The Impact of Botanical Science on current developments in Food Production.

Current trends in food production are, as they have always been, towards giving people more to eat. Every year, the world population rises by twenty-five million individuals, and each of these has the right to receive sufficient food. It was in 1798 that Malthus pointed out that population tends to increase by geometric progression, food production by arithmetic. At that time, the population of Great Britain was seven million, and there was enough food for all. Now, the population of Britain is fifty million, that of the world about two and a half thousand million, and it has been estimated that of the latter, about half eat barely enough to keep them alive. So somehow [or other], the amount of available food must be increased.

Many food-stuffs can now be made synthetically, but only a plant can take water, nitrogen, and lime minerals from the Earth, carbon from the air, and by the radiant energy of the Sun, convert them into those forms of food which are the basis of all life. Consequently any increase in food-production must, directly or indirectly, involve plants, and therefore Botanical Science.

Basically, there are four methods of supplementing the amount of food produced. These are:
1. Improving the yields of existing crops
2. Developing new crops
3. Improving the yields of those areas already under cultivation
4. Extending the area of productive land by bringing into cultivation virgin areas.

Of all these methods, Botanical Science has its part to play.

The exact limits of the term "Botanical Science" are hard to define. In the rigorous sense it concerns only plants themselves. The broader sense includes all aspects of the relation to the
environment and methods of improving the environment, it includes topics from soil science to genetics, from plant pathology to plant analysis. This is the broadening attitude in this essay.

Improvement in a crop's yield can be effected in several different ways. The most obvious is selective breeding to produce strains of the greatest possible productivity. The discovery of lethosis, or hybrid vigour, made possible big advances.

It was frequently noticed that when two plants of different genetic strains were crossed, the F₁ generation was superior to the parents in many respects, e.g., number and size of fruit, height of plant. This improvement is only found in the F₁; there is a gradual decline in vigour in the F₂ and later generations.

The cause of this is not yet clearly understood, but it is probably due to the bringing together in the F₁ of an unusual number of favourable genes. These are dominant, and the unfavourable recessive genes are masked until a further cross is made.

The commercial application of this is clear in the case of vegetatively propagated species in which the phenomenon occurs, but in important food plant falls into this group. However, in a few instances, the theory has been applied successfully to sexually reproducing species, notably maize. The maize plant is hermaphroditic, the male and female flowers are on different inflorescences on the same plant, and the male is at contact. If self-pollination takes place, the strain becomes weaker and weaker. To prevent this, the different strains are planted in alternate rows, and the male flowers of one strain are removed before they are ripe, thus leaving female rows which can only be fertilised from the male rows of the other parent. This leads to a marked increase in yield.

The Food and Agricultural Organisation of the United Nations has a programme for the
furthering of hybrid maize production. In Italy in 1951, only 3% of the area under maize was planted for hybridization, but even that was sufficient to increase the total yield by a hundred thousand tons.

The advantage of hybrid is also applicable to diseases which has self-culture induced lives. This species has a long life, and consequently the benefits of the &; disease can be reaped for several years.

With soft fruit, polyploidy sometimes increases the yield by the larger size of the individual fruit. The polyploidy is usually induced by electricity. It must be practiced in very much use, as it seems to lead to a deterioration in quality.

Disease is responsible for great falls in yield, and its control is one of the most costly items in food production. Thus greater yields can be thought about by breeding a crop with a view to genetic resistance to at least some of the diseases to which it is liable. One example of the success of this method can be drawn from potatoes.

The most serious and widespread disease of potatoes, both in U.S.A. and this country, is Phytophthora infestans, the late potato blight. The presence of this fungus is shown by brownish petals, reminiscent of frost damage, of the potato foliage, and a very characteristic smell. If infection is thought likely, inoculation can be employed with the larvae during July or August, and is fruitful. Inoculum can be obtained from diseased plants, and can be prepared by infecting sterile plants or by using diseased plant material in a medium. The disease is transmitted by wind, water, and other means, and is very persistent. The disease is often spread by wind, and can be controlled by the use of fungicides.

Inoculum development of foliage does not necessarily result in infection of the leaves. The latter are not infected by leaves which fall to the ground, and are that spread if they are covered with snow. The chief cause of tuber infection, however, is from "green hoops."
tubers left from a previous year, and infection contracted in this way may not show on the foliage.

There is a Mexican variety of wild potato, Solanum demissum, which is immune to late blight (and also to the attacks of many insects, e.g., Colorado beetle). It has seventy-two chromosomes; Solanum tuberosum, the domestic potato has forty-eight, but crosses can be made. The female of the wild type is crossed to the domestic type and the F₁ and F₂ generations back-crossed to domestic varieties. The progeny must be of good commercial quality as well as being resistant. *Solanum petraefolium* is a very resistant tuberous Mexican species, and to awaiting probably be more commercially more successful, but so far no crosses have been achieved.

In this country there are three strains of the fungus, and varieties resistant to all of these are desirable. Unfortunately, the production of new genotypes must keep pace with mutations in the fungus.

Varieties of potato are now available which are resistant to at least one of the following — wild mosaic, leaf-roll, late blight, crown rot (Annisotipula scabies), potato wart (Synchronum endobioticum), flat beetle, etc.

In crops where breeding for disease resistance has not yet been successful, other methods of prevention have to be used, such as the pre-treatment or cereal seeds against rust and bunt. This is hardly a "current development," as the suggestion that wheat grain should be steeped in copper sulphate solution was first made in 1761, but there have been extensive recent refinements.

*Fusarium* caries (covered smut of wheat), *Ustilago hordei* (covered smut of barley), *Helminthosporium gramineum* (leaf spot of barley), *Helminthosporium kolhead* (black foot of oats), *Helminthosporium virens* (leaf spot and heading blight of oats) and *Helminthosporium victoriae* (stripe smut of oats) are all seed-borne cereal diseases in
which the mycelium is superficial. They are preventable only by seed-treatment.

Research is now going on in Australia in which wheat is being back-crossed for resistance to "Pullorum" and "H. pestis." One gene, probably recessive, has been found to operate against five races of "Pullorum" in Australia. Behaviours are different with different physiological races, and the method has not so far been commercially applied.

Originally, copper sulphate was used, but it was useful only for wheat. Formalin was tried next, but it was effective only against some of the diseases mentioned. Ethyl chloride is a liquid, and the use of liquid for seed-deciding has several disadvantages, chief among which is the fact that if the grain is not thoroughly and quickly dried, germination is adversely affected.

The most favoured disinfectants used are organic mercury compounds, in powder form, which are mixed into the grain by rotation in a barrel or churn-like machine. There are many of these compounds on the market all proprietary brands of varying composition. The Ministry of Agriculture and Fisheries, and the Department of Agriculture for Scotland, have schemes of approval for certain of these brands. Such disinfection does not harm the vitality of the grain, unless the latter is stored long under damp, ill-ventilated conditions.

Research is still in progress regarding grain disinfection problems. There was a suggestion that "plant hormones" should be mixed with these powders, with a view to promoting root growth. Work in this country gave little or no evidence of increased yields by this practice, and experiments in Canada and the U.S.A. suggested that while a theoretical stimulation of physiological activity might be possible, conditions favouring this should actually occur only very rarely.

These seed-decplings are useless against fungi such as "H. pestis," "T. italii" (close friend of wheat) and "H. solani" (close friend of barley). These, although the infection is dead bone, the
Mycelium is internal. Thermal treatment is the only effective remedy known, and this is a very risky business. It consists of immersing the grain in water at such a temperature that the mycelium is killed, but not the embryos. These are often only a few degrees of latitude, and as the grain has first to be soaked in cold water, the maintenance of the correct temperature is particularly difficult. Taking *Ostilago restricta* as an example, if the temperature is less than 52°C, the fungus will survive, while if it is higher than 54°C, most of the grain will be killed. The grain is immersed in cold water for four hours, and in hot water for ten minutes.

General increase in knowledge of plant pathology will lead to still further improvements in disease control. The complete life cycle of many fungi is not yet known, so some fungi are not yet included in the environmental conditions. This can only be discovered by field trials carried out on a suitably large scale, and with a suitable number of replicates.

The second basic method mentioned for increasing food production is the development of new crops. In the discovery of a completely new crop is unlikely. This usually means the exploitation of some hitherto neglected source of food at a commercial scale. Even this has not occurred very frequently, but a good example is found in the recent researches into the possibility of using algae as food. For a long time certain seaweeds, e.g., *Euglena* (carageen) have been eaten in the West of Scotland and Ireland, although this practice is now dying out. In Japan, some
Sea-weeds are harvested, and they form a valuable supplement to the national diet. Japan and Israel are paying much attention to algae culture—since Israel is a "wheat" country, the people have no tradition of agriculture, and consequently are more ready to adopt unconventional methods of farming. Green algae are grown in tanks, and a yield of thirty tons per acre of food rich in nutrients has been harvested. This compares with one or two tons per acre, the average for wheat or rice.

Water-plants grow all the year round, and grow so thickly that all the sun's light falling on them is absorbed. There is no waste of energy. The idea of algal cultivation is particularly attractive in dry areas, where more normal crops could not be grown. The soil is needed, and if closed tanks are used, there is no evaporation. Much research is required on which species of algae have the most food value, and are most suited for this form of cultivation.

Agribusiness is by no means entirely botanical, but it has its vegetable elements, and it too has been investigated as a possible source of food. While it is unlikely ever to form any large part of general food production, it may play a very useful role as an emergency measure in some instances.

Ways of improving the yield of already cultivated areas tend to be more agricultural than purely botanical. It has been estimated that if all farmers employed the methods of the best farmers, food production could be doubled without any increase in the area of land cultivated.

Irrigation machinery in backward areas, and good crop rotation would do much to increase the world's food supply. Next to faring increasing the area of productive land, in many places it is a struggle even to keep control of what vegetation there is. This is the terrible battle against erosion.
Erosion is very liable to occur when the natural vegetation of an area is removed. It is very much in evidence in the central state of America, where thousands of acres of natural grassland were ploughed up, and wheat was planted. When the crop is harvested, the soil is left unprotected and erosion follows swiftly. The substratum becomes unstable and intensified—three million tons of phosphate per year are lost from U.S.A. lands by erosion, while two and a half million are lost by grazing and cropping. If the wheat is cut so thick as to ruble of about six inches high is left, the force of the wind directly over the field is reduced considerably, and erosion is less likely.

Indiscriminate lumbering is another cause of erosion. With the rise in importance of ecology, however, people are beginning to look at the countryside as a unit and to realize that good permanent agriculture depends on good permanent forestry. The cutting down of trees may have evil far-reaching effects, e.g., in the Mississippi basin whose desolation of the forest from the waters which have been a contributory factor to floods, a thousand miles down river.

Erosion is particularly to be found in young countries that have been colonised rapidly without regard to proper land management, e.g., U.S.A., Australia, Latin America, S. Africa. It is also encountered in very old countries such as China and India with a long tradition of agriculture. China has records of agriculture going back four thousand years and great pressure of population.

Much can fortunately be done to check erosion and reclaim land already laid waste. In central U.S.A., strip-cropping is now the rule, so that there are never wide stretches of unprotected soil. The planting of grassland is one of the first stages in bold reclamation—the method is given in an more detail later on.

If a crop is not doing as well in a certain place as might be expected, the obvious thought
is that there is some deficiency in the soil. The practice of fertilising land is as old as agriculture itself, but new and better methods are continually being discovered. The exact determination of a plant's requirements and tests to see which of a series of fertilizers is most effective, is the botanist's province.

It has been found that some nutrients are absorbed best in the presence of other substances; for example, sugar-cane most effectively takes up phosphates, when the nitrogen supply is in the form of ammonium nitrate. The phosphate uptake also seems to be impeded by the presence of magnesium. Which root weed is needed at this phenomenon. What is true for sugar-cane is likely to hold for other plants too, and this discovery may have considerable agricultural importance.

A fairly new technique is tissue analysis on the leaves petioles of plants to discover nutritional requirements and mineral deficiencies. Studies can also be made in nutrition and growth by use of radio-active tracer elements.

The methods of applying fertilizers and the times of treatment are also important. Again there are deviations from the old established paths. One of these is the injection of volatile liquids under pressure into the soil. Another is leaf spraying.

Leaf spraying is a very old idea, but for a long time the idea of a plant absorbing nutrients through the leaves has been completely disregarded. This method is most valuable in fruit growing, particularly in orchards under glass. Leaf feeding is very economical - it can be sprayed along with weed killer and insecticides - the response is quicker and less fertilizer is needed. Although it can be used for supplementing deficient minerals, possibly the most effective use is in supplying nitrogen generally in the form of urea. For fruit trees, the amount of nitrogen supplied
can be adjusted according to the quantity of fruit set. In apples, the greatest effect occurs if they are sprayed just after petal fall.

An interesting experiment was that of electrical stimulus of growing crops. Significant increases in the growth of wheat were observed in this country, but when the same apparatus was used in Australia, no effect at all could be induced. This is unlikely to have any commercial application, however.

The more fertile a soil is, the more trouble a farmer has with weeds. Excessive presence of weeds definitely has an adverse effect on a crop's yield. In a wheat field, weeds lead to a decrease in the grain yield and the number of ear-bearing tillers per plant. When sample plots were kept weedless for a period of three years, significant increases were noted in the yields of wheat. The lessening of competition due to removal of weeds, leads to an increase in the number of ear-bearing tillers, and thus to an increase of grain per plant and a greater yield per acre. The poorer the soil and the poorer the nutrients, the more severe is the competition. It was suggested that the increased yields were due not to less competition, but to the nutrients formed when the remains of the weeds lay on the ground. This theory was dispelled, as significant increases were still obtained when the weeds were removed completely.

The discovery of chemical weed-killers, selective and non-selective, was a great advance. It has been shown that potatoes can be grown after planting without the use of any tool except a sprayer for weed-killers, fungicides and pesticides. By the use of chemical weed-killers, a crop, e.g., potatoes, can be planted more closely than was necessary when mechanical methods of clearing were used. This enables a larger quantity to be planted per acre, thus leading to greater yields. With this closer cultivation, however, more fertilizer per acre must be applied.
Under the pressure of ever-growing populations, the cultivation of parts of the world hitherto believed unpromising if not impossible for food-production, is now being considered. Sometimes this has been successful. Sometimes it has not. In the latter instance, the reason is usually that insufficient attention was paid to the ecology of the crop and the proposed new environment. A classic example of this was the ground-nut scheme.

The ground-nut, is in the family Leguminosae. When the flower is fertilized, the stalk bends over, and the ovary is pushed into the ground. Therefore, a light sandy soil is required. The crop is of considerable commercial value, as about 40% of the yield is edible oil, the rest goes to make cattle cake.

Only 3% of Kalganji is cultivated. The soil is light, and there is a short rainy season. The ground-nut is an annual, and in East Africa it is planted in November to December at the start of the rains, and harvested about five months later. The original plan was to plant about two and a half million acres in five years.

Theoretically, this was an excellent idea, the utilization of an unproductive area by growing in it a valuable food-crop. Unfortunately the practice did not work out so well. With the clearing of the natural soil, the old enemy of land sterilization set in—erosion. The ground-nut, as an annual, had insufficient stabilizing action. Also, although little rainfall is required, the crop needs more than fell. Perhaps there was a period of exceptional drought, but the ground was held to hand that the sterilized byplasie could not effect an entry, and then it revolved up and died. Sunblacks seeds were planted as a safe-guard and emergency measure, but they too did not survive. Had a fuller study been made of the conditions of Kalganji and the requirements of the ground-nut, the plan might have been a success.
smallest, more experimental and less expensive scale. An example of an unproductive area successfully reclaimed, if affected by the pruning lands of New Zealand. There lies in a volcanic past, they have long been infertile. The top soil consists of lava, peauite and volcanic ash, and is markedly cobalt deficient. How it is reckoned that three hundred thousand acres can be made productive. The existing vegetation, a poor shrub, is flattened, and turned into the soil by ploughing deep enough to get below the volcanic crust. The soil is fertilized, and grass is sown. Once the latter is established, stock are introduced which tread the soil and give a firm base. United Nations are to be avoided, as the beasts tend to tread between the tufts and wear pathways. Much the same soil conditions obtain in Iceland, another country which is trying to found its agriculture. Efforts are being made to re-vegetate and to allocate approximately half of the area estimated to have agricultural possibilities, mainly as cultivated grassland and grass grazing. It seems likely that the grasslands were once extensive forage, but had become eroded through indiscriminate lumbering and over-grazing. The area is fertilized, particularly with phosphoric acid and nitrogen, and grass is again planted with clover, particularly of herbage species and Blennius linearis. Orygium andother auburn chamois grass is often introduced as a primary colonizer in the more arid parts. To roots penetrate deeply, and to dense tufts, and summers have a stabilizing action. Here the ground is not level as in the prairie lands of New Zealand, and so the grasslands are not grazed until they are quite dry.

Clearing and planting of tropical forest areas almost always is followed by erosion. Much devastation has been caused in Africa by the native habit of clearing an area, cultivating it until its productivity is exhausted, and then moving on, and leaving it to the wind and the weeds.
The colder parts of the world have more possibilities, with increasing knowledge of the theory and the technique of artificialization, agriculture could expand further and further west.

Winter wheat is planted in autumn, it appears above ground in spring and matures in summer. In artificialization, the grains are partly germinated, then subjected to freezing, and stored so that the seedlings remain at the same stage of development throughout the winter. This partially developed grain is planted in spring and develops as if it had been in the ground all winter. If untreated winter wheat is planted in spring, germination occurs and the seedlings grow, but the grain does not mature.

Artificialization is claimed to increase the hardness of a strain and also its resistance to certain types of insect attack. Sometimes the grains are subjected to three alternate soakings and freezings, being allowed to germinate further each time.

Using this method, wheat can be successfully established in places where the winter temperatures are too low to kill any seeds left in the ground over winter. Areas in Canada and Russia once thought hopeless for food production, now yield valuable crops of wheat.

Artificialization originated in Russia. The principle is that each type of seed has optimum temperature conditions for the various phases of development. In artificialization, the grains are subjected to a controlled form of these conditions before true development begins. Only with cereals has the effect been sufficiently investigated for it to be adopted for commercial purposes.

Apart from totally unproductive areas, every country has its areas of marginal land. This is particularly so in Scotland and much work is being done at present towards bringing more of it under cultivation. The growth of which now has been established. The growth of which now has been stabilized.
as sand dunes were studied, and species with a
similar action planted. Species of lupin were
found very successful; they thrive in acid
conditions, and the nitrogen-fixing bacteria in
the root-nodules increase the fertility of the soil.
So far the area has not been used for agriculture
but only for forestry, but are frequently follow
the others.

Bracken is a pest covering many
thousands of acres of hill land, particularly
in the North. The prothallia are delicate and
have a high mortality rate, but once one
becomes established, it forms a carpet of
spread, and the effects may be very far
reaching. The plant has two stages: one
reproductive stage just below the soil surface, and
the other a few feet deep. It is this last stage
that makes the plant hard to eradicate. Few
several experiments have been carried out over
a period of years to test the effect of various
attitudes at clearance, e.g. cutting, slashing and
shredding. Frequently the plant becomes
less conspicuous both in size and number.
This allows the sheep to penetrate the bracken
patch and drop the spores that often grow there
very quickly. It has actually been suggested
that their bracken is disadvantageous as it affects
sheep's ability to use it without interfering with
their grazing.

It is deplorably desirable, however, to have the
plant cleared completely. Research is now in
progress, tackling the problem from the purely
botanical angle, by first of all making a
thorough investigation of the morphology,
ecology, and physiology of the species. This
will tell whether or not this will be successful.

So far we have chiefly considered the direct
impact of botany on food-production, but that
part of the world's food supply which comes
from plants, or considerable indirect effect
becomes apparent when animal feeders is taken
into account.
The most important animals from the edible point of view are cattle and sheep, followed by pigs and poultry. The last two have simple stomachs, and do not digest fibrous matter, although poultry eat grass for the vitamins and minerals.

The immense importance of grassland is now realised. Range control to check erosion, is effectively practised, in America. Much attention is now being paid to permanent pastures in this country, chiefly hill land. Special values as terms of pasture, grasses are being evolved.

The point quadrat method is that most frequently used for pasture analysis. By studying the same sample plot at different periods of the year, it has been found that the composition of a herd does not change constant until about the beginning of July. The effects of over- and under-grazing are important. Under-grazing tends to lead to a predominance of undesirable grasses, as Baccharis and stubble, as when beets have plenty of choice, they tend to eat only the more palatable weeds. Over-grazing, which reduces at the expense of the rough grasses. In this country over-grazing is rarely encountered, but in other countries it leads to erosion and complete destruction of the pasture.

It has been a debatable point whether pasture fallowing and grazing, which covers a large area, has any real value. For a long time it was thought to have virtually none, because of the high percentage of lignin, but now it is claimed from evidence provided by digestibility trials on sheep, that it has a food value about equal to that of poor or mediocre hay. bombers does not seem very unpalatable, however, as the sheep only eat it if there is nothing better available.

The food value of hay itself varies with the season. It is now understood that the earlier it is cut, the greater is the food value, because of
the rapid shift for nutrients found for the developing seeds. Changes also occur with the drying of
the grass, etc., and sometimes a valuable source of
vitamin H is lost. Some of this is avoided by
making silage instead. Also a knowledge of the
chemical composition of various species is
necessary. Great acidity is to be avoided and the
more weed there are, the more acid the silage
will be. It is possible to procure special seed
kinds of non-fermenting grasses, when the
seed is enclosed for silage.

The type of food for sheep and cattle that has
gained a leading role into prominence is fodder of
high nutritive value between mangoes and sugarcane, with a sucrose content of 17-20%. If it has been so recently
developed, there is little differentiation as yet
between strains.

All root crops have great individual
variation, and the reason for this has not been
discovered. Turnips, mangoes and sugarcane have a core up, with different parts being analyzed for sugars, nitrogen, and
water content. There are all regular
indicators in the amount of all of these may
be found, plus to the top and outside, the
old way of sampling was by means of a core
slicer instead eliminated, and the great variation
seen in the main a reflection of the way the
crops were infected. Now in a long root, the core
is taken horizontally, in a round root
diagonally, and not much more can be seen.

By a knowledge of the analysis of the different
foods also of the beasts' requirements, exact
feeding ration for various animals can be calculated.

As magnesium deficiency has been developing
in pastures in recent years, the effects are slow
in appearing but when they appear they
are very noticeable and dangerous. No improvement
results; it magnesium compounds are fed to stock,
but if the compounds, such as Epsom salts, are
put as the pasture, both the latter and the stock benefit. Obviously, the magnesium must be present in the vegetation in a certain chemical form before it can be utilised by animals. Little is known about this yet.

Since the war, a general deficiency in calcium has also become apparent. This is probably because agriculturalists have been concentrating more on the land's phosphate requirements. So it is important to know which food plants are rich in calcium and to feed these to stock, particularly pigs and dairy cattle.

There must be a limit to the expansion of both crop and animal husbandry as land. Fifths of the earth's surface, however, is almost entirely untramped by man—the sea. Freshwater fish-farming is an ancient tradition in China, where a triangular economy has been evolved with grass-growing, pigs and hogs, and also in parts of Eastern Europe. About 300 lbs. of fish per acre can be produced on some of these lands, as compared to 2 lbs. of beef per acre of upland. Recently, the spade has been tried in shallow coastal water. The sea has much vegetable matter and when fertilisers are added, there is an enormous increase in this, leading to an increase in the animal plant life, and so to greater size and quantity of fish. Less attention has so far been paid to the botanical aspect of sea life than to the zoological, and it would be useful to know its requirements in more detail.

So it can be seen that, while considerable increases in food production are necessary to meet the ever-increasing demands of the ever-growing world population, this is not impossible. As Watttins and government predicted, considerable progress is being made, and biological science has valuable contributions to add. Indeed, as plants are the basis of all food, botany will be fundamental to all agricultural knowledge.