Reprinted from AGRONOMY JOURNAL
Vol. 68, Nov.-Dec. 1976, p. 958-960

Plant Population Effects on the Seed Yield of *Phaseolus vulgaris* L.[1]

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ABSTRACT

Seed yields of *Phaseolus vulgaris* L. have not increased under the current production systems even with more precise management inputs. Recent studies of snap beans grown for processing suggested that yields could be increased by high density planting. Our study was made to evaluate the effects of plant populations on the seed yields of four representative field and snap bean cultivars grown under sprinkler irrigation on a Portneuf silt loam (Xerollic Calciorthid).

Two cultivars each of bush snap beans and semivining field beans were grown in plant populations of 107,600 to 968,700 plants/ha in nearly equidistant plant arrangements. The optimum plant population for seed yield for the bush cultivars was approximately 400,000 plants/ha and less than 300,000 plants/ha for the semivining cultivars. At smaller plant populations, seed yields decreased for the bush cultivars and remained constant for the semivining cultivars. The harvest index (seed weight/total plant weight) increased slightly for the bush cultivars as their plant population decreased, but remained constant for the semivining cultivars up to 300,000 plants/ha, then increased rapidly. The production index (seed yield/amount seeded) increased curvilinearly as plant population decreased for all cultivars. Plant maturity was advanced 7 to 10 days at the highest plant populations for all cultivars. Pods were located at upper nodes on the plants as the populations increased. These results suggest that greater seed yields could be expected with the equidistant plant arrangements as compared with conventional row plantings for the bush cultivars, but not for the semivining cultivars, primarily because of the ability of the semivining cultivars to compensate for the increased area/plant at smaller plant populations.

Additional index words: **Plant populations, Harvest index, Production index, Pod distribution.**

DRY edible field and snap bean (*Phaseolus vulgaris* L.) cultivars grown for seed under furrow irrigation are presently planted in row widths of 50 to 60-cm and spaced 5 to 7 cm apart within the row for maximum yields (9, 13). Under this production system, improving soil fertility levels and other management practices has not always increased bean seed yields.

The practice of using herbicides for weed control, increased sprinkler irrigation, greater flexibility in the harvesting methods, and the release of erect, higher pod setting cultivars has renewed interest in solid stand plantings as one way of increasing seed yields. Planting the rows closer, while simultaneously varying the within-row spacing, so that the plants are arranged more equidistantly, has been shown to increase seed yields (2, 4). Studies with snap beans for processing showed that pod yields could be increased up to 64% by planting in 30-cm rows as compared to 91-cm rows (5). Pod yields were highest for plants planted in a square (12.7 × 12.7-cm to 15.2 × 15.2-cm), with the optimum plant spacing depending upon the cultivar (11). Larger percentages of smaller pods were found in the closer plant spacings, however this may have been due to pod maturity differences between spacings at harvest.

Limited data indicate that seed yields are directly related to pod yields (8). However, the principle of yield component compensation states that the correlation among yield components will be negative if there is intraplant competition for nutrients and metabolites (1, 6). For example, an increase in number of pods/plant could cause a decrease in the number of seeds/pod and the weight/seed, resulting in no seed yield increase.

We made this study in 1972 and 1973 to evaluate the effects of equidistant spaced plant populations on the seed yields of four bean cultivars.

METHODS AND MATERIALS

Two bush snap bean cultivars, 'Canyon' and 'Blue Lake 274,' and two semivining field bean cultivars, 'UI-114' (a Pinto) and 'Big Bend' (a Red Mexican), were planted on a Portneuf silt loam soil (Xerollic Calciorthid) (Table 1). Fertilizers that supplied 56 kg N, 56 kg P, and 11 kg Zn/ha were disked into the seedbed prior to planting. No other fertilizers were applied. A preplant herbicide was applied each year, followed by handweeding during the growing season, when necessary. Plots were sprinkler-irrigated when tensiometers at a depth of 20 to 25 cm indicated that approximately 55% of the available soil moisture remained.

We used a systematic planting design where the positions of the plants were determined by the intersections of radii and arcs of concentric circles (12). The growing area occupied by each plant increased systematically as the radius increased. General characteristics of the design were:

A_1 — area/plant at the highest plant population $= 0.00985$ m^2
A_n — area/plant at the lowest plant population $= 0.09698$ m^2
τ — the rectangularity of the area occupied by a plant $= 1.0$
N — the number of spacings or populations in 1972 $= 8$; in 1973 $= 9$
θ — the angle between successive radii in 1972 $= 2°56'$; 1973 $= 2°40'$

Slightly different designs in 1972 and 1973 caused different plant populations, varying from 107,600/ha (43,560/acre) to 968,700/ha (392,040/acre). One complete circle (360°) was overplanted with a cultivar the last week of May and thinned to one plant/arc-radius intersect within 1 week after emergence.

Seed yield data were recorded from pairs of concentric circles for each plant population, with one concentric circle of plants used as a border between yield rows. Harvest index (seed weight/total plant weight) was recorded at harvest in 1972 from 20 plants/population. Only one replication of the Blue Lake 274 cultivar was harvested because of disease problems with the other replication. The numbers of pods/node were recorded at harvest for the Blue Lake 274 and Big Bend cultivars in 1973. Other general information observed was length of time to maturity, disease severity, and production index (seed yield/amount seeded).

Although these data were not suitable for routine statistical analysis because the plant spacing treatments are not random, we did calculate the coefficients of variation on the projected seed yields assuming a completely randomized design for comparative purposes.

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[1] Contribution from the Western Region, ARS, USDA; Univ. of Idaho College of Agric. Res. and Ext. Center cooperating. Received 3 Apr. 1976.

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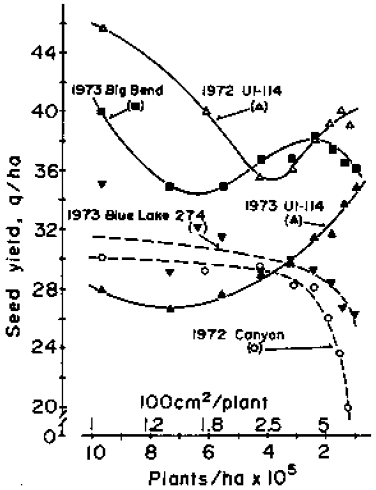

Fig. 1. Relationships between plant populations and seed yields.

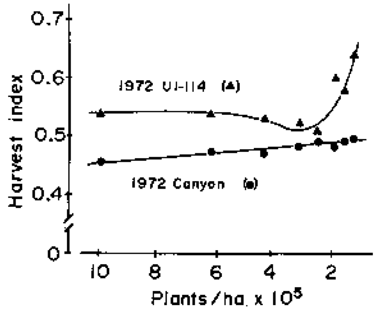

Fig. 2. Effect of plant population on harvest index (seed weight/total plant weight) for two bean cultivars.

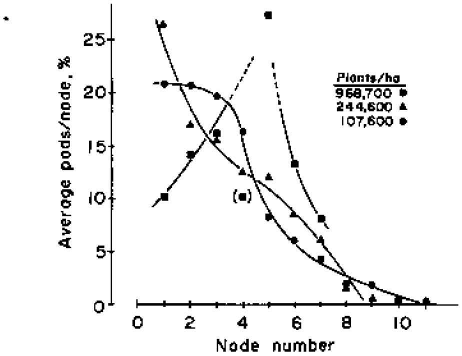

Fig. 3. Average pod distribution/node for three plant populations (point in parentheses not considered in curves).

RESULTS AND DISCUSSION

The seed yields of both bush cultivars (Canyon and Blue Lake 274) did not decrease appreciably until the plant population was less than 300,000 plants/ha (Fig. 1), where seed yields dropped rapidly for both cultivars but faster for the Canyon cultivar. In comparison, the seed yield responses of the semivining cultivars (UI-114 and Big Bend) to changes in plant populations were not the same (Fig. 1). Both cultivars showed a plant population at which yield was a minimum. The seed yield of UI-114 increased at plant populations less than 400,000 plants/ha, whereas that of the Big Bend increased up to about 200,000 plants/ha and then decreased at smaller populations.

These yield differences between cultivars probably were related to their growth characteristics. The Canyon cultivar is a smaller plant at maturity than Blue Lake 274 and, therefore, probably is unable to compensate for the increased area/plant at the lower plant populations. Also, UI-114 has more vining characteristics than Big Bend, which may enable it to utilize the larger area/plant at the lower plant populations. Semi-vining cultivars have been shown to increase yields at the lower plant populations as compared with bush cultivars in Washington (4).

Considerable differences for the seed yield/plant population response also existed between 1972 and 1973 for UI-114, particularly at the higher plant populations (Fig. 1). Seed yields were generally more erratic at the higher plant populations because of white mold [*Sclerotinia sclerotiorum* (Lib.) d By.] and severe lodging, which was much more pronounced in 1973 than in 1972. Lodging was not a problem with the bush cultivars, but was with the semivining cultivars. White mold was present in all cultivars in 1973 at the higher plant populations. However, at plant populations below 350,000 plants/ha, the seed yield response trends of UI-114 were similar both years.

Research with soybean plant types suggests that significant vegetative growth will occur in the indeterminate types during the flowering and pod setting period (7). This could cause more competition for photosynthate between the reproductive and vegetative growth. Perhaps a similar mechanism caused the yield depressions in the semivining bean cultivars since the plants in the 300,000 to 700,000 plants/ha populations were up to 15 cm taller than the adjacent populations at early bloom. These taller plants may have been producing vegetative growth at the expense of seed yields.

The harvest index (seed weight/total plant weight) was higher for UI-114 than for Canyon at all plant populations (Fig. 2). The harvest index of Canyon increased slightly as the plant population decreased, whereas that for UI-114 decreased slightly at 300,000 to 400,000 plants/ha, and then increased rapidly at smaller plant populations. This decrease in harvest index occurred within the same population range as did the depression in UI-114's seed yield (Fig. 1). The relative competition for photosynthate between reproductive and vegetative growth in the indeterminate plant appears more dependent upon plant population levels than in the determinate plant types.

Similar pod distributions were obtained for the Big Bend and Blue Lake 274 cultivars. The values for both cultivars are averaged in Fig. 3 for three plant populations. The two smallest plant populations had similar pod distributions; the 107,600 plants/ha plant population having 68% of the pods at the lower nodes, 1 to 3. The largest plant population (968,700 plants/ha) had 67% of the pods at nodes 3 to 6. This indicates that the larger plant populations would be better for direct harvesting, since the pods are positioned higher above the soil surface.

Table 1. Cultivars, number of replications, days to seed maturity, and coefficients of variation of seed yields.

Year	Bean cultivar	No. replication	Days to seed maturity†	C.V. of seed yield‡
1972	Canyon	3	100	8.9
	UI-114	3	95	5.3
1973	Blue Lake 274	1	105	--
	UI-114	2	95	10.5
	Big Bend	2	100	9.2

† Planted in 61-cm rows. ‡ Coefficient of variation.

Plants growing at the higher populations had lateral branches that died back at the lower nodes, and stems that were spindly. Interplant competition in these populations was also severe enough to cause a reduction in stands by the time the pods were mature. Maturity was 7 to 10 days earlier for both the bush and semivining cultivars at the higher plant populations.

The relationship between the production index (seed yield/amount seeded) and plant populations is curvilinear for all cultivars (Fig. 4a, b). This index ranged from a low of 10 to near 70 for the bush cultivars and from below 10 to over 110 for the semivining cultivars. High plant populations, although having relatively high seed yields, seem impractical since a percentage of the initial plants do not contribute to final seed yields because of stand mortality. With limited seed stocks, seed yield returns would be optimized at the lower plant populations, even though seed yields at these populations may not be maximum.

This study indicated a cultivar × plant population interaction for seed yields and harvest index. The differences between plant types reflect the semivining cultivar's ability to compensate for the increased area/plant, as shown by the increased harvest index at the smaller plant populations (Fig. 2). A cultivar's response to changes in plant population would, therefore, seem to be dependent upon its growth characteristics.

The optimum plant population for seed production by the bush cultivar is approximately 400,000 plants/ha, a population similar to that reported for optimum pod yields for the snap bean processing industry (11). This suggests that increased pod yields caused the increased seed yields. An analysis of the effect of plant population on the seed yield components in this study has shown that the number of pods/area was the major yield component influencing seed yields, with very little influence of either seed weight or seeds/pod on seed yields/area (D. T. Westermann and S. E. Crothers, 1974, Agron. Abstr. p. 83). For the semivining cultivars, the optimum plant population is 300,000 plants/ha or smaller.

These equidistant spaced plant populations are similar to the plant populations now being recommended for 55-cm row plantings (9, 10). A previous study showed that the seed yields of the semivining cultivars could be increased by closer row spacing and by increasing the distance between plants within the row (4). This modified planting method could provide a practical way for obtaining high plant densities with less crowding of plants within the row. It is also especially significant where bean yields are reduced by root rot, caused principally by *Fusarium solani* f. sp *phaseoli*, since root rot damage has been shown to increase as plant spacing decreases within rows (3). Our range of optimum plant spacings also suggest that extremely accurate precision planting is not necessary to produce maximum seed yields for any specific cultivar. These results suggest that higher seed yields could be obtained with the bush cultivars, but not with the semivining cultivars, with the more equidistant plant spacings as compared to conventional row plantings.

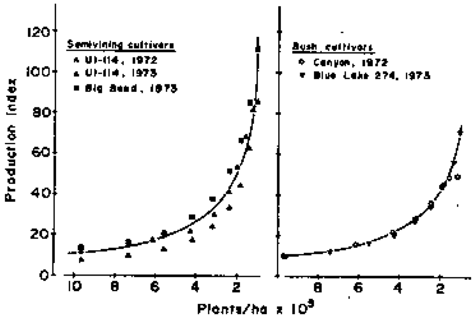

Fig. 4. Effect of plant population on production index (seed yield/amount seeded).

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