a symbiotic association in which the bacteria provide protein, and the plant provides carbohydrates. This is one of the reasons why pulses and fodder legumes are such valuable crops. It is possible to isolate the bacteria from these nodules, and culture them in order to inoculate the seed of leguminous crops. Commercial cultures of Rhizobium are known as legume inoculants. Some species of legume have Rhizobium strains in common, while other have their own special strains. It has become fashionable to use the plural name ‘Rhizobia’ but this usage should be discouraged. We might just as well refer to crocuses as ‘croci’.

Nitrogenous fertilisers

All crops need nitrogenous fertilisers, either in the form of artificial fertilisers, organic manures, green manures, or by nitrogen-fixing micro-organisms and legumes.

Nocturnal

During the hours of darkness, as opposed to diurnal.

Node

A joint in a plant stem that bears one or more leaves, usually with an axillary bud between the petiole and the stem.

No-eye pea

See: Cajanus cajan.

Non-industrial country

Previously called 'Third World' or 'less-developed' countries, these are the poorer countries in which up to 80% of the population are engaged in agriculture, which is mostly subsistence agriculture. They are provided with overseas aid by the rich industrial countries, and plant breeding clubs, particularly in universities, show promise of becoming the most effective form of aid in agriculture.

Non-linear system

See: Linear system, and Self-organisation.

Non-matching

In terms of the gene-for-gene relationship, an infection is described as non-matching when the parasitism gene(s) of the parasite do not match the resistance gene(s) of the host (i.e., the biochemical key of the parasite does not fit the biochemical lock of the host). The vertical resistance then functions and the infection is unsuccessful. See also: Matching.

Non-target organisms

Organisms, particularly insects, that are unintentionally killed by crop protection chemicals. The most important are pollinating bees, and the agents of biological control.

Normal distribution

The mathematical characteristics of a population in which a quantitative variable, such as horizontal resistance, shows every degree of continuous difference between a minimum and a maximum. The normal distribution is defined by two parameters: the mean or average, which locates the centre of the distribution, and the standard deviation, which determines the spread of the distribution. When plotted as a graph, the normal distribution is a bell-shaped or Gaussian curve. See also: Skewed distribution.

Noug oil

See: Brassica carinata.

Nucellar embryo

A plant embryo that has developed from the maternal tissue of the nucellus, without pollination. Such an embryo will produce a plant that is genetically identical to the maternal parent. This is a form of apomixis.

Nucellar seed

In most plants, seeds are produced as a result of fertilisation of an ovule by a pollen cell. In a few plants (e.g., citrus, mango), embryos can also be produced directly from maternal tissue (the nucellus), without any fertilisation by pollen. Seeds with nucellar embryos are called nucellar seeds, and they have two agricultural advantages. First, like true seeds, they do not carry virus diseases, or any of the other parasites whose transmission is blocked by seed propagation. Second, they are genetically identical to the female parent, and they constitute a form of vegetative propagation . Nucellar seeds can thus be used to produce clones, with few of the dangers of transmitting parasites that are normally associated with vegetative propagation . See also: Apomixis.

Nucellus

The nutritive maternal tissue surrounding an ovule.

Nucleus

That part of a Eucaryote cell that contains the chromosomes.

Nutmeg

See: Myristica fragrans.

Nutrition

While the nutrition of mammals requires organic chemicals, the nutrition of plants requires inorganic chemicals, the exception, in both cases, being iron. This is why artificial fertilisers are so important in agriculture.

Organic farmers ban the use of artificial fertilisers on the grounds that they are synthetic chemicals but, in the long view, this has to be a mistake. Humanity as a whole cannot feed itself without artificial fertilisers and, so long as organic farmers forbid them, the total organic farming will be restricted by the supply of organic manures, which are very limited.

O

Oats

See: Avena sativa.

Obligate parasite

A parasite that is able to extract nutrients only from a living host. It cannot extract nutrients from non-living material. See also: Facultative parasite.

Oidium

This is the generic name given to the conidial stage of all powdery mildews, the Erysiphales. The conidia are consistently similar throughout this family, being unbranched and producing chains of hyaline, oval conidia.

Oil insecticides

A thin film of mineral oil (e.g., kerosene) on water will kill mosquito larvae by depriving them of oxygen. This is an example of a stable insecticide which is beyond the capacity for micro-evolutionary change of the parasite.

Oil palm

See: Elaeis guineensis.

Oil seed crops

Any crop that is cultivated specifically for its seed, which has a high vegetable oil content. Temperate oil seeds include canola, sunflower, and linseed. Tropical oil seeds include oil palm, sesame, and coconut. Oil is also extracted, on an industrial basis, from other seeds, such as maize, soybean, peanut, and cotton, which are not cultivated specifically for their oil. Oil is also extracted from the fruit tissues of olives, avocado, and oil palm.

Okra

See: Abelmoschus esculentus.

Old encounter parasite

A parasite that has been in continual contact with its crop host since the earliest domestication. Wheat rust in Europe is an old encounter parasite. If the crop host is moved to a new area (e.g., from the Old

World to the New), and the parasite is moved with it, as happened with wheat rust in North America, it is still an old encounter parasite. See also: New encounter, re-encounter.

Olea europaea

The olive. This crop is an excellent example of both ancient clones that demonstrate the utility and durability of horizontal resistance, and of an ancient domestication that achieved results that modern plant breeding cannot improve. However, an entirely new, modern requirement is the need for mechanical harvesting, which will necessitate fruits that ripen simultaneously, and that are easily detached. This is a task for professional breeders, and this crop is not recommended for amateur breeders .

Oligocyclic parasite

A parasite that has several, but not many, life cycles in each crop cycle, or season. See also: Polycyclic, Monocyclic.

Olive

See: Olea europaea.

Omnivore

A consumer of both animal and plant foods. Humans are omnivores as some two million years of hunter-gathering demonstrate. Our teeth also indicate our fundamental omnivorous nature. See also: Vegetarian, Vegan.

One-pathotype technique

A technique for ensuring that all vertical resistance are matched during the process of screening for horizontal resistance. The technique requires the designation of a single vertical pathotype of the parasite in question. All the original parents of the breeding population must be susceptible to (i.e., matched by) the designated pathotype, which is then used in all screening for resistance to that parasite, during the entire the breeding program. The designated pathotype is usually cultured on the matching designated host. See also: Saturation technique.

Onion

See: Allium cepa.

Onobrychis viciifolia

Sainfoin. This is a fodder legume that was often used in place of alfalfa, but which is now in decline from competition with improved strains of clovers and alfalfa. It may be of local limited interest to amateur breeders

On-site selection

Because the epidemiological competence of parasites varies from one agro-ecosystem to another, the requirement for horizontal resistance, to each of these parasite, also varies. If a cultivar is to be fully adapted to its agro-ecosystem, its selection during breeding must be conducted within that agro-ecosystem. Although this is called on-site selection, it means three things: that the selection work is conducted in the area of future cultivation, during the time of year of future cultivation, and according to the farming system of future cultivation. The purpose of on-site selection is to achieve local optimisation of the many quantitative variables that can occur within a cultivar, including the various horizontal resistances to locally important parasites.

Oospore

The microscopic spores produced by sexual fusion in many parasitic fungi belonging to the Peronosporles (downy mildews). Most oospores are very hardy, and are formed at the end of a discontinuous epidemic. They are resistant to desiccation and cold, and they enable the fungus to survive an adverse season, such as a tropical dry season, or a temperate winter, when no host tissue is available to the parasite. Being the result of sexual recombination, they also produce a wide diversity of vertical pathotypes at the beginning of the epidemic, when there is a wide diversity of vertical pathodemes to be matched. Oospores should not be confused with conidia that are produced asexually .

Open pollination

See: cross-pollination.

Open-pollinated crops

This term is synonymous with cross-pollination. Open-pollinated crops can be divided into those that are obligately cross-pollinated, and those that have an optional self-pollination. It may be generally assumed that cross-pollinated crops do not tolerate inbreeding, otherwise they would be cultivated as pure lines. However, inbreeding is often employed in order to produce hybrid varieties. Many open-pollinated crops are cultivated as clones, because this is the only way of preserving their agriculturally valuable characteristics.

Ophiobolus

Ophiobolus graminis is the old name for Gaumanniensis graminis, the fungus that causes “Take-All” disease of cereals.

Opium

See: Papaver somniferum.

Opposite leaves, branches

A pair of leaves or branches that occur on opposite sides of each node on a stem.

Optical microscope

The light microscope, as opposed to an electron microscope. There are two basic types of light microscope. A compound microscope has two sets of lenses; the first set is called the objective, and it determines the resolution. The second set is called the eye-piece, and it determines to final magnification. A dissecting microscope consists of two compound microscopes so aligned that they focus on a single point. This provides stereoscopic vision. A dissecting microscope has a low magnification and it is used for delicate operations that require vision in depth.

Orange

See: Citrus spp.

Order

A level in the taxonomic hierarchy. An order is a group of closely related families.

Organ

Any significant, macroscopic component of an organism.

Organelles

The internal, microscopic organs of a single cell.

Organic chemicals

Originally, chemical substances that had been produced by living organisms were called ‘organic’ chemicals, as opposed to the ‘inorganic’ chemicals such as rocks and water, which had not been produced by living organisms. Nowadays, the term ‘organic chemical’ refers to any carbon-based compound, including the synthetic organic chemicals. The original meaning is retained in terms such as organic and inorganic fertilisers, farming, etc.

Organic farming

Farming that eschews any use of synthetic chemicals or GMOs.

Organic fertilisers

Any manure that has been produced by a living organism. The term includes farmyard manure, night soil, guano, sewage solids, bone meal, dried blood, and green manure.

Organic food

Food that has been produced on an organic farm without any use of synthetic chemicals or GMOs.

Organism

Any living individual; the word is derived from *organised.*

Original parents

In a program of recurrent mass selection , the parents of the first polycross.

Ornamentals

Horticultural crops grown for a decorative function. Ornamentals are usually cut flowers but the term also includes decorative foliage, dried flowers, etc.

Orobanche spp.

Broomrape. These species are parasitic angiosperms that lack chlorophyll. They attack a wide range of herbaceous crops and can be an agricultural nuisance.

Orthotropic branches

In a plant with dimorphic branching, the orthotropic branch is the vertical stem that carries the apical meristem. This is the branch that must be used for cuttings in crops such as coffee, cotton, and black pepper. See also: Plagiotropic.

Oryza sativa

Rice. There are three subspecies of *Oryza sativa*, called *japonica*, *indica*, and *javanica*. As their names imply, they are suited to temperate, subtropical and tropical regions respectively. There are many thousands of cultivars, worldwide. The most recent are the so-called 'miracle' or 'dwarf' rices of the Green Revolution which, having short straw, can take large applications of nitrogenous fertiliser without lodging.

Rice is the second most important food crop after wheat. Rice is a warm season crop cultivated in flooded fields. It is very high yielding and, in tropical areas, two or three crops can be grown each year. Rice countries are usually densely populated for this reason. Fuel is scarce in these regions, and the main objective of the 'stir-fry' method of cooking is to conserve fuel. However, the flooding provides excellent soil conservation, and most rice cultures are ancient and continue to be productive. This is in contrast to many of the ancient wheat cultures, mainly in the Middle East, which have declined or disappeared because of soil erosion.

Rice seed is usually germinated in a seedbed and transplanted when the seedlings are several inches high. The flooded fields are allowed to dry out prior to harvest. The rice is usually reaped by

hand and carried to a threshing floor. Both the growing crop, and the unhusked grain, are known as paddy. In the United States, rice cultivation is fully mechanised.

After harvesting, the husks are removed, by milling and winnowing, to produce brown rice. Further milling removes the outer layers of the seed, which contain most of the proteins and vitamins. This milling produces white rice but, unlike the milling of wheat, which grinds the entire grain to flour, rice milling aims to preserve the grain. Rice is usually boiled or steamed to produce the most digestible of all foods, and it is often prescribed for invalids. But undue reliance on a diet of white rice can lead to nutrient deficiencies such as beri-beri. Rice is also fermented to produce beer and saki, and it has many other uses of less commercial importance.

The principle disease is 'Blast' cause by the fungus *Piricularia oryzae*. There is quantitative vertical resistance to this disease and breeding for horizontal resistance will need careful use of the one-pathotype technique. The chief insect pest in the miracle rices is the brown plant hopper, and there are vertical resistance against this parasite also. Nevertheless, this is a crop suitable for amateur breeders, and there is great need for improvements in horizontal resistance. Rice is normally self-pollinated but the use of male gametocides is feasible. However, the multiplication rate of rice is so great that relatively few hand-pollinations are necessary for recurrent mass selection.

Upland rice is grown on land that is not flooded but it still requires a high rainfall. At the opposite extreme, swamp rice is grown in flood plains and its stems can grow as rapidly as the flood rises. An inferior rice (*Oryza glaberrima*) originated in Africa but is generally being replaced with *O. sativa*. The so-called wild rice (Zizania aquatica) of North America is not related.

See also: IRRI.

Osmosis

The passage of a solvent, such as water, through a semi-permeable membrane, such as a cell membrane, from a less concentrated solution into a more concentrated solution. This process produces osmotic pressure, and is responsible for the turgidity of plant cells. See also: Reverse osmosis.

Outbreeder

A species of plant that is allogamous (i.e., cross-pollinating).

Outbreeding cereals

The outbreeding cereals are maize, sorghum, millets, and rye. See also: Inbreeding cereals.

Outbreeding legumes

Most cultivated legumes are inbreeders. The outbreeding grain legumes are: pigeon pea (Cajanus cajan), broad bean (Vicia faba), and cowpea (Vigna unguiculata). The outbreeding fodder legumes are: alfalfa (Medicago sativa) and various clovers (Trifolium spp.).

Outcross

The progeny of a cross-pollination.

Ovary

The animal equivalent of an ovule.

Over-wintering

The method that an organism uses for surviving a winter. See also: Aestivation.

Ovule

The female cell of a plant which, when fertilised by a pollen cell, develops into an embryo.

P

Paddy

See: Oryza sativa.

Palmae

The palm family. All palms are tropical or sub-tropical. The most important crop palms are coconut, oil palm, and date palm. Palms are difficult to breed and, with exception of the coconut in certain circumstances, they are not recommended for amateur breeders .

Panama disease of banana

See: Musa sapientum.

Panicum maximum

Guinea grass. A tropical fodder grass native to East Africa.

Panicum miliaceum

This is the common millet. It is a cereal of ancient domestication, originating in eastern Asia. It was cultivated by the Chinese before the introduction of rice, by the pre-historic Lake Dwellers, and by the ancient Greeks and Romans. Its wild progenitors are extinct. It has a short growing season (60-90

days) and it is drought-resistant. Some cross-pollination occurs, and this crop is suitable for amateur breeders.

Papaver somniferum

This is the opium poppy. Its cultivation is illegal in most countries.

Papaya

See: Carica papaya.

Paprika

See: Capsicum spp.

Parameter

A measurable or quantifiable characteristic which is often definitive.

Parasite

Any organism in which the individual spends a major part of its life cycle inhabiting, and obtaining nutrients from, a single host individual. The term may be applied to a species, a population, or an individual. Plant parasites include insects, mites, nematodes, Angiosperms, fungi, bacteria, phytoplasmas, viruses, and viroids.

Parasite gradients

The distribution of a parasite within a crop is usually uneven, with a gradual variation from a high density to a low density. This variation is known as a parasite gradient. Unless it is taken into account during recurrent mass selection, it can cause serious errors in the assessing of the level of horizontal resistance in individual selections. This problem can be overcome by the use of grid screening. See also: Patchy distribution.

Parasite identification

See: CABI.

Parasite interference

When the levels of parasitism are being measured in small test plots, the movement of parasites from one plot to another can cause measurement errors of several hundred-fold. This phenomenon is called parasite interference, or interplot interference. Because it involves allo-infections, the effects of unmatched vertical resistance are greatly enhanced in small plots, in comparison with the effects of horizontal resistance which are greatly diminished. More than any other, this phenomenon has misled crop scientists over the relative values of the two kinds of resistance. Parasite interference has also caused serious errors in field trials that have led to unnecessarily high rates of pesticide use.

Parasitic ability

The ability of a parasite to cause parasitism, and to inhabit and obtain nutrients from a living host, in spite of the resistance of that host. There are two kinds of parasitic ability called vertical and horizontal parasitic ability respectively.

Parasitism

The process in which a parasite inhabits, and obtains nutrients from, its host.

Parenchyma

Plant tissue consisting of unspecialised cells, usually with air spaces between them. Many plant organs, such as the inside of many stems (e.g., pith), are made up mainly of parenchyma.

Paris Green

A singularly nasty pesticide containing copper and arsenic, which was widely used until replaced with DDT.

Parsley

See: Petroselinum crispum.

Parsnips

See: Pastinaca sativa.

Parthenocarpic

The production of fruit without pollination, as with bananas.

Parthenogenetic

The development of an individual from a gamete without fertilisation.

Partial resistance

This term, meaning 'incomplete', was originally used to describe horizontal resistance. Unfortunately, 'partial' also means biased, and the term would better describe vertical resistance. Horizontal resistance would then be impartial resistance. These terms are best avoided.

Pascal's triangle

A mathematical device for calculating the possibilities of 'either-or' events, such as 'boy or girl' in single-child births, or the presence or absence of vertical genes. For example, with three births, there are one possibility of three boys, three possibilities of two boys and a girl (i.e., 'boy-boy-girl', 'boy-girl-boy', and 'girl-boy-boy'), three possibilities of two girls and a boy, and one possibility of three girls. These possibilities are called the binomial coefficients. They are important for calculating the

numbers of biochemical locks and keys that there will be in the n/2 model of the gene-for-gene relationship and the vertical subsystem.

Paspalum spp.

Tropical fodder grasses from South America.

Passiflora edulis

The passion flower, which is cultivated for its fruit that are used to add flavour to fruit salads and drinks. This crop is open-pollinated and offers scope for amateur breeders who should aim at horizontal resistance to locally important parasites, increased fruit size and juice content, and yield.

Passion fruit

See: Passiflora edulis.

Pasta wheat

See: Triticum durum.

Pasteurisation

Named after Louis Pasteur, this is a technique of heating wine, milk, food, or soil to about 80°C in order to destroy harmful micro-organisms. This level of heating does not lead to a complete sterilisation, for which a temperature of about 120°C is required. Pasteurised soil can be used as soon as it is cool, whereas sterilised soil usually needs about three weeks to recover its beneficial micro-biological activity.

Pastinaca sativa

The parsnip, which is an open-pollinated, biennial member of the Umbelliferae, and is cultivated for it large, yellow, tapering root, which is eaten as a vegetable. Amenable to breeding by amateurs.

Pasture

Land covered with fodder grasses and legumes, and used for grazing farm animals such as cattle and sheep.

Pasture grasses

See: Fodder grasses.

Pasture legumes

See: Fodder legumes.

Patchy distribution

The converse of a uniform distribution. With a patchy distribution of parasites, some individuals in the host population may be heavily parasitised, while others may escape entirely. Patchy distributions

occur typically with soil-borne parasites, and gregarious insects (e.g., the leaf hoppers of maize streak virus). A patchy distribution is a nuisance when screening plants for horizontal resistance because it produces escapes from parasitism, and these provide a false indication of resistance. A patchy distribution can be overcome during screening for resistance by using a grid screening. That is, the screening population is divided into a grid of perhaps one-metre squares, and the best individual in each square is kept, provided parasites are present in that square.

A patchy distribution can also occur over time. For example, swarms of the desert locust occur only once in 10-15 years. This period is long enough for a population of an annual host to lose most of its resistance to these insects.

A patchy distribution is an evolutionary survival advantage for the parasite, because it prevents the host from accumulating resistance. See also: Frequency, injury.

Pathodeme

A sub-population of a host that is defined by a stated characteristic of resistance. For example, many different cultivars may possess vertical resistance gene 2, but no others) even though they differ in many other respects. Horizontal pathodemes differ in their levels of horizontal resistance.

Pathogen

A category of plant parasite that causes disease and is studied by plant pathologists. The term includes fungi, bacteria, phytoplasmas, viruses, and viroids. When nematodes are studied by plant pathologists, they too are called pathogens.

Pathogenic

An organism, called the pathogen, is described as pathogenic when it is able to induce disease in another organism, called the host.

Pathologic race

An obsolete term meaning vertical pathotype. See also: Physiologic race.

Pathology

The study of diseases. Plant diseases are studied by plant pathologists, sometimes called phytopathologists.

Pathosystem

A subsystem of an ecosystem, and one that is defined by parasitism. A pathosystem normally involves the interaction between a population of one species of host, and a population of one species of parasite. In a plant pathosystem, the host species is a plant. The parasite is any species which

spends a major part of its life cycle inhabiting, and drawing nutrients from, one host individual. The parasite may thus be an insect, mite, nematode, parasitic Angiosperm, fungus, bacterium, phytoplasma, virus, or viroid. However, herbivores which graze populations of plants are usually regarded as belonging to the wider concept of the ecosystem. See also: Continuous pathosystem, crop pathosystem, Discontinuous pathosystem, Heteroecious, and wild pathosystem.

Pathotype

A sub-population of a parasite that is defined by a stated characteristic of parasitic ability. Thus vertical pathotype and Horizontal pathotype. See also: Pathodeme.

Pattern

The basic unit of a system. A word is a pattern of letters; a molecule is a pattern of atoms, a wall is a pattern of bricks, and so on. A system is a pattern of patterns, and each pattern of patterns is called a systems level.

Pea

See: Pisum sativum.

Pea, pigeon

See: Cajanus cajan.

Pea, winged

See: Psophocarpus tetragonobolus.

Peach

See: Prunus persica.

Peanut

See: Arachis hypogea.

Pear

See: Pyrus communis.

Pearl millet

See: Pennisetum typhoides.

Peat moss

Dead moss of the genus *Sphagnum*, commonly used in potting mixtures.

Pecan

See: Carya pecan.

Pedigree breeding

The breeding method of the Mendelian ***s***, also known as the gene-transfer breeding technique, which usually involves the transfer of a single gene from a wild plant to a cultivar. In practice, this gene usually controls resistance to a parasite, and it confers vertical resistance. The wild plant and the cultivar are hybridised, and the progeny segregate into those which carry the gene and those which do not. The progeny are mostly half way between the two parents in their yield and crop qualities. The best of the individuals which are carrying the gene for resistance is back-crossed to the original cultivar, with further segregation for resistance. The back-crossing is repeated until the progeny have all the desirable qualities of the original cultivar, as well as the gene for resistance from the wild plant. See also: population breeding, recurrent mass selection .

Pedology

The science of soils, including their classification, formation, structure, and composition.

Peduncle

The stalk of an inflorescence.

Penicillin

The antibiotic obtained from the fungus Penicillium. This antibiotic is an example of an unstable protection mechanism.

Pennisetum clandestinum

Kikuyu grass. A fodder grass from Kenya that is now widespread throughout the tropics.

Pennisetum purpureum

Elephant grass, also known as Napier grass. This grass is so-called because it grows tall enough to hide an African elephant. It occurs wild in the general area of Uganda. It is a highly productive fodder, and it provides an excellent mulch. It is usually propagated by stem cuttings of 3-4 nodes. Seed is produced abundantly but is difficult to collect. An appropriate target for a small local breeding club.

Pennisetum typhoides

Pearl millet, also known as bulrush millet, spiked millet, and cat-tail millet, and as bajra in India. This is an ancient crop and the most important of all the millets. It originated in Africa but was taken to India at an early date. Its value lies in its tolerance of poor soils and low rainfall. The plant is open-pollinated and exhibits extreme variation. An attempt to produce hybrid varieties in India was highly successful until the breakdown of vertical resistance to downy mildew (*Sclerospora graminicola*). A

suitable crop for amateur breeders who should aim at horizontal resistance and purely local requirements.

Pentaploid

A plant with five sets of chromosomes. Pentaploids are usually sterile.

Pepper

For black pepper (also green and red peppercorns) see Piper nigrum. For red peppers (also sweet, green, Jalapeno, etc., peppers) see Capsicum spp.

Perennial

A plant that lives for several years, and usually flowers every year. See also: Annual, biennial.

Perithecium

A sexually produced fungal body of an Ascomycete that contains one or more asci.

Permeability

The ease with which a substance will cross a membrane. For example, polyethylene film is permeable to oxygen and carbon dioxide, but impermeable to water vapour. For this reason, it makes an excellent protective cover for delicate cuttings, etc.

Peronospora destructor

Downy mildew of onion.

Peronospora nicotianae

Blue mould of tobacco.

Peronospora parasitica

Downy mildew of Brassicas.

Peronospora schachtii

Downy mildew of sugar beet.

Peronospora viticola

Downy mildew of grapes. This fungus originated in North America and was accidentally introduced to Europe during the import of rootstocks resistant to Phylloxera. Bordeaux mixture was discovered in connection with this disease.

Peronosporales

An Order of the Phycomycetes which includes the downy mildews, including potato blight.

Persea americana

The avocado pear. A highly nutritious salad fruit containing up to 30% oil that has a composition similar to olive oil. The avocado originated in Central America (Mexico-Guatemala) but is now grown in most tropical and subtropical countries. The seed is highly heterozygous and selected clones must be propagated vegetatively as grafts on seedling stocks. A good project for breeding clubs which should aim at selection within local populations.

Persistent organic pollutants (POPs)

Hazardous synthetic chemicals that cause birth defects and fatalities among both humans and wild species . Many POPs are crop protection chemicals. See also: Dirty dozen.

Person-Habgood differential interaction

This differential interaction is the definitive characteristic of the gene-for-gene relationship. It was first described by Robinson (Plant Pathosystems, 1976, Springer-Verlag, Heidelberg, New York, & London) and the details are not necessary for amateur plant breeding.

Pest

In its widest sense, any organism that interferes with the activities of humankind. In the sense of pest control, or pest management, the term includes all agricultural, medical, veterinary, industrial, and domestic pests. This gives a very wide meaning to the term pesticide, which has a more restricted definition in this guide.

Pesticide

Any substance that kills pests. In the present guide, the term pesticide refers exclusively to substances that kill crop parasites. Competitors, such as weeds, and the substances that kill them (i.e., weed killers, herbicides), are specifically excluded from the definition. Insecticides, fungicides, bacteriocides, miticides, and nematocides are all pesticides that kill crop parasites. They may be applied as liquids, dusts, vapours, or pellets, and they may be applied to the crop itself, to the soil, or to the seed.

Pesticide over-kill

This term describes any application of a pesticide that involves a greater dosage, or a higher frequency of application, than is necessary for a control of the pest in question.

Pesticide overload

This term is usually used to describe the long-term effects of an excessive use of pesticides .

Pesticide pollution

The pollution of food, fodder, fields, and the environment with pesticides

Petal

The components of a corolla of a flower. Each petal is a modified bract and is delicate. Petals are usually brightly coloured to attract pollinating insects, and even birds. Wind-pollinated plants do not need such attractants, and usually have inconspicuous flowers (e.g., grasses).

Petroselinum crispum

Parsley, a member of the family Umbelliferae. An ancient crop from the Mediterranean, known to the classical Greeks and Romans. The leaves are rich in Vitamin C, and are used as a flavouring in soups and salads. Hybridisation with celery has produced new variants of both species .

Petiole

The stalk that joins a leaf to a stem.

pH

A system of measuring acidity on a scale of 1-14, with neutrality at pH7.0, with increasing acidity below, and increasing alkalinity above pH7.0. The scale is logarithmic. This means that, say, pH4 is ten times more acid than pH5, which is ten times more acid than pH6, and so on.

Phaseolous acutifolius

The Tepary bean is of very ancient domestication in Mexico and was later replaced to a large extent by Phaseolus vulgaris. Of limited interest to amateur breeders .

Phaseolus aconitifolius

Moth, or mat bean. This is a very drought-resistant, self-pollinated grain legume that requires hot tropical temperatures. The green pods may be eaten as a vegetable, the seeds are eaten cooked, and the plant makes a useful forage crop. Of local interest to amateur breeders .

Phaseolus angularis

The Adzuki bean, probably a native of Japan, has been established since antiquity in China. The plants are self-fertile when bagged but cross-pollination is frequent. This makes it an easy crop for amateur breeders .

Phaseolus aureus

The green or golden gram, Mung bean. A popular bean in China and India because it causes little flatulence. In China it is used for making ‘bean sprouts’. This bean is self-pollinating and amateur breeders should commence by selection within existing populations.

This is a domesticated crop whose wild progenitors are extinct.

Phaseolus calcaratus

The rice bean. This is a self-pollinating Old World tropical bean that is eaten with rice, or in place of rice, in the Far East.

Phaseolus coccineus

The scarlet runner bean. A plant of the humid tropical uplands which originated in Central America. The young green pods are eaten sliced and boiled, and the dried seeds can also be cooked and eaten. Of local interest.

Phaseolus lunatus

The Lima or Sieva bean, also known as the butter bean. Named after the capital of Peru, archaeological remains of this bean have been found there dating from 6000BC. However, it is thought that this bean probably originated in the Guatemala area of Central America and was taken to South America by early travellers. The green shelled beans are eaten as a vegetable, and the dried beans are also cooked and eaten. The plant is self-pollinating, but some natural cross-pollination occurs. Of interest to amateur breeders working with horizontal resistance.

Phaseolus mungo

Black gram. This is a highly prized pulse in India. The flowers are self-pollinating and cross-pollination is very rare. Of local interest to amateur breeders who should commence by selecting within existing populations.

The wild progenitors of this crop are extinct.

Phaseolus vulgaris

The haricot bean, also known as the French bean, common bean, kidney bean, salad bean, runner bean, snap bean, string bean, and *frijoles*. The species originated in Mexico and it shows great variation, with beans ranging in size from the small ‘pea beans’ to the large ‘kidney beans’, and with colours ranging from white through yellow, pink, brown, and red to black. The so-called ‘pinto’ beans are speckled brown. Both determinate and indeterminate plants occur.

This is the most widely grown species of *Phaseolus* and it is the most important single source of vegetable protein in the human diet. It offers great scope for amateur breeders working with horizontal resistance. In non-industrial countries, selection within existing landraces should be the first step. The plant is self-pollinated and, when hand-pollinating, some manual dexterity is required in emasculating the flowers. Late selection should be used.

An alternative approach is to use black beans as a genetic marker, using recurrent mass selection . If the breeding involves white beans, a mixture of white bean cultivars is planted in alternate rows with mixtures of black bean cultivar. About 1-5% cross-pollination will occur. The white beans are harvested and grown as a crop whose harvest is separated into white and black beans. The black beans, which are the product of cross-pollination, are then grown and harvested, and the white beans of that harvest are kept for late selection and eventual use as parents in the second breeding cycle. The black beans of that harvest are kept for use as parents in the second breeding cycle.

Virtually all bean breeding during the twentieth century has involved Pedigree breeding and vertical resistance. The exception is a horizontal resistance breeding program in Mexico, which has revealed both the great potential for the development of horizontal resistance, with an average 18% genetic advance in the early breeding cycles, and the feasibility of amateur breeding (See Garcia Espinosa, *et al*., Chapter 25, in *Broadening the Genetic Base of Crop Production*, Eds H.D.Cooper, C.Spillane, T.Hodgkin, ISBN 0-85199-411-3, CABI Publishing, 2001). The main diseases that will require use of the one-pathotype technique in order to inactivate all vertical resistances during screening are anthracnose (*Colletotrichum lindemuthianum*), and rust (*Uromyces phaseoli*). Other major diseases are bacterial blight (*Xanthomonas campestris* f.sp. *phaseoli*), halo blight (*Pseudomonas phaseolicola*), and bean mosaic virus. The insect pests include many aphids, white flies, leaf hoppers, and beetles. The Mexican bean beetle (*Epilachna varivesta*) is serious in Central America and the USA. The bean fly (*Melanagromyza phaseoli*) is important in Africa, Asia, and Australia.

Phenotype

The observable properties of an organism produced by the interaction of its genotype and the environment. For example, recessive characters are part of the genotype, but they are not expressed phenotypically in the heterozygous state. And the Person-Habgood differential interaction is a phenotypic demonstration of a gene-for-gene relationship, but a genotypic demonstration would require inheritance studies in both the host and the parasite.

Pheromone

A sex attractant chemical. These chemicals can now be synthesised, and used in insect traps to prevent sexual fertilisation, thus providing a control of some species of obnoxious insects.

Phleum pratense

Timothy grass. One of the relatively few fodder grasses sown for grazing.

Phloem

The food-conducting tissues of a plant, as opposed to the xylem, which conducts water. In general, the phloem carries carbohydrates downwards from the leaves, while the xylem carries water and minerals upwards from the roots.

Phoenix dactylifera

The date palm, which has a sub-tropical, semi-arid origin in the Middle East. This is possibly the oldest plant domestication in the world. The plant is dioecious and breeding is exceptionally difficult. Propagation by seeds is a waste of time, because of the loss of fruit quality, and vegetative propagation with basal suckers is essential. The quality of the date fruit is affected by metaxenia. A new-encounter killer-disease, 'Bayoud disease' (Fusarium oxysporum ***f.sp.*** albidinis) is spreading inexorably from Morocco eastwards. Breeding is exceptionally difficult, but local people should be on the lookout for the rare, high quality, seedling palm that is also resistant to Bayoud disease.

Phosphate

Compounds of phosphorus, phosphates are an essential plant nutrient. Organic phosphate fertilisers are usually rock phosphate or bone meal. The artificial phosphate fertilisers have had their soluble phosphate content increased by industrial means. Phosphate deficiency symptoms include poor growth, and leaves with a bluish-green to purple coloration.

Photoperiod-sensitive

Photoperiod-sensitive plants depend on a particular day-length to initiate flowering or some other stage of development. For example, short-day potatoes will initiate tuber-production at any time of year in the tropics, where there is an approximately twelve-hour day throughout the year. But when taken to temperate regions, these potatoes will start tuber formation only as the September equinox approaches, and the delayed crop will then be killed by frost before it is mature. This explains why potatoes could not be grown in Europe until day-neutral (or photoperiod-insensitive) cultivars were found.

Photosynthesis

All living organisms can be divided into three groups called producers, reducers, and consumers. Producers are the only organisms that can convert solar energy into the sugars and starches (carbohydrates) on which all life is based. This process is called photosynthesis and it converts solar energy, water, and carbon dioxide into carbohydrates, giving off oxygen as a waste product. It occurs mainly in green plants that contain chlorophyll, but it can also occur in more primitive organisms

such as the cyano-bacteria. Photosynthesising plants are thus at the bottom of the food chain and all life depends on them. They are also responsible for maintaining the world's supply of oxygen.

Phycomycete

A fungus characterised by the absence of cross-walls in the mycelium and, when sexual reproduction occurs, it produces an oospore, and it does not involve an ascus or a basidium. The most important plant pathogenic Phycomycetes are the Peronosporales (downy mildews).

Phyllactinia

A genus of the powdery mildews in which the cleistothecia contain many asci, and the rigid appendages lift the cleistothecia from the leaf so that they fall to the ground.

Phyllotaxis

The arrangement of leaves on a stem. This arrangement may involve opposite pairs, whorls, alternates, etc.

Phylloxera vitifoliae

Now renamed *Daktulosphaira vitifoliae*, this is the famous *Phylloxera* root-inhabiting aphid that was taken from America to France, in the mid-nineteenth century, and threatened the European wine industry with ruin. The problem was solved by grafting the classic wine grapes to wild American grape roostocks that were resistant. However, importing these rootstocks introduced the American downy mildew of grapes, threatening ruin for the second time.

Phylogeny

The evolutionary relationship, based on evolutionary history, between any two taxonomic levels.

Physiologic disorder

A plant disease that is non-parasitic. Both nutrient deficiencies and toxicities, as well as frost damage, etc., are physiologic disorders.

Physiological race

An obsolete term meaning vertical pathotype. See also: Pathologic race.

Physiological source/sink

In a plant, a physiological source is tissue that generates nutrients. Thus the leaves generate carbohydrates by photosynthesis, and the roots generate water and minerals from the soil. A physiological sink is tissue that assimilates those nutrients, usually taking precedence over other tissues. Thus the actively growing shoots, the flowers, and, above all, the seeds, are physiological sinks which grow at the expense of other parts of the plant.

Phytoalexin

A fungus-inhibiting substance produced in a plant.

Phytopathogenic

A term meaning 'pathogenic to plants'.

Phytopathology

See: Plant pathology.

Phytophthora colocasiae

Downy mildew of taro, also known as taro leaf blight. Developing horizontal resistance to this disease is a useful and feasible project for amateur breeders.

Phytophthora infestans

This is the fungus that causes potato blight, which is historically the first and most important plant disease, and was responsible for the 'Hungry Forties' of the nineteenth century, and the great Irish famine. It was this disease that initiated the science of plant pathology.

Phytophthora infestans has two mating types, known as A1 and A2. Each mating type is hermaphrodite but self-sterile. This means that oospores can be formed only if both mating types are present, as happens in the centre of origin in Mexico. When blight was accidentally taken to New York, and then to Europe, in the mid-nineteenth century, it was taken as A1 only and, for 150 years, it could reproduce asexually only. This meant that the fungus could over-winter only in potato tubers. The initial inoculum was small, and the epidemic developed slowly. It was known as 'late blight' for this reason. In the late twentieth century, A2 was taken to Europe, and it was spread all over the northern hemisphere in certified seed potatoes. This means that functional oospores are now being formed in most of the potato-growing areas of the world. The initial inoculum will now be much greater, and late blight is likely to become early blight. The variability of the fungus is likely to increase considerably, and unstable resistances (i.e., vertical resistances) and unstable fungicides will break down much more quickly. And higher levels of horizontal resistance will now be required to provide a full control of the disease.

Potatoes are an excellent crop for amateur breeders, and the need for horizontal resistance to blight and other pests and diseases is acute.

Phytoplasma

A mycoplasma that is parasitic in plants. A mycoplasma is a micro-organism smaller than a bacterium and without a cell wall.

Phytosanitation

The national and international regulations that control the movement of plant propagating material around the world. The purpose of these regulations is to prevent the spread of dangerous crop parasites to those parts of the world that are still free of them. Phytosanitation can be international, regional, or local. International phytosanitation is usually effective because of border controls. Regional phytosanitation within a country is usually ineffectual because of the lack of border controls. Local phytosanitation involves a single farm, and it can be very effective against soil-borne and seed-borne parasites.

Phytosociology

The study of plant communities. There is a loose parallel between animal and plant domestication. Just as herders found that social animals were the easiest to domesticate, so agriculturalists found that 'social' plants (i.e., those that tend to grow in pure stands), such as the wild progenitors of the cereals, were the easiest to domesticate.

Phytotoxin

This term means a substance that is toxic to plants; the adjective is phytotoxic.

Picea spp.

Spruce. Some five species of spruce are grown as softwood plantation trees. Not recommended for amateur breeders .

Pigeon pea

See: Cajanus cajan.

Pimenta dioica

Pimento or allspice. The fruits of this Central American, functionally dioecious tree were mistaken for black pepper by Columbus who thought he had reached India. Not an easy crop to breed.

Pimento

See: Pimenta dioica.

Pine

See: Pinus spp.

Pineapple

See: Ananas comosus.

Pinnate

A compound leaf that has leaflets arranged on either side of a stalk.

Pinus spp.

The pine trees, which are members of the family *Pinaceae*, in the order *Coniferae*, which is one of the five orders of the Gymnosperms. These are particularly important timber trees that provide much of the world's soft wood. Selection within existing populations, particularly in North America, looking for horizontal resistance to white pine blister rust (Cronartium ribicola) would be an appropriate activity for a university breeding club made up of forestry students.

Piper nigrum

Black pepper. A vegetatively propagated, tropical crop that is difficult to breed, and one that is not recommended for amateur breeders . This species is a good example of ancient clones that demonstrate the value and durability of horizontal resistance.

Piperonyl butoxide

A chemical used as a synergist to improve the insecticidal effectiveness of natural pyrethrins.

Piricularia oryzae

This is the fungus that causes the very important disease called rice blast. There is vertical resistance to this disease and amateur breeders looking for horizontal resistance would have to consider using the one-pathotype technique, particularly as some of the vertical resistances are quantitative.

Pistachio

See: Pistacia vera.

Pistacia vera

Pistachio nuts. A dioecious and evergreen tree native to the Near East, these nuts have been cultivated for 3-4 millennia. Not recommended for amateur breeders .

Pistil

The female part of a flower consisting of the ovary, style, and stigma.

Pisum sativum

The garden pea, or green pea. Peas have been found in the oldest agricultural sites in Europe and the Middle East. Traditionally, peas were harvested mature, and the dried peas were used to make pea soup and peas pudding. Believed to be the fourth most important grain legume in terms of human nutrition, this pulse is now grown mainly for harvesting the immature seeds for freezing as a green vegetable. The production of improved horticultural varieties is a possibility for amateur breeders , but they should not attempt to compete with professional breeders in the production of cultivars for the frozen food market.

The wild progenitor of Pisum sativum is extinct.

Pith

Parenchymatous tissue that stiffens the inside of a stem.

Plagiotropic branches

In a plant with dimorphic branching, the plagiotropic branches are the side branches that tend to grow horizontally and that bear the flowers and fruit. The orthotropic branch is the vertical stem that carries the apical meristem, and this is the branch that must be used for cuttings in crops such as coffee, cotton, and black pepper.

Plant

The plant kingdom includes all multi-cellular organisms that contain chlorophyll. These are the multi-cellular algae, mosses, ferns, gymnosperms, and angiosperms. With the exception of some forest trees, all cultivated plants are angiosperms. Note that a few angiosperms that are parasitic (e.g., dodder, Striga, broomrape) do not contain chlorophyll. However, these parasites originally possessed chlorophyll.

Plant breeders' rights

Plant breeders' rights are the equivalent of authors' copyrights. A registered cultivar will earn royalties for its breeder on all licensed sales of seed. amateur breeders should check the legislation and regulations of their own country.

Plant breeding

The scientific discipline concerned with crop improvement by genetic methods. See also: Pedigree breeding, population breeding, Genetic engineering.

Plant breeding club

An association of determined amateur breeders who would normally wish to breed crops for horizontal resistance with a view to reducing the losses from crop parasites, reducing the use of crop protection chemicals, reducing the environmental and human health hazards caused by crop protection chemicals, and/or earning plant breeders' royalties by breeding for comprehensive horizontal resistance.

See also: University breeding clubs.

Plant breeding institutes

Plant breeding institutes, often with a large staff of specialists, were deemed necessary because of the problems associated with breeding for single-gene, vertical resistance that were part of a gene-for-

gene relationship. The problems associated with this kind of plant breeding are the overall cost, the relatively few cultivar produced, and the short agricultural life of most of the cultivars which have ephemeral resistance. See also: Professional plant breeding.

Plant disease

A plant disease may be infectious, and caused by a parasite, or it may be physiological, and caused by an environmental factor such as frost, a nutrient deficiency, or a toxin. The parasites that cause plant disease are usually called pathogens, and they include fungi, bacteria, phytoplasmas, viruses, and viroids. Parasitic nematodes and angiosperms are often considered plant pathogens also. Plant diseases are studied by plant pathologists, who are sometimes called phytopathologists.

Plant growth chambers

These are research chambers, which may even be an entire room, in which all variables contributing to plant growth can be controlled. These variables include light intensity, light quality, day-length, temperature, humidity, nutrients, presence or absence of parasites, and so on.

Plant hoppers

Homopterous insects characterised by antennae located on the sides of the head, below the eyes. Closely related to the cicadas, whiteflies, aphids, and scale insects.

Plant pathology

The scientific discipline concerned with the study and control of plant diseases, which are usually caused by micro-organisms called pathogen, such as fungi, bacteria, phytoplasmas, viruses, and viroids.

Plant quarantine

The isolation of newly imported plants to ensure that they are not introducing any foreign parasites. The term quarantine may refer to the quarantine station itself, or to the process of testing and purifying the plant material.

Plantain

In the tropics, a plantain is a starchy banana that is eaten cooked. In the industrial countries a plantain is a large sweet banana that is eaten raw.

Plantation forest

Man-made forest in the sense that the tree species used, their planting densities, and other factors, are controlled in much the same way as an agricultural crop is controlled.

Plants as food

Humankind evolved as a hunter-gatherer and an omnivore, and our most natural diet consists of both meat and plant foods. In general, meat provides up to twenty times more nutrition than most plant foods. Consider the food supply of hunter-gatherers. Our centre of origin is in East and Southern Africa. This is an area of savannah that carries up to 20,000 kilograms of herbivore game animals per square kilometre, and these convert inedible grass into edible meat. At the other extreme, tropical rain forest carries only 5-10 kg/sq.km. It is no accident that rain forests have the fewest archaeological remains of hunter-gatherers, or that our hominid ancestors favoured open grasslands. Plant foods are also essential in the human diet as they provide various vitamins, fibres, etc. Vegans prefer a diet made up exclusively of plant foods, while vegetarians usually tolerate dairy products, eggs, and fish.

Plasmopora viticola

The microscopic fungus that causes downy mildew of grapes. This was a new encounter disease , as it originated in the New World and was taken to Europe on rootstocks of wild American grapes intended for grafting to control Phylloxera. This was the disease in which Millardet discovered Bordeaux mixture. In 1822, he found that vines next to the public road at the Château Beaucaillon, in the Médoc district of Bordeaux were free of the disease, and he discovered that they had been spattered with a poisonous-looking substance to discourage passers-by from eating the grapes. This substance was the mixture of copper sulphate and lime that we now call Bordeaux mixture.

Plum

See: Prunus spp.

Pod

An ill-defined term for a dry dehiscent fruit, typically in the family Leguminoseae.

Podosphaera

One of the six genera of the powdery mildews (Erysiphales). The cleistothecia have a single ascus and dichotomously branched appendages. Various species cause powdery mildews of the stone and pome fruits.

Polhill

A farmer in Kenya who, in the 1950's, bred a famous cultivar of pyrethrum, now named after him, proving that plant breeding of many crops is within the capacity of amateur breeders .

Pollen

The male cells of higher plants, produced in the anthers of Angiosperms, or the male cones of Gymnosperms. Plants have many and varied mechanisms for transferring pollen to the female organs for fertilisation. The most common are pollination by wind or insects.

Pollen mother cell

The cell which, as a result of meiosis, becomes the mother of pollen cells in an anther. The pollen mother cell of some crops can be used to produce a haploid plantlet for later doubling of the chromosome number into a doubled monploid. Not a technique for amateur breeders .

Pollinating insects

Insects that pollinate plants. These are usually bees which are attracted to flowers by the offer of honey, but many other species of insects are involved in a wide variety of specialised flowers, such as those that stink of rotten meat to attract flies.

Pollination

The placing of pollen on a stigma for the purpose of sexual fertilisation. There are a variety of methods of natural pollination, of which wind and insects are the most common. Artificial pollination is usually done by hand, but a male gametocide may also be used. See also: Allogamy, Autogamy, cross-pollination, Inbreeder, Outbreeder, Self-pollination.

Pollution

Any form of contamination. In a modern context, the word is usually used to mean environmental pollution with crop protection chemicals, factory exhausts, and other forms of agricultural or industrial waste.

Polycross

A system of mating in which a number of parents are represented in various combinations. Thus, full diallel cross, half diallel cross, random polycross.

Polycyclic parasites

Parasites which have several life cycles in the course of one epidemic cycle, or one season. See also: Monocyclic parasite; Oligocyclic parasite.

Polyethylene

Also called ‘polythene’. A thermoplastic, translucent polymer of ethylene that is impermeable to water vapour but permeable to oxygen and carbon dioxide. It makes a valuable protection for delicate seedlings, cuttings, etc. It is also used in the construction of plastic greenhouses.

Polygene

A gene of small effect contributing to the control of the inheritance of a quantitatively variable character that is controlled by many polygenes.

Polygenic inheritance

Any inheritance that is genetically controlled by many genes of small effect, called polygenes. Polygenic inheritance is quantitative in its expression, and it exhibits every degree of difference between a minimum and a maximum, usually with a normal distribution.

Polyphyletic

A species that originated by hybridisation from more than one wild progenitor.

Polyploid

An organism, usually a plant, which has more than two basic sets of chromosomes. Thus triploid, tetraploid, etc. See also: Allopolyploid, autopolyploid.

Pome fruits

Fruits of the botanical family Rosaceae which contain several seeds in a so-called 'core'. The term includes apples, pears, quince, and medlar. See also: Stone fruits.

Pomegranite

See: Punica granatum.

Poplar

See: Populus spp.

Poppy

See: Papaver somniferum.

POPS

Persistent organic pollutants.

Population

A group of individuals of one species occupying a particular area. A population may be either homogeneous or heterogeneous; or either homogenous or heterogenous. (Check these curiously similar words for differences of meaning and pronounciation).

Population breeding

The breeding method of the Biometricians, which is concerned with small improvements in quantitative characters that are genetically controlled by polygenes. Population breeding usually involves recurrent mass selection . Population breeding is easy while Pedigree breeding is technical.

During the twentieth century, population breeding has rarely been used in most crops, particularly the autogamous crops. This leaves the field wide open for amateur breeders.

Population explosion

The very rapid population growth that can occur with an r-strategists species during a favourable season. Many crop parasites are *r*-strategists, and it is their population explosions that are can be so alarming, and so difficult to control.

The function of the gene-for-gene relationship and the vertical subsystem in a wild plant pathosystem is to control the population explosion of a parasite, but it can do this only if it functions as a system of locking based on genetic diversity. Horizontal resistance can also reduce the rate of population growth of the parasite to the point where the epidemic can no longer develop, and this is called population immunity.

See also: Population extinction.

Population extinction

The death of most of the individuals of an r-strategists population that occurs at the end of a favourable season. With plant parasites, this happens typically in a discontinuous pathosystem, with the loss of host tissue that occurs with leaf-fall in a deciduous host species, or with the death of all plant parts, except the seeds, in an annual host species. With crop parasites, it often occurs with harvest, such as the digging of potatoes, or the combine harvesting of cereals. See also: Population explosion.

Population growth

Unlike an individual, a population can have growth that is positive, static, or negative. Positive population growth occurs when each individual, on average, spawns more than one progeny. Static (or zero) growth occurs when each individual, on average, spawns exactly one progeny. Negative growth occurs when each individual, on average, spawns less than one progeny. See also: Population immunity.

Population immunity

A host population that is less than immune, but which does not suffer an epidemic. Each host individual may be carrying the parasite, but the level of horizontal resistance is such that the population growth of the parasite is zero or negative.

Populus spp.

Poplar trees, used in plantation forests to produce hardwoods. Not receommended for amateur breeders .

Positive feedback

See: Feedback.

Positive screening

A plant breeding technique in which the best individuals in a genetically diverse population are preserved to become the parents, either of the next screening generation, or of new cultivar. See also: Negative screening.

Post-harvest losses

Crop losses due to parasites that occur after harvest, usually in the store. These losses can be reduced or prevented by ensuring (i) that the stored product is dry, to prevent moulds developing, and (ii) that the product is in an airtight container that lacks oxygen, to prevent various animal pests from eating it.

Potassium

A major nutrient of plants, represented chemically by the letter 'K', as in NPK, which stands for nitrogen, phosphate, and potassium. The deficiency symptoms are complex. The older leaves show browning of the tips and margins, with numerous brown spots close to the margins. There may also be dieback of the shoots.

Potato

See: Solanum tuberosum.

Potato blight

See: Phytophthora infestans.

Potato viruses

In the eighteenth century, in England, a group of farmers decided to breed potatoes for resistance to the 'decline' of potato stocks. At this time, it was discovered that seed tubers coming from the Yorkshire Moors did not suffer this decline. This was a crucial parting of the ways. It was decided that importing clean seed tubers was easier than breeding for resistance. From that day to this, we have been controlling potato viruses by certifying seed tubers free of them. The potato viruses spread rather slowly and, for that reason, they rarely appear in plant breeders' screening populations. If one seedling became infected, it was thrown out on the grounds of susceptibility. But the clones that were

kept were escapes from infection and they were just as susceptible. We have been losing horizontal resistance to these viruses during more than two centuries of potato breeding. As a consequence, this is a wonderful opportunity for amateur breeders .

Powdery mildews

See: Erysphales.

ppm

Parts per million; a measure of concentration. On the same basis, percentage is parts per hundred, and ppb is part per billion.

Predator

In the context of crop parasites, a predator is any animal, usually an insect or a nematode, that eats the parasites, and thereby contributes to biological control. See also: Hyper-parasite.

Predator-prey relationship

The category of parasitism in which there is a very low frequency of parasitism, but a very high injury from parasitism. For example, lions parasitise zebras. They only parasitise one zebra at a time, so the frequency of parasitism is minimal. But they consume that one zebra entirely, so the injury from parasitism is maximal. See also: Host-parasite relationship.

Pre-harvest losses

Crop losses from parasites that occur in the field, as opposed to post-harvest losses that occur in the store.

Princess pea

See: Psophocarpus tetragonobolus.

Procaryote

A taxonomic category of primitive, mainly one-celled organisms, that lack a true nucleus and other specialised organelles. The DNA occurs as a loop in the cytoplasm. These are among the most primitive of living organisms and include all bacteria and cyano-bacteria. See also: Eucaryote.

Producers

In an evolutionary sense, producers are those organisms that convert solar energy into dietary calories. They do this by using chlorophyll as a catalyst to combine carbon dioxide and water to form carbohydrates. See also: Reducers, Consumers.

In an agricultural sense, producers are farmers, because they produce food, as opposed to consumers who buy and eat it.

Proefstation Oost Java

This was the Dutch sugarcane breeding station in Java where the famous POJ 2878 cane cultivar was produced. This cultivar has subsequently entered into the pedigree of just about every modern cane cultivar.

Professional plant breeding

There were no professional plant breeders before 1900. Plant breeding was undertaken by farmers, and it was often a hobby undertaken by amateurs, even clergymen (who often had time on their hands). Mendel's laws of inheritance and single-gene characters, such as vertical resistance, were unknown, and all this breeding involved quantitative, many-gene characters and horizontal resistance. It was unscientific but effective.

During the whole of the twentieth century, the great majority of professional plant breeders were in love with Mendelian genetics, and single-gene characters. This tradition continues today with genetic engineering which, of necessity, can handle only single-gene characters. See also: Amateur plant breeders.

Progenitor

In a plant breeding context, a progenitor is the wild ancestor of a crop species . Many crop species, such as maize and wheat, have been changed so much by domestication that their progenitors are difficult to identify. Many other progenitors became extinct because of hunter-gathering, while their domesticated cousins survived in the hands of farmers.

Progeny

In a plant breeding context, a progeny is the offspring of a controlled cross-pollination.

Prokaryote

See: Procaryote.

Propagation

Plant propagation may be by true seed (sexual) or it may be vegetative (asexual). Seed propagation may involve segregating seed, which does not 'breed true', a pure line, which does 'breed true', or a hybrid variety, which has hybrid vigour. Vegetative propagation is achieved with tubers, rhizomes, cuttings, grafts, bulbs, corms, etc.

Protective fungicide

See: Fungicide.

Protein

A nitrogenous organic compound that is an essential part of a living organism. Structural proteins form exoskeletons, hair, hoof and horn, muscles, etc. Functional proteins include most enzymes, antibodies, etc. Protein molecules are built up from about twenty different amino acids that are arranged in different orders in polypeptide chains. The grain legumes, or pulses, are the main source of plant protein in the human diet. Some plant proteins are not digestible by humans and these are liable to ferment in the lower gut causing flatulence.

Proto-Indo-European (PIE)

The ancestor of all Indo-European languages, believed to have been the language of early wheat farmers in southern Turkey. See also: Renfrew hypothesis.

Protoplasm

The living contents of a cell, including the nucleus. See also: Cytoplasm.

Proximal

That part of a plant organ that is closest to its point of attachment. See also: Distal.

Prunus americana

The North American plum, which is a diploid . See also: Prunus domestica. Of rather specialised interest to amateur breeders .

Prunus amygdalus

The almond, which is closely related to the peach and which originated in central and western Asia. It is self-incompatible and cross-pollination is essential for fruit formation. Almonds are cultivated for the seeds, known as nuts, mainly in Turkey and the Mediterranean, as well as in California. In the Old World, almonds are normally grown from seed, while in North America, they are propagated vegetatively. Selection within the Old World crops could be profitable for amateur breeders but a more formal breeding program is not recommended.

Prunus armeniaca

The apricot, which originated in western China and, like the peach, is normally self-pollinated. Apricots can be hybridised with plums to produce 'plumcots'. Not recommended for amateur breeders .

Prunus avium

The sweet cherry, which is a diploid . There are also a number of other cherry species , some of which are tetraploid, including the sour cherry, Prunus cerasus. The commercial importance of

cherries has declined with rising labour costs and the rewards for amateur breeders are unlikely to be great.

Prunus domestica

The European plum, which is a hexaploid. Of rather specialised interest to amateur breeders. See also: Prunus americana.

Prunus persica

The peach, which is the most important of the stone fruits. It originated in China and is a self-pollinating diploid. amateur breeders would face stiff competition from professional breeders.

Pseudo-cereals

The grain amaranths, mainly Quinoa (Chenopodium quinoa), and buckwheat (Fagopyrum spp), are cereal-like grains that are not of grass origin and are often called pseudo-cereals.

Pseudomonas solanacearum

A tropical and subtropical, bacterial plant pathogen with an extraordinarily wide host range. The most serious diseases caused by it are bacterial wilt of potatoes and tomatoes, Granville wilt of tobacco, and Moko disease of bananas. It is a pathogen of minor importance on a wide range of other crops. No vertical resistance are known and all resistance breeding must be for horizontal resistance.

Pseudostem

A false stem. Bananas have pseudostems which look like tree trunks but are not. Each banana stem consists of layers of leaf sheaths, with the flower peduncle growing up through the centre and emerging at the centre of the crown. It is a mistake to call a banana plant a tree, as it has no woody tissues. It is the largest known herb.

Pseudostuga menziesii

Douglas fir. An important softwood for plantation forests in Northwst America. Not recommended for amateur breeders.

Psidium guajava

Guava. This tart fruit is widely grown throughout the tropics and offers scope to amateur breeders, mainly by selecting within existing populations, which are very variable.

Psophocarpus tetragonolobus

The winged bean; also known as asparagus pea, four-angled bean, Manila bean, and princess pea.

Pteridophytes

The ferns.

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Puccinia coronata

Rust of oats. It seems that all breeding for resistance to this disease has involved vertical resistance. However some interesting experiments have been undertaken with multilines. There is much scope for work with horizontal resistance.

Puccinia erianthi

Sugarcane rust which is of interest because no vertical resistance occurs against it (although a few cases have been falsely reported). This is because sugarcane is derived from a continuous wild pathosystem. The disease has occasionally been damaging when it appeared in an area of susceptible cane, as happened recently in Cuba. In general, however, the disease is quite unimportant, as it has been completely and permanently controlled with horizontal resistance.

Puccinia graminis tritici

Stem rust of wheat. There are three rusts of wheat, the others being yellow rust (Puccinia striiformis) and leaf rust (Puccinia recondita). Stem rust has probably attracted more research than any other plant disease and, sadly, virtually all of it has been associated with vertical resistance. There is now great scope for work with horizontal resistance and this is within the capacity for amateur breeders who are willing to tackle some of the more technical aspects of plant breeding.

Stem rust is a heteroecious parasite, and its winter host is the barberry (*Berberis* spp). It has long been known that wheat that was growing near barberry bushes was more quickly and more severely diseased with rust. In Britain, it proved possible to eradicate all the barberries and stem rust is no longer a serious problem. However, the eradication of barberry in larger areas, such as North America, presented insuperable difficulties.

Puccinia hordei

Rust of barley. It seems that all breeding for resistance to this disease has involved vertical resistance and there is much scope for work with horizontal resistance.

Puccinia polysora

The tropical rust of maize which was accidentally taken to Africa some four centuries after maize itself. This was consequently a re-encounter disease and, at low altitudes near the equator, it was extremely damaging. Attempts to breed for vertical resistance proved futile and, in the course of

some 10-15 maize generations (i.e., 5-7 years) the disease declined to unimportance, as a result of a natural accumulation of horizontal resistance. This phenomenon has been largely ignored by most plant pathologists but it is, in fact, one of the most important plant pathological events of the twentieth century, as it has taught us exactly how to breed for horizontal resistance. There is a full account Return to Resistance, available as shareware at this website.

Puccinia purpurea

Rust of sorghum. This is generally an unimportant disease because sorghum is open-pollinated, and it responds to selection pressures for horizontal resistance during cultivation.

Puccinia recondita

Leaf rust of wheat and rye. On rye, this disease is unimportant because rye is open-pollinated and, because it responds to selection pressures during cultivation, it has adequate horizontal resistance. On wheat, however, it is an important disease, mainly because all breeding during the twentieth century has involved vertical resistance. Amateur breeders working with wheat should definitely aim at horizontal resistance to this disease.

Puccinia sorghi

The common rust of maize. Unlike Puccinia polysora, which has epidemiological competence only in the lowland tropics, the common rust occurs wherever maize is cultivated. It is rarely important because most maize cultivars have adequate horizontal resistance to it, because they are open-pollinated and can respond to selection pressures during cultivation.

Puccinia striiformis

Yellow or stripe rust of wheat. This rust also attacks barley, and rye. As a general rule, stem rust is a serious disease in the warmer wheat areas, while stripe rust is serious in the cooler areas. They are rarely both serious in one area. amateur breeders working with wheat should consequently be concerned about one or the other but not both. And they should pay strict attention to on-site selection.

Pulses

Crops of the family Leguminoseae in which the harvestable product is the seed, otherwise known as grain legumes. Includes various categories of beans, peas, lentils, and grams.

Pumpkin

See: Cucurbita pepo.

Punica granatum

The pomegranite, a native of Iran but well known to the ancient Romans.

Pure line

A cultivar of a seed-propagated, inbreeding species in which all the individuals are effectively identical and are almost homozygous. A pure line thus 'breeds true to type'. It is produced by self-pollinating the best heterozygous individual in a mixed breeding population for several generations. In each generation, the progeny show a reduced variability, and the process is repeated 4-6 times until no further variability is apparent. See also: Single seed descent.

Pyrenophora

This is the Latin name of the perfect (i.e., sexual) stage of many species of Helminthosporium.

Pyrethrins

Natural insecticides extracted from the flowers of Chrysanthemum cinerariifolium, which is a native of Dalmatia. This plant is now cultivated in a number of countries and the extracted pyrethrins are used mainly in household aerosols. This insecticide is completely non-toxic to mammals, and it leaves no toxic residues. It also has a very rapid 'knockdown' effect. It has been used for centuries by local people in Dalmatia, who put dried pyrethrum flowers in their bedding to control fleas and bed bugs, and no resistance has been known to develop to it in any species of insect. It is thus a stable insecticide.

At present, this very safe insecticide is too expensive to be used routinely on food crops. However, with improved yields of both flowers and pyrethrin content, and the development of a mechanical system of harvesting, the price might be brought down sufficiently to allow its use on food crops. This would form an excellent project for a plant breeding clubs.

If the price of natural pyrethrins could be brought down sufficiently, by high yields and high pyrethrin content, and mechanical harvesting, the market for crop protection is virtually unlimited. This insecticide would be widely used both by organic farmers, and the producers of those fruits and vegetables in which the actual sprayed surface is eaten by people. Pyrethrum is also a potential replacement crop for tobacco farmers.

Natural pyrethrins have several advantages over synthetic insecticides. First, as already mentioned, they are stable; they do not break down to new race of the insect. Second, their mammalian toxicity is extremely low and this is one of the safest insecticides available. Third, they break down to carbon dioxide and water after twenty-four hours of exposure to sunlight. Fourth, they

leave no residues whatever. Finally, they are a very powerful insecticide. Their chief disadvantage is their cost, and the overall objective of amateur breeders should be cost reductions sufficient to make natural pyrethrins competitive with synthetic insecticides for crop protection. A second disadvantage is that pyrethrum paralyses insects, but they are likely to recover, unless the insecticide is formulated with a synergist such as piperonyl butoxide. Such additives may preclude its use by organic farmers. However, sesame oil is a natural synergist.

In order to make pyrethrum a commercial success, a simple machine for mechanical harvesting will have to be developed. The harvested flowers must be carefully dried without over-heating, and then sold to an extraction factory.

Pyrethroids

Synthetic pyrethrins. Unlike natural pyrethrins, pyrethroids are unstable and are liable to break down to new strains of an insect pest.

Pyrethrum

See: Chrysanthemum cineriifolium.

Pyricularia oryzae

Blast disease of rice. This is probably the most damaging disease of rice, causing a seedling blight, leaf blight, and neck rot. There is an urgent need for work on horizontal resistance, but this is difficult as vertical resistance complicate the situation, particularly as some of them are apparently quantitative vertical resistances.

Pyrus communis

The pear, which is one of the pome fruits. Pears and apples are antique fruits, and both Homer and Pliny the Elder recorded the names of ancient cultivars of each. Pears are easy to breed but amateur breeders should be aware of the fairly extreme difficulties associated with establishing a new cultivar.

Pythium

A genus of the downy mildews (Peronosporales). Some species cause stem and root rots, as well as damping-off of seedlings.

Q

Qualitative variation

Genetic variation in which a character shows differences in kind. The character is either present or absent, with no intermediates. This variation is typical of Mendelian genetics. The term 'discontinuous variation' is synonymous. See also: Quantitative variation, Continuous variation.

Quality of crop product

This is one of the four main objectives in plant breeding, the others being yield, agronomic suitability, and resistance to parasites.

Quantitative variation

Genetic variation in which a character shows differences in degree. The character can be present at any level between a minimum and a maximum. This variation is typical of biometrical genetics. The term 'continuous variation' is synonymous. See also: Qualitative variation.

Quantitative vertical resistance

Quantitative vertical resistance is confusing because its inheritance is qualitative while its effects are quantitative. It can easily be confused with horizontal resistance, and the best way to avoid it in a breeding program is by choosing only parents that exhibit the normal, qualitative, vertical resistance. Fortunately, quantitative vertical resistance is rare, and occurs mainly in the small grain cereals, such as wheat and barley. Vertical resistance to wheat Hessian fly (Mayetiola destructor), and rice blast, are examples.

Quarantine

See: Plant quarantine.

Queensland arrowroot

See: Canna edulis.

Quinine

See: Cinchona spp.

Quinoa

See: Chenopodium quinoa.

R

Race

Vertical pathotypes are often called physiologic races, or pathologic races, and some plant pathologists still use these antiquated terms.

Race-non-specific resistance

This clumsy term is often used as a synonym for horizontal resistance. Note that 'non-race-specific resistance' is meaningless.

Race-specific resistance

This term is closely synonymous with vertical resistance.

Radish

See: Raphanus sativus.

Ragi

See: Eleusine coracana.

Random polycross

A polycross in which the pollination is random. This is possible with allogamous species, and with an autogamous species, which responds to a male gametocide, or which has an easily controlled genetic male sterility. The advantage of a random polycross is that it produces very large numbers of crosses with very little labour. The disadvantage is that there is no control over the pollination and some parents may be more widely represented than others.

Ramie

See: Boehmeria nivea.

Rape seed

See: Brassica campestris.

Raphanus sativus

The radish. There are four basic types, and all of them belong to this one species. The small radish is the temperate zone garden vegetable, grown commercially on quite a large scale. The large radish is

popular in the Far East. Mougri-radish is grown in Southeast Asia, solely for its leaves and young seed pods, as it has no fleshy root. Fodder-radish is similar to Mougri. Suitable for amateur breeders .

Rapid multiplication

With some crop species , it is possible to use a rapid multiplication technique in order to accelerate production of a new cultivar. For example, green cuttings of a potato clone can be rooted in a mist propagator and, when planted out, the cuttings will themselves produce more cuttings.

Raspberry

See: Rubus spp.

Ratio

The relation between two similar numbers determined by the number of times one contains the other.

Ratoon

When a sugarcane crop is harvested, the root systems can be left to sprout new canes, which are known as ratoons. Several successive ratoon crops may be taken from one field, and they are known as first ratoon, second ratoon, etc. However, the yields of the successive ratoons gradually decline, and there is a limit to the number of ratoons that can be commercially viable. The first crop to be harvested, before any ratoons are taken, is known as the 'plant crop'.

Recessive character

A genetic character, or an allele, is described as recessive when it is eclipsed by the dominant allele.

Reciprocal cross

A second cross, which is similar to the first except that the sexes of the parents are interchanged. For example (A♀ x B♂) is the reciprocal cross of (A♂ x B♀).

Recombination

Sexual recombination occurs at the time of fertilisation and the mixing of the alleles of the male and female gametes,

Recommended reading

The appendix to this guide lists a few books recommended for amateur plant breeders.

Recurrent mass selection

The breeding method of the Biometricians, designed to increase the levels of desirable, quantitative variables by changing the frequency of polygenes. In each screening generation, the best individuals are selected, and they become the parents of the next screening generation. This process is repeated for as many generations as necessary, but the rate of progress declines dramatically after a few

generations. See also: early selection, Family selection, Late selection, Pedigree breeding, population breeding, recurrent mass selection .

Red gram

See: Cajanus cajan.

Reducers

Evolution has produced three basic types of organism called producers, reducers, and consumers. Reducers break down the organic chemicals of dead organisms, and they make these nutrients available for re-use by other organisms.

Reduction division

See: Meiosis.

Reductionism

In science, reductionism has two quite distinct meanings. The first meaning concerns the search for basic fundamentals, and this is good science. The second means working at the lower systems levels, and this is the opposite of the holistic approach. It is called the merological approach, which can be very dangerous because it leads so easily to suboptimisation.

Redwood

Redwood trees are evergreens that live for two millennia or more and they are a good example of the durability of horizontal resistance. Having continuous pathosystems, they may be assumed to have no vertical resistances.

Re-encounter parasite

When a crop host is taken to another part of the world, some of its parasites may be left behind in the area of origin, as happened with tropical rust, when maize was taken from the New World to Africa. If the parasite arrives in the new area at a later date, it is described as a re-encounter parasite. A re-encounter parasite is usually very damaging because the crop host tends to lose horizontal resistance during the absence of that parasite. See also: Old encounter, New encounter.

Relative measurements

horizontal resistance can be measured only in terms of the level of parasitism. Because this level is affected by so many other factors, it is impossible to devise an absolute scale of measurement of horizontal resistance. Consequently, we can measure horizontal resistance only in terms of its relation to the level in other cultivar of known field performance. That is, we can say that cultivar ‘A’ has

more resistance to a given parasite than cultivar 'B'. But we are unable to develop a scale of resistance similar to the Celsius scale of temperature.

Renfrew hypothesis

This is the hypothesis that the proto-Indo-European language (PIE) spread across Europe, and across the Middle East to India, with the cultivation of wheat. It postulates that wheat farmers had population densities about fifty times greater than those of hunter-gatherers, and they gradually spread into the hunter-gatherer territories and swamped both their languages and their genes with their superior numbers. See also: Austronesian family of languages, Coconut.

Reproduction

There are several kinds of biological reproduction. First perhaps is the distinction between *r*-strategists (quantity breeders) and K-strategist (quality breeders). Second, there is the distinction between sexual and asexual reproduction. The most rapid reproduction occurs with asexual *r*-strategists that may also be crop parasites. It is the population explosions of such parasites that can be so damaging and so difficult to control. The vertical subsystem (i.e., gene-for-gene relationship) evolved to stabilise such population explosions by operating as a system of biochemical locks and keys.

Reproductive advantage and disadvantage

In ecological terms, individuals within a population which have a reproductive advantage (e.g., more resistance to parasites) tend to proliferate, while those with a reproductive disadvantage (e.g., less resistance to parasites) tend to disappear. See also: Micro-evolution.

Research

Study designed to discover or confirm new facts or concepts. Experimental research involves the use of experiments, which can occasionally be highly original and innovative. Conceptual research involves original thinking that attempts to discover a new idea, concept, hypothesis, or theory. Modelling, particularly computer modelling, is a form of research designed to test ideas that would be difficult to test in reality. Finally, library research is designed to discover the extent of existing knowledge in order to save time, and to avoid unnecessary repetition.

Most amateurs believe that research can be conducted only by highly trained scientists. This is not true, and amateur breeders should never be afraid of conducting their own research if they think it is within their capacity, and will solve one or more their problems.

Resistance

The ability of a host to impede or prevent parasitism, in spite of the parasitic ability of the parasite. There are two kinds of resistance called vertical resistance and horizontal resistance respectively.

Resistant rootstocks

Many vegetatively propagated tree crops have superb agricultural or horticultural characteristics but are susceptible to various soil-borne parasites. They are then grafted on to resistant rootstocks. The classic example of this was the grafting of classic, European, wine grapes on to American rootstocks to control Phylloxera. Many fruit trees (e.g., stone and pome fruits, citrus) and other high-yielding clones (e.g., rubber) are grafted on to resistant rootstocks for this reason.

Respiration

The inhaling or absorbing of air for the purpose of obtaining oxygen. Plants normally respire at night, absorbing oxygen through the stomata. This is in direct contrast to their behaviour during daylight when they absorb carbon dioxide and expel oxygen in order to photosynthesise and produce carbohydrates.

Resting spore

The spore of a microscopic organism that remains dormant during an adverse season such as a temperate winter or a tropical dry season. Resting spores are usually produced following sexual recombination and this provides a wide variety of phenotypes when the dormancy ends. This is important, for example, with vertical pathotypes**,** which have to match a wide variety of vertical pathodemes in the system of locks and keys of a vertical subsystem.

Reverse osmosis

Osmosis is the passage of a solvent (e.g., water) through a semi-permeable membrane from a less concentrated solution to a more concentrated solution. This is the phenomenon that keeps plant cells turgid. Without water, turgidity is lost and the plant wilts. Reverse osmosis involves forcing a solvent in the opposite direction with physical pressure. It is an artificial process used for purifying water, and for concentrating fruit juices.

Rheum rhaponticum

Rhubarb. An ancient clone that does not breed true. Not recommended for amateur breeders .

Rhizobium

This is the bacterium that forms a symbiotic relationship in the root nodules of plants belonging to the family Leguminosae. The plant provides the bacterium with carbohydrates while the bacterium

provides the plant with nitrates obtained by nitrogen fixation. The chemistry of this process remains a scientific mystery which industrial chemists would dearly like to imitate. A further scientific mystery is the fact that the nitrogen-fixing nodules are pink inside, and this colour is due to a form of haemoglobin that is closely related to mammalian haemoglobin.

Rhizoctonia

One of the soil-borne fungi that can cause damping-off of seedlings, and other root and stem rots.

Rhizome

An underground stem with buds that produce new roots and shoots, and which often acts as a food storage organ, and as a survival mechanism from one season to the next.

Rhizomorph

See: Armillaria.

Rhizosphere

The micro-environment that surrounds a root and is influenced by that root.

Rhodes grass

See: Chloris gayana.

Rhubarb

See: Rheum rhaponticum.

Ribes grossularia

The gooseberry. An ancient crop known to the classical Greeks and Romans. A powdery mildew (Sphaerotheca *mors-uvae*) native to North America has prevented cultivation on that continent, and its introduction to Europe in 1905 caused severe damage. There is scope for breeding for horizontal resistance by amateurs.

Ribes spp.

The garden currants. There are a number of cultivated species of black and red currants, and white currants are a variety of *Ribes sativum*, the main red currant. *Ribes* spp., are the alternate host of white pine blister rust, which largely prevents their cultivation in North America. There is much scope for amateur breeders willing to work with horizontal resistance to a number of pests and diseases in these crops of somewhat limited commercial importance.

Rice

See: Oryza sativa.

Ricinus communis

The castor oil plant. Castor oil has extraordinary lubrication properties because its viscosity changes only slightly with temperature, and it has a wide range of industrial uses. The plant cannot stand frost and its cultivation is limited to the tropics and subtropics. This is an easy crop to breed but its commercial importance is limited.

Rimpau

Rimpau was a European farmer, who lived in Schlanstedt, and worked with rye, which is open-pollinated. At each harvest, he would collect the best looking heads and keep them for seed and, after twenty years, in the mid-nineteenth century, his rye was famous as the 'Schlanstedt Rye', with long heads and kernels that were nearly double the size of the unimproved, local, rye landraces.

RNA

Ribonucleic acid, which exists in a variety of forms. These substances are present in all living cells and their function is to act as messengers carrying instructions from DNA for controlling the production of proteins.

Rogue

In the course of seed certification for purity of cultivar, the parent crop is inspected, and any plants that belong to another cultivar are called rogues. They must be removed, in a process called 'roguing', before the seed from that crop can be certified.

Root

Many of the larger plants have two kinds of root called feeder roots and anchor roots. The feeder roots are generally near the soil surface and their function is to absorb water and nutrients that are sent up the root and stem systems to the leaves and flowers. The anchor roots may have these functions also, but their primary function is to anchor the plant in the ground. Many other plants (e.g., grasses) have only one type of root, which fulfils both functions.

Root hairs

Elongated cells that emerge from the roots like hairs. Their function is to absorb water and nutrients from the soil.

Root nodules

See: Rhizobium.

Rooting hormones

Synthetic plant hormones that stimulate the production of roots on cuttings. With the development of mist propagators, the need for these hormones has largely disappeared.

Rorippa nasturtium-aquaticum

Watercress. diploid and tetraploid forms of this ancient crop occur. There is scope for amateur breeders working with horizontal resistance, except that the crop is of limited commercial importance.

Rosaceae

The rose family which includes the stone and pome fruits, and berry fruits such as strawberry, raspberry, and blackberry.

Roses

Probably the most popular of all ornamentals, roses are divided into long-stem and short-stem varieties. Not recommended for amateur breeders because of the intense competition from professional breeders.

Rot

Any process of decay, usually induced by rotting organisms. Some plant diseases are called rots, particularly the root rots and fruit rots.

Rotation

A sequential changing of crop species on an annual basis, usually in a regular pattern, primarily in order to control soil-borne pests and diseases. Rotation can also facilitate weed control, and it can optimise fertiliser use.

Rotenone

A natural insecticide extracted from the roots of *Derris elliptica* in S.E. Asia, where it is used to control body lice, and from *Lonchocarpus* in South America, where it is used for paralysing fish. These plants are cultivated in a number of tropical countries and improved cultivars are available. No resistance to rotenone has ever been known to develop in any species of insect.

Royalties

Plant breeders can earn royalties on the sale of their cultivars in the same way that an author earns royalties on his books. This is a relatively recent legal development and it was designed specifically to encourage private endeavour in plant breeding.

r-strategist

A species in which the population size is governed by the rate of reproduction, which is normally abbreviated to *r*. In its turn, the rate of reproduction is governed by the season. An *r*-strategist reproduces very cheaply, and very rapidly, with large numbers of very small offspring, whenever the weather and food supply permit. This behaviour produces a population explosion that is inevitably followed by a population extinction. Many plant parasites are *r*-strategists, and it is their population explosions that can be so alarming, so damaging, and so difficult to control. The gene-for-gene relationship, and the system of locking of the vertical subsystem, apparently evolved for the sole function of dampening the population explosions of *r*-strategist parasites. See also: K-strategist.

Rubber

See: Hevea brasiliensis.

Rubus spp.

The raspberries and blackberries. Several species are involved but this is not easy breeding for amateur breeders .

Runner

Many plants have runners, which are a form of vegetative propagation . Runners are probably best known in strawberries, which can send out a stem that eventually produces a plantlet at its end.

Russet Burbank

Possibly the most famous potato cultivar of them all.

Rusts

See: Uredinales.

Ryania

A natural insecticide extracted from the roots of a shrub of this name in Trinidad. It is so safe that it can be used on food crops without a waiting period. However, it is difficult to obtain.

Rye

See: Secale cereale.

S

Saaz hops

See: Humulus lupulus.

Sabadilla

This natural insecticide has the lowest known mammalian toxicity. However, it is difficult to obtain commercially.

Saccharum officinarum

Sugarcane. This giant grass is of very ancient domestication in New Guinea and it is derived from a continuous pathosystem. It consequently has no vertical resistance and it provides many magnificent examples of the utility and durability of horizontal resistance. There are about twenty-five cane breeding stations in the world and most of them still use pedigree breeding. The most notable exception is Hawaii, which uses a population breeding technique called the 'melting pot'.

There is a detailed account in *Return to Resistance*, available as a sharebook at this website (<sharebooks.ca>).

Safflower

See: Carthamus tinctoris.

Saffron

See: Crocus sativa.

Sago palm

See: Metroxylon spp.

Sainfoin

See: Onobrychis viciifolia.

Saline

Salty, with reference to sodium chloride. Soils can become saline from inappropriate irrigation which allows excessive surface evaporation and salt accumulation. The ancient civilisations of the Tigris-Euphrates Valley declined, in part, from soil salination, but also from soil erosion.

Sanitation

Plant sanitation is generally taken to mean the use of clean seed, equipment, and soil, all with a view to reducing plant disease.

Sapodilla

See: Manilkara zapota.

Saprophyte

Loosely, a saprophyte is an organism that derives its nutrients from dead material, as opposed to a parasite that derives its nutrients from living material. Strictly, a saprophyte is a plant, and any other organism living in this way is a saprotroph.

Saturation technique

This is a technique for ensuring that no vertical resistance are functioning during screening for horizontal resistance. For example, it is no longer necessary to use the one-pathotype technique when breeding for resistance to potato blight in the Northern Hemisphere, because the presence of the second mating type (A2) ensures that all vertical resistances will be matched very quickly. Equally, when screening for horizontal resistance to wheat stem rust, the presence of the alternate host, which is barberry, will produce a similar saturation of vertical pathotype. However, it is illegal in some countries to cultivate barberry in this way.

Scab

A plant disease that produces scab-like symptoms. For example, ***potato*** common scab is caused by the bacterium *Streptomyces scabies*, and potato powdery scab is cause by the fungus *Spongospora subterranea*.

Scale insects

Members of the *Homoptera* (aphids, whiteflies, etc.), scale insects are often pests of crops. The first instar is an active insect with legs and antennae, but the subsequent instars are immobile and protected with a scale-like covering. Some species are valuable and are cultivated to produce shellac or cochineal.

Scarlet runner

See: Phaseolus coccineus.

Schistocerca gregaria

The desert locust. A species of grasshopper that has huge population explosions and very destructive migrations in Africa and the Middle East. A large swarm may conrain a million tons of locusts, and each insect eats its own weight in green matter every day. This is the most destructive of many species of grasshopper with similar habits in various parts of the world.

Schlanstedt rye

See: Rimpau.

School children

It is entirely feasible to have a secondary school plant breeding clubs in which the children do the actual breeding. Ideally, such a club should be 'twinned' with a nearby university breeding club. This approach to a combined education and plant breeding was first used in Nigeria when IITA scientists gave true seed of cassava to school children for this purpose.

Schooling of fish

The schooling of fish provides an excellent example of systems levels, emergent properties, and the suboptimisation that can occur with reductionism (i.e., working at too low a systems level). A scientist studying a single fish in an aquarium cannot possibly see or study schooling, which requires the holistic approach. This explains the suboptimisation in the use of vertical resistance during the twentieth century, which resulted from the fact that scientists studied individuals and not populations (i.e., pathosystems). See also: Flocking of birds, n/2 model.

Scientific monopolies

Science thrives on competition and a scientific monopoly is debilitating because it kills competition. The International Research Centres of the CGIAR tend to scientific monopolies, and all of them have a tradition that favours vertical resistance.

Scion

The piece of a plant that is used for grafting on to another plant, which is called the stock.

Sclerenchyma

Plant tissue in which the cell walls are thickened to provide mechanical strength. These cells have usually lost their living contents.

Sclerospora graminicola

A fungal plant pathogen belonging to the Order Peronosporales (i.e., downy mildews). It causes a mildew on many grasses in the tropics and subtropics and can be damaging on cereals such as millets, sorghum and maize.

Sclerotina sclerotiorum

An Ascomycete fungus that can cause severe disease on a wide range of crops, and is characterised by the formation of black sclerotia. The disease if often worse under wet conditions, such as water-logging or continuing heavy rain.

Sclerotium

An over-wintering body of that is produced by some Ascomycetes. Sclerotia are usually visible to the naked eye and may be up to a centimetre long. They have a black surface but are usually white inside. They germinate to produce an apothecium lined with asci. (Plural: sclerotia).

Screening

An essential step in population breeding. A large heterogeneous population is screened to find the best individuals that are to become the parents of the next generation. When breeding for horizontal resistance, the best approach is to let the locally important plant parasites do much of the screening by spoiling or killing all the susceptible individuals. The holistic approach is to screen for high yield, on the basis that only resistant plants can yield well. All measurements should be relative. That is, only the highest yielding plants are kept, regardless of how poor their yield may be in commercial terms.

Screening overkill

When screening a large population for horizontal resistance, there is a danger, in the early breeding cycles, that every individual will be killed and the entire breeding population lost. This overkill can be prevented by using crop protection chemicals late in the season to ensure that the least susceptible plants produce a few seeds. If the breeding is being conducted on an organic farm, where crop protection chemicals cannot be used, it may be preferable to rent some land on a conventional farm for these early breeding cycles.

Seasonal tissue

The system of locks and keys of the gene-for-gene relationship and the vertical subsystem requires a discontinuous pathosystem in order to function. In practice, this means that vertical resistance will occur only in seasonal tissues. That is, in all tissues of an annual plant, and in the leaf and fruit tissues of deciduous trees and shrubs. Crops that are derived from continuous pathosystems (e.g., sugarcane, sweet potato, cassava, olives) will not have any vertical resistances. However some crops have perennial tissue that is functionally seasonal, as with coffee leaf rust.

Secale cereale

Rye, which differs from all the other temperate cereals in being open-pollinated (maize is technically a tropical cereal). For this reason, rye responds to selection pressures during cultivation and it generally has good levels of horizontal resistance to all locally important parasite.

Rye is the least important of the temperate cereals and it is used mainly in the manufacture of rye bread and rye whisky. Historically, it was important in those areas of Europe that could not grow wheat and which suffered periodically from ergot poisoning. These areas, such as Ireland, eastern Germany, Poland, and western Russia later replaced rye with potatoes, and they suffered more than most from potato blight. See also: Rimpau.

Seed

In the strict sense, seeds are the result of pollination and sexual fertilisation. Apomictic seeds are true seeds produced from maternal tissue only without sexual fertilisation. Farmers often refer to the units of vegetative propagation as 'seed'. Thus seed tubers, seed setts, etc.

Seed certification

Seed can be officially certified in various ways. True seed can be certified for identity of cultivar, purity of cultivar, freedom from pests, weeds, and disease , cleanliness, and germination percentage. Seed tubers, setts, and other units of vegetative propagation , can be certified for identity of cultivar, purity of cultivar, freedom from pests, weeds, and diseases, with special emphasis on diseases that are not carried by true seed, such as virus diseases.

Seed cleaning

The main reason for cleaning grains that are intended for planting is to eliminate weed seeds and various insects. However, grain that is intended for milling, or marketing as food, must be cleaned of all foreign matter, such as chaff, soil, stones, etc.

Seed colour

Seed colour is important in some grain crops. Haricot beans, for example, have a wide variety of colours and local preferences can be strong. Seed colour is also important in some cereals, such as maize, and in some pseudo-cereals, such as amaranth. Some seed colours can be used as marker genes in a breeding program.

Seed counting

Seed counting is important when determining the 'hundred seed weight' or the 'thousand seed weight' to ensure that high yields of grain crops are due to many large seeds, rather then to very many small seeds. The manufacturers of seed testing equipment have various designs of equipment for counting and weighing seeds.

Seed disinfection

Infected seed (i.e., seed carrying an internal pathogen) can be disinfected. The most usual method is a hot water treatment. From the point of view of amateur plant breeding, seed disinfection should be avoided because the disease reveals and eliminates susceptible individuals.

Seed dormancy

Many plants produce dormant seeds, and these have various survival advantages. In annuals, dormant seeds will ensure long-term survival if some ecological disaster, such as a major drought, has entirely destroyed the current population. In perennials, dormant seeds often germinate during an exceptionally favourable situation, such as after a forest fire.

Seed dormancy can occasionally be a nuisance in plant breeding and the dormancy must be broken. There are various techniques for doing this, such as hot water treatment, or physical damage to the seed coat with abrasives or acid.

Seed dressing

A pesticide that is applied to the external surface of seeds.

Seed industries

In many crop species, there are farmers specialised in seed production. In addition, there are specialised seed merchants, and there is often legislative control backed by seed inspectors and seed testing laboratories. These various groups are known collectively as the seed industry for that crop. It is noteworthy that the importance of a seed industry is directly proportional to the pest and disease susceptibility of that crop. For example, the need for certified seed potatoes is absolute, while the need for certified seed setts of sugarcane is negligible.

Seed lot

A seed lot is usually a batch of seed that has all come from one farm or one crop. The whole of one seed lot can be covered by one seed certificate, and it can be expected to behave uniformly.

Seed production

See: Seed industries.

Seed testing

Seed offered for sale is usually tested in a seed testing laboratory. The main test is for germination percentage, but other tests can include seed health, freedom from weed seeds, identity and purity of cultivar, etc.

Seed-borne parasites

Some parasites are carried in the seed, both true seed and vegetative seed tubers etc. True seed can be contaminated, infected, or infested. Contaminated seed carries pathogen externally and these can be destroyed by seed dressings. Infected seed carries pathogens internally and can be disinfected by heat treatment. Infested seed carries post-harvest insects. However, seed-borne parasites are the exception rather than the rule and the use of true seed eliminates most parasites.

In the cereals, loose smuts produce infected seed, while covered smuts produce contaminated seed.

Seed tubers, setts, etc that are used for vegetative propagation will carry any parasite that happened to invade the parent plant. This explains why the need for seed health certification is so much more important with crops that are vegetatively propagated, and which have suffered a major vertifolia effect because of inappropriate breeding.

Segregation

In plant genetics, the term 'segregation' refers to the separation of specified traits within the population of the next generation.

Selection

The selection of individuals within a plant population can be positive or negative. Positive selection identifies the individuals to be kept, usually as parents of the next breeding cycle. Negative selection identifies individuals that must be eliminated, or at least prevented from producing pollen, to ensure that they are not represented in future generations.

These terms can also be applied to selection within variable populations of tree crops. For example, a cocoa plantation might be suffering from witch's broom disease (*Crinpellis perniciosa*). A positive selection would identify the most resistant trees for propagation in a new plantation. A negative selection would identify the most susceptible trees for elimination, on the grounds that they were causing severe parasite interference, and their removal would greatly reduce the overall disease incidence.

Selection coefficient

The proportion of plants selected in the screening population during recurrent mass selection. A selection coefficient of 10% means that the best 10% of the plants in the screening population are kept to become parents of the next generation. Selection coefficients of 1% and 0.1% are often used, and they exert very strong selection pressures.

Selection pressure

Pressure (in the sense of coercion, persuasion, or bringing pressure to bear) that induces changes in the genetic composition of a mixed population. The mechanism of selection pressure is that the fittest individuals have a reproduction advantage, while less fit individuals have a reproduction disadvantage. Thus, in the face of parasitism, resistant individuals are advantaged, while susceptible individuals are disadvantaged. Selection pressures can function only in a population that is genetically diverse and genetically flexible.

Selection pressures can be either natural (i.e., in a wild ecosystem) or artificial (i.e., in a plant breeding program). The term selection pressure usually refers to micro-evolution. Natural selection pressures produce new ecotypes, and artificial selection pressures produce new agro-ecotypes, or cultivars. Selection pressures can be positive or negative. Positive selection pressure leads to the accumulation of a quantitative variable (e.g., horizontal resistance) that is deficient, while negative selection pressure leads to the decline of a variable that is excessive or otherwise unnecessary (e.g., horizontal resistance in the absence of a parasite). See also: Vertifolia effect.

Selection, family

See: Family selection.

Self-compatible

Flowers, or plants, that are self-compatible are able to pollinate themselves. See also: Self-incompatible.

Self-fertile

See: Self-compatible.

Self-incompatible

Flowers, or plants, that are self-incompatible are unable to pollinate themselves. See also: Self-compatible.

Self-organisation

This is a crucially important property of non-linear systems in which the concept of 'organisation' must be elaborated to that of 'self-organisation'. Fritjof Capra (see Appendix) has defined self-organisation as the "spontaneous emergence of new structures and new forms of behaviour in open systems far from equilibrium, characterised by internal feedback loops and described mathematically by non-linear equations".

All living systems are non-linear systems, and have the property of self-organisation, which includes the property of reproduction and self-replication. Life itself is an emergent property of such non-linear systems and so too are all those characteristics of life that used to be called 'vital forces'.

In political terms, self-organisation is democracy, while a denial of self-organisation by an authoritarian government is fascism or dictatorship.

The importance of this phenomenon of self-organisation was first recognised by Adam Smith (1723-1790) in his book *The Wealth of Nations*, published in 1776, although Immanuel Kant (1724-1804) was apparently the first to use the term 'self-organisation'

Self-organising crop improvement

This concept is closely related to that of the self-organising system of food production. There were no professional plant breeders before 1900, and all crop improvement was undertaken by farmers and amateur breeders . With the re-discovery of Mendel's laws of inheritance, and the consequent emphasis on single-gene characters, plant breeding became difficult, technical, expensive, and professional. The range of cultivar was severely reduced, and farmers were given little choice in the cultivars that they could grow. In a political analogy, this represents dictatorship, in which a single institute can virtually compel a farmer to grow a particular cultivar.

If there were thousands of amateur breeders around the world, usually organised into plant breeding clubs, working with population breeding and horizontal resistance, and each producing cultivars perfectly balanced for their own local agro-ecosystem, crop improvement would become self-organising. In a political analogy, this would represent democracy. It would also produce a wide diversity of cultivars, and it is a fundamental ecological principle that diversity leads to stability.

Self-organising system of food production

If we consider the food production of a country, we find a self-organising system. Many farmers, acting individually, choose what crops to grow, and what cultivar of those crops to grow. Their decisions are based mainly on their environment, and on market demand, which comes from the decisions of individual merchants who buy their produce. Systems of transport and food processing convert raw materials into marketable products and retailers make these products available to consumers through stores and super-markets. These consumers choose what they buy, usually on a basis of either cost or quality. The stores prefer to stock items that move the most quickly, according to customer preferences. There must be some government control to ensure purity and hygiene, and to prevent monopolies and cornered markets. But, in general, too much government control is

damaging. This was revealed dramatically by the failure of the Soviet system of State-controlled agriculture. Government control must be kept to the essential minimum, and the entire system should be self-organising. In a political analogy, self-organisation represents democracy, while over-control by a single institute represents dictatorship.

Self-pollination

Fertilisation with pollen coming from the same flower, or the same plant. Repeated self-pollination leads to homozygosity, and the formation of a pure lines. Note that cross-pollination within a clones (e.g., potatoes) is equivalent to self-pollination. See also: autogamy, inbreeder, cross-pollination.

Self-sown seedlings

In some crops, such as sweet potato, self-sown seedlings can be a useful source of genetic variation, and they can provide material for screening.

Self-sterile

See: Self-incompatible.

Semi-permeable membrane

A membrane that allows the passage of some (usually small) molecules but not (usually large) others. See also: Osmotic pressure.

Senescence

The aging of plant tissues, as with the ripening of fruit, or the leaf-fall of a deciduous tree. A feature of senescent tissue is that it loses resistance to parasites. For this reason, it is not normally feasible to breed for resistance to fruit rots and similar problems.

Sepal

The outer covering of a flower is made up of sepals, which may be either free or united. Their primary function is to protect the unopened bud.

Septoria

A fungus belonging to the Sphaeropsidales which are imperfect fungi that are believed to be Ascomycetes although no asci have yet been found. Various species of Septoria cause disease on a number of vegetable and cereal crops.

Sesame

See: Sesamum indicum.

Sesamum indicum

This tropical crop is known variously as sesame (pronounced says-**a**-me), simsim, beniseed, gingelly, and till. It became famous in literature as the code word ("Open Sesame") for entering the treasure cave in the Arabian Nights. Its seeds are the source of sesame oil, which is often regarded as being second only to olive oil in quality. The crop is self-pollinated and it exhibits very great variation in many characteristics. A dehiscent strain is suitable for combine harvesters. There is scope for amateur breeders .

Setaria italica

Foxtail millet. This cereal is used as human food in sub-tropical Europe and northern Africa. It is also important in India, Japan, and China. In Russia, it is used for brewing beer. In Britain, it is used as birdseed, and in USA it is grown for hay and silage. Both self-pollination and cross-pollination occur. This crop offers scope for amateur breeders .

Setts

Pieces of stem of sugarcane used for vegetative propagation . Each sett usually has three nodes and the cut ends are often dipped in a mixture of insecticide and fungicide. The first crop from these setts is called the 'plant crop' while all subsequent crops are called ratoon crops, until replanting becomes necessary. The term 'sett' is occasionally used for vegetative propagation in other crops.

Sewage solids

Solids separated out from sewage and used as a low quality organic manure.

Sex attractant chemicals

See: Pheromones.

Sexual fertilisation

See: Fertilisation.

Sexual recombination

The recombining of genetic traits that occurs when a male gamete fuses with a female gamete.

Shallot

See: Allium cepa.

Shareware

Computer software that is copyrighted but that can be distributed free of charge to anyone. The author of shareware requests a voluntary donation from regular users who find the software useful.

Shifting cultivation

A system of agriculture in areas of low population density. New land is cleared each season, and this provides better plant nutrition, and an escape from parasites. This system is also known as ‘slash and burn’.

Short-day

Many tropical plants are photoperiod-sensitive, and depend on a short, twelve-hour day to initiate flower production and, possibly, other processes, such as tuber formation. Equally many temperate plants depend on a long day to initiate these processes. Some plants are photoperiod-insensitive, or day-neutral. See also: potatoes.

Shot-hole

A leaf disease in which the dead central portion of a roughly circular lesion falls out, leaving a hole. When a plant has many of these lesions, it looks as if it had been hit with a charge from a shotgun.

Shrub

A woody, perennial plant that is too small to be called a tree.

Sibling

In common usage, this term means brother or sister, without the gender being specified. In plant breeding, siblings are all the plants that come from one parent, and they are often referred to as ‘sibs’. Full-sibs have the same male and female parents. Half-sibs have the same female parent that was randomly cross-pollinated, and the male parents are thus unknown.

Sigmoid growth curve

The seasonal, S-shaped, population growth curve of an r-strategists organism such as a crop parasite. Typically, the curve shows an initial slow growth (the lag phase), followed by a population explosion with logarithmic growth (the log phase), followed by a rapid slowdown (the leg phase) as environmental factors become unfavourable. This kind of population growth is usually followed by a population extinction.

Silage

Green fodder crop material, such as grass or clover, that has been stored in a silo, or in a large plastic film tube, and allowed to ferment to become food for cattle. This is a chemical fermentation and it produces heat that both stops the fermentation and sterilises the silage.

Silica gel

This substance absorbs water vapour and it is put into air-tight containers to keep the contents dry. It is particularly valuable for the long-term storage of seeds in genetic conservation.

Sinapis alba

See: Brassica alba.

Single seed descent (SSD)

A quick method of producing pure lines in crops that are inbreeding, and seed-propagated, such as many cereals and grain legumes. A breeding population may contain many individuals that are both genetically diverse and heterozygous. A single self-pollinated seed is taken from each individual and is grown to maturity. This process is repeated up to six times. Each individual becomes more or less homozygous, but the population is still diverse. The best individuals are selected and kept as new pure lines, or as the parents of the next generation of recurrent mass selection . The idea behind SSD is to save time. There is no screening until the process is complete. With perhaps three generations of SSD each year, with the aid of hydroponics and a greenhouse, it is possible to produce homozygous lines in two years, or less. The more traditional method would require screening under field conditions in each generation of selfing and, in a temperate climate, with only one screening season each year, this would require up to six years.

Single-gene character

Any genetic character whose inheritance is controlled by a single gene. The inheritance of a single-gene character follows Mendel's laws of inheritance.

Single-gene resistances

This term covers both vertical resistance and genetically engineered resistance. Neither kind of resistance is likely to be stable.

Sisal

See: Agave sisalana.

Skewed distribution

A normal or Gaussian distribution that is slanted towards one extreme or the other.

Smuts

Plant parasitic fungi of the Order Ustilaginales, so called because they usually produce large quantities of black spores that resemble soot.

Soap insecticides

A solution of soft soap (i.e., potassium soap) has been traditionally used to control aphids and similar insect pests. These days, water with a small content of washing-up detergent, can be used. The affected insects are unable to breathe and these insecticides are stable.

Sociability scale

A five-point scale used to indicate the sociability (i.e., the degree of gregariousness or clumping) of a plant species . The scale runs from 1 (solitary) to 5 (pure stand). The most successful plant domestications have involved species with a high sociability.

Social

A species is described as social when the individuals remain together in social groups. The converse is described as a 'solitary' species, in which individuals usually come together only purposes of mating. Social animals are easier to domesticate and dogs, horses, cattle, sheep, and goats are all social species. Social insects include the ants, termites, and bees. It is also possible to speak of 'social' plants that tend to grow in pure stands in the wild. These too are easier to domesticate than solitary species. See also: Sociability scale.

Softwoods

Timber trees that are Conifers. The timber of these trees is able to store large amounts of water and this permits growth in areas that have dry summers. Softwood lumber is used mainly for building, and it is generally unsuitable for furniture.

Soil

The upper-most layer of the ground, soil is a complex mixture of minerals and micro-organisms, which has been described as both a micro-ecosystem, and the most complex of any ecosystem. Soil is essential for most plant growth, providing both nutrients and a substrate to anchor the roots. Depleted soils are those in which the microbiological and/or nutritional components have been seriously reduced. Depleted soils can best be restored to good condition with organic manures.

Soil conservation

Practices which are designed to prevent or reduce soil erosion. The principle methods are minimum tillage, contour ploughing, terracing, and mulching. The planting of trees to make windbreaks is also helpful. Soil conservation is one of the more important aspects of sustainable agriculture.

Soil erosion

The loss of soil to either wind or water. During the 1930s drought in the American mid-west, the wind-erosion was so severe that this area became known as the 'dust bowl'. Similarly, the water-erosion in the Tigris-Euphrates Valley during some five millennia has extended the mouth of the combined rivers about one hundred miles into the Arabian Gulf. Soil erosion can be prevented by suitable soil conservation practices and this is one of the more important concerns of sustainable agriculture. It is notable that rice paddies conserve soil very well, and that ancient rice-based cultures still thrive while ancient wheat-based cultures are often extinct, as in the Tigris-Euphrates Valley..

Soil inoculation

Soil can be inoculated with either beneficial or parasitic micro-organisms. The most commonly used beneficial inoculants involve Rhizobium to encourage nitrogen fixation by leguminous plants. Inoculation with soil-borne parasites is undertaken for the purpose of plant breeding and screening a heterogeneous plant population for horizontal resistance. The most effective method of soil inoculation is to transplant inoculated seedlings.

Soil nutrients

Except for iron, plants absorb all their nutrients as inorganic chemicals, and most of them are extracted from the soil. Carbon dioxide, oxygen, and some water, are extracted from the atmosphere, but all others come from the soil. The three major nutrients are nitrogen, phosphates, and potash (NPK). Minor nutrients are calcium, sulphur, iron, boron, and magnesium. Trace elements include zinc, copper, manganese, etc. See also: Deficiency diseases; Mobile and immobile nutrients.

Soil pasteurisation

Soil pasteurisation means that the soil has been heated to only 80°C. This kills most pests and pathogens without a complete sterilisation. Pasteurised soil can be used as soon as it is cool, whereas sterilised soil must be kept for some three weeks for its microbiological activity to be restored.

Soil science

See: Pedology.

Soil sieves

Soil sieves are designed for the mechanical analysis of soils, separating the soil particles on the basis of their size. The sieves come in sets which fit securely into each other, with the coarsest at the top, and the finest at the bottom. A set of soil sieves can be very useful for separating small seeds**,** which may be either wet or dry, from the debris of their extraction.

Soil structure

This term usually refers to the particle size of the various mineral components of the soil, and the proportions of those minerals. Thus, a heavy soil has a high proportion of clay particles, which are very small. Such a soil is heavy to work, and has poor drainage. A light soil has a high proportion of sand and silt particles. It is easy to work, and is free-draining. A soil with the optimum structure for plant growth is often called a loam.

Soil-borne parasites

Plant parasites that are carried in the soil and are immobile. They are usually dormant until a suitable plant root grows close to them. They include ***fungi***, ***nematodes***, ***bacteria***, and ***insects***. rotation is the most common method of controlling soil-borne parasites, but they should be taken into account when breeding for ***comprehensive*** horizontal resistance to all locally important parasites.

Solanaceae

The potato botanical family (Solanaceae) includes the cultivated species Eggplant, Peppers, Potato, Tobacco, and Tomato. Except for the eggplant, which originated in India, all these crops are of a New World origin.

Solanum melongena

Eggplant, also known as aubergine or brinjal, originated in India and is the only important Old World cultivated species of the family Solanaceae. The crop is cultivated for its fruit which is eaten as a vegetable. It is open-pollinated and hybrid varieties are useful. Quite an easy crop for amateur breeders .

Solanum tuberosum

The potato, which originated in the equatorial highlands of South America. The potato of commerce is a tetraploid that is self-compatible but somewhat intolerant of inbreeding. In addition, there are a number of both wild and cultivated diploid species that are self-incompatible and allogamous . The original imports to Europe involved short-day potatoes in which tuber initiation was delayed until the autumn equinox in late September. This meant that the crop was likely to be destroyed by frost before it was mature. During the eighteenth century, day-neutral potatoes were developed in Europe, partly by deliberate breeding, and partly by natural selection. Unfortunately, nearly all development work during the past century has involved disease-free certification of seed tubers of very susceptible cultivars, as well as breeding under conditions favouring the vertifolia effect. As a result, modern potato cultivars have very low levels of horizontal resistance to very many pests and diseases, and

this crop is one of the most heavily treated with crop protection chemicals. This problem has been greatly aggravated by the second mating type of Phytophthora infestans.

This is an excellent crop for amateur breeders working with horizontal resistance, particularly as even small increases in the levels of quantitative resistance will greatly assist organic farmers. There is a more detailed account in *Return to Resistance*, available as a sharebook at this website (<sharebooks.ca>).

See also: Neo-tuberosum, Sweet potato.

Sorghum

See: Sorghum bicolor.

Sorghum bicolor

Sorghum, also known as: milo, kafir, durra, feterita, kaoliang, mtata, sorgo, jola, jawa, guinea corn, and cholam. It is grown mainly in Africa, India, China, and USA.

Sorghum is the fourth most important cereal in the world, after wheat, rice, and maize. It is very drought-resistant and this makes it an important food crop in arid and semi-arid areas. Grain sorghums, as their name implies, are grown for grain which is used either for food or brewing. Sorgos and sweet sorghums are used mainly as fodder and for syrup production. Broom corn is used for making brooms. Relatively new dwarf hybrids allow harvesting by combine, and they have led to an increased cultivation of sorghum.

Sorghum is an open-pollinated, short-day plant. Hybrid varieties have been produced in USA. It is an excellent crop for plant breeding clubs that are located in an appropriate area.

Sorghum vulgare

Synonym of Sorghum bicolor.

Sorgo

See: Sorghum bicolor.

Source of resistance

Mendelian breeders always need a source of resistance in order to undertake breeding for resistance to crop parasites. This source of resistance is usually controlled genetically by a single gene which is part of a gene-for-gene relationship, and which confers vertical resistance. If a source of resistance cannot be found, the breeding cannot be started. Biometricians working with polygenically controlled horizontal resistance do not need a source of resistance. This is because they only have to change the frequency of polygenes that are already present, at a low frequency, in the screening population,

using recurrent mass selection . However, this general rule does not prohibit the use of resistant parents in a breeding program.

Sowing

The process of planting seed (c.f., sewing).

Soybean

See: Glycine max.

sp. & spp.

Single and plural taxonomic abbreviations for species .

Specialists

amateur breeders should never hesitate to consult a specialist when they need factual information. However, they should beware specialists who belittle horizontal resistance.

Species

A term that has never been satisfactorily defined. Its most usual definition is a group of individuals that are sexually compatible with each other, but not with other members of the same genus or family. A crop species is usually made up of different commercial varieties, agro-ecotypes, or pathodemes which are all sexually compatible with each other, but not with other crop species in the same genus of family. However, both inter-specific and inter-generic hybridisation are often possible. For example, wheat and rye are different genera, but they have been hybridised to produce and inter-specific hybrid called Triticale.

Sphaerotheca

A member of the Erysiphales (powdery mildews) characterised by cleistothecia with simple, unbranched appendages and a single ascus. Sphaerotheca macularis causes powdery mildew of strawberry; S. mors-uvae attacks currants and gooseberries; S. pannosa attacks peaches and roses.

Spinach

See: Spinacia oleracea.

Spinacia oleracea

Spinach, a member of the Chenopodiacea family. A potherb crop with complex genetics that is not generally recommended for amateur breeders

Spine

See: Thorn.

Spore

A microscopic, reproductive body of fungi, bacteria, and other organisms. Spores may be produced either sexually or asexually. They have the same reproductive, dissemination, and survival functions as the seeds of higher plants, except that asexually produced spores do not exhibit sexual recombination and variation.

Sport

Mutants within a clone are often called sports. Many ornamental plants with variegated foliage are sports.

Sprayers

Any machine, whether hand held or tractor-mounted, and used for applying liquid pesticides to a crop, is known as a sprayer. Most sprayers use pressure to force the liquid through a nozzle in order to produce a fine mist. Various nozzle designs produce solid cone, hollow cone, flat fan, and flooding applications, with different flow rates and different droplet sizes. Air-blast sprayers run the liquid into an air blast that breaks it into small droplets and, at the same time, tosses the leaves around in the blast to ensure that all plant surfaces are covered. Ultra-low volume (ULV) sprayers produce extremely small droplets and are used in areas where water is scarce. They are particularly useful against insects such as locusts, which have to eat the insecticide from only one droplet to be killed.

Spreader rows

Spreader rows are rows of a susceptible cultivar that run through a screening population in order to provide inoculum of appropriate pests and diseases. The purpose of spreader rows is to reduce parasite gradients as much as possible. Great care must be taken with open-pollinated crops to ensure that no pollen from the susceptible cultivar enters the gene pool of the recurrent mass selection. This undesirable pollination can be avoided by either by decapitating or cutting down the spreader rows, or by asynchronous planting so that the spreader rows produce pollen only before or after the screening population is receptive.

Spreader surrounds

Spreader surrounds differ from spreader rows in that they surround the screening population rather than run through it. They are used when parasite gradients are not a problem.

Spring and winter cereals

Spring cereals are sown in the spring, as soon as the land is dry enough to take a tractor. Winter cereals are sown in the previous Fall, and they have the advantage of being several weeks ahead of

the spring cereals. Breeding for winter hardiness is very similar to breeding for horizontal resistance. A heterogeneous population is sown in the Fall, and only those individuals that survive the winter can be screened the following summer. Nature does the breeding work for us.

Spruce

See: Picea spp.

Squash

See: Cucurbita spp.

Stable protection mechanisms

Any mechanism that protects a host from a parasite can be divided into one of two classes. A stable mechanism is one that does not break down to new strains of the parasite, which are unaffected by that mechanism. This is because the mechanism is beyond the capacity for micro-evolutionary change of the parasite. Stable mechanisms include horizontal resistance, natural pyrethins, nicotine sulphate, rotenones, mineral oil, Bordeaux mixture and other copper fungicides, dithiocarbamates.

See also: Unstable protection mechanisms.

Stamen

The male organ of a flower. When mature, the anthers release pollen for the fertilisation of a female ovule.

Staple

The main item of a diet, hence ‘staple crop’ and ‘staple food’. Staple crops can be divided in to major and minor staples.

Starch

Starch is a polysaccharide used by many plants as a method of storing carbohydrates. It is a major constituent of the human diet, being obtained mainly from cereals and potatoes.

Starvation

The word starvation is derived from the old English word meaning ‘to die’ but, in modern usage, it can also mean malnutrition. In either event, it is the result of a food deficiency.

Statistics

The phrase “Lies, damn lies, and statistics” is a reference to inaccuracies in the news media. Mathematically, the term is entirely respectable and it provides a technique for determining the accuracy of quantitatively variable data. In this sense, it is widely used in field trials for comparing many different factors, such as choice of cultivar, fertiliser use, plant spacing, and time of sowing.

However, the use of statistically controlled field trials in entomology and plant pathology has led to major errors in the past because of parasite interference. Statistical analysis used to be the bane of agricultural students and agronomists, but it is now quite easy with modern computer software. Amateur breeders working with horizontal resistance will not normally need to use statistics.

Stem

The part of the plant that carries the leaves and flowers. It is usually vertical, and it may be branched. An underground stem is called a rhizome.

Stem borers

The larval stage of various species of insect, so called because they bore a tunnel up the stem of herbaceous plants, often killing the stem.

Stem pitting

See: Tristeza.

Sterile

A sterile organism is one that is unable to reproduce. A sterile container or environment is one that is completely devoid of life of any description.

Sterile males

An entomological technique for controlling certain insect pests. Large numbers of male insects are made sterile, usually by radio-active radiation, and are then released. They mate with females which then lay infertile eggs. The technique works best with species in which the males mate many times but the females mate only once.

Stigma

The female part of a flower that receives pollen.

Stock

The plant or rootstock on to which a scion is grafted.

Stolon

An underground stem (e.g., the stalk by which a potato tuber is attached to its parent plant).

Stoma

(Plural: stomata). Microscopic pores in the leaf epidermis, which allow the passage of carbon dioxide, oxygen, and water vapour. The size of the pores is controlled by guard cells, which can close them completely, if necessary.

Stone fruits

Fruits of the botanical family Rosaceae that contain a single hard seed, called a stone, pit, or pip. The term includes plums, cherries, greengages, peaches, apricots, almonds, and sloes. See also: Pome fruits.

Strain

In a taxonomic sense, a strain is a subdivision of a species , often defined in terms of a physiological or parasitism criterion.

Straw

The dried stems and leaves of a cereal or pseudo-cereal crop. Straw is used mainly as bedding for farm animals and it is a major component of farmyard manure. Mechanisation has greatly reduced the demand for straw bedding, and dwarf varieties have greatly reduced the supply.

Strawberry

See: Fragaria ananassa.

Striga spp.

These tropical and sub-tropical species , known as witch weed, are members of the family *Scrophulariaceae*, and they are semi-parasitic, often causing considerable damage to maize, sorghum, and other crops. The plants contain some chlorophyll and they damage their hosts mainly by robbing them of water. The seeds are minute, and are produced in huge numbers. They can remain dormant in the soil for years, and they germinate only in the presence of roots of a suitable host. Scientists at IITA have bred maize with horizontal resistance to *Striga*.

Style

The stalk that supports the stigma.

Stylet

In a zoological context, a stylet is the piercing mouthpart of an insect.

Suboptimisation

The process in which a system is either damaged or misunderstood because of working at too low a systems level. The detriment occurs either because emergents at higher systems levels remain unobserved, and/or because other subsystems are not taken into account. A triple suboptimisation occurred when Mendelian plant breeders attempted to control various crop pathosystem***s*** using (i) the vertical subsystem only, (ii) only one vertical resistance employed on a basis of uniformity, and

(iii) a vertical resistance controlled by only one gene. See also: Holistic approach, Merological approach.

Subsistence crops

Crop species that are more or less confined to subsistence farming (e.g., taro).

Subsistence farmers

Farmers who grow crops primarily to feed themselves and their family. They may sell subsistence surpluses, but the demand for such produce is usually low. They may also grow one of more cash crops, such as coffee or pyrethrum.

Subsistence farming

Farming which feeds the farmer and his family but produces few surpluses for sale. The converse is usually called commercial farming. Similarly, one speaks of subsistence crops and cash crops. Almost all subsistence farming is now in the tropics. Subsistence crops are often mixtures of several different species, and each species is usually cultivated as a landrace. Subsistence crops are thus genetically diverse, and genetically flexible. Because they are cultivated without any use of pesticides, they have high levels of horizontal resistance. However, their yields and quality are usually considerably less than the modern cultivars of commercial farming. Subsistence crops are thus about half way between a commercial crop pathosystem and a wild pathosystem.

Subsystem

A lower systems level. Thus, a functioning gene-for-gene relationship constitutes the vertical subsystem of a plant pathosystem, which is itself a subsystem of an ecosystem.

Succulent

In a botanical context, a succulent is a drought-resistant plant that usually contains a considerable store of water. This store is usually protected with very sharp spines, or some form of toxin or deterrent taste. Cacti are typical succulents.

Sucker

An underground shoot arising from either from the roots or the subsurface stem of a tree or shrub. Suckers are often an important means (occasionally the only means, e.g., date palm) of vegetative propagation.

Sucking bugs

See: Miridae.

Sugar

The sugars are sweet-tasting, soluble, crystalline carbohydrates. There are a number of different sugars in the human diet, the most common being sucrose, extracted from either sugarcane or sugar beet.

Sugar beet

See: Beta vulgaris.

Sugarcane

See: Saccharum officinarum.

Sulphur

Sulphur, in the form of sulphates, is a plant nutrient. It is an immobile element and deficiency symptoms, which resemble those of nitrogen deficiency, appear in the young leaves first.

Sulphuric acid

Often known as 'battery acid', this acid used to be sprayed on to potato crops to kill the haulms, in order to prevent spores of blight penetrating the soil and reaching the tubers. Other chemicals can also be used but, now that the second mating type is present, with functional oospores in the soil, there is probably no further point in this practice.

Sunflower

See: Helianthus annuus.

Survival advantage

This term refers to both macro- and micro-evolution. That is, it applies to both evolutionary competition and ecological competition. It refers to any characteristic (e.g., horizontal resistance) that enables an individual to reproduce more effectively then its competitors.

Survival of the fittest

A phrase often taken to mean natural selection.

Susceptibility

The converse of resistance. A host is described as being susceptible to a parasite when that parasite is able to parasitise it, and extract nutrients from it. Agriculturally, a susceptible cultivar is likely to be destroyed by its parasites if it is not protected with pesticides .

Sustainable agriculture

A system of farming in which a son inherits the family farm in as good, or better, condition than did his father. No soil is eroded, no groundwater is depleted, no weed seeds have accumulated, no pests or diseases flourish, and no toxic chemicals lurk.

Swedes

See: Brassica napus.

Sweet potato

See: Ipomea batatas.

Sweet sorghum

See: Sorghum bicolor.

Symbiosis

A form of 'living together' in which each organism benefits the other. For example, a lichen is a symbiosis between a fungus and an alga. And the nitrogen-fixing root nodules of legumes are a symbiosis between the legume and the Rhizobium.

Symbiosystem

A subsystem of an ecosystem that involves symbiosis, or cooperation, between two entirely different species of organism. Probably the most important example of symbiosis in crop husbandry is the nitrogen fixing root nodules on the roots of pulses and fodder legumes, formed by species of a bacterium called Rhizobium.

Symptom

A change in the nature or appearance of a plant that is indicative of disease.

Symptomless carrier

A plant, or cultivar, that has so much horizontal resistance to a virus disease that it exhibits no symptoms of that disease, in spite of being infected with it. Symptomless carriers can be a source of infection for nearby susceptible crops. However, if all cultivars were symptomless carriers, the virus disease would no longer be important.

Synchytrium endobioticum

The fungus that causes wart disease of potatoes.

Synergism

The effect produced when two or more factors, operating jointly, is greater then the sum of their effects when operating independently.

Synergist

A chemical which improves the effectiveness of another chemical. Thus piperonyl butoxide is a synergist of natural pyrethrins. The pyrethrins alone have a 'knock down' effect, but the insects are likely to recover. When the pyrethrins are used with an appropriate synergist, however, the insects are killed.

Synonym

In taxonomy, an alternative name.

Synthetic chemicals

The artificial production of chemical compounds. The definition of organic farming is that it uses no synthetic chemicals. That is, it uses no artificial fertilisers, no synthetic herbicides, no synthetic insecticides, and no synthetic fungicides. However, it may use natural chemicals, such as rock phosphate, natural pyrethrins, etc.

Synthetic variety

An improved variety of an outbreeding species , such as maize, sorghum, or alfalfa, which is a genetically diverse population. Although this population consists of a cross-pollinating, seed-propagated species, most of the plants within it are high yielding, high quality, with high resistances, and agronomic suitability. These qualities may be preserved, or even enhanced, by careful selection of the individual plants destined for seed. Alternatively, if this selection is not practised, the qualities may decline after a few generations, and the seed stocks must then be renewed.

System of locking

In a wild plant pathosystem, the gene-for-gene relationship acts as a system of locking which controls allo-infections, and reduces the population explosion of an r-strategists parasite. This system of locking is an emergent, which can be observed only at the population level of the system. See also: Vertical subsystem, n/2 model.

Systemic

In a wide sense, 'systemic' means involving the entire system. In the context of crop protection chemicals, it means an insecticide or fungicide that penetrates the entire plant, and which kills a parasite inside that plant. Systemic pesticide can thus cure parasitism, while protective pesticides merely prevent parasitism, but cannot cure it once the parasite has penetrated inside the host tissues. The practical difference is that protective pesticides must be applied before an epidemic or infestation starts, as a form of insurance premium. Systemic pesticides can be applied after the epidemic or

infestation has started. There is also a toxicological difference in that protective chemicals can be washed off, but systemic chemicals can linger.

Systems level

Most systems may be considered in terms of a hierarchical organisation, and each rank in the hierarchy is called a systems level. Thus, a system consists of various ranks of subsystems, and is itself part of a super-system. A pathosystem is a subsystem of an ecosystem, and it has subsystems such as the vertical subsystem, and the horizontal subsystem.

Systems theory

See: General systems theory.

Systems thinking

The basis of systems thinking is the holistic approach, of seeing the system as a whole, of seeing the forest rather than the trees. A system cannot be understood by an analysis of its parts. Analytical thinking is concerned with the parts of a system. Systems thinking concerns the organisation of those parts, as a single system, and the emergent properties that emanate from that organisation.

T

Tamarind

See: Tamarindus indica.

Tamarindus indica

A tropical, leguminous tree native to Africa but cultivated in India since antiquity. The seeds are coated with a highly prized, sweet pulp used as a flavouring.

Take-all disease

See: Gaümannomyces graminis.

Tannia

See: Xanthosoma sagittifolium.

Tannier

See: Xanthosoma sagittifolium.

Taraxacum

A genus of the family *Compositae* that includes *T. officinale*, the dandelion, a widespread weed now known to be resistant to various herbicides.

Taro

See: Colocasia esculenta.

Taxon

A taxonomic rank (e.g., family, genus, species).

Taxonomy, taxonomist

The classification and naming of living organisms, and a person who studies this classification. See also: Linnaeus.

Tea

See: Thea assamensis and T. sinensis.

Teak

See: Tectona grandis.

Tectona grandis

Teak, a tropical hardwood used in plantation forests. Not recommended for amateur breeders.

Teff

See: Eragrostis tef.

Temperate grasses

The most important sown temperate grasses are Lolium, Festuca, Dactylis, Phleum, and Bromus.

Temperate regions

The regions between the Arctic Circle and the Tropic of Cancer, in the northern hemisphere, and between the Antarctic Circle and the Tropic of Capricorn, in the southern hemisphere. In terms of agriculture, there are just the two regions of temperate and tropical, although many people also recognise the subtropics. Tropical regions are characterised by short days and freedom from frost. Temperate regions have freezing, short-day winters, as well as warm, long-day summers. The crops of each region are profoundly different, although a few tropical annuals can be grown in a temperate summer (e.g., tomatoes, tobacco). See also: Day-length.

Temporary resistance

vertical resistance are temporary in that they stop functioning on the appearance of a matching vertical pathotype. They are within the capacity for micro-evolutionary change of the parasite.

However, this is not an exclusive trait, and other kinds of resistance, such as the single-gene resistances of genetic engineering, are also expected to be within the capacity for micro-evolutionary change of the parasite.

Tendril

A thread-like appendage used by vines as an aid to climbing. Tendrils usually twist around suitably sized objects.

Terminal

This word means 'at the end of' as in terminal bud, etc.

Terracing

Converting hillsides into terraces that follow the contour is a method of soil conservation. It is an expensive process but, once completed, it is both effective and easily maintained.

Terracotta pots

Flower pots made of terracotta (baked clay) are more expensive than plastic pots, but they provide a superior aeration to plant roots.

Tetraploid

A cell or plant with four sets of chromosomes. A tetraploid usually develops from a more normal diploid, by an accidental doubling of its two sets of chromosomes. See also: Doubled monoploid, Haploid, Auto-polyploid, Allo-polyploid.

Thea assamensis

Often called *Camellia assamensis*, this is the tea of India and Sri Lanka (Ceylon). It contains considerable germplasm from Thea sinensis, and it represents a vast hybrid swarm between these two species. Most commercial tea plantations are grown from true seed and the tea bushes show enormous variation, often with some 60% of the yield coming from about 30% of the bushes. Furthermore, the fermentation time of each bush is also variable, and this causes difficulties in the tea factory. The use of high-yielding, high quality clones eliminates these difficulties, and produces greatly increased yield and quality. However, a tea plantation is usually good for a hundred years, and replanting is an expensive business.

The selection of tea clones is an appropriate task for amateur breeders. The should select the best yielding bushes out of a large area of seedling tea (up to one million bushes), and these selections are gradually reduced in number with a series of increasingly complex tests.

Thea sinensis

Often called *Camellia sinensis*, this is the tea of China. See also: Thea assamensis.

Theobroma cacao

The tree is often called cacao, while the product is called cocoa, from which chocolate is manufactured. But it is entirely correct to call them both cocoa. Note that cocoa was originally spelled coco, as in coconut and coco-yam, and the 'a' was added as a printing error in Johnson's dictionary. The old-fashioned spelling 'cocoanut' is incorrect.

The centre of origin of cocoa is on the eastern equatorial slopes of the Andes, and cocoa occurs throughout the Amazon Valley where it provides an interesting example of a cline. All the wild trees in the centre of origin are self-incompatible. As one moves down the Amazon, self-compatible types become increasingly common and, at the river mouth, they are all self-compatible.

All the cocoa in West Africa is self-compatible and very uniform, with a very narrow genetic base. When a very destructive African virus, called 'swollen shoot', appeared, the Government introduced a very unpopular eradication program which was not effective. In those days, horizontal resistance was not recognised. There is now considerable scope for a university breeding club to test buds of carefully quarantined foreign material grafted on to virus-infected trees. It should not be difficult to accumulate adequate horizontal resistance once the genetic base has been widened.

In Latin America, most cocoa populations are heterogeneous and are suitable targets for negative screening, with a view to eliminating the parasite interference coming from a few susceptible trees, in order to establish population immunity against witch's broom disease.

Theoretical science

The agricultural sciences have been excessively empiricist during the twentieth century, and the theoretical aspects of these agricultural studies have been neglected. Good science must have a nice balance of both facts and ideas. One of the many advantages of theoretical science is its ability to predict novelty. For example, when Dimitri Mendeleev developed the periodic table, he was able to predict the existence of chemical elements that had not yet been discovered. Similarly, the Person-Habgood differential interaction can predict new vertical resistances and vertical parasitic abilities that have not yet been discovered. The n/2 model is also a prediction of novelty based on theoretical science. This model has yet to be shown to occur in nature but, if this demonstration is made, it will provide an elegant example of the powers of prediction of theoretical science.

Thorn

A sharp-pointed projection on a plant that provides a defence against grazing animals. Thorns occur typically on roses but also on cacti, when they are generally called spines.

Thousand seed weight

See: Hundred seed weight.

Threshing

The separation of grain from its husk. Ancient threshing consisted of pounding the grain and then throwing it into the wind, which would carry off the light husks and allow the clean grain to fall to a mat. Modern methods use a wide range of machines that vary from small hand-driven machines to combine harvesters.

Thrips

Small (0.5-2.0 mm) insects of the Order *Thysanoptera*, which are mostly plant feeders. Many are crop parasites, and some are responsible for spreading plant virus diseases.

Ticks

Blood-sucking arachnids.

Tiller

(1) A side shoot of a cereal. (2) One who tills (i.e., cultivates) the soil.

Tilth

The condition of soil: “In good tilth”.

Timber

Timber refers to the growing tree. Lumber is the sawn planks that come out of a saw mill. Wood is the same material when it is a finished product in buildings or furniture.

Timber trees

In general, trees have a long breeding cycle and are not suitable for amateur breeders . But selection within existing populations is possible. For example, most of the five-needle pines in North America have been killed by white pine blister rust. Those that survive are likely to be resistant and they merit study. Similarly, selection of the fastest growing gum trees is possible in areas that depend on firewood for cooking.

The main species used in plantation forests are divided into softwoods and hardwoods. The principle softwoods are various species of pine, spruce, fir, and larch,. The principle hardwoods are species of gum trees, beech, birch, poplar, and teak.

Toadstool

Similar to a mushroom except that toadstools are usually inedible, even poisonous.

Tobacco

See: Nicotiana tabacum.

Tolerance

This is an ill-defined, much misused term that is sometimes taken to mean horizontal resistance. Strictly speaking, tolerance means that, if two different plants are equally diseased, the tolerant one will suffer less of a yield loss. However, to demonstrate tolerance, it must first be shown that those two plants have equal yields when disease-free. A term to be avoided whenever possible. See also: Field resistance.

Tollocan

The name of a Mexican, short-day potato which has an exceptionally high level of horizontal resistance to blight.

Tomato

See: Lycopersicon esculentum.

Toxicity

The degree of poisonousness of a substance such as a pesticide. Toxicity is usually measured in terms of the LD_{50}, which stands for the lethal dose required to kill 50% of a population, usually of insects or laboratory rats. The LD_{50} is normally expressed as milligrams of poison per kilogram of body weight, but other ratios are possible.

For the purposes of labelling, the USA recognises four categories of toxicity. Category One involve substances with an acute oral LD_{50} of 0-50 mg/kg and these are very dangerous. Category Two are moderately toxic substances with LD_{50} of 50-500 mg/kg. Category Three substances have LD_{50} of 500-5000 mg/kg and are only mildly toxic. Category Four have an LD_{50} greater than 5000 mg/kg. However, these categories involve oral ingestion only, and they take no account of inhalation and skin penetration, or of hormone mimics that can damage the development of young children and foetuses.

Toxicology

The scientific study of toxins. See also: Toxicity.

Toxin

A poisonous substance. The term is sometimes restricted to toxins produced by a living organism but, it the context of crop science, it can also be applied to pesticides and other synthetic chemicals.

Tramlines

Parallel tracks in European corn (i.e., wheat) fields, visible from the air, and produced by tractor wheels when spraying the crop with pesticides .

Transgressive segregation

The phenomenon in which some of the progeny have a higher level of a quantitative character, such as horizontal resistance, than either of their parents. Suppose that two parents, which are highly susceptible, each have only 10% of all of the alleles contributing to horizontal resistance to a parasite. If each parent has a different 10% of alleles, some of their progeny will have more than 10% of the total available alleles. These individuals in the progeny will then be more resistant than either of their parents. Transgressive segregation can continue in each generation of recurrent mass selection until no further progress is possible, because the maximum number of alleles has been accumulated.

Transmission

Many virus diseases are transmitted by plant parasitic insects that migrate from one host to another. This transmission clearly involves allo-infections.

Transpiration

The loss of water from a plant. The rate of transpiration is controlled by the stomata. See also: Guttation.

Tree

Technically, any plant with woody tissues, as opposed to a herb that has no woody tissues. In practice, many of the smaller trees are called shrubs.

Tree tomato

See: Cyphomandra betacea.

Trifoliate

This term means ‘three leaves’ and refers to the leaves of plants such as *Trifolium* spp., (clovers), or *Oxalis*, that are divided into three leaflets.

Trifolium spp.

The clovers are important as fodder crops, usually sown in mixtures with grasses. They also occur commonly in natural grasslands in humid temperate areas, and in tropical highlands. There are ten species of clover that are considered agriculturally important:

T. alexandrinum	Egyptian or Berseem clover (annual)
T. ambiguum	Caucasian or Kura clover (perennial)
T. dubium	Yellow suckling clover (annual)
T. fragiferum	Strawberry clover (perennial)
T. hybridum	Alsike clover (perennial)
T. incarnatum	Crimson clover (annual)
T. pratense	Red clover (perennial)
T. repens	White clover (perennial)
T. resupinatum	Persian clover (annual)
T. subterraneum	Subterranean clover (annual)

The clovers are important because of their nitrogen-fixation with Rhizobium root nodules. Because the deliberate cultivation of pasture crops is fairly recent, most clover cultivar are fairly close to their wild progenitors. With only minor exceptions, the annual species are self-compatible while the perennial species are self-incompatible. Pollination is by insects and the clovers are suitable crops for plant breeding clubs.

Trigonella foenum-graecum

Fenugreek is a member of the family *Leguminosae* and its seeds are used as a component of curry powder in India.

Trillion

A trillion is 10^9 or 1,000,000,000. See also: Billion.

Triploid

A plant that has three sets of chromosomes in place of the usual two. Triploids are usually sterile, and they are difficult to breed (e.g., banana).

Tristeza

'Tristeza' means sadness in Spanish, and this is the name of a virus disease of citrus, also known as 'stem pitting'. The diagnostic symptom is a flattening of the branches and, when the bark is peeled off, there are pits in the wood, with corresponding projections in the bark. Diseased trees usually die,

following severe dieback. Tristeza is a graft incompatibility disease, and it is serious mainly on trees grafted on to sour orange rootstocks. Resistant scion-stock combinations have rootstocks of sweet orange, rough lemon, and 'Cleopatra mandarin'.

Triticale

A modern inter-generic hybrid between wheat and rye. It has not proved particularly successful as the uses for its grain are limited.

Triticum spp.

Triticum aestivum (also known as *T. vulgare*) is a hexaploid, and is bread wheat, which is the most important crop in the world. *Triticum durum* is a tetraploid and is pasta wheat, which has a very high gluten content, and is used for making pasta (e.g., macaroni, spaghetti, etc.) and couscous, or semolina. Diploid wheats also occur but none is economically important.

Wheat is a major staple (c.f., rice and maize) and it permitted the growth of civilisations in the Fertile Crescent, ancient Egypt, Greece, Rome, northern India, and modern Europe. The Indo-European languages are associated with the spread of wheat cultivation, according to the Renfrew hypothesis.

Wheat breeding for pest and disease resistance during the twentieth century has concentrated almost totally on both vertical resistance, and early maturity, which was aimed at disease escape. There is enormous scope for breeding for horizontal resistance, and wheat is an excellent challenge for the more adventurous plant breeding clubs. The use of a male gametocide is recommended in order to obtain large heterogeneous populations for recurrent mass selection.

Tropical grasses

The most important cultivated tropical grasses are Digitaria, Eragrostis, Chloris, Cenchrus, Melinis, Panicum, Pennisetum, Cynodon, and Paspalum.

Tropics

The Tropic of Cancer (23°27′ N), and the Tropic of Capricorn (23°27′ S). In common usage, any latitude between the two tropics, which lie to the north and south of the equator, and which mark the limits at which the sun is vertically overhead for at least one day of the year. The tropical regions have no winter or summer, and their seasons are often defined by rainy and dry periods, as the inter-tropical convergence zone moves from the northern to the southern hemisphere, and back again, in the course of one year.

Tuber

The swollen part of a rhizome that is used as a storage organ, as in a potato.

Tumour

An abnormal swelling of tissue. In plants, tumours are often called galls.

Tung oil

See: Aleurites spp.

Turmeric

See: Curcuma domestica.

Turnips

See: Brassica campestris.

U

Umbelliferae

A large family that includes carrots, parsnips, and celery. The flowers are borne in umbels, in which all the flower stalks arise at the end of a stem, giving it the look of an umbrella.

Uncinula

One of the genera of the powdery mildews (*Erysiphales*) in which the cleistothecium contains several asci, and has curled ends to the appendages. The chief plant pathogen is *U. necator*, which causes a powdery mildew of grapes and other hosts.

UNDP

United Nations Development Program, located in New York, USA.

UNEP

United Nations Environmental Program, located in Nairobi, Kenya.

UNESCO

United Nations Educational, Scientific, and Cultural Organisation, located in Paris, France.

Uniform distribution

The converse of a patchy distribution. With a uniform distribution of parasitism, every individual in the host population is more or less equally exposed to the parasite. A uniform distribution of

parasitism is very desirable when screening plants for horizontal resistance because differences in the level of parasitism then represent differences in the level of resistance. See also: Frequency, Injury.

Uniformity

"What happens when every door in the town has the same lock, and every householder has the same key that firs every lock?" A system of locking is ruined by uniformity, but this is exactly how vertical resistance has been misused during the twentieth century. See also: n/2 model.

University breeding clubs

University breeding clubs are in a halfway position between the true amateurs and the professionals. Their function should be to concentrate on population breeding and horizontal resistance. They have a number of prominent advantages: -

Plant breeding is somewhat intimidating for beginners. The ambience of a university breeding club is undoubtedly the best way of overcoming this intimidation.

The techniques of breeding for horizontal resistance require 'hands-on' experience and a breeding club is the best means of providing such experience. The students themselves would do all the work of breeding and they would gain practical experience in every aspect of the breeding process.

As one of the inducements to join, students should earn course credits from their breeding club membership and participation. The professor in charge of a breeding club would earn teaching credits for this activity.

On graduation, students should be given life membership in their club or clubs. This would entitle them to consult the university experts, and to receive, test, report on, and utilise new lines coming out of their club(s) for the rest of their lives.

Graduates would be encouraged to start one or more new breeding clubs among farmers and other interested parties, in their new place of work. This would lead to a proliferation of breeding activity. plant breeding clubs would provide a new approach to teaching in which the students themselves are involved in the actual achievements of both demonstrating the value of horizontal resistance, and of producing new resistant cultivar.

Short-term research grants have no guarantee of renewal and our current system of short-term financing of agricultural research discourages long-term research projects, such as breeding for horizontal resistance. Because the breeding club work would be a teaching activity, its continuation would be secure, and the professor in charge could undertake long-term research in this topic. It need hardly be added that this is an area that has been seriously neglected, and that such research is

urgently needed. In no small measure, this neglect has been due to the long-term nature of the research, and the insecurity of the research grant system.

The production of an assortment of valuable new cultivars in a range of locally important crops could provide valuable prestige for a university.

One of the chief criticisms of institutional and corporate plant breeding is that their work is so expensive, and that they are so specialised, and so technical, that their total breeding output is severely limited. A multiplicity of plant breeding clubs would provide a greatly increased amount of plant breeding.

University plant breeding clubs could provide an entirely new technique for overseas aid in agriculture. Overseas aid organisations could initiate these clubs in Third World universities, and support them with technical and financial assistance until they could stand on their own feet. If successful, these clubs could eventually prove to be the most effective agricultural assistance technique of them all. These clubs could also prove to be one of the cheapest techniques of overseas aid.

University clubs should be encouraged to 'twin' with a secondary school club in order to assist school children. A similar 'twinning' with amateur clubs should also be encouraged.

Unstable protection mechanisms

Any mechanism that protects a host from a parasite can be divided into one of two classes. Unstable protection mechanisms are those that protect a host only until a new strain of the parasite appears that is unaffected by that mechanism. This is because the mechanism is within the capacity for micro-evolutionary change of the parasite. Unstable mechanisms include vertical resistance, and most modern synthetic fungicides and insecticides. It is highly probable that genetically engineered resistances will also be unstable.

See also: Stable protection mechanisms.

Uredinales

The order of Basidiomycete fungi that cause rust disease .

Uromyces

A genus of fungi in which various species cause rust diseases of *Phaseolus vulgaris, Vicia faba, Pisum sativium, Trifolium* spp., and *Beta vulgaris*.

Ustilaginales

The order of Basidiomycete fungi that cause smut diseases.

Ustilago

A genus of fungi that cause smut diseases in maize, wheat, barley, and oats.

V

Vaccinium spp.

The blueberry and cranberry. There are several species with edible berries, and these are the only cultivated members of the heather family, the *Ericaceae*. Scope for amateur breeders.

Vanderplank

Possibly the greatest plant pathologist who ever lived, J.E. Vanderplank both developed the concepts, and coined the terms, of vertical resistance and horizontal resistance. He can be said to have transformed plant pathology by his development of theoretical aspects of this discipline. He died in 1997.

Vanilla

See: Vanilla fragrans.

Vanilla fragrans

This species is the only orchid grown for purposes other than ornamental. It originated in Mexico and the vanilla is extracted by fermenting the unripe pods and infusing them in alcohol. The main producer is now the Malagasy Republic (Madagascar). The crop is propagated vegetatively and few clones are known to exist. There may be scope for selection by amateur breeders in the centre of origin.

Variable ranking

See: Differential interaction.

Variation

Differences displayed by individuals within a species.

Variety

In a botanical context, this term means a subdivision of a species. An agricultural or horticultural variety is called a cultivar.

Vascular

Vascular tissue is plant tissue which transports water or nutrients. Vascular plants are those that contain vascular tissue, and are the ferns and seed-bearing plants (Angiosperms and Gymnosperms).

Vector

In a plant pathological context, a vector is an insect that transits a virus disease.

Vegan

A person who does not eat or use any animal products whatsoever. See also: Vegetarian.

Vegetables

Any part of a plant, other than the fruit or seed, that is used for food. Culinary usage is often different from horticultural usage. In the kitchen, tomatoes and cucumbers are vegetables but, botanically, they are fruits. Similarly, rhubarb is technically a vegetable, but is called a fruit in the kitchen.

Vegetarian

A person who generally eschews animal foods, particularly meat, but who may eat eggs and dairy products, and possibly fish. See also: Vegan.

Vegetative bud

A bud that grows into stems and leaves, as opposed to a flower bud.

Vegetative propagation

Plant propagation without sexual reproduction, usually by means of cuttings, grafts, tubers, bulbs, or corms. The population derived by vegetative propagation from a single individual is known as a clone. All the individuals within a clone are genetically identical, apart from an occasional mutant or 'sport'. Vegetative propagation is thus a useful means of obtaining genetic uniformity, and of preserving agriculturally valuable characteristics.

Venturia inaequalis

This Ascomycete fungus is the cause of apple scab.

Vermiculite

When biotite (black mica) is roasted, it expands into vermiculite that is a useful addition to potting soils.

Vernalisation

A treatment with low temperatures to induce flowering. Some winter cereals will not produce flowers if they are sown in the following spring, and they must be sown in the autumn if an entire summer is

not to be wasted. To vernalise winter cereals, the seed is wetted to initiate germination, and then stored at just above freezing for several weeks. This seed can then be sown in the spring to produce a crop in the same year. This technique is useful for breeders working with winter cereals.

Vertical

In a plant epidemiological context, this term is entirely abstract, and it means that a gene-for-gene relationship is present. Vertical resistance and vertical parasitic ability both result from a gene-for-gene relationship. A vertical subsystem of a plant pathosystem is defined by the presence of a gene-for-gene relationship. The individual genes of a gene-for-gene relationship are called vertical resistance genes, and vertical parasitism genes respectively, and are usually labelled with numbers, with matching genes being given the same number. Similarly, pathotypes and pathodemes that are defined by the presence of vertical genes, are labelled with the numbers of those genes. See also: Vertical parasitic ability, vertical resistance, n/2 model, System of locking, Habgood nomenclature.

Vertical parasitic ability

Parasitic ability that results from a gene-for-gene relationship. Vertical parasitic ability is the parasitic ability of the Mendelians; its inheritance is normally controlled by single genes, each of which has a corresponding, or matching gene in the host. In the wild pathosystem, vertical parasitic ability is part of a system of locking which can control allo-infections only, and which depends on genetic diversity in the host population. See also: Horizontal parasitic ability, vertical resistance**,** n/2 model, Habgood nomeclature.

Vertical parasitism genes

The gene-for-gene relationship involves pairs of genes, with one of each pair in the parasite and the other in the host. The genes in the parasite are called vertical parasitism genes and they confer vertical parasitic ability. Note that a single vertical parasitism may be conferred by more than one vertical parasitism gene.

Vertical pathodeme

A population of a host in which all the individuals have a stated vertical resistance in common. Note that these individuals may differ in other respects (i.e., they may be different cultivars).

Vertical pathotype

A population of a parasite in which all the individuals have a stated vertical parasitic ability in common. Note that these individuals may differ in other respects (i.e., they may be different varieties as defined by other criteria).

Vertical resistance

Resistance that is conferred by a gene-for-gene relationship, but which provides no protection against a matching allo-infections. It is thought that the sole evolutionary function of all vertical resistances is to control the population explosions of *r*-strategist parasites. Vertical resistance normally achieves this with a system of locking that greatly reduces the proportion of allo-infections that are matching infections. This reduction is usually achieved by killing the non-matching, allo-infecting parasite. Quantitative vertical resistance does not kill non-matching parasites, but it does prevent them from reproducing, and this satisfies the evolutionary function. Alternatively, quantitative vertical resistance allows non-matching parasites (particularly fungi) to reproduce, but at such a low rate of reproduction that the population explosion is reduced to unimportance.

Vertical resistance is the resistance of the Mendelians; its inheritance is normally controlled by single genes, each of which has a corresponding, or matching gene in the parasite. In the wild pathosystem, vertical resistance is part of a system of locking which can control allo-infection only, and which depends on genetic diversity in the host population. When employed on a basis of genetic uniformity in a crop pathosystem, vertical resistance is temporary resistance in the sense that a single matching allo-infection rapidly leads to the failure of the entire cultivar. See also: Horizontal resistance, Race-specific resistance, Vertical parasitic ability, n/2 model.

Vertical resistance genes

The gene-for-gene relationship involves pairs of genes, with one of each pair in the parasite and the other in the host. The genes in the host are called vertical resistance genes and they confer vertical resistance. Note that a single vertical resistance may be conferred by more than one vertical resistance gene.

Vertical resistance, inactivation

Breeding for horizontal resistance is possible only if all vertical resistance are either absent or inactivated during the screening process. In some crops (e.g., wheat) it is impossible to find parents that lack vertical resistance genes entirely. The vertical resistance must then be inactivated. One method of doing this is to use the one-pathotype technique. Another is to use the saturation technique.

Vertical resistance, ultimate function

It appears that the ultimate function of vertical resistance is to reduce the population explosion of an *r*-strategist parasite, which is usually a parasite with a very rapid asexual reproduction. The reduction is normally achieved by reducing the frequency of allo-infections that are matching

infections. However, in some pathosystems, the reduction is achieved by preventing or reducing the reproduction of the parasite. See also: Quantitative vertical resistance.

Vertical subsystem

A subsystem of a pathosystem that is defined by the presence of a gene-for-gene relationship.

Verticillium

A fungus that causes wilt diseases in an exceptionally wide host range. The symptoms are a wilt that happens in spite of an adequate soil moisture. These symptoms are identical to the Fusarium wilts, except that they tend to occur at somewhat lower temperatures.

Vertifolia effect

The effect, first recognised by Vanderplank, in which horizontal resistance is lost during breeding for vertical resistance or during breeding under protection from pesticides . The effect is named after the potato cultivar 'Vertifolia' because of its very low level of horizontal resistance to blight, revealed when its vertical resistance was matched. The mechanism of this effect is that the level of horizontal resistance is concealed in the absence of parasitism, if there is a functioning vertical resistance, or protection from pesticides . Plants with high levels of horizontal resistance are relatively rare in a screening population, and plants with lower levels of horizontal resistance tend to be selected on the basis of their other attributes. In the course of decades of breeding, the level of horizontal resistance can reach dangerously low levels.

Vested interests

There is a widespread antipathy to horizontal resistance and the reason probably lies in various vested interests. For example, a major effort to increase horizontal resistance would lead to a severe decline in the demand for crop protection chemicals. Much of the research funding comes from the big chemical corporations whose vested interests prevent them from funding research into horizontal resistance. Similarly, many senior scientists have devoted their careers to crop protection chemicals or to vertical resistance. Their vested interest in their scientific reputations prevents them from admitting that there may have been a better approach. See also: Mindset.

Vetch

See: Vicia sativa.

Vicia faba

The broad bean, also known as horse, field, tick, or Windsor bean.

Vicia sativa.

Vetch. This and other species are useful fodder legumes but their use is declining in favour of alfalfa.

Vigna unguiculata

Synonym: *Vigna sinensis*. Cowpea; also known as black-eye pea, black-eye bean, China pea, Kaffir pea, marble pea, and southern bean. Some cultivar are grown for their green pods which are known as yard-long bean, asparagus bean, snake bean, and Bodi bean. Cowpeas are one of the main pulses of Africa and many other tropical and subtropical areas. They are utilised as dried beans and as pot herbs. The plants are normally self-pollinating, but considerable cross-pollination by large insects occurs in the wetter areas.

There is scope for accumulating horizontal resistance by amateur breeders.

Vine

A slender climbing stem, this term is often used as a name for grapes.

Viroid

A primitive form of virus which consists of little more than genetic code. Viroids cause a few plant diseases and they differ from virus diseases mainly in that they are seed-transmitted. Spindle tuber disease of potatoes is caused by a viroid.

Virus

Viruses are too small to be seen with an optical microscope, and require an electron microscope. They are obligate parasites that cause a wide range of diseases in most crop species. Many viruses are transmitted from plant to plant by insects, mostly aphids and leaf hoppers. However, others can be transmitted by simple contact, or by soil-inhabiting organisms such as nematodes and fungi. See also: Viroid, Vector.

Vitamins

Organic compounds that are essential in small quantities for human nutrition, but which cannot be manufactured in the human body. They occur in a wide variety of foods, and they are one of the main justifications for a healthy and balanced diet.

Vitis vinifera

The grape vine, cultivated primarily for the manufacture of red and white wines, but also for table grapes and raisins. Grapes have been cultivated for millennia in Europe without any use of crop protection chemicals, and their levels of horizontal resistance to all their old-encounter diseases was entirely adequate. However, they had little resistance to Phylloxera, downy mildew, and

other new encounter parasites that originated in the New World. It is probably impossible to improve the horizontal resistance of the classic wine grapes to these new encounter parasites without an unacceptable loss of wine quality. However, *Phylloxera* is controlled by grafting classic vines on to wild vine rootstocks that are resistant, but this leads to a significant loss of yield. There is scope for amateur breeders to breed *Vitis vinifera* rootstocks with horizontal resistance to *Phylloxera*.

Viviparous

Giving birth to live young, as opposed to laying eggs. Many aphids, and other insects, are viviparous, and this increases their rate of population growth considerably, making them *r*-strategists.

Voandezia subterranea

Bambara groundnut. This is a minor indigenous African crop with edible seeds that are formed underground like peanuts. There is probably scope for improvement by local plant breeding clubs.

Vulnerability

Crop vulnerability is defined as susceptibility to an absent, foreign parasite that has epidemiological competence in the area in question. Should that parasite be imported, the vulnerability will be revealed and potential damage will become actual damage. Some crop vulnerabilities are particularly severe, the most famous example being the vulnerability of potatoes in Ireland to blight.

W

Wallace, A. R.

An English naturalist who formulated the theory of evolution independently of Darwin. He lived 1823-1913.

Walnut

See: Juglans regia.

Wasp

Although the common wasp is much disliked, because of its propensity to sting, many wasps are hyper-parasites of crop pests and they make a significant contribution to biological control.

Water-borne parasites

Any parasite that is disseminated in water. Relatively few crop parasites are water-borne, and those are mainly bacterial.

Watercress

See: Rorippa nasturtium-aquaticum.

Watermelon

See: Citrullus lanatus.

Weed

A plant growing where it is not wanted. Weeds can cause serious damage to crops by competing for light, space and nutrients. In the old days, weeds were controlled largely by ploughing and hand-tilling. These days, selective herbicides which kill the weeds, but not the crop plants, are used. Note that weeds are competitors, not parasites.

Weed suppression

Some crops, such as potatoes, are good at suppressing weeds. This is a useful alternative for organic farmers who may not use herbicides.

Weeding

The process of controlling or removing weeds.

Wheat

See: Triticum spp.

Whiteflies

Small plant parasitic insects of the Order *Homoptera*, which also includes aphids. So-called because their wings and bodies are covered with white scales. Whiteflies like a warm climate and they are mostly tropical, subtropical, or greenhouse pests.

Wild oats

See: Avena fatua.

Wild plant pathosystem

An entirely autonomous (i.e., self-organising) pathosystem in which people have not interfered, either directly or indirectly. It is characterised by its stability, by genetic diversity, and by genetic flexibility. It may be either continuous or discontinuous. A vertical subsystem can evolve only in a discontinuous wild pathosystem. Research into plant parasitism has been confined almost entirely to crop pathosystem***s***, and there is an urgent need for research into wild plant pathosystems.

Wild progenitor

In crop science, the term 'progenitor' usually means the original wild ancestor. Every cultivated species of plant has one or more wild progenitors, some of which are extinct.

Wilt disease

A plant disease in which the principle symptom is wilting, in spite of an adequate moisture in the soil. Wilts are usually caused by microscopic fungi such as Verticillium spp., or Fusarium spp., or by bacteria such as Pseudomonas spp. The wilting results from the fact that the water conducting vessels of the plant are occupied by the parasite, and are partly blocked. The parasite may also produce toxins that induce wilting.

Wind-borne parasites

Any parasite that is dispersed by wind. Most fungi and many insects are wind-borne. Wind dispersal can carry parasites for hundreds of miles. There is even evidence of aphids being carried across oceans on the jet stream.

Windbreak

A hedge or line of trees planted to protect crops from persistent winds.

Winged bean

See: Psophocarpus tetragonobolus.

Winter cereal

As their name suggests, winter cereals are sown in the autumn, and are able to continue growing, quite slowly, throughout the winter. Spring cereals, on the other hand, cannot survive a winter and must be sown in the spring.

Winter cereals have the advantage that they can begin active growth in the spring as soon as the thaw sets in, probably several weeks before tractors can get onto wet land in order to sow spring cereals. This permits either (i) a longer growing season with a correspondingly higher yield, or (ii) an early harvest that escapes the full development of pests and disease epidemics.

Winter hardiness

The ability of a crop to withstand winter. Winter cereals are a typical example of winter hardiness.

Witches' broom

A cluster of proliferating twigs, usually at the end of a branch, that resembles an old-fashioned broom made from a bundle of rushes tied to a stick. Witches' broom is usually cause by a parasite, the most important being the fungus *Crinipellis perniciosis* that causes witches' broom of cocoa.

Witchweed

See: Striga spp.

Woad

See: Isatis tinctora

World food problem

The very real fear that the human population will exceed the food supply.

X

x

The letter ‘x’ is often used to indicate the basic chromosome number of a plant or species (e.g., x = 7). That is, ‘x’ is the number of chromosomes in a monoploid, or a single gamete. Assume x = 7; then 2x = 14, and is a fertile diploid ; 3x = 21, and is a sterile triploid; 4x = 28 and is a tetraploid which will be fully fertile if it is an allotetraploid ; 5x = 35 and is a sterile pentaploid; and 6x = 42 and is a hexaploid that is likely to be sterile.

Xanthomonas

A genus of gram-negative bacteria that cause bacterial blights in beans, soybeans, cotton, rice, stone fruits, tomato, pepper, sugarcane, and various ornamentals.

Xanthosoma sagittifolium.

Tannia, tannier, yautia, cocoyam. A typical aroid that differs from Colocasia in having sagittate leaves (i.e., leaves shaped like an arrow with an arrow-head), and in that it originated in the New World.

Xenia

Some visible characters of seeds, such as colour, shape, etc., can be induced by the pollen on either the maternal tissue or the embryo. This phenomenon is called xenia and it provides a useful means of identifying hybrids.

Xerophyte

A plant able to withstand drought.

Xylem

The woody tissues of a plant, consisting of microscopic water-conducting tubes, as well as thick lignified cells, which collectively provide strength to the stem,. Timber consists largely of xylem.

Y

Yam

See: Dioscorea spp.

Yautia

See: Xanthosoma sagittifolium.

Yield

The yield of a crop is usually expressed as weight per acre (or hectare). Yield is one of the four major objectives of plant breeding, the others being quality of crop product, agronomic suitability, and resistance to crop parasites.

Z

Zea mais

The cereal known as 'corn' in the USA and Canada, and as maize in all other countries, and in all other languages. Maize is the third most important crop in the world. It is cross-pollinating and it exhibits severe inbreeding depression which permits the production of hybrid varieties. Unlike wheat and rice, commercially grown maize is not normally consumed directly, and it is sent to factories for processing into many industrial products. It is also used as fodder, both as feed grains and silage. In subsistence farming, it is consumed directly by people.

Maize is a major staple (c.f., wheat and rice) that permitted the growth of cities in the New World. It also contributed to huge population increases in the Old World (c.f., beans, potatoes). There is a detailed account in *Return to Resistance*.

Zinc

Zinc is a trace element nutrient of plants. The deficiency symptoms show mainly as an inter-veinal chlorosis in the leaves which later become purple and necrotic.

Zingerberaceae

The botanical family that includes ginger, turmeric, and cardamom.

Zingiber officinale

Ginger, which probably originated in India and is of great antiquity in the Far East. It was also known to the Ancient Romans. The wild progenitors are extinct. The crop is propagated vegetatively and few clones are known. Flowering is rare, and this is a difficult crop to breed.

Zizania aquatica

Wild rice. Although a member of the grass family (*Gramineae*), it is not related to true rice.

Zygomorphic

An organism of irregular shape but which has two halves that are mirror images of each other. That is, the organism is divisible in only one plane into two mirror-image halves.

Zygote

A cell that was produced by the union of a male gamete and a female gamete.

Recommended Reading

Capra, Fritjof (1996): *The Web of Life*, Anchor Books, New York, (ISBN 0-385-47675-2).

Robinson, Raoul A. (2002): *Return to Resistance*, second (revised) edition, available as a sharebook at www.sharebooks.ca.