SHOOT ORIENTATION EFFECTS ON GROWTH AND FLOWER-BUD FORMATION IN APPLE

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SUMMARY

Evidence was supplied that the stimulation of flower-bud formation on horizontal shoots of one year old Cox's Orange Pippin trees was entirely due to shoot orientation. An additional effect of shoot growth as influenced by shoot orientation could not be shown.

1. INTRODUCTION

In previous work (TROMP 1968) it was shown that flowering on spurs of potted Golden Delicious trees placed horizontally throughout or during half of the growth season was stimulated considerably, and that the comparatively small growth differences induced by treatments could not explain this stimulation. It was suggested that tree orientation in relation to gravity has an influence on flower-bud formation independent of its effect on growth vigour. However, this does not rule out the possibility of an additional effect of shoot growth on flower-bud formation, especially on current year's shoots, when tree or shoot orientation influence shoot growth. The present experiment was undertaken to elucidate this point.

2. MATERIAL AND METHODS

The experimental technique was the same as described previously (TROMP 1968). In brief, in March 1967 one year old unfeathered Cox's Orange Pippin trees (rootstock M IX) were planted in pots and pruned back to about 70 cm. Only the uppermost four buds were allowed to grow out; the remaining buds were removed. Four treatments (in eight replicates each) were compared: 1) tree kept vertical throughout, shoots trained vertically; 2) tree kept horizontal from April to December, shoots trained horizontally; 3) tree initially kept vertical and shoots trained vertically, but after cessation of shoot growth, until December tree kept horizontal; 4) tree kept vertical throughout, shoots trained horizontally. The horizontal trees were rotated 120° three times a week.

3. RESULTS AND DISCUSSION

3.1. Shoot growth

Shoots in the horizontal position clearly showed less growth than shoots growing vertically (*table 1*). The reduction of growth was lowest in treatment 4, where only the shoots had the horizontal position. It is not known why growth

is inhibited in this position. A lower auxin content in the top of horizontally growing apple shoots as compared with upright shoots (KATO & ITO 1962) suggests that gravity may affect growth through the metabolism of endogenous growth-regulating substances. This finding supports the hypothesis that the supply of nutrients to the apex is controlled by auxin produced in the top meristem (LUCKWILL 1968). But it has also been reported (FULFORD *et al.* 1968), to the contrary, that the tendency to import auxin supplied to the shoot tip was much weaker in vigourously growing plants than in horizontal plants, which showed retarded growth. Furthermore, spraying young apple trees with auxins advanced the formation of the terminal bud. It is not clear why the inhibition of growth was more marked in treatment 2 than in treatment 4. Factors mentioned as associated with growth cessation are the accumulation of inhibiting substances occurring in full-grown leaves (LUCKWILL 1968) and the decrease of the supply of cytokinins from the roots which occurs in early summer (LUCKWILL & WHYTE 1968). It is not known whether these factors are influenced by shoot or stem orientation. Since in treatments 2 and 4 the orientation of the shoots is the same, the growth differences between them might be ascribable to a difference in root activity. The additional rotation given to the horizontal trees may have enhanced shoot growth slightly, as was found for apple and cherry (WAREING & NASR 1961) and in work on oat coleoptiles (ANKER 1960).

Table 1. The effect of tree or shoot orientation on growth and flower-bud formation.

Treatment	Mean shoot growth (cm)	Percentage of flower clusters (calculated from the total number of buds)			
		irrespective of flower quality	if number of well-developed flowers/cluster > 0	> 2	> 4
1 Stem and shoots vertical throughout (control)	140.3	57.9	42.8	34.1	23.0
2 Stem and shoots horizontal from April to December	75.8***[1]	78.7***	70.5***	62.2***	48.9***
3 Stem and shoots initially vertical, after shoot-growth cessation horizontal	132.8	77.1***	67.1***	59.1***	44.6**
4 Stem vertical, shoots horizontal	105.5*[2]	69.6*[3]	64.8**	59.2***	50.8***

*, **, *** significant difference from control at the 5%, 1%, 0,1% levels, respectively
[1] differs significantly from 132.8 at the 0,1% level and from 105.5 at the 5% level
[2] differs significantly from 132.8 at the 5% level
[3] differs significantly from 78.7 and 77.1 at the 5% level.

3.2. Flower-bud formation

The shoot orientation had a distinct effect on flower-bud formation (*table 1*). In 1968, flowering in treatments 2, 3, and 4 was significantly more abundant than in the controls. The quality of the flower clusters was rather poor: many flowers and sometimes whole clusters shrivelled and dropped prematurely. However, when the number of well-developed flowers is taken as a criterion, the quality of the flower clusters was markedly better in horizontal shoots, as *table 1* shows. The promotion of flowering in treatments 2, 3, and 4 was almost equal, whereas shoot growth responded differently to the various treatments, *i.e.*, a marked growth reduction in treatments 2 and 4 and no reduction at all in treatment 3, as compared to the controls. This suggests that the stimulated flower-bud formation in horizontal shoots was a direct effect of shoot orientation and was not related to any growth response. Obviously, the promotion of flowering and the reduction of shoot growth in horizontal shoots are independent phenomena.

How shoot orientation in relation to gravity acts on flower-bud formation is obscure. The promotion of flowering in horizontal pineapple plants has been ascribed to a redistribution of auxin between the upper and the lower side of the stem under the influence of gravity (VAN OVERBEEK & CRUZADO 1948), but since the trees in the present trial were rotated regularly, this explanation does not seem relevant. ZELLER (1960) showed that flower-bud formation on current year's shoots occurs for a great part during winter and early spring. In the present experiment, since the trees of treatments 2 and 3 were transferred to the upright position in December, the results clearly show that shoot orientation interferes comparatively early in the flower-formation process. Besides, it would otherwise not be clear why flowering on the continually horizontal shoots in treatment 4 and on the shoots of the trees kept vertical from December in treatment 2 and 3 were promoted almost in the same degree. ZELLER (1960) also stated that in contrast to the situation in spur buds, many flower primordia in buds on current year's shoots of apple trees die off and abort during the flower-formation process. This leads to the question of whether the enhanced flower-bud formation in horizontal shoots may be ascribed to a reduced flower abortion. The increased number of well-developed flowers per cluster on horizontal shoots fits this idea well. On the other hand, the promotion of flowering is not restricted to current year's shoots kept horizontal, since it was reported to occur on spurs on horizontal two year old branches as well (TROMP 1968).

ACKNOWLEDGEMENT

I am indebted to Mr. Ch. A. R. Römer for technical assistance.

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