spring only a few days may be suitable for working the soil. Continuous planting is 6 to 8 times faster than planting with the auger, and 1 worker can be eliminated. In a continuous furrow, roots are not confined to a hole environment. Instead, a mole hole system permits free movement of water and roots. Small family orchards could be planted with the aid of a ditch trencher, since it's use requires comparatively little operational skill. The ditch trencher was associated with better tree performance than the auger, but whether or not it was comparable to the tree planter was debatable. The blades on the trencher chain cut a smooth-sided ditch, a problem that could possibly be alleviated by reversing the blades on the chain. Tukey has tried this in Pennsylvania and reports that glazing is reduced. On orchards with shallow soils, heavy soils, stratified sands, or man-made compaction problems, it would be prudent to conduct personal tests. The subsoiler on the tree planter may be the solution in some cases, but there will probably be sites where backhoe renovation is needed. Although the backhoe is slow, a number of researchers have reported great success with this method, even on problem soils (3, 6). Finally, the fact cannot be ignored that tractor-mounted augers are established orchard equipment. The burnishing action of the auger could be reduced by modifying the side flange of the auger, or the sides of the auger-drilled hole could be broken up with a shovel. In this study, trees planted by the modified auger demonstrated growth comparable to the tree planter, but anchorage was inferior. Perhaps a better modification could be engineered.

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Growth Responses and Leaf Nutrient Concentrations of 'Fordhook 242' Lima Beans as Affected by Fertilizer Treatment and Plant Stand[1]

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Additional index words. Phaseolus lunatus, maturity, nitrogen source

Abstract. **'Fordhook 242' lima beans (*Phaseolus lunatus* L.) were grown in 1973-1974 with 16 fertilizer treatments and 2 plant stands (11 and 16 plants/m) at 0.96 m row width. Soils used were low in P and Mg, medium in K and high in Ca. Banded fertilizer treatments were 28 or 56 kg/ha of N, P, K, and Mg in various combinations, 5 N sources compared at 56-56-0 kg/ha, and 2 commercial fertilizers, 18-46-0 and 8-24-8. With an increase in plant stand from 11 to 16 plants/m of row, vine growth was increased and maturity was delayed but yield of marketable beans was not influenced. Yields were increased an average of 74% by 6 treatments at or close to 56-56-0 kg/ha with and without K when compared to check. N sources, P and K all affected maturity. Urea, $(NH_4)_2SO_4$, and NH_4NO_3 resulted in higher yields than $Ca(NO_3)_2$ and $NaNO_3$ primarily by hastening maturity. Leaf concentrations of Ca and Mg were enhanced by P and all N sources while leaf K was lowered. Applied K depressed leaf Mg. Thus when both K and Mg were added to NP treatment, Mg leaf concentration was not changed.**

The 'Fordhook 242' lima bean, the most common of the large seeded type, is widely grown in Pennsylvania for fresh market and freezing. There have been few spacing studies and little is known about its specific nutrient requirements.

Odland (6) showed that spacing in the row of 7.5 cm resulted in higher yields than either 15 or 30 cm spacing but results were not consistent. Larson and Peng-Fi (4) and McGillivray et al. (5) also showed that closer spacing in the row of 5-10 cm resulted in higher yields.

There have been few reports on fertilizer needs. Increased yields were obtained with an increase in 4-12-4 fertilizer from 392 to 784 kg/ha at 7.5 cm plant spacing by Odland (6). Dallyn and Sawyer (2) reported good yield responses to 112 and 224 kg/ha of N and P, respectively, but no response to K. Parker (7) showed that 1120 kg/ha of 6-12-5 fertilizer placed in bands 5 cm below and 5 cm to each side of the seed gave the highest yields when compared with 4 other placements. Only a few experiments have included plant analysis (3).

These experiments were carried out to determine more precisely the nutritional requirements using a wide range of

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fertilizer treatments and 2 plant stands. Comparing fertilizer responses and nutrient interactions of lima beans with those of snap beans (8) was of particular interest.

Materials and Methods

Fertilizer experiments using 'Fordhook 242' bush lima beans were carried out in 1973 and 1974 at the Horticultural Research Farm at Rock Springs in Centre County on adjacent areas of Hagerstown silt loam soil. Soil samples were taken before planting and analyzed by the Soil Testing Laboratory of the Pennsylvania State University. Soil analysis values for the 1973 and 1974 sites, respectively, were as follows: pH = 6.2 and 7.0, P = 62 and 50 kg/ha, CEC = 14.2 and 13.7 meq/100 g soil and % saturation, K = 2.2 and 2.6, Mg = 6.0 and 3.2 and Ca = 65 and 92. Both sites were interpreted to be low in P and Mg, medium in K and high in Ca.

Fertilizer treatments (Table 1) consisted basically of 28 and 56 kg/ha of N, P, K and Mg, some applied singly, and others in various combinations as urea, triple superphosphate, muriate of potash and Magox (trademark of Basic Chemicals, Cleveland, Ohio) respectively. Additional treatments included 4 N sources from $(NH_4)_2SO_4$, $NaNO_3$, $Ca(NO_3)_2$ and NH_4NO_3 at 56 kg/ha N and P, and 2 high-P commercial fertilizers, 18-46-0 [diammonium phosphate (DAP)] and 8-24-8 at 56 kg/ha P. Treatments were arranged in a randomized block design with 3 replications.

In each 6.1 m plot row, 150 seeds were planted and the fertilizer treatment was simultaneously applied in a single band, 5 cm to the side of and 5 cm below the seed, using a specially-developed tractor-mounted belt planter. All fertilizer plots consisted of 2 rows at 0.96 m spacing which were thinned to either 11 or 16 plants/m.

At time of bloom, the second oldest trifoliate leaf was selected from 10 plants for leaf analysis. The samples were cleaned by dipping in a detergent solution, thoroughly rinsed in distilled water, dried and ground. Samples were analyzed for N using a Technicon autoanalyzer with manual digestion (industrial method No. 103-70A) and 11 elements by means of an optical emission spectrometer (1).

All plots in a replication were harvested on the same day. Harvests averaged 74 and 84 days from seeding in 1973 and 1974, respectively. Lima beans in a 4.6 m section of each plot row were cut at ground level and weighed. Pods were picked, weighed, and divided into flat (immature), marketable, and rotten. Pod size (no./kg) and percent of shelled beans were determined. Shelled samples were steam-blanched in order to separate white from green beans. The percentage of white (mature) beans was used as the primary maturity rating. All field and leaf analyses data were subjected to analysis of variance. Duncan's LSD test was used to determine mean separation where K = 100 was considered equal to the 5% level (9).

Results and Discussion

Growth responses. Over-all responses to fertilizer treatments during the 2 years are shown in Table 1. Vine weight was higher in treatments 2, 5, and 9 when compared to the check (up to a 25% increase) but the magnitude of these differences was relatively small compared to those of pod yields. Pod yields were higher in 6 treatments varying from 11-12 MT/ha, and averaged 74% more than the check. These were treatments 9, 14, and 15 comprising N and P (56 kg/ha N from urea or ammonium nitrate and 56 kg/ha P and DAP at 56 kg/ha P) and treatments 5, 10, and 16 that included K (28 kg/ha of N, P and K, 56 kg/ha of N, P and K and 8-24-8 at 56 kg/ha P). Treatments 2-7 which had 28 kg/ha rates resulted in only moderate yield increases with the exception of the treatment with 28 kg/ha of N, P and K. Yields were higher with urea and ammonium nitrate than with the 3 other N sources.

In general, treatments that resulted in higher yields hastened maturity as judged by percentages of marketable and mature beans. For example, treatment 10, (56 kg/ha of N, P and K) had 93.2% marketable and 22% mature compared with 82.7% and 8.1% for the check, respectively. No treatment had a meaningful effect on the percentage of rotten pods which

Table 1. Effects of fertilizer treatments and in-row plant stands on yields, quality and maturity of 'Fordhook 242' lima beans.

N-P-K-Mg (source)[z] (kg/ha)	Vine[y] weight (MT/ha)	Pod yield (MT/ha)	Marketable pods (%)	Pod size (no./kg)	Shelled beans (%)	Mature beans (%)
1. 0- 0- 0- 0	11.8def	6.5f	82.7e	86.4ab	33.3fg	8.1f
2. 28- 0- 0- 0 (U)	13.3bc	8.1e	82.6e	86.7ab	34.7ef	17.1de
3. 0-28- 0- 0	10.6f	8.7e	90.0a-d	86.5ab	38.0bcd	20.7b-e
4. 28-28- 0- 0 (U)	11.6def	8.6e	88.4cd	86.0ab	36.8cde	20.9b-e
5. 28-28-28- 0 (U)	14.4ab	11.1ab	89.1bcd	83.9ab	35.8def	22.2bc
6. 28-28- 0-28 (U)	11.6def	9.9cd	90.5a-d	85.7ab	38.3bcd	22.5b
7. 28-28-28-28 (U)	12.5cd	8.8e	87.7d	83.5ab	35.9de	16.8e
8. 28-56- 0- 0 (U)	12.0de	10.5bcd	92.4abc	85.9ab	38.2bcd	19.7b-e
9. 56-56- 0- 0 (U)	14.7a	11.0ab	86.7de	82.0b	38.7bc	18.4b-e
10. 56-56-56- 0 (U)	12.6cd	12.0a	93.2ab	84.5ab	39.1bc	22.0bcd
11. 56-56- 0- 0 (AS)	11.5def	9.9cd	93.3ab	87.7ab	41.9a	31.8a
12. 56-56- 0- 0 (SN)	12.3cd	8.5e	77.7f	84.5ab	30.9g	10.1f
13. 56-56- 0- 0 (CN)	12.0de	8.5e	85.9de	82.7ab	37.9bcd	17.5cde
14. 56-56- 0- 0 (AN)	10.9ef	11.0ab	92.9abc	86.3ab	38.1bcd	22.8b
15. 50-56- 0- 0 (18-46-0)	11.4def	11.1ab	93.8a	88.6a	39.5ab	21.0b-e
16. 40-56-33- 0 (8-24-8)	12.1cde	11.6ab	93.4ab	83.0ab	38.3bcd	20.4b-e
In-row stand (plants/m)						
A. 11 (low)	11.2b	9.5a	89.3a	84.3b	38.4a	20.8a
B. 16 (high)	13.2a	10.0a	88.3a	86.2a	36.0b	18.1b

[z]N, P, K, and Mg were applied as urea (U), ammonium sulfate (AS), sodium nitrate (SN), calcium nitrate (CN), ammonium nitrate (AN), triple superphosphate, muriate of potash and Magox, respectively.

[y]Mean separation within a column for fertilizer or stand treatment by Duncan's Modified (Bayesian) LSD Test with K = 100.

Table 2. Effects of fertilizer treatments and in-row plant stands on leaf concentrations of 8 elements in 'Fordhook 242' lima beans.

N-P-K-Mg (source)^{z} (kg/ha)	Leaf concentrations (dry wt)^{y}							
	N^{x} (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (μg/g)	B (μg/g)	Na (μg/g)
1. 0- 0- 0- 0	3.89ab	.34a	2.45a	3.74g	.44h	134i	33b-e	114bc
2. 28- 0- 0- 0 (U)	3.96a	.31b	2.07cd	5.15def	.60cde	158hi	32cde	116bc
3. 0-28- 0- 0	3.27g	.31b	1.96de	6.08a	.59c-f	196gh	38a	95bc
4. 28-28- 0- 0 (U)	3.44efg	.27d	2.08cd	5.39b-e	.54fg	241def	34bc	105bc
5. 28-28-28- 0 (U)	3.41fg	.27d	2.25abc	5.56a-d	.45h	269bcd	33b-e	120b
6. 28-28- 0-28 (U)	3.60c-f	.27d	1.94de	5.57a-d	.67ab	216fg	34bc	105bc
7. 28-28-28-28 (U)	3.65cd	.27d	2.16bcd	4.91ef	.58def	202g	32cde	102bc
8. 28-56- 0- 0 (U)	3.45efg	.28cd	1.78ef	5.95ab	.56efg	218fg	33b-e	112bc
9. 56-56- 0- 0 (U)	3.60c-f	.26d	1.80ef	5.70a-d	.60cde	257cde	33b-e	98bc
10. 56-56-56- 0 (U)	3.57c-f	.28cd	2.34ab	5.73abc	.52g	270bcd	33b-e	116bc
11. 56-56- 0- 0 (AS)	3.62cde	.27d	1.67f	5.71a-d	.68a	334a	33b-e	109bc
12. 56-56- 0- 0 (SN)	3.94a	.31b	2.16bcd	4.60f	.53g	137i	32cde	219a
13. 56-56- 0- 0 (CN)	3.97a	.31b	2.06cd	5.21cde	.58def	155i	33b-e	106bc
14. 56-56- 0- 0 (AN)	3.77bc	.27d	1.69f	5.76abc	.63bcd	231efg	33b-e	90c
15. 50-56- 0- 0 (18-46-0)	3.60c-f	.30bc	1.68f	5.70a-d	.63bcd	305ab	35b	92c
16. 40-56-33- 0 (8-24-8)	3.53def	.27d	2.26abc	5.42b-e	.56efg	288bc	31e	99bc
In-row stand (plants/m)								
A. 11 (low)	3.70a	.29a	2.08a	5.29a	.57a	227a	32b	110a
B. 16 (high)	3.59b	.28b	1.96b	5.48a	.57a	224a	34a	114a

^{z}N, P, K and Mg were applied as urea (U), ammonium sulfate (AS), sodium nitrate (SN), calcium nitrate (CN), ammonium nitrate (AN), triple superphosphate, muriate of potash and Magox, respectively.

^{y}No treatment affected significantly the leaf concentration of Fe, Cu, Al or Zn which averaged 388, 13, 438, and 22 μg/g, respectively.

^{x}Mean separation within a column for fertilizer or stand treatment by Duncan's Modified (Bayesian) LSD Test with K=100.

averaged 0.3%. Maturity was hastened by the ammonium-N sources and delayed by the nitrate-N sources, as shown by percentages or marketable and mature beans.

Higher in-row plant stand (Table 1), increased vine weight but not pod yield. Also pod size was smaller, and percentages of shelled and mature beans were lower with the higher plant density. Thus the higher plant stand did increase vine growth but not yield of marketable beans, probably because maturity was delayed.

Leaf analyses. Over-all elemental leaf composition as affected by fertilizer treatments is shown in Table 2. No fertilizer treatment increased the leaf concentration of N, P, or K over the check. When N alone was added, leaf K concentrations were decreased, and leaf concentrations of Ca and Mg were substantially increased. When P alone was added, leaf concentrations of N, P, and K were decreased and those of Ca, Mg, Mn, and B were much higher than those of the check (Ca by 62%). When the NP treatment (28 kg/ha N and P) was compared to the check, N, P, and K leaf concentrations were reduced by 12, 20 and 15%, respectively, while Ca, Mg, and Mn leaf concentrations were enhanced by 44, 23, and 80%, respectively. When 28 kg/ha of K was added to the NP treatment (treatment 5), leaf Mg was reduced to a level similar to that of the check. When 28 kg/ha of Mg was added to the NP treatment (treatment 6), leaf Mg was increased but when both K and Mg were added (treatment 7), Mg was no higher than in the NP treatment and Mn leaf concentration was reduced. When an additional 28 kg/ha of P was added to NP treatment (treatment 8), leaf K was reduced. When 56 kg/ha rates of N and P (treatment 9) were compared to 28 kg/ha rates, only leaf Mg was increased. When 56 kg/ha of K were added to 2N2P treatment (treatment 10), leaf K increased and leaf Mg decreased.

Many differences in leaf concentrations resulted when N sources were compared. Application of $NaNO_3$ and $Ca(NO_3)_2$ resulted in higher levels of N, P, and K and lower levels of Mn when compared to urea and NH_4NO_3. The treatment with $NaNO_3$ source lowered leaf Ca and Mg and increased leaf Na. The treatment with NH_4NO_3 resulted in the highest Mg and Mn leaf levels. Urea and NH_4NO_3 had similar effects on leaf concentrations. Leaf levels from the 18-46-0 treatment were similar to those from the 56-56-0 treatment with NH_4NO_3 source except that the Mn concentration was higher. When 8-24-8 was compared to 18-46-0, leaf K was higher while leaf concentrations of P, Mg, Mn, and B were lower.

The higher plant stand (Table 2) had relatively minor effects on leaf nutrient concentrations. Leaf N, P, and K were about 5% lower at the higher stand. Considering the much higher vine weight with the high stand, fertilizer must have been used more efficiently or a greater portion must have been obtained from soil reserves. There was no indication that a higher rate of fertilizer was needed with the higher stand.

Compared to snap beans in previous experiments with similar fertilizer treatments (8), there was relatively little response in vigor (vine weight) with lima beans but much stronger responses in pod yields, primarily because of hastened maturity. With lima beans, yield increase was not associated with substantial increase in vine weight as was true with snap beans. In general, lima beans responded well to 56 kg/ha of N and P and thus had higher requirements for these 2 nutrients when compared with snap beans but results with K additions were inconsistent. Similar nutrient interactions to those shown for snap beans (8) were evident in that applications of N or P enhanced leaf Ca and Mg while applied K reduced leaf Mg. When both K and Mg were added to N and P, Mg leaf concentration was no higher than when neither was added.

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Flowering Crab Apples as Potential Pollinizers for Commercial Apple Cultivars[1]

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Additional index words. Malus sp., pollination, bloom date, flower color

Abstract. **Fifty-nine flowering crab apple cultivars (*Malus* spp.) were evaluated in 1977 and 1978 to determine time and pattern of bloom period relative to that of 5 commercial cultivars. The crab apple cultivars 'David', 'Simpson 10-35', and 'Ellen Gerhart' had similar bloom patterns with the commercial cultivars, 'Delicious', 'Jonathan', 'Golden Delicious' and 'Gallia Beauty'. Bloom patterns of 'Donald Wyman' and 'Indian Magic' were similar to the bloom patterns of 'Jonathan', 'Golden Delicious', and 'Delicious'. 'E.H. Wilson', *M. robusta* 'Erecta', 'Ormiston Roy', 'Sentinel', and 'Turesi' had bloom patterns that were similar with 'McIntosh'. Hand pollination with pollen from 10 crab apple cultivars resulted in fruit set on 'Delicious' equal to open pollination or hand pollination with 'Jonathan' pollen.**

Recent investigations in England (1, 2) and the United States (8, 10) have shown that flowering crab apples are effective pollinizers for commercial apple cultivars. The use of flowering crab apples would allow growers to plant solid blocks of one commercial cultivar, eliminating less profitable cultivars used solely for pollination purposes. Flowering crabs on dwarfing rootstocks may be interplanted between the trees of the apple cultivars and pruned so that they minimize the use of productive orchard space. Our study was initiated in 1977 to determine which flowering crab apples might be suitable pollinizers for commercial apple cultivars.

Materials and Methods

The study was conducted over a 2-year period using the crab apples available in the Secrest Arboretum at the Ohio Agricultural Research and Development Center. The study was concentrated in 3 phases: (a) evaluation of fruit setting capabilities of crab apple pollen on 'Delicious'; (b) evaluation of flower morphology and disease susceptibility; (c) evaluation of flower bud development and bloom patterns on both crab apples and commercial apple cultivars.

In fruit set studies, limbs bearing about 20 flower clusters on 23-year-old trees of an unknown red strain (Double Red) of 'Delicious' were covered with cheesecloth bags without emasculating prior to anthesis. At full bloom the bags were briefly removed and the flowers thinned to 2 per cluster to minimize effects of nutritional competition. Pollen from each of 10 flowering crab apples was applied with the tip of the finger to stigmas on 10 replicate limbs. The limbs were recovered until fruit set counts were taken just prior to the "June drop" (June 6, 1978).

Samples of the pollen were tested for their germination on an agar medium enriched with 10% sucrose and 30 ppm boron. Percent germination was determined after 24 hr by microscopic examination.

Evaluation of disease susceptibility was based on data compiled yearly over the past 15 years at various locations throughout the Midwest (7). The trees were evaluated in the field for the presence of apple scab, cedar apple rust, powdery mildew, and fireblight.

Flower bud development and bloom patterns were evaluated daily on all the crab apples and selected apple cultivars. Evaluations began when the earliest crab apple reached full pink and ceased when the last of the 5 commercial cultivars reached full bloom. The ratings were based on the percentage of open flowers in a 5-flower cluster, with counts made on 10-15 clusters selected at random over the entire tree. The average percentage value for each data was rounded to the nearest 10% and then correlated with flowering stage of the apple cultivar over the bloom period (1977, 16 days of evaluation; 1978, 21 days of evaluation). A significant correlation coefficient indicated that the development of crab apple bloom pattern was similar with that of the commercial cultivar. Overlapping bloom periods did not necessarily have significant correlations of bloom patterns. Crab apple flowering may have commenced prior to, or extended beyond flowering of the commercial cultivars; as in the relationship of 'Indian Summer' and 'McIntosh' in 1977. Free (5) has pointed out the necessity of overlapping and coinciding bloom patterns to ensure cross-pollination by bees.

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