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# The 'Maffei 15' Lima Bean Compensates for Reduced Plant Stand

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***Abstract.* 'Maffei 15' baby lima bean seeds were sown every 6 cm in rows 76 cm apart to yield a nominal stand of 215,000 plants/ha at two locations in Delaware over 2 years. Seedlings were thinned within 2 weeks of planting to provide 0%, 16.7%, 33.3%, and 50.0% stand reduction at two in-row spacing patterns to determine subsequent effects on vegetative and reproductive growth. Shoot fresh weight per square meter was decreased only in 2003 by 21% and bean fresh weight per square meter was decreased only in 2004 by 13.8% when plant stand decreased to 50%. This disproportional vegetative and reproductive growth response to stand reduction resulted from a compensatory linear increase in shoot fresh weight, usable pod number, and bean fresh weight of individual plants. Thus, 'Maffei 15' lima bean tolerates a considerable loss of plant stand with little or no effect on yield.**

The green lima bean is a major processing crop in the mid-Atlantic region with 7200 ha planted annually (Tarburton et al., 2000) and Delaware producing about 40% of the lima beans sold in the United States. The effects of stand reduction on economic yield of baby lima beans have not been examined. Lima bean stands in Delaware can be reduced significantly by infection primarily from *Rhizoctonia solani* (Mulrooney et al., 2004). Stands of lima bean and other warm-season crops also can be reduced by imbibitional injury (Pollock, 1969; Pill and Kabilan, 1999) when seeds of low initial seed moisture rapidly imbibe causing an accumulation of intercotyledonary water that hinders oxygen transfer to the embryo axis. Other reasons for reduced stand could include planter malfunction, herbicide injury or soil crusting.

Smith (1980) showed that economic yield of 'Fodhook 242' lima bean, a large-seeded type, was unaffected as plants decreased from 16 to 11 per m of row. Although there are no known reports of the effects of baby lima bean stand reduction on crop growth and yield, the effects of plant population density have been reported. A positive correlation between seed yield of individual lima bean plants and their shoot dry matter production is documented (Fisher and Weaver, 1974; Lambeth, 1950; Rappaport and Carolus, 1956; Smittle, 1986). An inverse relationship between plant population density and lima bean economic yield has occurred with closer in-row spacing (Lachman and Snyder, 1943; Larson and Peng-Fi, 1948; Matthews, 1933), and closer row spacing (Larson and Peng-Fi, 1948). Presumably, the higher population density was unable to compensate for the reduced yield from the smaller plants. Sirait et al. (1994) noted that narrower rows increased economic yield of 'Maffei 15' lima beans, but only with irrigation, which increased leaf area index and shoot dry matter production per unit land area.

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Yield reductions were not proportional to percent stand reductions in soybean (*Glycine max* L. Merr.) because of the compensating ability of the remaining plants to develop more branches and pods (Johnson and Harris, 1967; Stivers and Swearingin, 1980). In fact, Torii et al. (1987) reported that a 25% reduction in plant stand reduced soybean yield by only 10%, and Vasilas et al. (1990) reported that a 66% stand reduction, imposed uniformly, and as gaps, reduced soybean yields by only 7 and 27%, respectively. Yield loss associated with replanting was greater than yield loss associated with a stand reduction of up to 66% (Vasilas et al., 1990).

The objective of our study was to determine the effects of stand reduction on vegetative and reproductive responses of 'Maffei 15' baby lima beans.

## Materials and Methods

The study was conducted during June to September on Kalmia loamy sand (fine loamy silicaceous, thermic Typic Hapludult) near Georgetown, Del. (lat. 38.7° N, long. 75.3° W) in 2003, and on Matapeake silt loam (fine silty, mixed mesic Typic Hapludult) in Newark, Del. (lat. 37.3°N, long. 75.5°W) in 2004. Seeds of 'Maffei 15' lima bean were machine planted every 6 cm in rows 76 cm apart to provide a nominal stand of 215,000 seeds/ha. Plant population densities were created by hand removal of plants within 2 weeks of planting. In addition to the full stand (0% stand reduction), three percentages of stand reduction were created at two in-row spacings (gaps) by removing plants. The percentages and gaps were 16.7% (one plant out of every consecutive six, or two consecutive plants out of every twelve); 33.0% (one plant out of every consecutive three, or two consecutive plants out of every six); and 50% (every other plant, or two consecutive plants out of every four). Each treatment consisted of four 6-m-long rows.

The 4 (stand reduction) × 2 (gaps) factorial experiment was arranged in randomized block design with four replications. Blocks consisted of four 6-m-long rows per treatment with two border rows on each side. Plots received 90 kg N/ha from 14N–3P–12K (14–7–14) on the day of planting. Imazethapur herbicide was incorporated preplant at 36g a.i./ha. Manual cultivation subsequently controlled weeds. Other pest control measures followed Univ. of Delaware (2003) recommendations. Plots received at least 50 mm of water each week from rain or irrigation from planting to harvest.

At the time of harvest, plants from the central 3 m of the two inner rows of each treatment were pulled out of the ground, counted and weighed. Pods were manually stripped from plants and separated and counted as flat (immature), usable (green), and dry (overly mature). The green pods were threshed mechanically and the seed fresh weight (economic yield) determined. All data were recorded on a per plant and per unit area ($m^2$) basis. In 2004, the numbers of nodes and branches on 10 plants from each treatment–replication combination were counted.

## Results and Discussion

Since in-row gaps had no effect on any variable in either year, only the results of percentage stand reduction are reported. Kahn et al. (1995) similarly noted that seed yield and harvest index of cowpea [*Vigna unguiculata* (L.) Walp] was unaffected by uniformity of within-row spacing. The 17.8 and 20.0 plants/$m^2$ achieved in 2003 and 2004, respectively, with no stand reduction (Table 1) represented 83% and 93% of the potential stand of 215, 000 plants/ha. The nominal 16.7%, 33.3%, and 50.0% nominal stand reductions were, respectively, 23.6%, 35.9%, and 49.4% in 2003, and 19.5%, 31.5%, and 49.5% in 2004.

As stand decreased from 100% to 50%, shoot fresh weight per square meter decreased only 21% in 2003 and was unaffected in 2004 ; while bean fresh weight per square meter was unaffected in 2003 and decreased only 13.8% in 2004 (Table 1). This absence or less than proportional decrease in shoot or bean fresh weight in response to stand reduction has been reported in soybean (Johnson and Harris, 1967; Stivers and Swearingin, 1980; Torii et al., 1987; Vasilas et al., 1990) and large-seeded lima bean (Smith, 1980), and reflects the ability of plants to respond vegetatively and reproductively in a compensating manner to the decreasing population density.

The numbers of flat, dry or usable pods/$m^2$ were unaffected by stand reduction in either year. In both years, the usable pods were 87% of the total pod number per plant, indicating that plant population density had no effect on crop maturation rate.

Linear increases in shoot fresh weight, number of usable pods and bean fresh weight of individual plants in response to decreasing stand during both years (Table 2) confirmed the ability of plants to respond positively to reduced population density. Early research revealed the positive correlation between seed yield and vegetative growth of lima bean plants (Fisher and Weaver, 1974; Lambeth, 1950; Rappaport and Corolus, 1956; Smittle, 1986). Decreas-

Table 1. Plant population, shoot fresh weight, number of pods (flat, dry and usable), and bean fresh weight on a per area basis in response to stand reduction of 'Maffei 15' lima bean during 2003 and 2004.

| Stand reduction | Plant population (plants/m$^2$) | | Shoot fresh wt (g·m$^{-2}$) | | Flat pods (pods/m$^2$) | | Dry pods (pods/m$^2$) | | Usable pods (pods/m$^2$) | | Bean fresh wt (g·m$^{-2}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (%) | 2003 | 2004 | 2003 | 2004 | 2003 | 2004 | 2003 | 2004 | 2003 | 2004 | 2003 | 2004 |
| 0 | 17.8 | 20.0 | 2378 | 3548 | 9.2 | 18.8 | 11.4 | 20.6 | 164 | 323 | 353 | 608 |
| 16.7 | 13.6 | 16.1 | 2262 | 3602 | 8.7 | 16.2 | 13.1 | 30.6 | 155 | 298 | 308 | 546 |
| 33.3 | 11.4 | 13.7 | 2165 | 3719 | 9.2 | 17.1 | 14.8 | 26.2 | 154 | 301 | 341 | 586 |
| 50.0 | 9.0 | 10.1 | 1874 | 2836 | 10.1 | 20.6 | 12.7 | 24.1 | 160 | 293 | 288 | 524 |
| Significance | $L^{***}$ | $L^{***}$ | $L^{NS}$ | $L^{NS}$ | $L^{NS}$ | $L^{NS}$ | $L^{NS}$ | $L^{NS}$ | $L^{NS}$ | $L^{*}$ | $L^{*}$ | $L^{NS}$ |
| | $Q^{*}$ | $Q^{***}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ |
| $LSD_{0.05}$ | 3.1 | 2.6 | 349 | 721 | 5.7 | 8.3 | 5.9 | 12.8 | 19 | 32 | 70 | 31 |

$^{NS,*,***}$Nonsignificant or significant at $P \leq 0.005$ or 0.001, respectively; L = linear, Q = quadratic.

Table 2. Per plant shoot fresh weight, number of pods (flat, dry and usable), and bean fresh weight in response to stand reduction of 'Maffei 15' lima bean during 2003 and 2004, and number of nodes and branches per plant in 2004.

| Stand reduction | Shoot fresh wt (g/plant) | | Flat pods (no./plant) | | Dry pods (no./plant) | | Usable pods (no./plant) | | Bean fresh wt (g/plant) | | Nodes/ plant (no.) | Branches/ plant (no.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (%) | 2003 | 2004 | 2003 | 2004 | 2003 | 2004 | 2003 | 2004 | 2003 | 2004 | 2004 | 2004 |
| 0 | 134 | 173 | 0.5 | 1.0 | 0.6 | 1.1 | 9.2 | 18.1 | 15.6 | 34.1 | 4.33 | 8.5 |
| 16.7 | 159 | 224 | 0.7 | 1.2 | 0.9 | 2.3 | 10.9 | 21.9 | 22.9 | 40.3 | 5.73 | 12.2 |
| 33.3 | 188 | 272 | 0.8 | 1.2 | 1.3 | 2.3 | 13.4 | 26.4 | 28.9 | 51.4 | 7.09 | 16.5 |
| 50.0 | 209 | 282 | 1.0 | 2.3 | 1.4 | 2.7 | 17.8 | 32.6 | 35.9 | 58.2 | 7.86 | 19.1 |
| Significance | $L^{**}$ | $L^{*}$ | $L^{NS}$ | $L^{**}$ | $L^{NS}$ | $L^{NS}$ | $L^{*}$ | $L^{*}$ | $L^{**}$ | $L^{***}$ | $L^{***}$ | $L^{***}$ |
| | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{*}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{ns}$ | $Q^{NS}$ | $Q^{NS}$ | $Q^{ns}$ | $Q^{NS}$ |
| $LSD_{0.05}$ | 13 | 8 | 0.8 | 0.3 | 3.4 | 5.5 | 2.8 | 3.9 | 5.1 | 6.4 | 0.87 | 2.3 |

$^{NS,*,**,***}$Nonsignificant or significant at $P \leq 0.001$, 0.01, or 0.05, respectively; L = linear, Q = quadratic.

ing stand from 100% to 50% resulted in linear increases in number of nodes and branches per plant of 81.5% and 124.7%, respectively. Seed yield of lima bean, similar to that of field bean (*Vicia faba* L.) (Pilbeam et al., 1990), is the product of several components: plant population density, podding nodes per plant, pods per podding node, seeds per pod, and single seed weight. The positive relationship between the number of usable pods or bean fresh weight with the numbers of nodes and branches per plant in response to decreasing plant stand may indicate that the increase in branches supported the increase in reproductive structures.

The reproductive structures of lima beans are indeterminate racemes, with the first flowers produced on the early inflorescences being the most critical for fruit production (Lambeth, 1950; Wootten et al., 1999). It remains unknown whether the greater pod set or retention and bean fresh weight of individual plants with decreasing plant stand (Table 2) was associated with more racemes borne on more branches. The greater leaf area per plant may have decreased the temperature and increased the relative humidity within the canopy, conditions that favor pod set and retention (Fisher and Weaver, 1974). Even though decreasing stand promoted more nodes and branches on individual plants, the observed delay in ground cover at lower population densities may favor weed growth. Sankula et al. (2001) determined, however, that neither herbicide rate nor application method affected lima bean biomass or yield, weed density, control, or biomass production.

The results of this study have shown that reducing 'Maffei 15' lima bean stand by up to 50% reduced bean fresh weight per unit area by only 16%, averaged over 2 years. This disproportional relationship resulted from increased vegetative growth and reproductive yield of individual plants which compensated for the reduced plant stand. It remains unknown whether indeterminate lima beans would compensate similarly for reduced plant stand. Cultivar growth habit (determinate *vs* indeterminate) affected the compensatory response of field bean (Pilbean et al., 1990), but not of soybean (Pepper and Walker (1988).

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