EFFECT OF DIFFERENT GIBBERELLINS ON TUBER DORMANCY AND SPROUT GROWTH OF POTATO UNDER CONTINUOUS LIGHT AND DARKNESS

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SUMMARY

The onset of sprouting in excised potato 'eyes' from freshly harvested dormant tubers takes place within a week from planting, but earlier under continuous light than under darkness. Gibberellins, morphactin, AMO-1618 or kinetin neither shorten nor prolong the dormant period in excised 'eyes' in light or darkness.

All GAs accelerate the elongation of sprouts, the order of their effectiveness being $GA_7 > GA_3 > GA_4 > GA_{13}$. At early stages of sprout elongation, GA_7 is more effective in dark than in continuous light, whereas other GAs are more effective in light. GAs when used in combination, do not promote sprout elongation either synergistically or by adding to the effect of each other, except $GA_3 + GA_4$ and $GA_4 + GA_{13}$ which show slight additive response.

Morphactin and AMO-1618 inhibit sprout growth in 'eyes'. The inhibition caused by morphactin is reversed by GA_3 only, while that caused by AMO is reversed by all GAs. Kinetin does not influence sprout growth, but when used in combination with GAs, suppresses the stimulatory effect of GA_3, GA_7 and GA_4 and increases the effect of GA_{13}.

Results are discussed in the light of available information on the mechanism of tuber dormancy in potato.

INTRODUCTION

Okazawa (1959), Smith and Rappaport (1960), and Racca and Tixio (1968) reported the occurrence of endogenous gibberellin-like substances in potato. It has also been reported that the concentration of these substances increases 20-fold with

sprouting in tubers (Smith and Rappaport, 1961, Rappaport and Smith, 1962). Based on these results, it is assumed that the level of endogenous gibberellins might be one of the limiting factors in tuber dormancy. This assumption is supported by the fact that gibberellic acid (GA_3), applied during the pre-harvest or the post-harvest period, breaks dormancy in potato (See Milthorpe and Moorby, 1966). With the discovery of a number of new gibberellins and lack of evidence to show a direct relationship between the loss of dormancy and changes in the level of endogenous gibberellin content, some questions arise: Do gibberellins break dormancy or simply accelerate sprout elongation from the preformed 'eyes'? Do all gibberellins affect dormancy and sprout elongation similarly? Which of the gibberellins are most active in tubers? Results that answer the first two questions, are communicated in this paper.

Materials and Methods

Forty 'eyes' (1 cm × 0·5 cm), excised from freshly harvested tubers of var. OT-No. were floated separately for 24 hrs in 1·0 and 10·0 mg/l each of GA_3, GA_4, GA_7, GA_{13}, Morphactin (methyl-2-chloro-9-hydroxy fluorene-(9)-carboxylate), AMO-1618, Kinetin singly and in combination in Petri-dishes and thereafter these were washed with distilled water and eyes from each test solution were planted in plastic pots containing sand, each pot having 5 eyes. Thus, eight plastic pots were used to plant eyes of one treatment group. The details of treatment combinations are given along with the results. One group of 40 'eyes' was treated with distilled water to serve as control. Four pots in each treatment-group of gibberellins were kept under continuous light (CL) with 2,000 lux, while the remaining 4 were transferred to continuous darkness (CD).

Daily observations on visible sprouting were recorded and the length of sprouts was measured at weekly intervals.

Results

Response to different GAs.—The number of days for visible sprouting and the number of 'eyes' showing sprouting in different treatments after 14 days are presented in Table I. The sprouting started earlier under CL than under CD. As sprouting started simultaneously in both gibberellin-treated and control 'eyes'

Table I. The number of "eyes" sprouted (out of 20) *treated with different gibberellins* 14 *days after treatment under CL and CD conditions. Figures in the parentheses show the mean number of days for sprout initiation*

Treatment (Gibberellins)	Concentration (mg/l)	Number of sprouted eyes under continuous light (CL)		Number of sprouted eyes under continuous dark (CD)	
Control	0	14	(5·7)	14	(7·2)
A_3	1	18	(5·5)	14	(7·2)
	10	16	(5·2)	20	(7·7)
A_4	1	16	(5·6)	20	(6·7)
	10	16	(5·4)	14	(6·5)
A_7	1	20	(5·3)	12	(7·0)
	10	16	(5·5)	18	(7·3)
A_{13}	1	16	(5·6)	18	(5·8)
	10	20	(5·4)	16	(7·8)
$A_3 + A_4$	10 each	20	(6·9)	16	(7·4)
$A_3 + A_7$	10 each	12	(6·3)	14	(7·8)
$A_3 + A_{13}$	10 each	12	(6·3)	14	(7·6)
$A_4 + A_7$	10 each	10	(7·0)	18	(8·6)
$A_4 + A_{13}$	10 each	14	(6·8)	10	(7·0)
$A_7 + A_{13}$	10 each	16	(6·6)	10	(7·0)
$A_3 + A_4 + A_7 + A_{13}$	10 each	10	(7·0)	12	(7·0)

under the respective light condition, it appears that different gibberellins have no effect on the time taken for sprouting. Similarly, no difference was observed in days for visible sprouting in control and those treated with morphactin, AMO-1618 or kinetin (unpublished). GAs used in combination slightly delayed sprouting under CL. The number of sprouted 'eyes' increased with GAs, when used separately, and was equal in controls under both light conditions, but when GAs were used in combination, the eyes showing sprouts decreased in some treatments (Table I). While 'eyes' with sprouts were more in higher concentration of GA_3 and GA_7 and lower concentration of GA_4 and GA_{13} under CD; these were more in lower concentration of GA_3 and in GA_7 and in higher concentration of the other two GAs under CL.

Table II. Length of sprouts in dormant 'eyes' of potato, var. 'OT-No.', treated with different gibberellins alone and in combination with each other, 14 days after treatment

Treatment (Gibberellins)	Concentration (mg/l)	Length of sprout(cm)under	
		continuous light (CL)	continuous dark (CD)
Control (water)	0	0·32±0·07	0·58±0·21
A_3	10	3·47±0·94	3·40±0·80
A_4	10	1·66±0·48	0·59±0·15
A_7	10	4·10±0·80	5·41±0·92
A_{13}	10	0·67±0·04	0·68±0·13
$A_3 + A_4$	10 each	4·04±0·51	4·42±1·06
$A_3 + A_7$	10 each	2·35±0·77	4·63±1·20
$A_3 + A_{13}$	10 each	2·12±0·73	2·85±0·80
$A_4 + A_7$	10 each	1·73±0·72	3·46±0·96
$A_4 + A_{13}$	10 each	1·00±0·24	1·49±0·65
$A_7 + A_{13}$	10 each	3·96±0·82	2·44±0·44
$A_3 + A_4 + A_7 + A_{13}$	10 each	2·44±0·93	3·09±0·88

L.S.D. at 5% level under CL=0·6017
L.S.D. at 5% level under CD=0·8212.

The length of sprouts 14 days after treatment under CL and CD is given in Table II. It was observed that sprouts in water-treated 'eyes' grew taller under CD than under CL. GAs stimulated sprout growth under both light conditions. The variations in the effectiveness of GAs under CD and CL were significant. Sprouts were the longest in GA_7-treated eyes, followed by GA_3, GA_4, and GA_{13}-treated ones. GA_7 and GA_{13} were more effective under CD than under CL, whereas other GAs were more effective under CL. It is interesting that GAs used in combination neither promote growth synergistically nor by adding to the effect of each other, except in the case of GA_3+GA_4 and GA_4+GA_{13} where the length of sprout was significantly more than in those treated with GA_3, GA_4 or GA_{13} alone. In fact, combination of other gibberellins reduced the length of sprout, and the effect was more marked under CL.

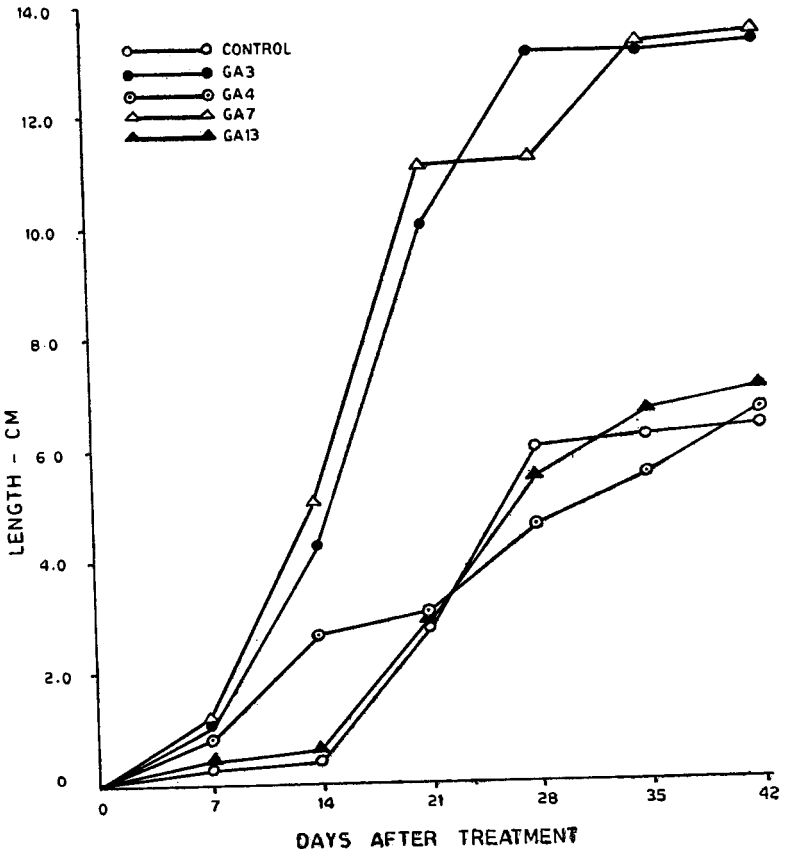

FIG. 1. Length of sprouts taken at weekly intervals in 'eyes' treated with 10 mg/l of different GAs under continuous light.

The length of sprouts is shown in Figs. 1 and 2. The rate of sprout elongation in all treatments under CL (Fig. 1) increased with time but only in control, GA_3 or GA_7 under CD (Fig. 2). Sprouts in GA_4 and GA_{13}-treated eyes, did not grow as fast as in other GAs under CD. It is interesting to note that the elongation of sprouts in GA_7 or GA_3-treated eyes continued at a rapid rate for 21 days, in control for 28 days under both light conditions, and in GA_4 or GA_{13}-treated ones till the termination of experiment under CL. The final length of sprouts in GA_3 or GA_7-treated eyes was more under CD than under CL, whereas in GA_4, GA_{13} or water-treated sprouts, the length was more under CL.

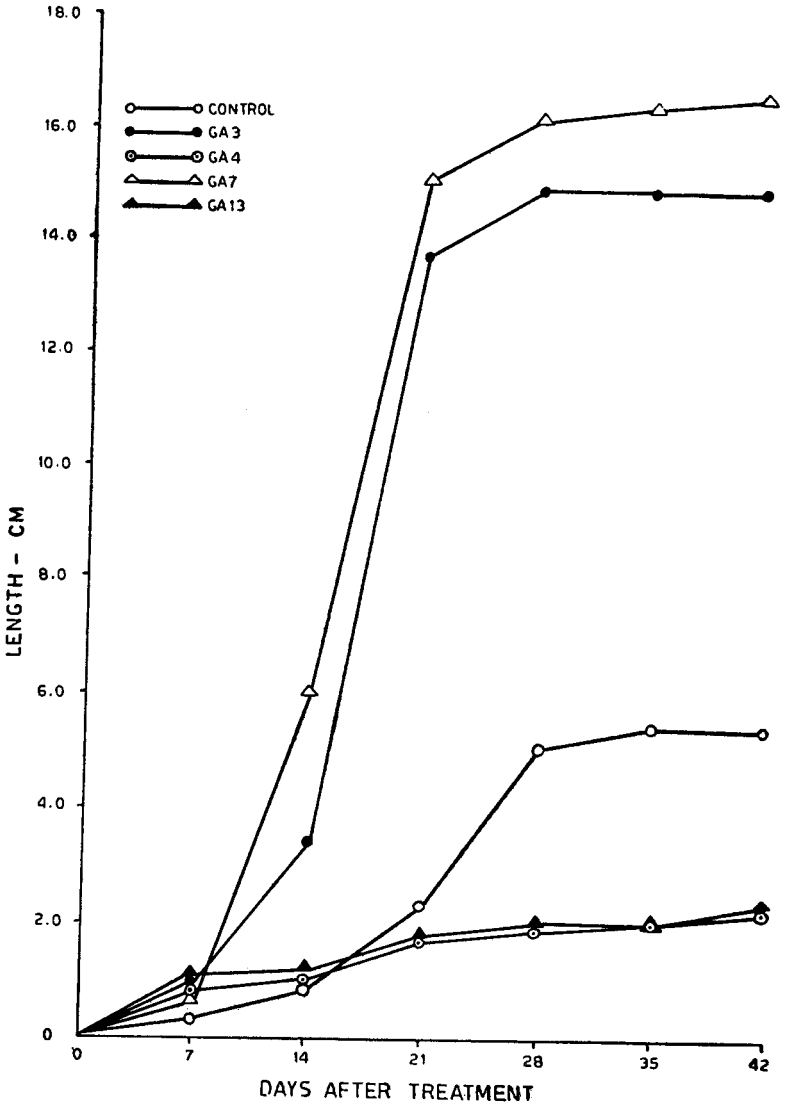

FIG. 2. Length of sprouts taken at weekly intervals in 'eyes' treated with 10 mg/l of different GAs under continuous dark.

Response to morphactin, AMO-1618 *and kinetin.*—The effect of morphactin, AMO-1618 and kinetin and their interaction with GAs was studied only under CL. The length of sprouts in different treatments is shown in the 3-dimensional grid graph (Fig. 3), in which abscissa represents 10 mg/l of GAs, the

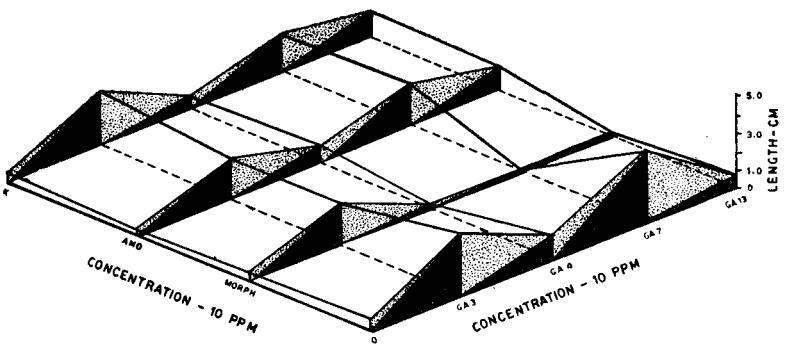

FIG. 3. Length of sprouts, 14 days after treatment, in eyes treated with 10 mg/l of different GAs, and morphactin, AMO–1618, and kinetin as such and in combination with different gibberellins.

ordinate, the mean length of 10 sprouts in each treatment and the third axis, the 10 mg/l of morphactin (morph.), AMO or kinetin (K). It is observed that morphactin and AMO-1618 inhibited sprout elongation whereas kinetin did not influence it significantly, when these were used alone. Sprouts in 'eyes' treated with GAs showed elongation in the order of $GA_7 > GA_3 > GA_4 > GA_{13}$, as discussed earlier. The effect of morphactin and kinetin increased with concentration (unpublished). It is interesting to note that the inhibition caused by morphactin was reversed only by GA_3 and not by other GAs. On the other hand, AMO-1618 induced inhibition was reversed by all GAs, although the length of sprout, when treated with GAs in combination with AMO, was less as compared to those treated with these GAs separately. Kinetin interacted differently with different gibberellins. It reduced the effectiveness of GA_3, GA_4 or GA_7 but added to that of GA_{13}.

DISCUSSION

The results presented in this paper support the previous reports (Appleman, 1914; Madec and Perennec, 1969; Vanes and Hartmans, 1969) that the onset of sprouting in excised 'eyes' takes place soon, and is neither hastened by GA_3 nor delayed by AMO-1618 and morphactin. It is, therefore, clear that none of the gibberellins contributes to the onset of sprouting because if it were so, GA_3 would have caused early sprouting and AMO-1618 delayed it as it blocks the synthesis of endogenous GAs (Baldev, Lang and Agatep, 1965).

Hastening effect of continuous light on sprouting agrees with an earlier report (Appleman, 1914) but no explanation can be put forth.

The stimulation in elongation of sprouts is in the order: $GA_0 > GA_3 > GA_4 > GA_{13}$, which is different from that obtained by other workers (Brian, *et al.*, 1964; Paleg *et al.*, 1964; Lyon and Smith, 1966) in other biological systems. Although it will not be proper to speculate about the differential response of different GAs, as little is known about how they are interrelated and how they control growth, it can be assumed that endogenous GAs contribute to further growth of sprouts after they have reached an active stage. Keeping in view that tubers as such, remain dormant for 2–3 months after harvest, whereas excised eyes from freshly harvested tubers start sprouting within a week, it remains to be clarified whether the delay in onset of sprouting is due to true dormancy or it is a phenomenon of competitive inhibition between different eyes and in either case what is the cause?

It is interesting that the magnitude of effect of different GAs in combination differs with the light condition. These do not promote sprout elongation either synergistically or by adding to the effect of each other. The length of sprouts is almost equal in all GAs till 7 days after treatment but differs subsequently (42 days after the treatment). While GA_3 and GA_7 are more effective under CD, GA_4 and GA_{13} show more response under CL after 42 days when the experiment was terminated. It, therefore, appears that while the response of tissues to some GAs might decrease in light, as proposed by other workers (Kende and Lang, 1964; Nanda *et al.*, 1968), that to other GAs increases. A slight additive effect of GA_3+GA_4 and GA_4+GA_{13} (Table II) is indicative of the fact that they might have a similar mode of action.

The most interesting finding of this investigation is the differential effectiveness of different GAs in the presence of morphactin, AMO or kinetin. The results domonstrate that while the growth inhibition caused by morphactin is reversed by GA_3 only, that caused by AMO is reversed by all GAs, although the length of sprouts when treated with AMO in combination with GAs was less as compared to those treated with GAs separately. It seems that morphactin, in contrast to AMO is not the competitive inhibitor of action of all GAs and is specific to only GA_3 in its mutual antagonistic

effect. Reduction in the effectiveness of GA_3, GA_4 and GA_7 and addition to that of GA_{13} in kinetin combination can not be explained at present. Work is in progress to check this point.

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References

Appleman, C. O. (1914). Biochemical and physiological study of the rest period in the tubers of *Solanum tuberosum*. *Maryland Agric. Exp. St. Bull. No.*, **183.**

Baldev, B., Lang, A. and Acatep, A. O. (1965). Gibberellin production in pea seeds developing in excised pods : Effect of growth retardant AMO–1618, *Science*, **147:** 155–57.

Brian, P. W., Hemming, H. G. and Lowe, D. (1964). Relative activity of gibberellins. *Ann. Bot.*, **28:** 369–89.

Kende, H., and Lang, A. (1964). Gibberellins and light inhibition of stem growth in peas. *Plant Physiol.*, **39:** 435–40.

Lyon, J. L., and Smith, O. E. (1966). Effect of gibberellins on abscission in cotton seedling explants. *Planta*, **69:** 347–56.

Madec, P. and Perennec, P. (1969). Levee de dormance de pomme de terre d'age different : action de la rindite, de la gibberelline et de l'oeilletonnage. *Eur. Potato J.*, **12:** 96–115.

Milthorpe, F. L. and Moorby, J. (1966). The growth of the potato. *Proc. Third Triennial Conf. EAPR.*, 51–70.

Nanda, K. K., Purohit, A. N. and Prabha, A. (1968). Mode of action of morphactins in epiphyllons buds of *Bryophyllum tubiflorum*. *Indian J. Plant Physiol.*, **11:** 20–26.

Okazawa, Y. (1959). Studies on the occurrence of natural gibberellin and its effects on the tuber formation of potato plants (in Japanese). *Proc. Crop. Sci. Japan*, **28:** 129–33.

Paleg, L., Aspinall, D. Coombe, B. and Nicholls, N. (1964). Physiological effects of gibberellic acid. VI. Other gibberellins in three test systems. *Plant Physiol.* **39:** 286–90.

Racca, R. W. and Tizio, R. (1968). A preliminary study of changes in content of gibberellin-like substances in potato in relation to the tuberization mechanism. *Eur. Potato J.*, **11:** 213–20.

Rappaport, L. and Smith, O. E. (1962). Gibberellins in the rest period of the potato tuber. *Eigenschaften und Wirkingen der Gibberelline* 37–45.

Smith, O. E. and Rappaport, L. (1960). Content of endogenous gibberellins in resting and sprouting tubers of the potato. *Abstract Proc. Ann. Meeting, Plant Physiol.*, **35:** (*Supplement*): 34–35.

——— and ——— (1961). Endogenous gibberellins in resting and sprouting potato tubers. *Adv. Chem. Sev.*, **28:** 42–48.

Vanes, A., and Hartmans, K. J. (1969). The influence of abscisin II and gibberellic acid on the sprouting of excised potato buds. *Eur. Potato J.*, **12:** 59–63.