AMMONIUM NUTRITION AND FLOWERING OF APPLE TREES

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[*Manuscript received March* 12, 1967]

Summary

Jonathan apple trees were grown in culture solution with nitrogen supplied either as nitrate, as ammonium, or in both forms. In all cases ammonium led to earlier flowering and to a much higher proportion of flowers among the total buds; but when ammonium was supplied throughout the season alone or as ammonium nitrate, vegetative growth was less than with nitrate alone. When the trees were given only nitrate during the preceding season, except for an interval of 2 months (December–January) in which ammonium nitrate was supplied, the merits of both ions were combined; the growth was not reduced and the total number of flowers in the succeeding spring was three times as great as with nitrate alone.

I. Introduction

The flowering of fruit trees has long been noted for its irregularity, culminating in "biennial bearing". It is well known that the flowers are initiated during the summer preceding blossoming. Much work, mostly inconclusive, has been done on the relation of this initiation to nitrogen nutrition, but the source of the nitrogen—whether ammonium or nitrate—has not been followed. In our own work (Grasmanis and Leeper 1965) in which apple trees were grown in pot cultures with the nitrogen supplied either as ammonium or as nitrate, it was noted that while ammonium checked the vegetative growth (as has been found before for other plants), the "ammonium" trees produced many more flowers than the "nitrate" trees. We therefore studied this novel effect of ammonium nutrition on flowering over two further seasons, and on both occasions observed a huge increase in flowering when ammonium was supplied. Since the use of ammonium through the season causes a reduction in growth as compared with nitrate, the experiment in the second of these seasons was devised to combine the respective merits of ammonium and nitrate; one set of experimental trees was grown on nitrate and only moved to ammonium-plus-nitrate for 2 months in summer, then back to nitrate. This use of ammonium led to a threefold increase in the number of flowers with no reduction in growth. The experiments are described here, and the suggested causes of heavy flowering are then mentioned.

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II. Experimental

Apple trees were grown in pot culture, as described elsewhere (Grasmanis and Leeper 1965). Plastic containers of 36 litres capacity and covered with aluminium foil 0·1 mm thick were used. Victorlome, a processed (at 650°C) siliceous volcanic rock, was used as root medium. (Its nutrient effect was shown to be negligible.) All treatments were replicated four times. Nutrient solutions were changed weekly and all pots were aerated for 24 hr daily. During the first season (1964–65) the trees were in a glasshouse provided with a cooling system; during the second season (1965–66) they were in a "bush-house" with the sides open to the atmosphere, and with a fibre-glass roof as the only shelter (see Plate 1, Fig. 1).

Table 1

GROWTH AND FLOWERING OF JONATHAN–MM 104 APPLE TREES PLANTED IN SEPTEMBER 1964 AND TREATED WITH DIFFERENT SOURCES OF NITROGEN

Values are means for four trees

Treatment	Mean Growth for Previous Season (cm/tree)	No. of Flower Buds in October 1965	
		Mean No. per Tree	No. per 100 cm of Growth*
A (solution 1)	94	11·4	12·1
B (solution 2)	215	34·4	16·0
C (solution 3)	400	8·0	2·0

* Values for treatments A and B differ significantly ($P < 0 \cdot 01$) from treatment C.

Besides nitrogen and sulphur, all solutions contained elements as follows (in p.p.m.): K 78, Ca 160, P 41, Na 31, Mg 36, Mn 0·43, Cu 0·06, Zn 0·06, B 0·02, Mo 0·02, and Fe 5·6. Details of the nitrogen and sulphur composition of the solutions used for the various treatments in experiments 1 and 2 are set out in the following tabulation:

	Nitrate Nitrogen (p.p.m.)	Ammonium Nitrogen (p.p.m.)	Sulphate Sulphur (p.p.m.)
Solution 1	—	112	315
Solution 2	84	28	123
Solution 3	112	—	59
Solution 4	56	56	187
Solution 5	—	56	251

(a) *Experiment 1*

MM 104 rootstocks were budded with Jonathan variety and planted on September 9, 1964. Treatments A, B, and C consisted respectively of solutions 1, 2, and 3 throughout the season.

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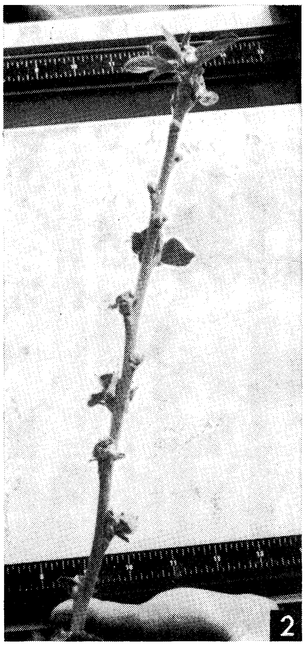

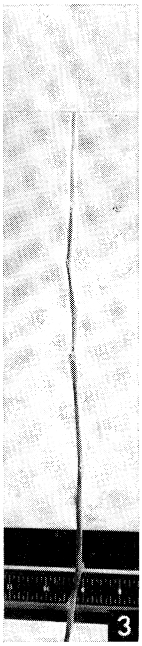

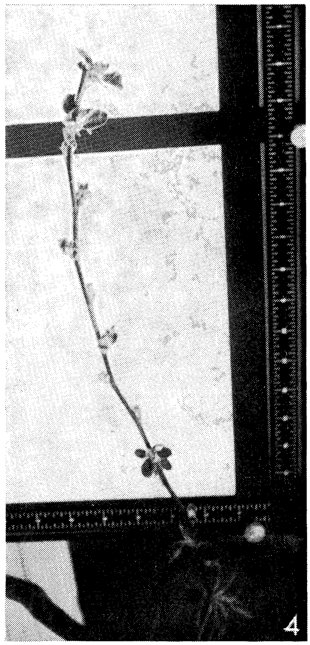

Fig. 1.—Showing structure and arrangement of apple trees in a bush-house.

Figs. 2–4.—Effect of treatments A (Fig. 2), C (Fig. 3), and D (Fig. 4) of experiment 2 on shoots of Jonathan–Northern Spy apple trees. Photographs taken on September 26, 1966.

(b) Experiment 2

Established grafts of Jonathan on Northern Spy rootstocks were planted in spring 1965. Treatment B was modified in this season by supplying pure nitrate (solution 3) for the first 8 weeks from planting till October 20, then solution 2. The

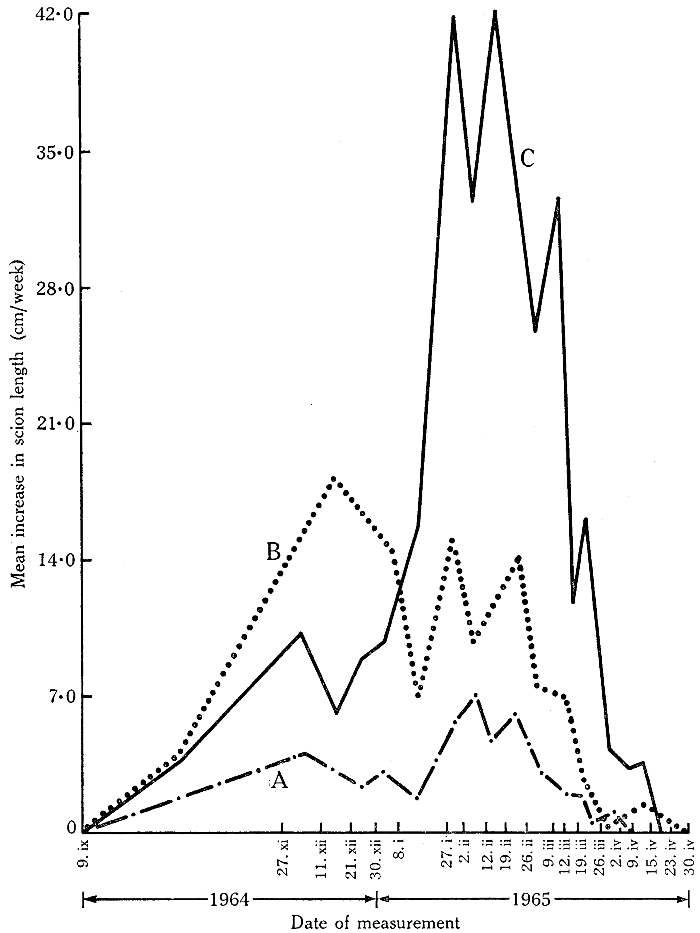

Fig. 1.—Mean increase in scion length of Jonathan–MM 104 apple trees during the 1964–65 season (expt. 1). Trees planted in September 1964. *A*, treatment A; *B*, treatment B; *C*, treatment C.

major new treatment was D, in which the trees had pure nitrate throughout except for December–January when they had ammonium nitrate (solution 4). Besides a treatment with ammonium nitrate throughout (E), a half-strength ammonium solution was also included in this experiment (F).

TABLE 2

FLOWERING OF JONATHAN–NORTHERN SPY APPLE TREES IN EXPERIMENT 2 (1965–66)

Treatment	Mean Growth for Previous Season (cm/tree)	Mean No. of Scars per Tree*	Mean No. of Side Growths per Tree*	Mean No. of Normal Buds per Tree*	Early Count of Flower Buds†		Count of Flower Buds at Pink Bud Stage		Final Count of Flower Buds at Full Bloom Stage	
					Mean No. per Tree	% of Normal Buds	Mean No. per Tree	% of Normal Buds	Number‡	% of Normal Buds§
A (solution 1)	290	39	5	80	12	15	30	38	42	53
B (solution 3 for first 8 weeks, then solution 2)	1351	177	24	299	3	1	95	32	149	50
C (solution 3)	1360	176	23	291	0	0	32	11	63	22
D [solution 3 except for 2 months (Dec.–Jan.) when solution 4 supplied]	1328	161	23	294	2	1	115	39	177	60
E (solution 4)	795	119	18	187	11	6	69	37	89	48
F (solution 5)	517	68	11	127	16	13	40	32	73	57

* As at September 1966.

† Flower buds at green and pink stage.

‡ Least significant difference ($P < 0 \cdot 01$) for number of buds = 60.

§ Least significant difference ($P < 0 \cdot 01$) for percentage of normal buds = 25.

III. Results

(a) *Experiment 1 (1964–65)*

The results are given in Table 1 and Figure 1. The total growth was much greater with nitrate alone than with ammonium alone; ammonium-plus-nitrate (B) was intermediate over the whole season, but exceeded the pure nitrate during the spring and early summer. The number of flower buds per tree was over four times as great when one-fourth of the nitrogen was given as ammonium; when the flowers were calculated per 100 cm of growth, there were six times as many for pure ammonium as for nitrate, and eight times as many for ammonium-plus-nitrate.

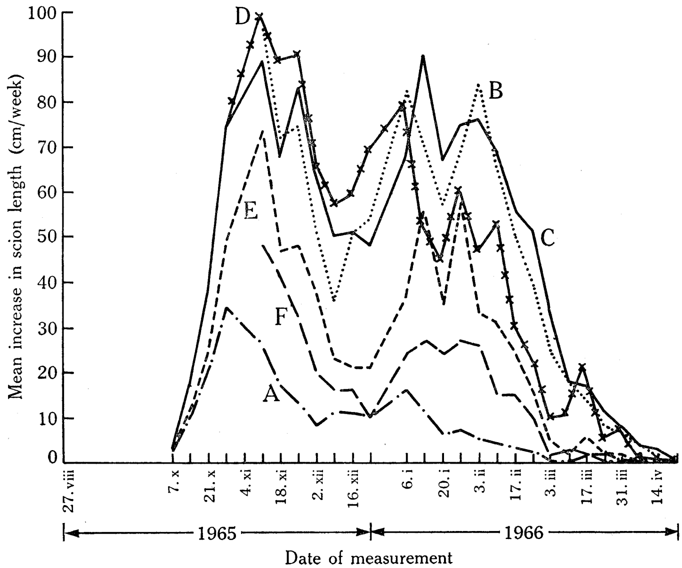

Fig. 2.—Mean increase in scion length of Jonathan–Northern Spy apple trees during the 1965–66 season (expt. 2). Trees planted August 27, 1965. Lettering on the graphs corresponds to treatments A–F of the experiment (Table 2).

(b) *Experiment 2 (1965–66)*

The results are given in Table 2 and in Figure 2. These trees, being grown from established grafts, produced much earlier growth than in experiment 1 and as a result there were two growth periods of similar intensity. In this experiment the introduction of one-fourth of the nitrogen as ammonium, following the first 8 weeks with pure nitrate (B), did not depress growth, and similar full growth was recorded by the new treatment (D), namely nitrate throughout the season except for 2 months in summer when ammonium nitrate was supplied. Pure ammonium (A, F) depressed growth, especially at the higher level, and straight ammonium nitrate (E) depressed growth somewhat less. Figure 2 shows how the two best treatments that included ammonium (B and D) rivalled the pure nitrate treatment up to the second flush of growth—presumably including the time when the flower buds were initiated. (The depression of growth in treatment D later in the season could not therefore be held responsible for the heavy flowering of the following spring.)

For flowering, the most interesting comparison is between nitrate alone (C) and the two most successful introductions of ammonium (B and D). These three are all closely similar for total growth, numbers of buds, scars, and side growth; as the last column of Table 2 shows, only 22% of the nitrate buds were flowers, as against 50 and 60% for B and D respectively. Every application of ammonium led to a high percentage of flowers, whether total growth was decreased or maintained; the earliness of all the ammonium plants is well shown in the middle columns in Table 2. The growth for treatments A, C, and D at an early stage (September 26, 1966) is shown in Plate 1, Figures 2, 3, and 4.

IV. Discussion

We have as yet no direct information on the proportion of the total nitrogen absorbed as ammonium and as nitrate from the mixed cultures. The invariably low pH (4·0 at time of changing) shown alike by pure ammonium solutions and by the ammonium-plus-nitrate solutions confirms what we infer from numerous other observations, namely that ammonium is absorbed in much greater amounts than nitrate. [The nitrogenous ions commonly dominate over all others, as quoted by Grasmanis and Leeper (1965); and the potassium ion, the only other cation whose uptake could conceivably have provoked such acidity, was no more concentrated in the trees with ammonium than with nitrate nutrition.] It is interesting that this acidity led to no obviously ill effects; theoretically it might even have decreased the excess intake of ammonium over nitrate, thus limiting the fall of pH. The elements aluminium and manganese, which damage plants on acid soils, are practically absent here.

These experiments are in controlled solutions, in which the ammonium remains as such. Nitrification would be slight during the week for which each nutrient solution is used, as was indicated by one experiment quoted earlier (Grasmanis and Leeper 1965) in which the addition of only 1·4 p.p.m. of nitrate nitrogen to an "ammonium" tree caused a marked improvement in its growth. However, in orchards nitrification is the rule. Yet in some orchard experiments with ammonium sulphate or ammonia in the past, some nitrogen may have been absorbed as ammonium and effects like these may have been noticed, though it has been generally assumed that nitrate is overwhelmingly the form absorbed in the field. In order to maximize the absorption of ammonium we have applied the various forms of nitrogen at fortnightly intervals during the summer to apple trees growing on loams of pH ranging from 5·5 to 6·5, and have obtained heavy flowering in the succeeding spring where the ratio of ammonium to nitrate was not less than one.

Little can be said as yet about the chemistry underlying the effects here reported. In our earlier experiments (Grasmanis and Leeper 1965) we recorded the high concentration of asparagine and of arginine in ammonium trees; it is plausible that other important molecules should be produced in different concentrations with ammonium nutrition. The flower-producing effect of ammonium might turn out to be related to the presence of growth inhibitors or to the absence of growth promoters.

Mention can be made here of Luckwill's (1957) finding of an auxin in developing apple seeds and of a growth inhibitor in mature apple leaves; of the isolation of the inhibitor phloridzin from apple leaves (Grochowska 1963, 1964); and of Sarapuu's studies (1965) on phloridzin and the enzyme which decomposes it in growing leaves. While such relations may be found in the future, it should be emphasized here that the heavy flowering in our experiments cannot be attributed to the checking of growth by ammonium, since it was best shown in those trees which had made as much growth as the pure nitrate trees.

V. References

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