hours after dusk and that shading was provided by milky polythene.

PLANT GROWTH SUBSTANCES

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The discovery that the growth of plants can be modified by the application of extremely small quantities of certain chemicals has given rise to developments of great agricultural importance. The events which led to this discovery began with observations of Charles Darwin in 1880 whose experiments led him to conclude that some "influence" was transmitted from the tips of roots and shoots which controlled their direction of growth.

Since then, many research workers have added to our knowledge and it is now known that plant growth is under the control of highly active chemicals known as growth hormones which occur within the plant itself. The most important is the auxin-type hormone — IAA. This substance is produced in the growing tip, and as it moves down the stem its makes the tiny cells below get bigger, so promoting growth. It is of interest to note that IAA was known as a chemical for fifty years before it was found to be a plant growth hormone in 1934. This discovery led to big developments for here was a substance that could be made in the laboratory and when applied to plants could exert profound effects on growth, not only at the site of treatment but also in other regions of the plant to which it became transported. Since IAA is a fairly simple substance it was logical for chemists to synthesise other compounds of a similar nature and test them for their capacity to produce growth responses in plants.

These researches paid a rich dividend for many new active compounds have been discovered. These synthetic materials, it must be noted, do not occur naturally in plants and are therefore not hormones; they are better described as plant growth substances. Amongst them may be mentioned the well-known compounds 2,4-D and MCPA. The striking feature of these materials is their potency; some of them will produce an effect on plant growth at a concentration as low as one part per million of water. They are able to pass rapidly into roots, leaves or stems and are then transported within the plant. At low concentrations they may affect growth beneficially but when applied at higher strengths, some of them may produce disastrous effects which kill certain species completely. Yet with the dosage rates used in practice, these materials are not poisonous to man or animals nor do toxic residues from them persist in the soil.

So far the greatest use of growth substances has been in protecting crop plants from weed infestation. For example, 2,4-D and MCPA are typical "selective" weedkillers which, applied at 4 to 32 oz. per acre, can destroy many species of broad-leaved weeds while leaving grasses and cereals unharmed. They are, therefore, valuable in clearing weeds from cereals, pastures and lawns.

Research work on plant growth substances is proceeding on many fronts. Fundamental investigations on the relationships between chemical structure and growth-regulating activity help us to understand their mode of action and often lead to the discovery of new active chemicals. Studies are also being made on the physiological changes brought about by growth substances acting within the plant. For all such work it is necessary to have teamwork, with close collaboration between chemists and biologists.

There have been some interesting developments with growth substances towards achieving further specificity in selective weed control. One of these developments arose from biochemical investigations at Wye College from which the "butyric" herbicides were discovered. These are themselves inactive in regulating plant growth but they are converted to active growth substances within the tissues of certain plants. The weedkiller, MCPB is a chemical of this type; it is relatively harmless, for example, to clover plants and certain varieties of peas yet is converted to the active growth substance MCPA by many weed species. Another such compound is 2,4-DB, used for selective weed control in clover and lucerne (alfalfa). Both MCPB and 2,4-DB at 24 to 48 oz. per acre are used for controlling weeds in undersown cereals. Another advantage of these materials is that they can be safely used on cereals at an early stage when 2,4-D and MCPA would prove injurious. From the general viewpoint, it is of interest that the discovery of the "butyric" herbicides provided a new approach to selective toxicity in that the plant species which succumbs is responsible for bringing about its own destruction.

Hormone-type herbicides are usually applied as sprays because of the low concentrations which are able to affect plant growth; the drift hazard with all these materials can be appreciable and care must be taken in applying them. In all chemical weed control operations, success may be influenced by climatic factors as well as soil type and situation. In many cases it is not necessary for the herbicide to kill a weed outright for, as the crop develops, its smothering action will either destroy the weeds or keep them so small that their competition with the crop is negligible. A thin, poorly growing crop, however, will not provide the competition necessary to prevent the recovery of weeds which have been checked and not killed by spraying. It follows, therefore, that good farm management in conjunction with chemical weed control is the best means by which land can be kept clean with the most economical use of labour.

Another important use of plant growth substances is for the rooting of cuttings. This represents an important method of plant propagation because a rooted cutting develops into a plant which, unlike those raised from seed, is "true to type" and shows all the characteristics of the plant from which the cutting was taken. Root production is normally promoted by the action of a natural growth hormone which moves down to the base of the cutting from the leaves and buds so that when this natural hormone supply is supplemented by treating the base of the cutting with a suitable growth substance, the rooting response is often greatly accelerated. The literature on the use of growth substances for the rooting of cuttings is extensive. Two of the most important chemicals for this purpose are IBA and NAA, both of which have the advantage of not moving readily from the base of the cutting following application. The concentration which is most active for rooting, however, is often close to the toxic concentration and it is therefore most important to follow the makers' instructions closely in regard to treatment. The safety margin is greater with IBA than NAA; furthermore, IBA usually produces a small number of roots which rapidly grow to form a strong fibrous system. There are various methods of treatment, the simplest being the application to the base of the cutting of an inert dust containing an appropriate quantity of the growth substance (0.02-0.1 per cent for herbaceous cuttings and 0.1-0.5 per cent for hardwood cuttings).

Recent work in the writer's laboratory has shown that exposure to light can be an important factor in the rooting of certain hardwood cuttings. Thus, for example, cuttings from the woody stems of poplar taken at about the time of bud burst rooted readily in darkness but not when exposed to light.

Growth substances are also used commercially for preventing the "pre-harvest drop" of apples, pears and certain other fruits. This premature falling of fruit is due to the cessation of hormone production by the developing seeds; this leads to the formation of a layer of specialised cells — an "abscission layer" — at the base of the fruit stalk, which is not strong enough to bear the weight of the fruit. Spraying the tree at the right time with a very dilute solution of a growth substance often prevents the formation of the abscission layer and so ensures that the fruit will remain on the tree until picked. In this way, losses as "windfalls" may be greatly reduced though under certain conditions, a hastening of maturity of fruit may result from this treatment. Of the many growth substances tested for capacity to prevent pre-harvest drop, NAA is probably the most versatile. It is used as its sodium salt in solution at about 10 ppm in water. Some cultivars of apple and pear, however, do not respond satisfactorily to this treatment and it is probable that in these cases the appropriate compound remains to be found.

Another important use of growth substances is for promoting the "setting" of unfertilized flowers of certain species. The result is a seedless fruit, quite different from the type which develops as a result of pollination and fertilization. Fruit setting sprays contain a growth substance such as beta-naphthoxy acetic acid at very low concentration, together with a wetting agent to ensure good coverage of the flower parts. Although such sprays are effective with a number of species, they have so far only been used commercially in this country on tomatoes. When such a spray is applied to an open tomato flower truss, the unfertilized ovaries develop rapidly and a good set of seedless fruits, all of which grow to uniform size, is obtained. With outdoor tomatoes when climatic conditions are such that natural setting is poor, spectacular increases in yield may be obtained by growth substance treatment.

Other uses of plant growth regulators in agriculture could have been discussed in this account. Many active substances are now available and as research proceeds there is no doubt that more uses will be found for these versatile compounds. Again, it must be stressed that the agricultural developments have all arisen from fundamental investigations on natural growth hormones. As the chemist and biologist pursue their joint researches within this field, the problems of plant growth and development are becoming better understood. It has now been established that the normal growth of plants depends not solely on hormones, as was at first thought, but also upon the presence of hormone inhibitors, two of which, — abscisic acid and xanthoxin — have been identified, the latter in the writer's laboratory. The levels of abscisic acid have been shown to increase in wilting plants. The effect is to slow down growth and reduce water loss from the leaves so helping the plant to survive during the stress period. Xanthoxin is a growth hormone inhibitor which is formed from certain leaf pigments when they are exposed to light, and its production affords an explanation of why plants grow taller in the dark than in the light.

Other hormone-type compounds such as gibberellins and cytokinins also occur in plants and all of these, together with the two inhibitors just mentioned, have their part to play in Nature's well-planned chemical control of growth. As these natural processes become understood, new and important agricultural developments may be expected.