A REVIEW OF PLANT GROWTH REGULATING CHEMICALS IN SUGARCANE CULTIVATION

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ABSTRACT

The future of sugarcane cultivation in many parts of the world may depend on how well plant growth regulating chemicals can be incorporated into cultivation systems. Economic factors have made it difficult to rely on hand-labour to grow and harvest the crop, and competition from sugarbeet grown in more highly developed and mechanized areas is bound to influence the future of sugarcane.

Research has shown that certain types of growth regulants influence germination, growth and sucrose storage in a wide range of cane varieties. Field trials have indicated the feasibility of applying such compounds under practical conditions at various times during the development of the crop. There is little doubt that more research is required to determine the long-range consequences of applying new growth regulants on a large scale, but the significance of the contribution of plant physiology to the future of a major world crop is likely to be a most important limiting factor.

INTRODUCTION

This paper deals with plant growth regulators and more specifically their probable role in sugarcane cultivation in the future. This is a subject of topical interest. In view of severe competition from sugarbeet there is a need to improve yields of sucrose from cane. The role of plant growth regulators can be vital in this.

Over the past 10 years my colleagues, B. H. Most, H. Cutler, A. Yates, and others have established that at least 4 groups of naturally-occurring plant growth regulators occur in sugarcane at various stages in its development. Auxins, gibberellins, cytokinins and various growth inhibitors have been shown to occur either as free acids or bases, and also as conjugates in which the acid or base is associated with a sugar moiety such as glucose or ribose. The auxins have been isolated from stem apical tissue, from the roots and from the seed. Gibberellins have been found in extracts and diffusates of immature stem and leaf apical tissue, in bleeding sap from cut stumps of sugarcane stems, in the roots and in dormant and developing lateral buds. Cyto-

Abscisic acid (ABA) has been isolated from immature stem and leaf apical tissues together with several other unidentified growth inhibitors. IAA and abscisic acid have been found so far only as the free acids, while the gibberellins and cytokinins have been found in the free and conjugated forms — but readily water soluble.
The occurrence of all 4 types of plant growth regulators in stem apical tissues suggested that the regulatory mechanism in cane involves changes in the balance between the 4 types. It is characteristic of the hormonal regulation of plant growth that more than one type of growth hormone is involved in any one growth process and that their functions often overlap.

Thus, auxins and gibberellins are both involved in promoting cell elongation, while auxins and cytokinins may both stimulate cell division. In other situations the actions of the same two hormones may be similar or opposed. For example, the presence of cytokinin and auxin enhances growth of callus in tissue culture while these same two hormones oppose one another in the germination of lateral buds.

**THEORETICAL CONSIDERATIONS**

The discovery by Most that sugarcane is rich in gibberellins and cytokinins and that ABA occurs in apical stem and leaf tissues, led him to the hypothesis that stem elongation in sugarcane is regulated by variations in the amounts of gibberellin and cytokinin, translocated from the roots to the stem apex. These variations are induced by water-stress, changes in temperature and other environmental pressures. It has been known for quite a long time that elongation of sugarcane stems under field conditions is inhibited by drought or by low temperature and that there is usually a corresponding increase in the percentage of sucrose extractable from the crop. It has been shown that, when the supply of gibberellins and cytokinins to the stem apex is plentiful, the growth inhibitory effects of abscisic acid are counteracted. Growth is then rapid, and sucrose levels drop. When the gibberellin supply is restricted, growth rate is reduced — more sucrose is then stored, but also there is a tendency for more cellulose to be formed.

In immature, stem apical tissues of fast-growing sugarcane there is sufficient auxin to allow a response of the tissues to gibberellins and cytokinins. There are also sufficient amounts of gibberellins and cytokinins to promote cell elongation and cell division, and to counteract the premature ageing of immature cells by ABA.

In slow-growing cane the supply of gibberellins and cytokinins to the meristem is restricted. Cell division and cell elongation almost cease and the synthesis of ABA is increased. There is then premature maturation of the cells. In this state more sucrose is stored but much of the carbohydrate is incorporated into cellulose and structural materials, but at different rates.

The so-called “suspended” state is one which represents an ideal and which can serve as a criterion for selecting chemical ripening agents for practical use in the field. The ideal chemical ripener would suspend all growth processes, cell division, cell elongation and differentiation as well as the formation of new cell wall material. All tissues would be maintained in an unchanged condition and all available carbohydrate would move into storage as sucrose. No doubt there is a particular hormonal balance which could produce this effect. In practice it is necessary to settle for something less than the ideal. It is possible to get a gradual progression from a state of rapid vegetative through a phase of suspended growth to one of slow growth, which can be fitted into the harvesting programme.
PLANT PHYSIOLOGY

SYNTHETIC CHEMICALS AND THEIR EFFECTS ON SUCROSE STORAGE

In the early work on cane ripening, much attention was given to the possible use of 2,4-D. Some authors reported increases in sucrose content of cane when 2,4-D had been applied as a foliar spray; others were unable to obtain a similar response. We believe that the variable results might have been due to differences in environmental conditions.

Allen found that sub-lethal applications of 2,4-D to cowpeas increased the activity of phosphofructokinase (PFK) activity in the light, but decreased the activity of the enzyme in the dark. At a 12-hour photoperiod and constant temperature of 25.6°C PFK is an important regulator of glycolytic respiration in plants. A reduction in its activity probably indicates a lowered rate of respiration. If 2,4-D has a similar effect on cane tissue then photoperiod and temperature could influence its effectiveness as a ripener. Best results might be expected under short day conditions with warm nights. In fact one may find that in those areas of the tropical world such as Cuba where 2,4-D has given positive results, the photoperiod and night temperatures fit the ideal situation.

Another synthetic auxin, 2,3,6-trichlorobenzoic acid (TBA) has been shown by Nickel and Tanimoto in Hawaii and by ourselves to be an effective ripener. Also mixtures of 2,3,6-TBA and MCPA have been found effective by some and not effective by others. Our group has studied the response of cane to this mixture in some detail, and published the following results.

The chemical causes an initial acceleration of stem elongation, followed by a long suppression of growth. The initial growth response is largely confined to one immature internode, but the growth of the younger internodes is completely suppressed. Similar results are obtained with applications of MCPA or TBA alone. Senescence of the oldest leaves is accelerated, and the emergence of new leaves can be prevented.

The response of cane to MCPA-TBA mixtures may be interpreted in terms of its possible effects on the internal hormonal balance. In rapidly elongating immature stem tissues the relative levels of the 4 types of hormones are as follows:

- auxin: medium
- gibberellin: high
- cytokinin: high
- ABA: low

Treatment with MCPA-TBA raises the auxin level and since this particular synthetic auxin is not readily degraded by cane tissues this increased auxin level would persist. The higher auxin level would initially enhance the activities of the gibberellins and cytokinins, thus promoting cell elongation and cell division. Soon afterwards the higher level of auxin would tend to promote the synthesis of ethylene. This could lead to auxin destruction, particularly of the native auxin, and to the oxidation of metabolites and certain enzymes. The growth-promoting activity of the gibberellins and cytokinins would be negated and growth would be suspended. Premature senescence of the oldest leaves may be due to ABA. Apart from its effect upon leaf tissues, the MCPA-TBA mixture is an effective ripener. Complementary administration of a gibberellin or a cytokinin might overcome this effect by balancing the increased activity of ABA.
The effect of GA on the accumulation of sucrose by cane has also been studied in recent years. Villareal and Santos in the Philippines and Coleman and his co-authors found no significant effect on sugar yields. But in Hawaii and Queensland, applications of GA may increase sucrose yields, especially in areas with relatively low (sub-tropical) temperatures.

Bull, in greenhouse experiments in Queensland found that weekly applications of GA over a 7- to 8-week period increased the length, fresh weight sugar and fibre contents of the stalks, but decreased leaf area and weight. The response of young (3-month-old) plants was greatest at low temperatures (17°C), but older (6-month-old) plants gave the largest response at higher temperatures (35°C).

In terms of its possible effect upon the hormonal balance, treatment of sugarcane with GA would be expected to stimulate stem elongation, particularly when the level of auxin is fairly high (i.e. in slow-growing cane). This hormone might also tend to retard senescence by opposing the activity of ABA. If this is so, the observed reduction in leaf area due to GA may to some extent be compensated for by a delayed senescence of old leaves. It is known that GA does not increase photosynthetic activity per unit leaf area.

Preliminary experiments with ABA and with 'Ethrel' (2-chloroethane phosphonic acid), a compound which releases ethylene in plant tissues, indicate that these chemicals may have potential as cane ripeners. Both retard stem elongation for about two weeks and this is followed by a period of rapid 'compensatory' growth. As might be expected, ABA treatment hastens senescence of the older leaves.

Treatment with Ethrel causes the loss of apical dominance as evidenced by the development of side shoots, tillers and strut roots. This is consistent with the finding that ethylene stimulates peroxidase activity in plant tissues, leading to the destruction of auxin.

Hormone transport is obviously an important step in the response of plants to environmental stimuli. There is evidence that most hormones are translocated in the plant as free acids (auxins) or readily water soluble conjugates (gibberellins and cytokinins). Several chemicals are known to inhibit auxin transport. One of these, 2,3,5-tri-iodobenzoic acid, has been tested on sugarcane but was found to be a weak growth retardant.

Chemicals which suppress the synthesis or activity of enzymes involved in the utilisation of sucrose may prove useful as ripeners. Thus Alexander found that treatment of sugarcane with 6-azauracil, a pyrimidine analogue which may inhibit RNA synthesis, caused a decline in growth and invertase activity, accompanied by an increase in sucrose content. The leaves of the plants were not affected, but the chemical caused malformation or death of meristematic tissue at the stem apex. Alexander also reports increased sucrose accumulation as a result of treating sugarcane with molybdenum or tungsten, which inhibit phosphatase activity, and with silicon, which inhibits invertase activity. It is interesting to note that co-administration of GA with 6-azauracil or with silicon appears to enhance their ripening effect.

REFERENCES

17. Most, B. H. (1969). Ripening of sugar cane. A model of how environmental changes can induce the ripening process in sugar cane, Tate & Lyle Ltd Res Centre Seminar,

REVISTA DE LOS PRODUCTOS QUIMICOS REGULADORES DEL CRECIMIENTO DE LA PLANTA EN EL CULTIVO DE LA CAÑA DE AZÚCAR

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RESUMEN

El futuro del cultivo de la caña de azúcar en muchas áreas del mundo, depende en gran medida en la forma eficiente en que se incorpore en las sistemas de cultivo, productos químicos reguladores del crecimiento de la planta. Factores económicos hacen difícil depender de mano de obra para cultivar y cosechar este cultivo, y la competencia de el azúcar de remolacha que se siembra en áreas altamente mechanizadas, influyen en el futuro de la caña de azúcar.

La investigación ha demostrado que ciertos tipos de reguladores de crecimiento, influyen en la germinación, crecimiento y almacenamiento de sacarosa en muchas variedades. Pruebas de campo indican la posibilidad de aplicar estos compuestos bajo condiciones prácticas en varias ocasiones durante el crecimiento de este cultivo.

No hay duda, que hace falta mas investigación para determinar las consecuencias a largo alcance de la aplicación en gran escala reguladores nuevos de crecimiento.

La importancia de la contribución de la fisiología de plantas para el futuro de este importante cultivo mundial, es ciertamente un factor limitante.