Speed and uniformity of pepper seed germination can be enhanced by providing GA_3 in the germination water during the 24 hr subsequent to radicle emergence. All cultivars tested responded with more rapid and uniform germination. Detrimental effects from suitable GA_3 treatments were not observed and some cultivars were stimulated in speed of emergence and seedling growth. Using GA_3 for germinating pepper seeds for use in fluid drilling would increase seed germination costs $15 to $20/ha (6 to 8 μg GA_3/mg of dry seed and 50 to 75 mg of seed/ml of solution). This additional cost is justified to avoid planter clogging and to gain uniformity in radical emergence, seedling emergence and possibly in crop maturity.

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Effects of Mechanical and Hand Pruning, Tree Spacing, and Limb Bending on Tree Development and Yield of Hedgerow 'Delicious' Apples on Malling Merton 106 Rootstock[1]

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Abstract. **A combination of mechanical and hand pruning each year from 1971–1976 reduced pruning time over that of hand pruning alone for 'Delicious' apple (*Malus domestica* Borkh.). Yield was not significantly affected by pruning method with one exception in 1975. The use of the mechanical pruner destroyed the framework of the tree by inducing a thick canopy and reducing light penetration. Yield was increased by limb positioning at both the 2.3- and 3.0-m spacings. In 1974, higher yields were obtained with the 1.5-m spaced trees and in 1979 with the 3.0-m spaced trees. Average fruit weight was less for the 1.5-m spaced trees than for the 3.0-m spaced trees.**

Two major problems of the apple industry are increasing costs of production and a lack of qualified workers, particularly for pruning and harvesting operations (1, 2, 7). Kelsey et al. (11) reported in 1971 that pruning accounted for over 30% of apple production cost. In 1979, Smith and Ferree (14) reported that training of trees accounted for 43% of preharvest labor requirements. In an effort to improve pruning efficiency and reduce cost, research with various mechanical pruners has been conducted by a number of research workers (1, 2, 4, 9, 13). Even though the use of mechanical cutter bars to hedge and top trees reduces time necessary to prune orchards, such pruning results in a dense periphery of vigorous shoot growth. This dense growth reduces light penetration into the canopy, which results in suppressed spur formation, spur death, and poorly colored, small fruit (1, 2, 7).

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Tukey (16) reported that tree topping and hedging do nothing more than set the limits of tree form. Whereas, hand pruning is a training operation which not only sets the limits of tree form, but more importantly helps regulate the productivity of the bearing wood. Higher quality, premium sized fruits are produced on two-year-old spurs and three-year-old branch portions than on older wood in the fruiting canopy (12, 16). These fruiting areas are more inclined to flower and less inclined toward alternate bearing (12). Detailed pruning and training in the older portion of the fruiting canopy will induce the development of young fruiting wood. This detailed pruning can only be done by hand. Proper hand pruning in certain trees has increased yields by 30% over those achieved by mechanical pruning (16). Yields are important in determining the cost of producing a bushel of fruit (4, 5). Non-harvest production cost per bushel decreases as yield per acre increases because the cost of most non-harvest operations does not change with yield differences. Pruning and thinning were the non-harvest operations most likely to increase in cost with increasing yields. However, the percentage of the cost of non-harvest operations for producing a bushel of fruit remained about the same for pruning in the estimated cost per box of fruit at selected annual yield levels (4).

This research was conducted to determine the effect of mechanical pruning and mechanical pruning plus supplemental hand pruning on time necessary to prune, on yield/ha, and on tree development; and the effect of limb positioning and tree spacing on yield/ha.

Materials and Methods

Mechanical and hand pruning. A pruning study was established on 'Vance Delicious' apples in their 9th leaf on MM 106 rootstock. The trees were planted at a spacing of 4.6 m (15 ft) by 6.1 m (20 ft). The trees were trained to a modified central leader and formed a hedgerow planting in the row. Trees were hand pruned at the beginning of the experiment. Treatments consisted of 1) mechanical pruning annually, 2) mechanical pruning plus detailed hand pruning annually, 3) hand pruning annually, and 4) mechanical pruning annually plus hand pruning the 1st, 3rd, and 5th years. Each treatment was replicated 4 times in a randomized complete block design with 10 trees per replication.

Mechanical pruning was accomplished with a Fossum tree pruner mounted on the front of a tractor. The pruner blade was set at an 80° angle from the horizontal, so that each side of the tree and top were cut at a slant, cone shape, removing the previous year's growth. Trees in the hand pruned treatments were maintained approximately the same size as the mechanically pruned trees by a mold and hold type pruning system. The time necessary to do both the mechanical and hand pruning was recorded. Tree fruiting height was maintained at 2.44 m (8 ft) to maintain a fruiting height that would allow harvesting without the use of ladders.

Light readings were taken in 1974 with a Weston Model 756 sunlight illumination meter in the center of the tree at depths of 0.3 m (1 ft), 0.6 m (2 ft) and 1.2 m (4 ft) below the canopy surface. Similar readings were taken near the outer periphery of the limb spread.

Recommended practices for fertilization and pest management were followed (3, 15). Fruit were thinned with 4.1 g/liter (2 lb/100 gal) of Sevin 21 days after full bloom, followed by hand spacing and thinning of clusters.

Limb bending. 'Wellspur Delicious' apple trees on MM 106 rootstock were planted in January 1969 with spacings of 1.5 m (5 ft), 2.3 m (7.5 ft), and 3.0 m (10 ft) between trees in the row and 6.7 m (22 ft) between rows. Trees were trained to a modified central leader with major scaffold limbs developed at a 65° to 90° from the horizontal by the use of wire spreaders during the first few years of the tree's life. In the spring of 1973 the trees were topped at a height of 2.44 m (8 ft) with a Fossum tree pruner, followed by uniform, detailed hand pruning. The 1.5 m spaced trees had formed a hedgerow by the time the pruning experiment was begun.

A randomized complete block design with 4 replications of 5-tree plots was used to determine how tree spacing, conventional training, and horizontal placement of major scaffold limbs would affect weight and number of fruit produced. With trees spaced between 2.3 and 3.0 meters apart, limbs were placed in a horizontal position by pulling them down and tying them in position (bending). Weight and number of fruit per tree were recorded annually from 1974 through 1977 and in 1979, and expressed on a hectare basis. Yield records were not recorded in 1978 because of a poor fruit set.

Results and Discussion

Mechanical and Hand Pruning. Use of the mechanical pruner destroyed the desired shape and framework of the tree. As many as 8–10 shoots developed around each cut made by the mechanical pruner, if detailed hand pruning was not done. Trees had a thick canopy which shaded out fruiting wood in the interior of the tree, made insect and disease control difficult, and reduced the amount and intensity of fruit red color development, as reported by earlier researchers (1, 2, 7).

Table 1. Time required to prune 'Vance Delicious' apple trees on MM 106 rootstock in a hedgerow and planted in 1964.[z]

	Mean time required to prune 10 trees (min)														
	1972			1973			1974			1975			1976		
Treatment	Hand	Machine	Total	Hand	Machine	Total	Hand	Machine	Total	Hand	Machine	Total	Hand	Machine	Total
Mechanical pruning only	none[y]	6	6	none	3	3c	none	3	3c	none	4	4c	none	4	4c
Mechanical pruning plus hand pruning	112b[x]	5	116b	145b	3	148b	163b	3	166b	232b	3	235b	240b	3	243b
Hand pruning only	148a	none	148a	249a	none	249a	266a	none	266a	296a	none	296a	355a	none	355a
Mechanical pruning annually plus hand pruning 1st, 3rd, and 5th years	111b	5	116b	none	3	3c	271a	3	274a	none	4	4c	315ab	3	318ab
		NS			NS			NS			NS				

[z]Experimental trees were established in 1964 and were in their ninth leaf at the initiation of the experiment in 1972.
[y]"none" indicates pruning not done as a treatment.
[x]Means within columns separated by Duncan's multiple range test, 5% level.

Table 2. Effect of pruning method on yield of 'Vance Delicious' apple trees on MM 106 rootstock in a hedgerow and planted in 1964.[z]

Treatment	MT/ha (based on 358 trees/ha)[y]				
	1972	1973	1974	1975	1976
Mechanical pruning only	20.5[x]	28.2	25.7	20.8b	25.5
Mechanical pruning plus hand pruning	19.2	26.0	31.2	27.6a	36.9
Hand pruning only	17.2	23.0	22.7	22.1ab	30.7
Mechanical pruning annually plus hand pruning 1st, 3rd and 5th years	20.5	29.2	30.8	26.0ab	36.2
	NS	NS	NS		NS

[z]The experimental trees were established in 1964 and were in their ninth leaf at the initiation of the experiment.
[y]Tree spacing 6.1 x 4.6 m (20 x 15 ft); 358 trees/ha.
[x]Means within columns separated by Duncan's multiple range test, 5% level.

A combination of annual mechanical and hand pruning reduced pruning time over that of just hand pruning (Table 1). Mechanical pruning prior to hand pruning reduced the time required to hand prune by 40, 39, 22, and 32% in the 2nd, 3rd, 4th, and 5th years, respectively. The plots which were mechanically pruned annually plus hand pruned in alternate years did not differ in time required to prune the treatments pruned only by hand. However, hand pruning time was reduced about 50% over the 4 years due to alternate year pruning. Time necessary for mechanical pruning did not vary between mechanically pruned treatments.

Light penetration into the center of hand pruned trees was 4–10 times greater than for trees mechanically pruned only, (data not presented). Small differences were recorded for light penetration into the branches on the outer periphery of the tree. Thus, there appeared to be little difference in light penetration among the treatments.

The heavy pruning necessary to maintain the trees at the 2.44 m fruiting height was severe, and resulted in excessive vegetative growth annually. Gilbert (8) reported that a grower in Washington grew closely spaced trees at a height of 4.3 m. Trees were maintained at this height by removing annually all terminal growth. It is desirable to maintain tree height as low as possible to increase harvest efficiency and to reduce the need for long ladders. McBirney (13) reported the harvest picking rate to decrease by 4.5 kg per hour for each 0.3 m increase in bearing height of the tree.

In general, yield was not significantly affected by pruning method (Table 2). The only exception was in 1975 where a greater yield was produced on trees receiving mechanical pruning plus hand pruning than on trees receiving mechanical pruning only. The general trend was for trees mechanically plus hand pruned (treatments 2 and 4) to produce higher yields than for trees either hand pruned only or mechanically pruned only.

Time required to hand prune was reduced by use of a mechanical pruner prior to hand pruning; yield was not adversely affected. However, this investigation shows that mechanical pruning to maintain a 2.44 m fruiting height of 'Vance Delicious' apples (a non-spur) on MM 106 rootstock is not satisfactory for high density orchards due to excessive vegetative growth and its effects on fruit coloring, light penetration, and tree shape. Results may have been different if a greater tree height had been maintained. However, Tukey (16) reported that possibly no other single operation in fruit production is as important as training, and to date, nothing has replaced trained labor for this particular operation. Proper training and care of apple trees in the early years of the orchard's life will enable the grower to cope with labor shortages and increasing production cost in properly managing the orchard for production of quality fruit in later years (6, 10).

Limb bending. Cumulative yield was higher for 1.5 m spaced trees than for both 2.3 and 3.0 m spaced trees where the major scaffold branches were not spread (Table 3). However, the 3.0 m spaced trees with major scaffold limbs spread had a cumulative yield equal to the 1.5 m spaced trees. Limb spreading caused an increase in cumulative yield on the 2.3 m spaced trees by 13.4 metric tons per hectare over non-spreading.

The 1.5 m spaced trees produced higher yields in the early years, but the 3.0 m spaced trees produced more in 1979. The number of fruits per hectare followed the same trend as the yield per hectare, except in 1979 when yield was reflected by a low average fruit weight and a large number of fruits.

Average fruit weight was less for the 1.5 m spaced trees except for the 2.3 m spaced trees with limbs not tied in position in 1979. However, limb positioning did not affect average fruit weight in

Table 3. Effect of tree spacing and limb bending in a hedgerow on yield of 'Wellspur Delicious' apple trees on MM 106 rootstock planted in 1969.

Treatment of major scaffold limbs	MT/hectare						
	1974 (6th leaf)	1975 (7th leaf)	1976 (8th leaf)	1977 (9th leaf)	1978[z] (10th leaf)	1979 (11th leaf)	Cumulative yield/ha
3.0-m (10.0-ft) spacing in row (497 trees/ha)							
Bent[y]	11.5b[x]	14.0bc	15.5a	24.1b	---	45.0a	110.1a
Check	9.7b	12.3c	13.7a	18.3b	---	42.7ab	96.7b
2.3-m (7.5-ft) spacing in row (648 trees/ha)							
Bent	16.5a	19.2a	18.4a	17.5b	---	30.8bc	102.4b
Check	11.6b	16.1abc	13.3a	18.1b	---	29.8bc	89.0c
1.5-m (5.0-ft) spacing in row (995 trees/ha)							
Check	20.8a	17.5ab	15.8a	36.5a	---	22.8c	113.4a

[z]No crop.
[y]The major scaffold limbs present on the 5-year-old central leader trees were tied down to a horizontal position at the initiation of the experiment. The check treatment consisted of trees that were trained to a central leader and the major scaffold limbs were not bent to a horizontal position.
[x]Means within columns separated by Duncan's multiple range test, 5% level.

Table 4. Effect of tree spacing and limb bending in a hedgerow on average weight of fruit produced by 'Wellspur Delicious' apple trees on MM 106 rootstock planted in 1969.

Treatment of major scaffold limbs	Mean wt (g)/fruit						
	1974	1975	1976	1977	1978[z]	1979	avg.
3.0-m (10.0-ft) spacing in row (497 trees/ha)							
Bent[y]	163	162	199	147	---	171a[x]	168ab
Check	163	175	215	150	---	159a	172a
2.3-m (7.5-ft) spacing in row (648 trees/ha)							
Bent	158	161	200	132	---	149a	160b
Check	153	178	204	145	---	146a	165ab
1.5-m (5.0-ft) spacing in row (995 trees/ha)							
Check	143	168	211	136	---	95b	151b
	NS	NS	NS	NS			

[z]No crop.

[y]The major scaffold limbs present on the 5-year-old central leader trees were tied down to a horizontal position at the initiation of the experiment. The check treatment consisted of trees that were trained to a central leader and the major scaffold limbs were not bent to a horizontal position.

[x]Means within columns separated by Duncan's multiple range test, 5% level.

any given season (Table 4). The 5-year average fruit weight was less for the 1.5 m spaced trees than for the 3.0 m spaced trees on which the branches were not positioned, but did not differ from the 2.3 m spaced trees.

The 3.0 m spacing was shown to be better for 'Wellspur Delicious' (a spur-type) on MM 106 rootstock in a hedgerow than the 1.5 and 2.3 m spacings. The closer spacings had more plants per hectare, and the 1.5 m spaced trees soon became crowded. Major scaffold limb positioning developed a tree that has the potential for producing a higher yield.

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