INTERACTION OF SUCCINIC ACID-2,2-DIMETHYLHYDRAZIDE AND GIBBERELLIC ACID ON DWARF BEAN AND DWARF CORN*

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Although succinic acid-2,2-dimethylhydrazide (Alar) is usually classed as an antagonist of gibberellins, it does not inhibit synthesis of gibberellin in *Fusarium* (Ninneman *et al.* 1964; Dennis, Upper, and West 1965), nor inhibit release of reducing sugars from barley endosperm by gibberellic acid (GA_3) (Paleg *et al.* 1965) or interact additively with ammonium(5-hydroxycarvacryl)trimethyl chloride piperidine carboxylate (Amo 1618) or (2-chloroethyl)trimethylammonium chloride (CCC) (Moore 1967). In addition, Alar reverses inhibition of growth of rice plants induced by CCC (Hishra and Paul 1967). In this paper we show that while Alar antagonizes the action of GA_3 in dwarf bean, it shows positive synergism with GA_3 in stimulating the growth of the first leaf sheath of dwarf corn (d_1).

Materials and Methods

Corn seed (*Zea mays* L.) of the dwarf variety d_1, supplied by Dr. B. O. Phinney, University of California, Los Angeles, was germinated in a soil–vermiculite mixture under glass. Approximately 14 days later, normal plants were removed and dwarf seedlings treated with drops containing $0 \cdot 1$ ml of the appropriate solutions; GA_3 and Alar were applied to the same seedlings at intervals of about 3 hr. After 7 days, the length of the first leaf sheath of the seedlings was measured to the nearest millimetre.

Seed of dwarf bean (*Phaseolus vulgaris* L. cv. Hawksbury Wonder) was sown in 5-in. unglazed pots (three seeds per pot) containing mountain soil, compost, and sand, and germinated under glass. After germination, seedlings were thinned to one uniform plant per pot. Six days after germination, treatments were applied as foliar sprays to the whole plant; GA_3 and Alar were applied to the same seedlings at intervals of about 2 hr. The height of each plant was measured on alternate days, starting at least 2 days before spraying.

GA_3 was supplied by ICIANZ Ltd., and Alar by Naugatuck Chemical Division of United States Rubber Co. at 85% purity. Solutions were prepared in $0 \cdot 05$% (v/v) Tween 20 (polyoxyethylene sorbitan monolaurate) and control treatments of Tween 20 were applied where appropriate.

Results

(i) *Dwarf Bean*.—Figure 1 shows the daily growth of bean seedlings measured for 8 days after treatment, and Figure 2 shows the effect of Alar on growth induced by GA_3 at concentrations ranging from 10^{-6} to 10^{-2}M.

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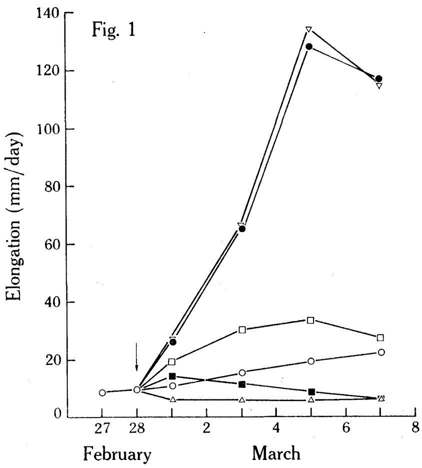
(ii) *Dwarf Corn*.—Table 1 shows the mean length of the first leaf sheath of dwarf corn (d_1) treated with Alar (10^{-2}M) and GA_3 (10^{-6} and 10^{-3}M) separately or in combination. In this experiment, Alar did not inhibit the growth of the leaf sheath;



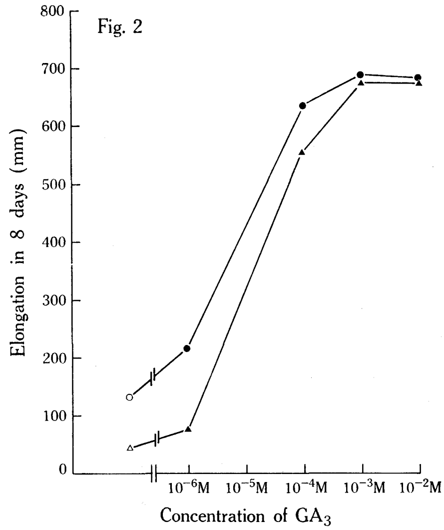


Fig. 1.—Daily growth of dwarf bean seedlings. ○ Control. △ Alar 10^{-2}M. ▽ GA_3 10^{-2}M. □ GA_3 10^{-6}M. ● Alar 10^{-2}M+GA_3 10^{-2}M. ■ Alar 10^{-2}M+GA_3 10^{-6}M. ↓ Day on which spray applied.

Fig. 2.—Interaction between GA_3 and Alar in affecting elongation of dwarf been seedlings. ○ Control. ● GA_3. △ Alar 10^{-2}M. ▲ Alar 10^{-2}M+GA_3.

the lower concentration of GA_3 (10^{-6}M) alone did not stimulate growth significantly at the 5% level, but did so in conjunction with Alar. Growth stimulation with

Table 1

EFFECT OF ALAR AND GA_3 ON ELONGATION OF FIRST LEAF SHEATH OF *ZEA MAYS* d_1 SEEDLINGS

Treatment†	Height of First Leaf Sheath (mm)	Height as % of Control
Control	21·6	100
Alar (10^{-2}M)	21·4	99
GA_3 (10^{-6}M)	25·2	117
GA_3 (10^{-3}M)	37·2***	172
Alar (10^{-2}M)+GA_3 (10^{-6}M)	27·5*	127
Alar (10^{-2}M)+GA_3 (10^{-3}M)	44·9***	208

* Significantly different from the control at $P<0·05$ (L.S.D. = 5·2).
** Significantly different from the control at $P<0·01$ (L.S.D. = 6·9).
*** Significantly different from the control at $P<0·001$ (L.S.D. = 9·1).
† Tween 20 was added to all treatments (including control) at 0·05% (w/v).

10^{-3}M GA_3 was highly significant at 0·1% level, and applying GA_3 with Alar caused yet a further increase in growth.

Discussion

These experiments show that, while Alar interacts with GA_3 on growth of dwarf bean plants in the same way as tributyl-2,4-dichlorobenzylphosphonium chloride (Phosphon-D) and CCC (Lockhart 1962) and *N*-dimethylaminomaleamic acid (CO11) (Bukovac 1964), this compound shows positive synergism with GA_3 on the growth of the first leaf sheath of dwarf corn (d_1).

The growth retardants are active primarily on dicotyledons and they only affect a few species in monocotyledons (Cathey 1964). Despite numerous investigations, the mode of action of Alar in plant growth control has not yet been clarified (Williams and Stahly 1970). Accordingly the positive synergism between Alar and GA_3 reported here is not readily explained. If Alar interferes with synthesis of indoleacetic acid (IAA) as suggested by Williams and Stahly, the interaction between IAA and GA_3 in the leaf sheath of dwarf corn may be similar to that in the internodes of oat, where Kaufmann (1967) has shown that exogenous IAA (1–100 mg/l) inhibits growth stimulated by GA_3. Thus, in the leaf sheath of dwarf corn, Alar could lower the concentration of IAA, partially reversing the inhibition of GA_3 action by IAA.

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