Effect of Gibberellic Acid, Several Growth Retardants and Nitrogen Levels on Yield and Quality of Sugarbeets[1]

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In recent years, considerable interest has developed in the use of plant growth regulators, growth retardants, and metabolic inhibitors as means to increase the yield and sucrose content of sugarbeets. Several investigators reported that foliar applications of gibberellic acid (GA) increased root yield per acre, but the increase in yield generally was accompanied by a reduction in sucrose content and resulted in no gain in gross sucrose production per acre. Nelson and Wood (7)[4] noted that 10 ppm GA applied to the foliage 3 or 6 weeks before harvest significantly increased yield but had no effect on sucrose percentage. One hundred ppm GA applied on the same dates increased root yield but lowered sucrose content. Peterson (8) found that concentrations of 10 and 100 ppm of the potassium salt of GA applied to the foliage early in the growing season had little effect on either root yield or sucrose content. Application of 500 ppm GA decreased both root yield and sucrose percentage. Humphries and French (4) showed that GA decreased the number of leaves, elongated the growing points, increase total dry matter content of roots, but had no effect on weight of the storage root. In the same study, the application of 2-chloroethyltrimethyl ammonium chloride (CCC) had the opposite effect.

Schreiber and Ferguson (10) established experiments to determine the effect of foliar sprays of GA and maleic hydrazide (MH) on yield and quality of sugarbeets. They showed that application of 250 and 500 ppm GA consistently increased yields and decreased sucrose contents, whereas a 0.3% solution of MH increased sucrose content but decreased yield. In a later study the same authors (11) found that combinations of GA and MH had no effect on yield or extractable sucrose produc-

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[4] Numbers in parentheses refer to literature cited.

tion. The depressing effect of MH on yield of roots and its influence on raising the sucrose content was reported also by Wittwer and Hansen (13), and Peto *et al.* (9). Conversely, Mikkelson *et al.* (6) reported that MH applied to beets in July or in early September increased both root yield and sucrose content of beets grown in California. This beneficial effect may be the result of a more favorable growth condition in contrast to most other field experiments conducted at locations where the growing season was considerably shorter than in California and where MH was applied relatively later in the season when conditions are less favorable for plant growth. In a greenhouse experiment, Wort and Singh (14) reported that foliar applications of MH reduced respiration in both roots and leaves and increased the photosynthetic rate.

In other studies, metabolic inhibitors and growth retardants were used to inhibit nitrate reductase activity in attempts to depress top growth and increase the sucrose content of the sugarbeet root. Singh (12) suggested that MH, pyrocatechol (PC), and oxy vanadium sulfate (VS) had an inhibitory effect on nitrate reductase and transaminase activities with a corresponding increase in percentage sucrose.

The objective of the research presented in this paper was to study the effect of a growth regulator, four growth inhibitors, fertility level, and their interactions on yield and quality of the sugarbeets. The growth regulator was gibberellic acid (GA), and the four growth inhibitors were maleic hydrazide (MH), pyrocatechol (PC), oxy vanadium sulfate (VS), and 2-chloro-ethyltrimethyl ammonium chloride (CCC).

Materials and Methods

Three experiments were conducted at the Colorado State University Research Center near Fort Collins. The soil on the Research Center is a calcareous Nunn clay loam. Concentrated superphosphate fertilizer was applied to each experiment to provide adequate supplies of phosphorus and soil moisture was maintained at optimum levels by irrigation. G.W. A-type open pollinated seed was planted in 1962 and 1963 and a G.W. hybrid A-type blend in 1968. There were no serious insect or disease problems in any of the experiments. Details of each experiment follow.

1962 Experiment

An experiment using split-plot design with six replications was conducted to study possible interactions between fertility level and chemical growth regulators for yield and quality of sugarbeets. The main plot treatments, in pounds per acre of active material, were: 1) 2.50 lb of CCC in 0.2% solution; and

2) 6.6 lb of MH (acid form) in 0.2% solution; and 3) 600 lb of sugar. Each main plot in turn was split for ammonium nitrate (33.5% N) applied at rates of zero and 150 lb N per acre. The chemical growth inhibitors (CCC and MH) were applied as foliar sprays. The total application was split with one-half applied on September 6 and one-half on September 24 with Tween-20[5] as a spreader. The sugar was broadcast September 10, and sprinkler irrigated on September 12. Sugar was applied in an attempt to rapidly immobilize the mineral soil-nitrogen. The beets were harvested October 16 for yield and sucrose determinations on the roots. Petioles also were sampled the same date and analyzed for nitrate-nitrogen (5).

1963 Experiment

Five foliar spray treatments were applied at three rates of nitrogen in a split-plot design with nitrogen level as main plots. Ammonium nitrate was applied to give rates of 0, 75, and 200 lb N per acre. Foliar treatments in per-acre rates of active material were: 1) 3.35 lb MH applied as a 0.45% solution at each of 2 dates, August 26 and September 4; 2) 3.5 lb MH applied in a 0.45% solution September 27; 3) a total of 1.5 lb. CCC applied in 0.2% solution split between two applications, July 10 and August 2; 4) 0.6 lb CCC applied in 0.2% solution on August 2; and 5) control. The second application of MH on September 4 for treatment 1 was applied because of a heavy rain within an hour after the MH was applied on August 26.

The beets were harvested October 16 for determination of yield and sucrose content, and petioles and roots were analyzed for total nitrogen (1).

1968 Experiment

This experiment was planted on April 8, and plants were thinned to a uniform 9-inch stand by mid-June. Ammonium nitrate at the rate of 150 lb. N per acre was applied in the furrow on July 13 and the experiment irrigated on July 14. A split-split-plot design was used with GA treatments (with or without GA) as main plots, 3 dates of application (1, 3, and 6 weeks before harvest) as sub-plots, and four growth-regulator treatments as sub-sub-plots. The growth-regulator treatments included a control, MH, PC, and VS. There were 4 replications.

Each sub-sub-plot consisted of four 50-ft rows spaced 22 in apart. The sodium salt of GA (83.1% GA) was applied at 200 ppm in 60 gallons of solution per acre on September 1. A new formulation of MH containing 18.8% potassium salt of 6 hy-

[5] The trade name for polyoxyethylene sorbitan monolaurate.

droxy-3-(2H) was sprayed as a 0.3% solution of MH (0.75 lb per A). PC and VS were applied at the rate of 3 lb of material per acre.

With the exception of the MH, Tween-20 was used as a wetting agent in all solutions. VS, PC, and MH were applied in 30 gallons of solution per acre.

Two rows, 45 ft long, were harvested on October 25 for yield. Percentage sucrose and purity were determined as outlined by A.O.A.C. (1) and by Carruthers and Oldfield (2), respectively. Recoverable sucrose (3) was calculated from purity and percent sucrose by the use of tables developed from the Great Western Sugar Company formula which assumes a 62.5 molasses purity and 0.3% factory loss.

Results and Discussion

Results of the 1962 experiment are summarized in Table 1. The main effects for treatment were significant for the MH treatment only. Foliar applications of MH increased the sucrose content about 1% but reduced root yields nearly a ton per acre. Sucrose production per acre was about the same for all treatments. The MH treatment reduced the nitrate-nitrogen content of the petiole at harvest, but without the foliar symptoms observed in the later experiments. Application of sugar did not influence available soil nitrate as indicated by yield, sucrose content, and petiole nitrate levels. The CCC treatment had no appreciable effect on yield or quality of the roots.

Table 1.—Influence of applications of nitrogen fertilizer, growth retardants, and sugar on yield of roots, sucrose content, and petiole nitrate, 1962.

	Roots T/A	Sucrose %	Sucrose T/A	Petiole nitrate ppm NO_3-N
Foliar treatment				
Control	19.7	13.6	2.68	9050
CCC, 2.5 lb/A	19.5	13.5	2.63	8760
MH, 6.6 lb/A	18.6#	14.5**	2.70	7430#
Sugar, 600 lb/A	19.2	13.2	2.53	9220
Nitrogen level				
0 lb N/A	19.3	13.9	2.68	8700
150 lb N/A	19.3	13.8	2.66	8100

Differs from mean of other treatments at 10% level of significance.

** Differs from mean of other treatments at 1% level of significance.

Nitrogen fertilizer had little effect on yield or sucrose production (Table 1). The low sucrose content of the roots for all treatments indicates that the initial available soil nitrogen was so high that little response to nitrogen fertilization would be expected.

Results of the 1963 experiment are given in Table 2. The application of nitrogen increased root yields but decreased sucrose content, consequently sucrose production per acre was not affected. Total nitrogen content of roots and petioles sampled at harvest was greater where nitrogen fertilizer was applied. There was no interaction between foliar treatment and level of fertilizer nitrogen, apparently because of the high nitrogen fertility level of the soil.

Table 2.—Influence of nitrogen fertilization and CCC and MH foliage sprays on the yield and quality of sugarbeets, 1963.

	Roots T/A	Sucrose %	Sucrose T/A	Total N in plant parts (% N) Roots	Petioles
Nitrogen treatment					
None	20.3	15.7	3.19	0.77	1.61
75 lb N/A	21.4	15.5	3.32	0.90	1.65
200 lb N/A	22.2*	14.8#	3.29	1.09**	1.85**
Foliar treatment					
Control	22.4	14.8	3.32	0.93	1.72
CCC, 1.5 lb/A	21.8	14.9	3.25	0.92	1.80
CCC, 0.6 lb/A	22.0	15.1	3.32	0.91	1.67
MH, 7.0 lb/A‡	18.5**	17.3**	3.20	0.89	1.44*
MH, 3.5 lb/A‡	20.6*	15.3*	3.15	0.92	1.74

Differs from zero nitrogen at 10% level of significance.
* Differs from zero nitrogen or foliar control at 5% level of significance.
** Differs from zero nitrogen or foliar control at 1% level of significance.
‡ The 7.0 lb treatment was applied August 26 - September 4; the 3.5 lb treatment was applied September 27.

Again in 1963, foliar applications of MH increased sucrose content but decreased root yields, while sucrose production remained about the same. These results are in agreement with the 1962 experiment and are typical of other experiments reported in the literature (9,10,13). Foliar applications of CCC had no effect on yield or quality.

The higher rate of MH had the greater effect on both yield reduction and sucrose increase, although sugar production was about the same for the two MH treatments (Table 2). The higher rate of MH decreased the total nitrogen content of the petioles but had no effect on the total nitrogen content of the roots. It can be assumed from the results that the greater influence of the high rate of MH was a rate effect rather than one of time of application.

Applications of MH caused a general yellowing of plants for the 1963 experiment that resembled nitrogen deficiency and was in marked contrast to the dark green leaves for the untreated plots. The yellowing was greater for the higher rate of MH. Closer examination of the chlorotic plants, however, revealed characteristics that differed from nitrogen deficiency. Many petioles exhibited a purple coloring and occasionally this was seen also on the leaves. Petioles were brittle and some were twisted, and because of these formative effects they were difficult to sample by the usual procedures.

In both the 1962 and 1963 experiments, applications of 6.6 or 7.0 lb MH per acre decreased nitrate nitrogen or total nitrogen in the petioles. In 1963 the higher rate of MH caused chlorotic plants and slight chlorosis was noted in 1968. Although an increase in sucrose percentage generally is observed for nitrogen deficient beets, the cause-effect relationship involved in these experiments cannot be resolved.

The main effects for GA and growth retardants for the 1968 experiment are summarized in Table 3. The three application dates for growth retardants were averaged because the time of application had no differential effect on the response to GA or to growth-retardant treatments. There were no significant interactions except for GA $\times$ growth-retardant for the dry matter content of the roots.

Table 3.—Influence of foliar applications of GA and growth retardants on yield and selected plant characteristics, 1968.

	Growth-retardant effects				Gibberellin effects	
	Control	MH	PC	VS	No-GA	GA
Root yield, T/A	20.3	20.0	20.6	19.9	18.9	21.5**
Sucrose, %	14.8	15.0	15.1*	14.7	16.0	13.8**
Gross sucrose, T/A	3.00	3.00	3.11*	2.93	3.02	2.97
Purity, %	91.1	90.7	91.3	90.4	91.5	90.3#
Recoverable sucrose, T/A	2.41	2.43	2.60**	2.34	2.49	2.39**
Dry matter, tops, %	12.3	12.6	12.5	12.1	12.8	11.9**
Dry matter, roots, %	28.6	28.1	28.4	27.5	28.6	27.7#
Total dry matter in roots, T/A	5.79	5.63	5.85	5.29	5.31	5.96#

Differs from no-GA at 10% level of significance.
* Differs from control or no-GA at 5% level of significance.
** Differs from control or no-GA at 1% level of significance.

Foliar application of GA produced highly significant effects for root yield, sucrose percentage, recoverable sucrose, and dry matter content of the tops. GA increased the average root yield 2.6 tons per acre but decreased the sucrose content 2.2%. Although gross sugar production per acre was not affected appreciably, the application of GA caused a decrease in recoverable sugar, largely as the result of 1.2% lower purity where GA was applied.

A second effect of GA was to increase plant succulence as shown by a significantly lower dry matter content of the tops and the same trend for the roots. Total dry matter production, however, was slightly higher for the GA treatment.

Main effects for growth retardants were significant for sucrose percentage, gross sucrose, and recoverable sucrose. The PC treatment significantly increased the sucrose percentage and yield of sucrose over the control treatment (Table 3). Significance was attained for small PC differences because the experimental design gave high precision for growth-retardant effect. Neither MH nor VS had an effect on yield or quality.

In contrast with the earlier experiments, the HM treatment in 1968 had no effect on yield or sucrose content, but the plants did show the yellowing characteristic of MH applied in the 1963 experiment. Growing conditions in the fall were about average for the local area during the three growing seasons, thus the difference in response to MH in 1968 probably was not one of growing season but of application rate. MH was applied at a considerably lower rate in 1968, 0.75 lb/A in 1968 vs. 3.5 to 7.0 lb in the earlier experiments.

As noted previously, there was a significant GA $\times$ growth-retardant interaction for dry matter content of the roots. The interaction was caused by an increase in percent dry matter in the roots when VS was applied in combination with GA, whereas with the control, MH and PC treatments, the dry matter content decreased when GA was applied (Figure 1). Although the dry matter content of the root increased, the sucrose concentration remained unaffected by the VS treatment. An increase in sucrose might be expected because a reciprocal relationship between sucrose concentration and percentage dry matter in the root is observed frequently for sugarbeets. In contrast to the interaction for root dry matter, all growth-retardant treatments decreased by the dry matter content of the tops when applied in combination with GA. The main effect of GA on dry matter content of the tops was highly significant (Table 3).

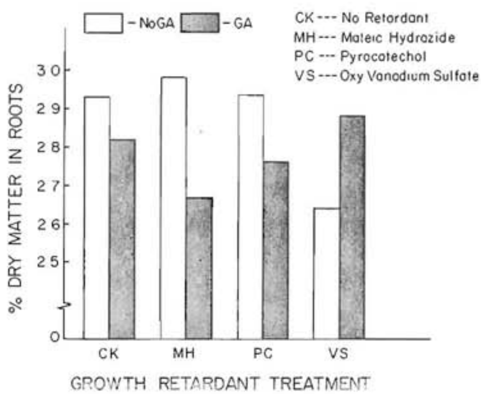

Figure 1.—Effect of gibberellin and growth retardants on dry matter content of sugarbeet roots.

Of the various growth-retardant chemicals applied to the foliage in these experiments, only the PC treatment for the 1968 experiment increased gross sucrose and recoverable sucrose production per acre. The effect of PC was to increase sucrose percentage while maintaining the yield. The increase in recoverable sucrose was about 8%. This is considerably less than the 16 to 22% increase reported by Singh (12) for a greenhouse experiment. Some leaf sclerosis and browning of leaf margins caused by the application of PC may have reduced its full effect.

The CCC in the 1962 and 1963 experiments and VS in 1968 did not influence growth or sucrose content. The foliar application of VS caused considerable sclerosis, necrotic patches, browning of leaf margins, faciation of petioles, and greater susceptibility to frost damage. This leaf damage may have prevented the beneficial effect on growth and sucrose content reported by Singh (12).

The increase in root yield and the decrease in sucrose content resulting from foliar application of GA are typical of published results (4,7,8,11). The lower sucrose content of the root was caused only in part by an increase in water in the root (Table 3). When calculated on a dry weight basis, the sucrose content of the roots was 55.8 and 49.8% for the no-GA and GA treatments, respectively. Thus, although GA did increase dry weight of the root slightly, the results indicated a lower quality root.

Summary

Three experiments were conducted on calcareous Nunn clay loam to study the effect of foliar applications of four growth retardants and gibberellic acid, a growth regulator, on the yield and quality of sugarbeets. The results are:

1. Foliar applications of pyrocatecol (PC) significantly increased the sucrose concentration in the root and recoverable sucrose production per acre.
2. Maleic hydrazide (MH) increased the sucrose content and decreased root yields in two experiments, but gross sucrose production remained about the same. The MH treatment reduced nitrate or total nitrogen contents of the petioles. MH applications caused a chlorosis which resembled nitrogen deficiency to develop on some plants.
3. Oxy vanadium sulfate (VS) and 2-chloro-ethyltrimethyl ammonium chloride (CCC) had little effect on yield or quality of the beets.
4. The foliar application of gibberellin (GA) increased root yields and total dry weight of the roots but decreased sucrose content. Gross sucrose production per acre remained about the same. Gibberellin decreased the dry matter content of the tops and roots for all treatments

except for the combination of GA and VS. The latter combination increased the dry matter content of the roots.

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