The Effect of Seedless Versus Seeded Fruit Development on Flower Bud Formation in Pear[1]

William H. Griggs, George C. Martin, and Ben T. Iwakiri
University of California, Davis

Abstract. 'Bartlett' spurs carrying seedless or seeded fruits produced relatively high percentages of flower buds. Spurs carrying seedless pears for 31 days after bloom produced more flower buds than did spurs carrying seeded pears. Also, the exudate from seedless pears had more growth-promoting activity. Beyond 31 days there were no consistent differences in flower bud formation in spurs carrying seedless vs. seeded pears. Carrying seeded pears 31 days largely inhibited flower bud initiation in 'Winter Nelis'. There was an inverse relationship between flower buds and seeds in fruits on spurs of both varieties defruited 61 days after bloom. The relationship was not distinct for spurs carrying fruits longer. Fluctuations in the growth-promoting activity of the fruit exudate indicate that the hormonal status, at the time the spur was defruited, influenced flower bud formation more than did number of fruits, seeds, or length of fruit-carrying period.

CHAN and Cain (3), working with the 'Spencer Seedless' apple, found that flower bud formation was inhibited in spurs bearing seeded fruits, while spurs bearing parthenocarpic fruits developed about as many flower buds as did spurs with no fruits. Seed formation appeared to be the controlling factor in flower initiation as opposed to nutritional competition by developing fruits.

The 'Bartlett' pear also provides excellent material for studying the effect of fruit and seed development on flower bud formation. Although self-incompatible, the 'Bartlett' is self-fruitful in most California orchards because of its ability to produce parthenocarpic fruits (5). Comparative studies (4) have revealed only small differences between seeded and parthenocarpic 'Bartletts'. The seeded pears tended to reach harvest maturity a few days earlier, and were slightly shorter, but larger in diameter, than the seedless ones.

The ability to produce heavy annual crops is an important attribute of the 'Bartlett' variety. In California, fluctuations in annual yields of 'Bartlett' are usually correlated with weather conditions during the bloom and fruit-setting period rather than with a biennial bearing pattern. 'Winter Nelis', which is often used as a pollenizer for 'Bartlett', is also self-incompatible. However, it does not set parthenocarpic fruits, and has a tendency for biennial bearing, especially when interplanted with 'Bartlett'.

Some growers feel that 'Bartlett' trees planted in solid blocks tend to bear more uniform crops than when interplanted with other varieties. This raises the question as to whether 'Bartlett' spurs bearing parthenocarpic pears initiate significantly more flower buds than do similar spurs bearing seeded fruits. This study was designed to probe this question and to obtain further information regarding the relation between fruit and seed development and flower bud initiation.

Materials and Methods

The study was done during 1968 in 2 mature, high-yielding 'Bartlett' orchards in the Sacramento River delta area. In the Fay-Sturtz orchard, 'Winter Nelis' pollenizers are interplanted at an approximate rate of every 5th tree in every 5th row. In the Leary orchard, the trees are in a solid block, and past experiments (5) have indicated that 95–100% of the pears produced are seedless. The orchards are approximately 2½ miles apart. Honey bees were provided at a rate of 1 colony per acre throughout the bloom period of the cross-pollinated orchard. Weather during the bloom and fruit-setting period was favorable, and all test trees set heavy crops.

Flower and fruit removal from spurs. Seedless and seeded fruits were removed from spurs at intervals to determine the effect of fruit and seed development on flower bud initiation. Sixteen 'Bartlett' and 8 'Winter Nelis' trees were selected in the cross-pollinated orchard for this study. Eight of the 'Bartlett' trees were adjacent to a 'Winter Nelis' pollenizer, and 8 were several tree spaces away from a pollenizer. To insure a supply of parthenocarpic pears for later removal, at least 150 spurs on each of the 'Bartlett' trees were bagged throughout the bloom period to prevent insect visitation. Later examination revealed that all pears on the previously bagged spurs were seedless, while practically all those developing next to a 'Winter Nelis' contained several seeds.

To provide nonfruiting control spurs, on March 8 flowers were removed from 32 spurs on each of the experimental trees. Both varieties were judged to be in full bloom (F B) on March 15. Four treatments for 'Bartlett' and 2 for 'Winter Nelis' were started 31 days after F B and repeated 47, 61, 77, and 112 days after F B. At least 32 bearing spurs, 4 on each of 8 trees, were included in each treatment. The treatments consisted of defruiting the spurs bearing: a) 1 seedless pear, b) 2 seedless pears, c) 1 seeded pear, and d) 2 seeded pears. Only treatments c and d were used with 'Winter Nelis' since it does not produce parthenocarpic fruits. After removal the pears were sliced transversally, seed count was determined, and the spur was tagged accordingly. Each experimental spur was examined for flower bud formation in December, and the length of each axillary shoot bearing a flower bud was recorded.

Bioassay of fruit exudate. 'Bartlett' pears were collected 21, 27, 38, 48, 55, 62, 69, 83, 97, 115, and 129 days after F B from 10 trees in each orchard to study the growth-promoting activity of the exudates from seedless versus seeded fruits. Five randomly selected fruits were removed from each tree by cutting through the base of the pedicel with hand shears. The pears were immediately placed in a collection rack, with each pedicel immersed in a vial of 2% sucrose solution. After about 1 hr the pears were transferred to holding racks in the laboratory, with the pedicels of 5 pears immersed in 1 ml of 2% sucrose buffered at pH 5 (K_2HPO_4 1.794 gm/liter + citric acid monohydrate 1.019 gm/liter). Starting 69 days after F B,

[1]Received for publication September 23, 1969.

the amount of buffered solution was increased to 2 ml to accommodate the larger fruits. The pears were removed after 2 hr in the buffered solution. The fruits were weighed, measured, examined for seed content, and air dried in an oven at 70 C. The buffered solution containing the exudate was bioassayed directly by the wheat coleoptile straight growth test (8). The unknown growth promotional factor(s) from the pear exudate was partitioned into acidic ether (7) and examined via TLC GF 254 plates in: 1) n-butanol: n-propanol: ammonium hydroxide: water (2:6:1:2 v/v/v/v), 2) benzene: methanol: formic acid (85:15:1.3 v/v/v), 3) benzene: ethyl acetate: formic acid (80:20:5 v/v/v), 4) isopropanol: ammonium hydroxide: water (8:1:1 v/v/v), and 5) chloroform: acetic acid: water (4:1:1 v/v/v).

Naphthalene acetic acid sprays to prevent preharvest drop were applied in both orchards during the last week in June. Branches on the test trees were bagged to prevent contamination of fruits to be collected 115 and 129 days after F B.

On each date pears were collected for bioassay, 2 extra 'Bartlett' pears were harvested from each tree for a study of ovule or seed development. Additional samples were collected 41 and 77 days after F B. Unfertilized ovules in the parthenocarpic pears were usually indiscernible from fertilized ovules in the cross-pollinated pears in samples collected prior to 38 days after F B. Starting at 38 days, the ovules and developing seeds and embryos from the 2 types of fruits were measured.

Results and Discussion

Effect of carrying seedless versus seeded fruits. The 'Bartlett' spurs had a remarkable ability to initiate flower buds while carrying seedless or seeded fruits (Table 1). With 'Winter Nelis', seeded fruits greatly inhibited flower bud formation (Table 2). In both varieties, most flower buds developed on short axillary extensions (shoots) from the spurs (Fig. 2). Chan and Cain (3) reported that the inhibitory effect of seed formation on flower bud formation of apple spurs was localized, and that the longer axillary shoots produced more flower buds. In the present experiment, there was no consistent relationship between treatment and the length of the axillary shoots.

'Bartlett' pear spurs carrying seedless fruits for 31 days after F B produced higher percentages of flower bud formation (93.8%) than did spurs carrying seeded pears (68.7%). With spurs carrying either 1 or 2 seedless or seeded pears for longer periods, there were no consistent significant differences in flower bud formation (Table 1). Spurs from which the flowers or fruits were removed early in the growing season produced more flower buds than spurs carrying fruits for longer periods, however, and spurs carrying seedless fruits produced more flower buds than did spurs carrying seeded ones (Fig. 1). Hence, on the basis of flower bud formation, there is an advantage in growing 'Bartlett' in solid blocks.

Chan and Cain (3) found that after flower removal, 97.6% of 'Spencer Seedless' apple spurs developed flower buds, while only 13.1% of spurs carrying seeded fruits

Table 1. The effect of seedless versus seeded fruit development on the ability of Bartlett pear spurs to produce flower buds in 1968.[x]

Treatment	Days after full bloom (March 15)	Percentage of spurs that produced flower buds on:			Mean length (mm) of:	
		Short axillary shoots (1–25mm)	Long axillary shoots (longer than 25mm)	All axillary shoots	Short axillary shoots (1–25mm)	Long axillary shoots (longer than 25mm)
Control (flowers removed)	0	74.2 ab	12.4 abcde	86.6 ab	6.2 a	157.6 a
Fruit removed from spurs bearing:						
Seedless pears[y]	31	84.4 a	9.4 bcde	93.8 a	6.2 a	145.0 a
1 seeded pear	31	65.6 abcd	3.1 de	68.7 b	4.5 a	133.5 a
2 seeded pears	31	56.2 bcde	12.5 abcde	68.7 b	6.3 a	190.0 a
1 seedless pear	47	62.5 abcd	14.6 abcde	77.1 ab	5.9 a	158.0 a
2 seedless pears	47	51.0 bcdef	11.4 abcde	62.4 bc	4.6 a	106.2 a
1 seeded pear	47	68.8 abc	12.5 abcde	81.3 ab	6.4 a	184.2 a
2 seeded pears	47	43.8 cdef	9.4 bcde	53.2 bc	6.5 a	162.3 a
1 seedless pear	61	49.0 bcdef	12.5 abcde	61.5 bc	7.0 a	197.5 a
2 seedless pears	61	56.2 bcde	21.9 abcd	78.1 ab	8.5 a	185.4 a
1 seeded pear	61	25.0 f	12.5 abcde	37.5 c	6.4 a	197.2 a
2 seeded pears	61	45.8 bcdef	32.3 a	78.1 ab	7.6 a	157.6 a
1 seedless pear	77	50.0 bcdef	6.2 cde	56.2 bc	6.3 a	155.0 a
2 seedless pears	77	53.1 bcde	31.2 ab	84.3 ab	6.5 a	233.2 a
1 seeded pear	77	31.2 ef	21.9 abcd	53.1 bc	7.7 a	169.6 a
2 seeded pears	77	40.6 cdef	31.2 ab	71.8 ab	8.9 a	152.6 a
1 seedless pear	112	37.5 def	25.0 abc	62.5 bc	7.5 a	252.6 a
2 seedless pears	112	28.0 ef	31.2 ab	59.2 bc	9.0 a	219.2 a
1 seeded pear	112	53.1 bcde	0.0 e	53.1 bc	8.5 a	——
2 seeded pears	112	42.8 cdef	19.8 abcde	62.6 bc	5.6 a	123.2 a

[x]Means within a column followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).
[y]At 31 days past full bloom, most spurs bearing seedless fruits still held 2 or more pears.

Table 2. The effect of seeded fruit development on the ability of Winter Nelis pear spurs to produce flower buds in 1968.[x]

Treatment	Days after full bloom (March 15)	Percentage of spurs that produced flower buds on:			Mean length (mm) of:	
		Short axillary shoots (1–25mm)	Long axillary shoots (longer than 25mm)	All axillary shoots	Short axillary shoots (1–25mm)	Long axillary shoots (longer than 25mm)
Control (flowers removed).....	0	66.6 a	10.7 a	77.3 a	6.8 a	159.2 a
Fruit removed from spurs bearing:						
1 seeded pear.....	31	18.8 b	3.1 a	21.9 bc	8.2 a	64.0 a
2 seeded pears.....	31	25.0 b	0.0 a	25.0 bc	6.6 a	—
1 seeded pear.....	47	12.5 b	6.2 a	18.7 bc	7.7 a	215.0 a
2 seeded pears.....	47	25.0 b	21.9 a	46.9 b	8.0 a	205.3 a
1 seeded pear.....	61	18.7 b	0.0 a	18.7 bc	8.3 a	—
2 seeded pears.....	61	15.6 b	21.9 a	37.5 bc	8.3 a	243.0 a
1 seeded pear.....	77	9.4 b	3.1 a	12.5 c	6.2 a	120.0 a
1 seeded pear.....	112	9.4 b	3.1 a	12.5 c	9.5 a	110.0 a

[x]Means within a column followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

to maturity formed such buds. Most of the inhibition of flowering occurred within 30 days after pollination. In the present experiment with 'Bartlett', 86.6% of the spurs that had their flowers removed and 57.8% of the spurs that carried seeded fruits to harvest maturity, developed flower buds (Table 1, Fig. 1). Thus, the inhibiting effect of seeded fruit development on flower-bud initiation in 'Bartlett' spurs was much less severe than in the 'Spencer Seedless' apple. With 'Winter Nelis', 77.3% of the spurs that had their flowers removed, and only 12.5% of the spurs that carried seeded fruits for 77 days or longer, developed flower buds (Table 2, Fig. 1). In this respect 'Winter Nelis' spurs behaved like apple spurs, which helps explain the biennial bearing tendency of this pear variety. Our data corroborate those of Chan and Cain regarding the period when most of the inhibitory effect occurred, i.e., within 31 days after F B.

With 'Spencer Seedless' apple, Chan and Cain (3) obtained about the same percentages of flowering spurs (95.3%) from spurs carrying seedless fruits to maturity as from spurs that had their flowers removed (97.3%). When 'Bartlett' spurs bearing seedless pears were defruited 31 days after F B, 93.8% of them produced flower buds

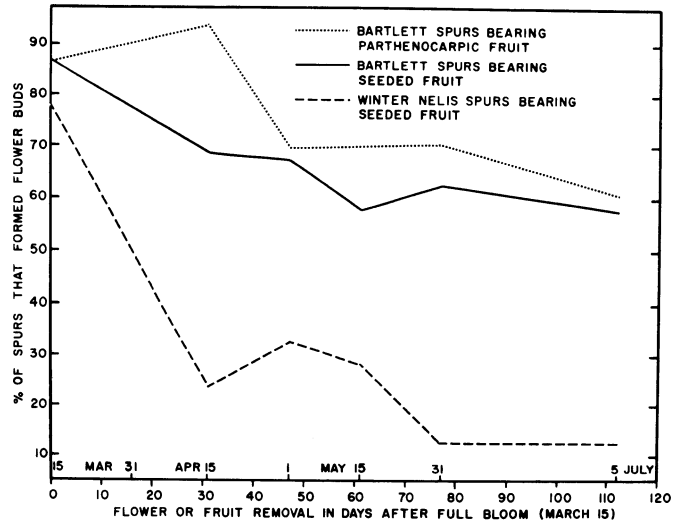

Fig. 1. The effect of the time of removal of seedless and seeded fruits on the ability of Bartlett and Winter Nelis pear spurs to produce flower buds. The data for spurs bearing either 1 or 2 pears were combined.

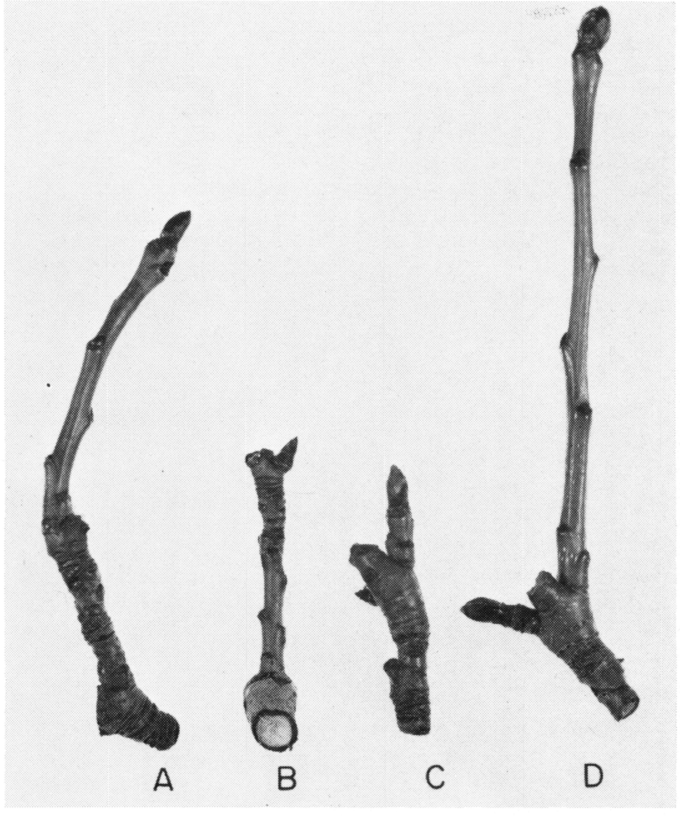

Fig. 2. Types of shoot and bud development, by December, 1968, of Bartlett pear spurs following flower or fruit removal during the spring and summer of 1968.
A. Flower bud on 56-mm shoot following removal of flower cluster at full bloom.
B. Vegetative bud on 2-mm shoot following removal of pear 31 days after full bloom.
C. Flower bud on 13-mm shoot following removal of pear 47 days after full bloom.
D. Flower bud on 104-mm shoot and flower bud on 8-mm shoot following removal of pear 77 days after full bloom.

(Table 1, Fig. 1). Spurs that had their seedless fruits removed at subsequent dates, however, had decreased percentages of flower bud formation; of those carrying either 1 or 2 seedless fruits until harvest, only 60.8% produced flower buds. Such reduction in flower bud formation in spurs with seedless fruits must be associated with some factor other than seed development, as no seeds were involved. Since the percentages of flower bud formation for 'Bartlett' spurs carrying either seedless or seeded fruits for periods longer than 31 days were similar, it seems logical to conclude that further reduction in flower bud formation was due to nutritional competition during fruit development. The fact that 'Winter Nelis' spurs carrying seeded fruits for 77 and 112 days produced only about half as many flower buds as spurs defruited after 31 days (Table 2), also indicates nutritional competition. Such a conclusion is inconsistent, however, with the fact that regardless of how long either seedless 'Bartlett' or seeded 'Bartlett' and 'Winter Nelis' fruits were carried, whether a spur carried 1 or 2 fruits had no consistent effect on flower bud formation (Tables 1, 2). This indicates that some growth regulator is probably more important in flower bud formation than simple nutritional competition from fruit development.

Effect of seed development. 'Bartlett' spurs carrying fruits with from 1 to 3 or 4 to 6 seeds developed almost as many flower buds as spurs carrying parthenocarpic fruit (Fig. 3). In spurs from which the fruits were removed 61 days after F B, there was a decrease in ability to form flower buds with an increase in number of developing seeds in the fruits they had carried. This relation was only slightly apparent for spurs defruited 77 days after F B, however, and was absent among spurs defruited at harvest, 112 days after F B. Chan and Cain (3) noted some increase in inhibition of flowering with increase in number of seeds per spur of 'Spencer Seedless' apple, but the greatest influence was the presence or absence of seeds.

With 'Winter Nelis', the ability of spurs defruited 61 days after F B to initiate flower buds decreased with increasing number of seeds up to 12 seeds per spur (Fig. 4).

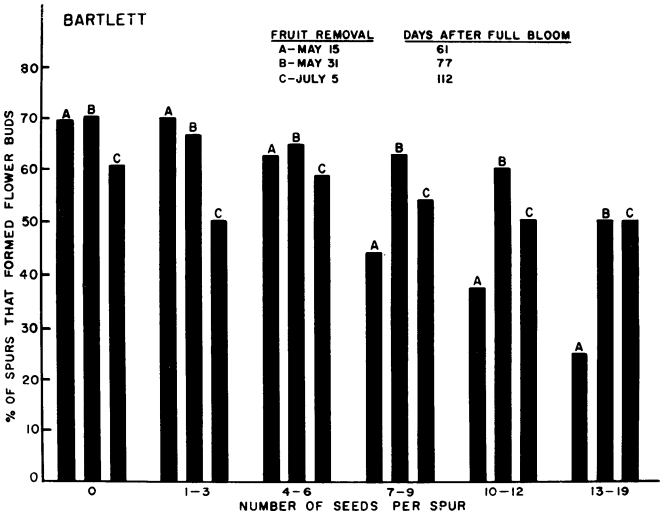

Fig. 3. The relation of the number of seeds in the fruit produced per spur of Bartlett to the percentage of spurs that formed flower buds. The large numbers of seeds are due to the presence of 2 fruits per spur. This figure and Fig. 1 are not directly comparable since the values in Fig. 1 are means for all spurs that carried seeded fruit and were defruited at a given time while those shown in this figure represent variable numbers of spurs that carried specific numbers of seed. The average number of seeds carried per Bartlett spur for 61, 77, and 112 days were respectively 7.2, 6.9, and 8.1.

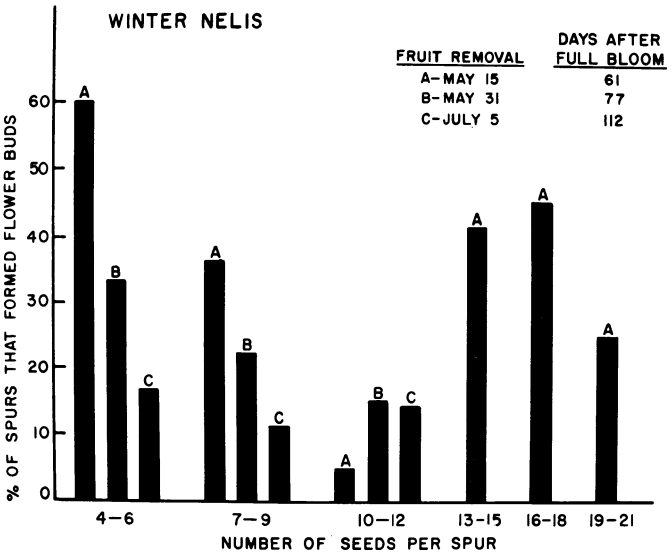

Fig. 4. The relation of the number of seeds in the fruit produced per spur of Winter Nelis to the percentage of spurs that formed flower buds. There were no fruits with less than 4 seeds, and the large numbers of seeds are due to the presence of 2 fruits per spur. No values are shown for 13 to 21 seeds per spur at 77 and 112 days after full bloom because sufficient numbers of spurs carrying 2 pears could not be found at these dates. This figure and Fig. 1 are not directly comparable since the values in Fig. 1 are means for all spurs defruited at a given time while those shown in this figure represent variable numbers of spurs that carried specific numbers of seed. The average number of seeds carried per Winter Nelis spur for 61, 77, and 112 days were respectively 12.1, 9.1, and 8.2.

With a higher number of seeds the relationship was inconsistent. Surprisingly, carrying 2 seeded fruits did not inhibit flower bud formation as much as did 1 fruit per spur. This is also suggested by the data in Table 2. In spurs defruited 77 days after F B there was only a slight decrease in ability to initiate flower buds with increasing number of seeds. In spurs defruited 112 days after F B, there was no distinct relationship between inhibition of flowering and seed number. With both 'Bartlett' and 'Winter Nelis', the stage of fruit or seed development at the time of removal appeared to have more influence on the ability of the spur to initiate flower buds than did the number of seeds or fruits the spur was carrying, or the length of time they had been carried.

By 61 days after F B, the 'Bartlett' seeds were 7.9 mm long and had attained 84% of their final length (Fig. 5). The embryos were 0.9 mm long, 11.4% of their final length. The seeds had reached nearly maximum length by 77 days, while the embryos had attained about half of their length and were in their most rapid period of growth. Both seed and embryo were close to full development at 112 days. In view of the data presented in Fig. 1 and 3, the influence of seed development on flower bud formation, whether due to utilization of a substance necessary for flower bud induction or to the exudation of a flower bud inhibiting substance, must have occurred during the early stages of growth. Perhaps, as reported for the apple (10), high levels of indoleacetic acid oxidase during the early stages of embryo growth resulted in reduced indoleacetic acid for flower bud formation.

The unfertilized ovules in the parthenocarpic fruits were in their most active period of growth between 41 and 62 days after F B, and reached maximum size about 77 days after F B (Fig. 5). It is interesting that these ovules continued growth for about the same period as the fertilized ovules in the seeded pears. Inhibition of

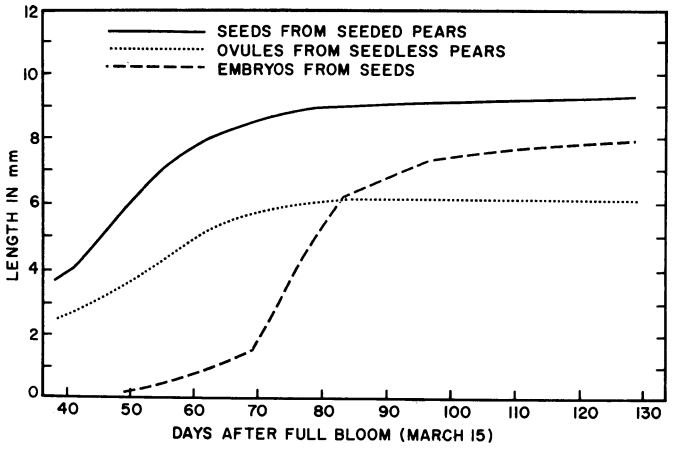

Fig. 5. Growth of seeds and embryos in seeded Bartlett pears versus growth of unfertilized ovules in seedless Bartlett pears.

flower bud formation in spurs carrying seedless fruits was first indicated in spurs defruited 47 days after F B and the level of inhibition remained relatively constant in spurs defruited 61 or 77 days after F B (Table 1, Fig. 1). Perhaps the actively developing ovules produced or utilized some substance that influenced flower bud formation. The fact that there was no inhibition of flower bud formation in spurs carrying seedless pears to 31 days past F B may indicate that at this time the ovules were not advanced enough to influence flower bud formation. The greater inhibition of flower buds in spurs that carried their fruits until harvest maturity must have been due to some other cause, since there was little or no ovular development after 77 days.

Growth promoter from fruit exudate. The growth-promoting activity of the exudate from the seedless pears was relatively high from 21 to 60 days after F B in relation to that of the seeded fruits (Fig. 6). This agrees with early evidence of Gustafson (6), who found that the auxin content of the ovaries of flowers from orange, lemon, and grape varieties that produce fruits parthenocarpically was higher than in the ovaries of corresponding varieties that required fertilization for fruit set. Since the greatest difference in flower bud formation between spurs

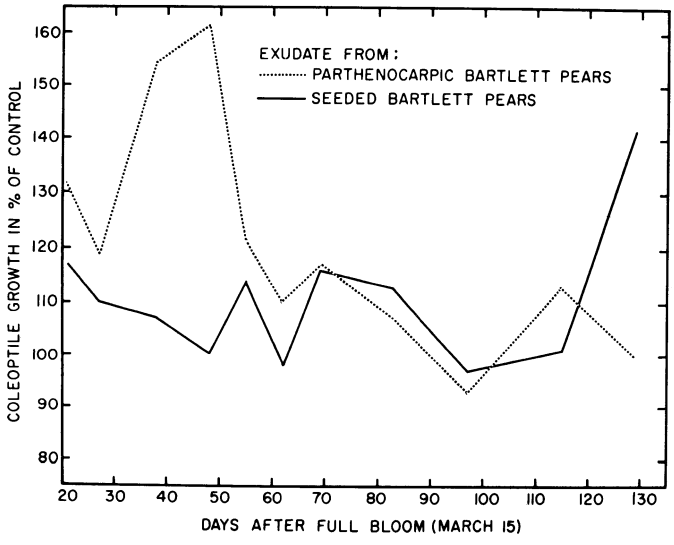

Fig. 6. The growth promoting activity, as expressed by wheat coleoptile elongation, of the exudate from seedless versus seeded Bartlett pears collected throughout the growing period. The results are expressed on the dry weight basis of the pears.

carrying seedless versus seeded fruits also occurred during this period (Fig. 1), it appears that the growth substance might be responsible for the increased flower bud initiation in spurs carrying seedless fruits. The maximum growth-promoting activity was effected by the exudates from parthenocarpic pears collected 38 and 48 days after F B (Fig. 6), but growth activity of the exudates from pears collected 55 and 62 days after F B was greatly diminished. The unfertilized ovules in the seedless pears were in their most rapid period of growth 55 days after F B (Fig. 5) and continued growth for about 3 weeks after the growth activity of the exudate from the seedless pears dropped to near that of the seeded fruits. The rapidly developing ovules apparently utilized or reduced the production of the growth-promoting substance and this caused a reduction in flower bud formation.

The seeded 'Bartlett' fruits were exuding minimum amounts of growth-promoting substance 48 and 62 days after F B (Fig. 6). Figure 1 indicates that spurs from which seeded fruits had been removed 61 days after F B had relatively low percentages of flower bud formation. Also, their ability to initiate flower buds decreased with increasing number of seeds (Fig. 3). At this time the embryos were still less than 1 mm in length (Fig. 5), and had not reached their period of most rapid growth. It is interesting that the greatest difference in growth-promoting activity between the exudates of seedless and seeded fruits occurred 38 and 48 days after F B, before and during the earliest stages of embryo development. Thus, fertilization and the earliest development of the embryo seemed to bind, or prevent the production of the growth-promoting substance. Another possibility is that interference by growth inhibitors from the seeded pears may have masked the presence of growth promoters, as pointed out by Powell and Pratt (9) from studies of growth substances in the flesh of developing peach fruits.

The spurs from which seeded 'Bartlett' pears were removed 77 days after F B had only slightly increased inhibition of flower bud formation with increased seed number (Fig. 3). At this time the embryos were approximately 4.4 mm in length, and were in their most rapid period of growth (Fig. 5). But, suprisingly, the growth activity from the exudate was relatively high for the seeded fruits (Fig. 6), and was approximately equal to that from the seedless pears. The flower-forming ability of the spurs carrying seeded fruits until harvest maturity apparently was not influenced by seed number (Fig. 3). The seedless fruits collected at this time exuded somewhat more growth-promoting chemical than did the seeded ones (Fig. 6), and spurs carrying the seedless fruits to harvest had somewhat higher percentages of flower buds than those carrying seeded ones (Fig. 1). At the final date of sampling, 129 days after F B, the seeded fruits exuded more of the growth-promoting substance than the seedless ones. This may have been due to the fact that at this time the seeds were fully developed, allowing the growth promoter to be released. The exudate from the seedless fruits, however, decreased as there was no reservoir of growth substance to be released. Exudation of the growth-promoting substance tended to fluctuate, and when seeded or seedless fruits were removed from the spur during or just following a period of relatively high exudation, flower bud initiation was more likely to follow. The response of the spur in regard to flower bud formation evidently was affected by the hormonal status at the time the flowers or fruits were removed.

The relationship between growth-promoting exudate and seed development was less distinct (Fig. 3, 5, 6) than that between growth-promoting exudate and flower bud

formation (Fig. 1, 6). Tukey (11) and Abbott (1) showed that seed destruction or removal reduced fruit set up to June drop, but after that time fruit set was not affected. In the present report the most dramatic effects of fruit removal on flower bud formation occurred up through June drop. Thereafter, removal of seeded or seedless fruits did not seem to be a primary factor in flower bud formation. The seeds may be the directing factor for both flower bud formation and fruit set through their influence on the growth regulator balance distal to the abscission zone. Although not shown for fruits, Addicott and Lynch (2) found that high levels of indoleacetic acid distal to the abscission zone were necessary to prevent leaf abscission. Obviously, seeds are not responsible for growth-promoter regulation in parthenocarpic pears, but early growth of their ovules (Fig. 5) may exert some control. The seedless pears did maintain a high level of growth promoter distal to the abscission zone prior to June drop, which may have influenced both flower bud formation and fruit set.

The growth-promoting aqueous exudates of seedless and seeded pears were partitioned into acidic ether and concentrated to a small volume. After spotting on TLC GF 254 plates, comparisons were made in 5 solvent systems. Depending upon the solvents used, separation indicated 1 to 8 compounds present in the exudates. There were no apparent differences between the compounds from the 2 types of fruits. From these comparisons, it appears that the differences in degree of response shown in Fig. 6 are a result of concentration rather than of the presence or absence of certain growth promoters. No attempt was made to identify the compounds in the promotive exudates or to catalog growth promotive versus inhibitory compounds. Hence, part of the difference in growth-promoting activity of the exudates from the 2 types of fruits could have been due to interference from variations in the amounts of growth-inhibiting substances.

LITERATURE CITED

1. ABBOTT, D. L. 1958. The effects of seed removal on the growth of apple fruitlets. *Ann. Rep. Long Ashton Res. Sta.* 1957. 52–56.
2. ADDICOTT, FREDRICK T., and RUTH STOCKING LYNCH. 1951. Acceleration and retardation of abscission by indoleacetic acid. *Science* 114:688–689.
3. CHAN, BOCK G., and JOHN C. CAIN. 1967. The effect of seed formation on subsequent flowering in apple. *Proc. Amer. Soc. Hort. Sci.* 91:63–68.
4. GRIGGS, W. H., L. L. CLAYPOOL, and BEN T. IWAKIRI. 1960. Further comparisons of growth, maturity, and quality of seedless and seeded Bartlett pears. *Proc. Amer. Soc. Hort. Sci.* 76:74–84.
5. ————, and BEN T. IWAKIRI. 1954. Pollination and parthenocarpy in the production of Bartlett pears in California. *Hilgardia* 22(19):643–678.
6. GUSTAFSON, FELIX G. 1939. The cause of natural parthenocarpy. *Amer. J. Bot.* 26:135–138.
7. MARTIN, GEORGE C., M. IONA R. MASON, and HAROLD I. FORDE. 1969. Changes in endogenous growth substances in the embryos of *Juglans regia* during stratification. *J. Amer. Soc. Hort. Sci.* 94(1):13–17.
8. NITSCH, J. P., and COLETTE NITSCH. 1956. Studies on the growth of coleoptile and first internode sections. A new sensitive, straight-growth test for auxins. *Plant Physiol.* 31:94–111.
9. POWELL, LOYDE E., and CHARLOTT PRATT. 1966. Growth promoting substances in the developing fruit of peach *(Prunus persica* L.). *J. Hort. Sci.* 41:331–348.
10. TEUBNER, F. G., and A. E. MURNEEK. 1955. Embryo abortion as mechanism of "hormone" thinning of fruit. *Mo. Agr. Exp. Sta. Res. Bul.* 590:1–88.
11. TUKEY, H. B. 1936. Development of cherry and peach fruits as affected by destruction of the embryo. *Bot. Gaz.* 98(1):1–24.

Lithium Toxicity in 'Marsh' Grapefruit in Arizona[1]

R. H. Hilgeman,[2] W. H. Fuller,[3] L. F. True,[4] G. C. Sharples,[5] and P. F. Smith[6]

University of Arizona, Tucson

Abstract. Surveys were made of Li in leaves, irrigation water and soil in groves of 37 to 43 year old 'Marsh' grapefruit on sour orange rootstock. Lithium in leaves increased during the late summer. Leaves with 50 to 60 ppm Li in September generally developed necrotic lesions on margins below the tip in November when they contained 60 to 90 ppm Li and abscissed within 1 to 4 months. Lithium varied widely between spring-cycle leaves on the same tree and within the leaf where it accumulated in the lesions. Severe Li toxicity symptoms were associated with 0.18 to 0.25 ppm Li in the irrigation water, 0.7 to 1.0 ppm in the soil and from 68 to 232 ppm in spring-cycle leaves in November. Vigorous growth and high yields occurred with 24 to 34 ppm Li in the leaves, 0.07 to 0.11 ppm Li in the irrigation water and 0.3 to 0.4 ppm in the soil. Severe leaf symptoms with Li content as high as 175 ppm were induced by soil applications of LiCl under field conditions.

In certain 'Marsh' grapefruit groves, planted between 1926 and 1932 in the Salt River Valley, leaves have developed necrotic lesions on the margins between November and March, followed by premature leaf abscission. In the South Mountain district this condition has ranged from 10 to 80% defoliation in different years and has occurred since 1939. The injury was attributed to Cl toxicity. Variations were assumed to be caused by differences in water quality which varied from low Cl when totally applied from the Salt River to high Cl when totally supplied from wells.

Beginning in 1963, several surveys were made to determine nutrient levels of leaves from groves with different fruit quality. These surveys showed low Cl (0.03 to 0.07%) and this was unrelated to leaf injury. In March 1968, the junior author collected leaves with necrotic lesions and found them to contain from 55 to 68 ppm Li.

[1]Received for publication September 30, 1969. University of Arizona Agricultural Experiment Station Journal Series paper No. 1560.

[2]Horticulturist, [3]Biochemist, [4]Agricultural Agent, [5]Assoc. Horticulturist, University of Arizona Agricultural Experiment Station, [6]Plant Physiologist, Crops Research Division, U. S. Department of Agriculture, Orlando, Florida.