Delaying ripening of pre-harvest bananas (Dwarf Cavendish) with gibberellins.

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TRAITEMENT A LA GIBBERELLINE AVANT RECOLTE DES BANANES (DWARF CAVENDISH) POUR EN RETARDER LA MATURATION

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RESUME - Les gibberellines A3 (Berelex) et A4A7 ont été appliquées sous forme liquide, pâteuse ou solide, à des régimes de bananes dans des vergers commerciaux, environ un mois avant récolte, afin d'en retarder la maturation.
Au cours de quatre expérimentations, les meilleurs traitements ont donné un retard moyen de 16 jours (extrêmes de 10 à 19 jours). A4A7 a été quatre fois plus efficace que A3, avec 70 mg par régime, donnant un retard maximum.
La méthode d'application n'a pas eu d'influence sur l'efficacité des produits.

INTRODUCTION

In a banana orchard a problem arises when more bunches reach maturity (ready for cutting) than can be marketed simultaneously.The excess bunches may ripen in the orchard before the market is able to accept them. This situation induced a search for chemicals capable of delaying ripening of pre-harvest fruit.

In preliminary trials various substances were tested, and gibberellic acid was the only one to show a delaying effect. A delaying effect of gibberellic acid on post-harvest bananas was reported by RUSSO et al. (1968), VENDRELL (1970) and DESAI et al. (1978). On the other hand LOCKARD (1975) did not observe a delaying effect on attached bananas by spraying the K-salt of gibberellic acid on inflorescences thrice during the first month after emergence. The present work reports four experiments in which different gibberellins and methods of application and timing were examined.

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MATERIALS AND METHODS

The gibberellins used were : A3 (as «Berelex»), A4, A7, A4A7, and the amine salts of A4A7 and of A3. All materials were supplied by I.C.I. A3 was dissolved in water and the other gibberellins in sodium bicarbonate or in alcohol. The oil-dissolved gibberellins were diluted in water and used as emulsions. The materials were applied as spray, paste or injection. For complete wetting 100 cc of solution plus the wetting agent «Triton X-100» were applied by hand sprayer to the bunch. No wetting agent was added to the oil-dissolved gibberellins or to one solution that contained also eight

per cent polyethylene glycol 4000. To prepare the paste gibberellin solutions were mixed with lanolin by stirring, occasionally aided by light warming. The paste was smeared on the bunch stalk right above the top hand. To inject solutions or dry materials a hole 5 mm in diameter was bored in the stem to extract a piece of stem tissue 3 cm in length. Gibberellin solution was poured into the hole, or a gelatine capsule containing gibberellin powder was introduced. Dry gibberellin was introduced also as tablet. Treatments were usually applied about one month before the commercial harvest, except when the trials were to examine the timing of treatment.

Selection of bunches.

Plant crop bunches were chosen for practical convenience, the height of plants being relatively small and bunches being easy to handle. Four experiments were conducted in four consecutive years. Each year one experiment was conducted in a different commercial orchard in the Western Galilee. To ensure uniformity, only bunches that emerged during a period of ten days were chosen. In experiment 4, it was required that at least two hands be open and the lower hands still closed. Bunches were covered with hessian bags. In experiment 4 bunches were covered with plastic sleeves. Once a week the bunches were inspected. A bunch was considered ripe when it had at least three yellow healthy fruits.

Experimental layout.

Treatments were distributed at random. In experiment 1 each treatment was given to two bunches with nine replications. Thereafter, each treatment was given to one bunch with 20 replications.

Experiment 1.

Two gibberellins (A3 and A4A7), two methods of application (sprays and lanolin paste) and different concentrations were tested. The lanolin paste was applied in doses of 35 g containing 20 g lanolin and 15 ml gibberellin solution. Examination of ripeness started one week after treatment and continued for nine weeks. Four separate control groups were included ; one of them received a water spray, the others were untreated ; the data are combined, since there was little variation between them.

Experiment 2.

Treatments were given as spray, lanolin paste or injection of solution. The main gibberellin used was A4A7. A3 was included only in formulations not previously tried. The components of A4A7 (A4 and A7) were tested separately to determine the activity of each of them. To improve uptake and thereby effectiveness, the gibberellins were given as amine salts dissolved in oil (a suggestion made by I.C.I.). For the same purpose eight per cent polyethylene glycol 4000 was added. Among the lanolin applications treatments 1, 2, 3 (table 2) received different quantities of the same paste - 44, 22, 11 g respectively, and treatments 4, 5, 6 received different pastes at the same quantity, 22 g. The amount of injected solution was 5 ml.Four untreated groups of bunches were included as controls. Recording of ripe bunches started one month after treatment application and continued for six weeks.

Experiment 3.

Only A4A7 was used in this experiment which examined the time of application and the use of solvent. A4A7 was dissolved in either ethanol or isopropanol, and compared with A4A7 dissolved in sodium bicarbonate. Three application times were compared : 6., 17., and 28./IV. Two of the lanolin applications were given twice, on 6th and 17th IV. All lanolin doses were reduced to 10 g. Three untreated groups of bunches were included as controls. Recording of ripe bunches started on the day of the last treatment and continued for seven weeks.

Experiment 4.

Injection of dry material was adopted as the main method of application, having more benefits than the other methods tried. Besides being effective it is also simple, accurate and clean in application, as well as easy to store. To enhance simplicity and accuracy, the powder was injected enclosed in a capsule.In one treatment the powder was given in tablet form. In another treatment application of lanolin paste was chosen as a connecting link with the previous experiments. A4A7 was the main gibberellin, but A3 was also added because it had not been tested before in this form. Most of the bunches were covered with silver-colored plastic, except one treatment which was covered with hessian bags. Likewise, control bunches were also covered in part with plastic, and in part with hessian bags. Timing of application was tested again, with four dates of application : 1.I., 3.II., 9.III., 23.III. In one treatment a capsule was given twice, on 9th and 23rd III.

RESULTS

The results of experiment 1 are shown in table 1. All treatments delayed ripening significantly except numbers 1 and 8 (100 mg A3). A4A7 was more potent than A3, as evidenced by comparison of all A4A7 treatments with all A3 treatments : applications of A4A7 totalling 700 mg caused delay aggregating 88 days, and 2450 mg A3 a delay of 70 days. In other words, for a delay of one day 8 mg of A4A7 was needed vs. 35 mg of A3. There was no important difference between application of spray or as a paste. The maximum delay in ripening achieved in this experiment was 19 days. The relationship between concentrations and delay was somewhat inconsistant, the uniformity of the increase in delay with increasing concentrations being broken twice (treatments 3 and 13).

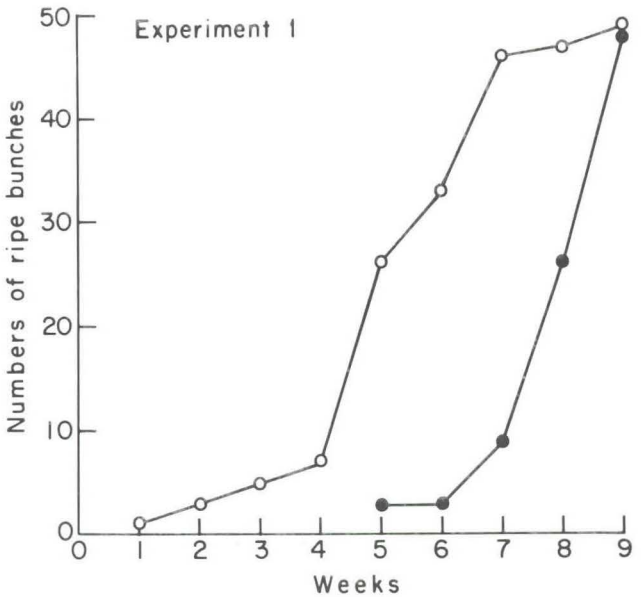

Fig. 1 • Experiment 1. Progress in ripening of gibberellin-treated bunches (treatments 4, 7, 12, 14 - combined) ●——●, and of untreated control bunches o——o, as recorded in weekly inspections. Numbers of ripe bunches are cumulative.

Figure 1 illustrates the course of ripening for two groups of bunches. One group is composed of the four best treatments (nos. 4, 7, 12, 14, table 1), and the other consists of the four controls. Only bunches in perfect condition were included (excluding damaged or impaired bunches). The curves show two harvests separated by three weeks.

Table 2 shows the results of experiment 2. A4A7 was effective with all methods of application, no other gibberellin being more effective. The efficiency of the paste was not affected by the quantity applied. A4 and A7 separately did not work better than combined as A4A7. A4 as lanolin paste failed, as did A3 in both methods of application. The cocoamine formulation did not improve effectiveness. The maximum delay in ripening achieved in this experiment was 10 days.

Figure 2 shows the course of ripening of the four combined controls and of the four good treatments (nos. 2, 3, 8, 13, table 2), also combined. The delay in ripening effected by the treatments was distinct at first, but disappeared toward the end of the season, probably due to a heat wave occurring at that time which raised temperatures to 40°C in the shade and caused quick ripening of all remaining bunches.

The results of experiment 3 are summarized in table 3. Maximum delay in ripening, compared with the controls, was 18 days, obtained by injection of 70 mg of A4A7 powder. Five other treatments also differed significantly from the controls (nos. 1, 5, 6, 7, 8). No clear answer was obtained to the question of the appropriate application time. The average ripening dates of the treatments (nos. 1, 2, 3) concerning application time were close to one another. Thus it seems that the range of three weeks for timing determinations was too narrow to allow the expression of a time effect. Differences between methods of application were non-significant. Four of the five treatments having ethanol as solvent gave the poorest results. Thus ethanol should be considered inept, were it not for treatment 5 (ethanol solvent) which was the next to best of all. Treatment 5 was involved in still another inconsistency, with respect to treatment 4. Both treatments included two applications differing only in the amount of active ingredient, which was double in treatment 4 ; yet the result of treatment 4 was the poorest of all treatments. We have no explanation for these inconsistencies.

Figure 3 depicts the course of ripening of treatment 9 (injection of powder) and of the average of the three controls. When all control bunches were ripe, half of the treated ones were still unripe.

In experiment 4 the fruits suffered severely from various troubles, such as sun-stroke, diseases, bunch break and unauthorized harvesting. About 50% of all bunches were affected by these troubles and were eliminated from the experiment. The data obtained from the remaining bunches do not allow an accurate estimation of the extent

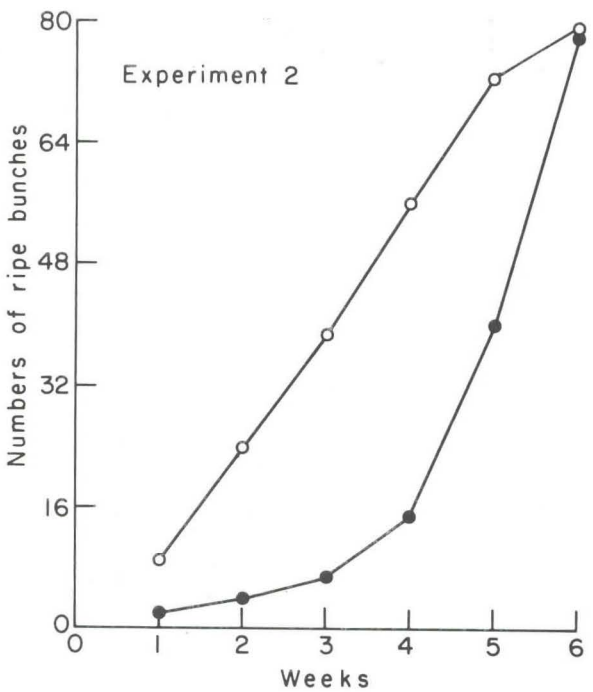

Fig. 2 • Experiment 2. Progress in ripening of gibberellin-treated bunches (treatments 2, 3, 8, 13 - combined) ●——●, and of untreated control bunches o——o, as recorded in weekly inspections. Numbers of ripe bunches are cumulative.

TABLE 1 - The effect of gibberellin treatments on the average ripening dates of Dwarf Cavendish bananas. Experiment 1.

Method of application	None	Spray							Lanolin paste						
Treatment	controls	A3				A4A7			A3				A4A7		
Treatment no.	15-18	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Gibberellin per bunch, mg	----	100	250	500	750	50	100	200	100	250	500	750	50	100	200
Average ripening date	17.VI	19.VI	30.VI	26.VI	4.VII	25.VI	1.VII	5.VII	22.VI	28.VI	30.VI	*	4.VII	29.VI	6.VII
Differences from control, days	0	2	13	9	17	8	14	18	5	11	13		17	12	19

Least significant difference (0.05) = 8 days.

* - This high concentration could not be used owing to separation of the components of the paste. Hence the (low) results of treatment no. 11 are omitted.

TABLE 2 - The effect of gibberellin treatments on the average ripening dates of Dwarf Cavendish bananas. Experiment 2.

Method of application	Treatment n°	Treatment	Gibberellin per bunch, mg	Average ripening date	Significance of difference from control
Lanolin	1	A4A7	270	21.V	**
paste	2	A4A7	135	22.V	**
	3	A4A7	67	22.V	**
	4	A4A7 cocoamine[+]	150	22.V	**
	5	A3 cocoamine	300	13.V	n.s.
	6	A4	250	15.V	n.s.
Injection	7	A4A7	100	19.V	*
Spray	8	A4A7	200	22.V	**
	9	A4A7 + addition[++]	100	18.V	n.s.
	10	A4A7 cocoamine	100	19.V	*
	11	A3cocoamine	200	14.V	n.s.
	12	A4	200	20.V	*
	13	A7	200	22.V	**
Nome (controls)	14-17	----		12.V	

[+] Amine salt of the material dissolved in oil [++] Polyethylene glycol 4000, 8%.

* - Least significant difference (0.05) = 7 days ** - Least significant difference (0.01) = 9 days.

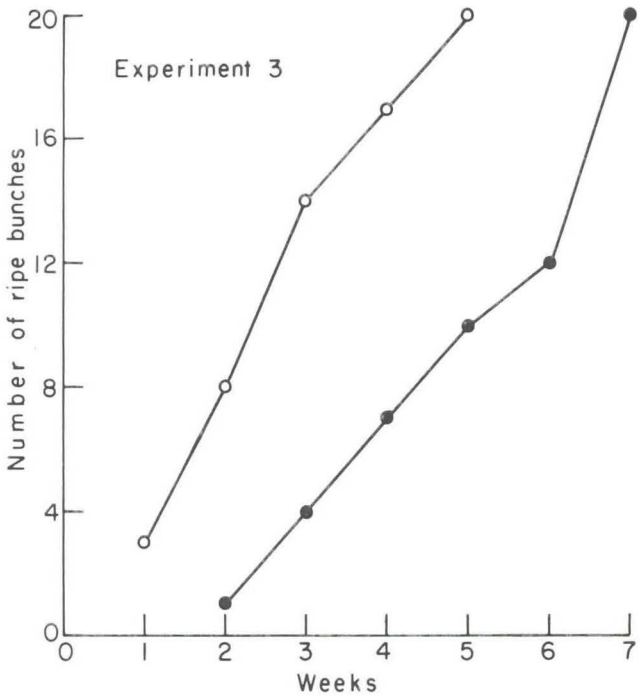

Fig. 3 • Experiment 3. Progress in ripening of gibberellin-treated bunches (treatment 9 - injection of powder) •——•, and of the averaged control o——o, as recorded in weekly inspections. Numbers of ripe bunches are cumulative.

of the delay but indicated clearly its effect. Table 4 shows the situation at the last inspection including only bunches in perfect condition. Both A4A7 and A3 were effective, but with different quantities of active ingredient. Treatment no. 2 was ineffective. This could mean that the gibberellin was applied too early. The point needs further investigation.

In a separate test it was found that both the gelatin capsule and the powder decompose gradually in the bunch stalk, and the last residues disappear a month after application. The tablet was decomposed completely after six weeks. The longer duration of the tablet does not imply that the gibberellin was not absorbed readily, as 30 % of the preparation consists of auxiliary material of low solubility.

Residue analysis.

The connection between applied gibberellin and delay in ripening was corroborated by residue analysis carried out in experiment 3, in the laboratories of I.C.I., England. One month after treatment, two green and firm fruits were sampled from ten hands of ten bunches per treatment. Treatments were found to raise the level of gibberellin in the pulp ; no differences were found in the peel (table 5).

DISCUSSION

Some of the questions posed in these experiments received an answer, while others did not. Throughout the experiments a consistent result was obtained : gibberellin, especially as A4A7, is capable of delaying ripening of pre-harvest bananas. The methods of application tried (spraying, lanolin paste, injection) did not influence its effectiveness. Timing proved not to be very crucial, permitting application within a period of about two months before ripening. Yet extending the period considerably could mean missing the effect. The best treatments in experiments 1, 2 and 3 gave a delay of 19, 10 and 18 days, averaging 16 days. Further work, including also other gibberellins, might lead to an

TABLE 3 - The effect of gibberellin treatments on the average ripening dates of Dwarf Cavendish Bananas. Experiment 3.

Treatment No.	Method of application	A4A7 per bunch, mg	solvent	application date	average ripening date	
1	Lanolin	70	Ethanol	6.IV	29.V	b
2	Lanolin	70	Ethanol	17.IV	26.V	ab
3	Lanolin	70	Ethanol	28.IV	28.V	ab
4	Lanolin	70	Ethanol	6.IV + 17.IV	24.V	ab
5	Lanolin	35	Ethanol	6.IV + 17.IV	4.VI	bc
6	Lanolin	70	Isopropanol	6.IV	2.VI	bc
7	Lanolin	70	Sodium bicarbonate	6.IV	2.VI	bc
8	Injection of solution	70	Sodium bicarbonate	6.IV	2.VI	bc
9	Injection of encapsulated powder	70	----	6.IV	7.VI	c
10-12	Nome (controls)	----	----	----	20.V	a

Least significant difference (0.01) = 9 days.

* - Average ripening dates followed by different letters differ significantly at P = 0.01.

TABLE 4 - The effect of gibberellin treatments on the number of ripe and green bunches at the end of experiment 4.

Treatment No.	GA application				Cover	Bunches			
	Active ingredients	mg	Method	Date		green (no.)	ripe (no.)	total (n.)	percentage of green
1	A4A7	70	Lanolin, 10 g	9.III	Plastic	7	1	8	88
2	A4A7	70	Capsules	1.I	Plastic	2	11	13	15
3	A4A7	70	Capsules	3.II	Plastic	10	1	11	91
4	A4A7	70	Capsules	9.III	Plastic	9	3	12	75
5	A4A7	70	Capsules	23.III	Plastic	6	2	8	75
6	A4A7	35	Capsules	9. + 23.III	Plastic	11	0	11	100
7	A4A7	70	Capsules	9.III	Hessian	8	2	10	80
8	A4A7	100	Tablets	23.III	Plastic	3	0	3	100
9	A3	300	Capsules	9.III	Plastic	8	2	1 0	80
10	A3	150	Capsules	9.III	Plastic	5	3	8	62
11	None				Plastic	3	4	7	43
12 controls	None				Plastic	1	7	8	12
13	None				Hessian	1	6	7	14

All treatments except no. 2 differed significantly from the controls.

TABLE 5 - Relationship between gibberellin content in the pulp of bananas and the average ripening date. Comparison with control as 100. Experiment 3.

Treatment No.	Comparative gibberellin content	Average ripening date
None (control)	100	20.V
7	155	1.VI
4	164	2.VI
9	220	7.VI

increase in the effect and raise the prospects of practical utility. Our efforts to enable easier application of GA led to the usage of a capsule containing dry powder that was injected into the stalk. A further step in this direction was by the development of a tablet which is intended to be forcefully introduced by means of a special device yet to be constructed.

Inconsistencies accompanied the experiments and some of them are not yet clear, as for instance the results of treatments no. 4 and 5 in experiment 3, which ranked in an order reverse to expectation. Other inconsistencies were connected with the carrier lanolin and the solvent ethanol. To clarify these points and also to establish a regular relationship between concentration and extent of delay, more work is needed.

It should be noted that the observation of LOCKARD (1975) about the lack of a delaying effect by gibberellin on ripening of bananas should not be considered as contradictory to our results ; first, because of the small scale of his trial ; secondly, considering that the treatment was applied during the first month after inflorescence emergence, his observation is actually in accord with ours, that too early an application has no delaying effect.

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