unaffected trees (Figs. 2A and 3A).

Comparison of the Mn levels for each tissue, for each sampling year, shows that leaf Mn concentration was 34% lower and wood Mn 69% lower in 1965 than in 1963. Bark Mn, however, was unchanged. This may mean that bark Mn levels are relatively less affected by environmental and physiological variations than are leaf and wood levels.

There is no indication in these data that Mn consistently declines in leaves as abscission approaches. There is also no compelling indication from an examination of the graphs or from correlation coefficients that, when leaf Mn declines, there is a concomitant increase in Mn concentration of bark or wood.

There is some suggestion from the graphs that leaf and wood Mn concentrations may rise and fall together. The rise in leaf Mn level from 10/22 to 11/9/65 and the increase during the subsequent sampling period in the Mn level of the wood of the trees high and low in initial Mn level is particularly evident (Figs. 3A and 3C). The correlation coefficient of + 0.563 for all trees is, however, nonsignificant.

In the one year when twig sampling was carried out (1965), there are no large concomitant changes in levels of bark or wood Mn which would suggest movement from one tissue to the other.

Literature Cited

1. Berg, A., G. Clulo (Berg) and C. R. Orton. 1958. Internal bark necrosis of apple resulting from manganese toxicity. *W. Va. Univ. Agr. Exp. Sta. Bul.* 414T.
2. Rogers, B. L., A. H. Thompson and L. E. Scott. 1965. Internal bark necrosis (measles) on Delicious apple trees under field conditions. *Proc. Amer. Soc. Hort. Sci.* 86:46-54.
3. Shannon, L. M. 1954. Internal bark necrosis of the Delicious apple. *Proc. Amer. Soc. Hort. Sci.* 64:165-174.

Effect of Gibberellins and Cytokinins on Development of Parthenocarpic Apples

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Gibberellins (GA) will stimulate parthenocarpic fruit development in apples (1, 4, 5, 9). Davison (4) found GA_3 to increase fruit set in the Red Jersey variety to a greater extent than in Sturmer. Bukovac (1) observed that GA_4 was more effective than GA_3 in promoting fruit set in the Sops-of-Wine variety. Varga (9) reported that GA_1, GA_2, GA_4, and GA_7 promoted parthenocarpic fruit set in the Lombartscalville variety but not in the Winston or Golden Delicious varieties.

Cytokinins will increase fruit set in grapes (10), muskmelons (7), and figs (3). We have compared the effect of cytokinins and gibberellins on parthenocarpic fruit set of Sturmer, Red Delicious, and Golden Delicious apples.

Flower buds were emasculated at the full pink stage by removing the petals, stamens and style with a pair of scissors. With each variety, at least 100 flowers on a limb on each of three trees were emasculated and used for one treatment. The Sturmer variety was treated at Auckland, New Zealand, in October, 1967. The Red Delicious and Golden Delicious were treated at Wenatchee, Washington, in April, 1968. The treatments consisted of an open-pollinated control, an emasculated control, GA_3 at 400 ppm, $GA_{4,7}$[1] at 400 ppm, N-6 purinyl-α-phenylglycine (NPG)[3] at 400 and 800 ppm, 6-benzylamino-9-(2-tetrahydropranyl)-9H-purine (SD8339)[4] at 400 and 800 ppm, Zeatin[5] at 800 ppm, and various combinations of gibberellins and cytokinins as shown in Tables 1 and 2. All of the growth regulators were applied as ethanol-water (1:4) solutions containing Tween-20[4] (2 drops/50 ml) as surfactant. A few drops of dilute NaOH were added to bring the NPG into solution. The solutions were applied by brush to the emasculated flowers. The number of fruits remaining to harvest were counted and the per cent fruit set was determined.

The $GA_{4,7}$ treatments resulted in significant fruit set. The GA_3 treatments were not significantly different from the emasculated controls (Table 1). Cytokinins used alone induced parthenocarpic fruit development, and SD8339 was more effective than NPG or Zeatin (Tables 1 and 2). The most effective treatment on Sturmer and Red Delicious was $GA_{4,7}$ at 400 ppm plus SD8339 at 400 ppm (Tables 1 and 2). The $GA_{4,7}$ alone was not as effective as when combined with a cytokinin. With the variety Sturmer, cytokinins and $GA_{4,7}$ appeared to act synergistically to promote set. The Red Delicious treatments, however, did not indicate any synergism. On Red Delicious the $GA_{4,7}$ treatment was just as effective as the combination treatment of $GA_{4,7}$ plus cytokinin.

Treatment with $GA_{4,7}$ and SD8339 increased the length-to-diameter ratios of the fruits. An increase in the length-to-diameter ratio of apples as a result of GA and cytokinin has been observed previously (2, 9, 11). The largest fruits in the present experiment resulted from the SD8339 and Zeatin treatments. Letham (8) reported an increase in cell number in fruits treated with cytokinins. An increase in cell number could account for the increased fruit size.

The concentration of all chemicals appeared to be higher than necessary for maximum response. We used 400 ppm of GA because Varga (9) indicated 800 ppm of the various gibberellins was more effective than 100 ppm. A combination of $GA_{4,7}$ and SD8339 at 200 ppm each was effective in setting fruit on Red Delicious as the same combination at 400 ppm. Even lower concentrations of $GA_{4,7}$ in combination with SD8339 may result in significant fruit set and development.

The Golden Delicious variety did not respond well to either gibberellins or cytokinins. These results agree with those obtained for GA on Golden Delicious by Varga (9). The specificity of apple varieties for different growth regulators is apparent, and must be carefully considered in fruit set experiments with different varieties.

We conclude that cytokinins will promote parthenocarpic fruit set and development of some apple varieties. Although less effective than gibberellins,

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[3]Supplied by D. S. Letham, Department of Scientific and Industrial Research, Fruit Research Division, Private Bag, Auckland, New Zealand.

[4]Supplied by Shell Development Company, Modesto, California.

[5]Mention of a trademark name or a proprietary product does not imply its approval by by USDA to the exclusion of other products that may also be available.

they certainly are part of the growth regulator complex controlling fruit set and development.

Literature Cited

1. Bukovac, M. J. 1963. Induction of parthenocarpic growth of apple fruits with gibberellins A_3 and A_4. *Bot Gaz.* 124:191-195.
2. ——— and S. Nakagawa. 1968. Gibberellin-induced asymmetric growth of apples. *HortSci.* 3:172-174.
3. Crane, J. C. 1965. The chemical induction of parthenocarpy in the Calimyrna fig and its physiological significance. *Plant Physiol.* 40:606-610.
4. Davison, R. M. 1960. Fruit setting of apples using gibberellic acid. *Nature* 188:681-682.
5. Dennis, F. G., and L. J. Edgerton. 1962. Induction of parthenocarpy in the apple with gibberellin, and the effects of supplementary auxin application. *Proc. Amer. Soc. Hort. Sci.* 80:58-63.
6. Duncan, D. B. 1955. Multiple range and multiple F tests. *Biometrics* 11:1-42.
7. Jones, C. M. 1965. Effects of benzyladenine on fruit set in muskmelons. *Proc. Amer. Soc. Hort. Sci.* 87:335-340.
8. Letham, D. S. 1968. Regulators of cell division in plant tissues. VI. The effects of Zeatin and other stimulants of cell division on apple fruit development. *New Zealand Jour. Agric. Research* (In Press).
9. Varga, A. 1966. The specificities of apple cultivars and of gibberellins in the induction of parthenocarpic fruits. *Proc. Biol. and Med. Sci.* (Amsterdam) 59:641-644.
10. Weaver, R. J., J. van Overbeek, and R. M. Pool. 1965. Induction of fruit set in *Vitis vinifera* L. by a kinin. *Nature* 206:952-953.
11. Williams, M. W., and E. A. Stahly. 1968. Effect of cytokinins and gibberellins on shape of 'Delicious' apple fruits. *Proc. Amer. Soc. Hort. Sci.* 94:17-18.

Table 1. Effect of gibberellins and cytokinins on parthenocarpic fruit set of emasculated Sturmer apple flowers at Auckland, New Zealand, 1967.

	Average per cent fruit set[1]		
	No GA	GA_3 400 ppm	$GA_{4,7}$ 400 ppm
No cytokinins	0 a	1.7 a	12.8 bc
NPG 400	6.8 ab	6.2 ab	19.2 bc
NPG 800	3.9 ab	3.9 ab	26.4 c
SD8339, 400	8.0 ab	7.1 ab	42.8 d
SD8339, 800	10.8 ab	10.5 ab	40.0 d

[1]Means with different letters are significantly different at the 5% level (6).

Table 2. Effect of gibberellin and cytokinins on parthenocarpic fruit set of emasculated Sturmer, Starking Delicious and Golden Delicious apple flowers.

Treatment[1] and Concentration	Sturmer[2] per cent fruit set	Red Delicious[3] per cent fruit set	Golden Delicious[3] per cent fruit set
Open pollinated control	6.1	21.3	22.4
Emasculated control	0	0	0
GA_3 400 ppm	1.7	3.3	4.7
Zeatin 800 ppm	6.0	-	-
SD8339 400 ppm	8.0	2.0	8.0
GA_3 400 ppm + SD8339 400 ppm	7.1	9.3	5.0
$GA_{4,7}$ 400 ppm	12.8	41.0	1.7
$GA_{4,7}$ 400 ppm + Zeatin 800 ppm	14.5	-	-
$GA_{4,7}$ 400 ppm + SD8339 400 ppm	42.8	49.0	6.3
$GA_{4,7}$ 200 ppm + SD8339 200 ppm		46.5	8.0

[1]Three replicates with 100 flowers per replication.
[2]At Auckland, New Zealand, 1967.
[3]At Wenatchee, Washington, 1968.

Promotion of Leaf Abscission of Deciduous Tree Fruit Nursery Stock with Abscisic Acid[1]

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Following publication in 1965 (9) of the identity of Abscisin II isolated from cotton by Addicott's group, it was established that sycamore dormin and Abscisin II have the same structure (3). Abscisin II was later named abscisic acid (1). This and other research (4, 8, 10) shows that this is apparently a widely distributed compound.

In spite of early optimism, the possiblity of abscisic acid becoming a natural defoliant (2) has not been realized. Commercial synthesis is costly and has only recently been accomplished. Experimentation, as a result, has been limited. There is some evidence that abscisic acid may not be as useful a defoliant as previously supposed on the basis of its natural occurrence and on laboratory work with explants.[3] Recent information, however, published by Hartmann, *et al* on induction of olive fruit abscission showed that the force required to remove fruit on branches sprayed with 1,000 or 2,000 ppm abscisic acid was greater than the control, but complete defoliation occurred, which indicated that leaf abscission was stimulated but fruit abscission was not (5).

The purpose of the work reported here was to observe the effects of

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