

Generation Means Analysis of Climbing Ability in Common Bean (*Phaseolus vulgaris* L.)

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Abstract

Climbing common bean (*Phaseolus vulgaris* L.) genotypes have among the highest yield potential of all accessions found in the species. Genetic improvement of climbing beans would benefit from an understanding of the inheritance of climbing capacity (made up of plant height [PH] and internode length [IL] traits). The objective of this study was to determine the inheritance of climbing capacity traits in 3 crosses made within and between gene pools (Andean \times Andean [BRB32 \times MAC47], Mesoamerican \times Mesoamerican [Tío Canela \times G2333], and Mesoamerican \times Andean [G2333 \times G19839]) using generation means analysis. For each population, we used 6 generations (P_1 , P_2 , F_1 , F_2 , BC_1P_1 , and BC_1P_2) that were evaluated at 2 growth stages (40 and 70 days after planting). Results showed the importance of additive compared with the dominant–additive portion of the genetic model. Broad-sense heritabilities for the traits varied from 62.3% to 85.6% for PH and from 66.5% to 83.7% for IL. The generation means analysis and estimates of heritability suggested that the inheritance of PH and IL in climbing beans is relatively simple.

Climbing bean varieties are morphologically distinct from bush bean varieties of common beans (*Phaseolus vulgaris* L.) characterized by tall growth, long internodes, and climbing ability. They are an important component of traditional agriculture in several parts of Latin America, especially Mexico, Guatemala, Colombia, Ecuador, and Peru (Voyses 2000), and have spread to the Great Lakes region of Africa (Sperling and Munyaneza 1995). Climbing bean cropping systems are classified as monoculture or intercropping, whereby farmers produce 2 or more species in the same area (Woolley and Davis 1991). Climbing beans are often grown in association with maize, either in relay or in simultaneous plantings, and maize provides the support required for the climbing beans to grow upward. This agronomic system is among the most representative of Latin America and has also been adopted in Eastern Africa as well (Francis and Sanders 1978; Woolley et al. 1991). In monoculture, climbing beans are planted with the support of wood or bamboo stakes or trellis systems. In this system, staking can provide a use for culled trees in agroforestry projects and has been cited as providing a stimulus for tree planting in Africa (Sperling and Munyaneza 1995). Trellising, a widespread system in the Andean region, is an alternative that reduces the need for stakes but requires an investment in wires and string for tying up bean vines

(Obando 1992; Sañudo et al. 1999). Trellising of climbing beans is economically justified because yield may surpass 4500 kg ha⁻¹. Although monoculture production is more laborious due to the need for hand labor, it is an important source of agricultural employment for on-farm and seasonal labor. Therefore, climbing beans are particularly useful for small landholdings in situations where labor is not limiting and where demand for beans is high.

One trait inherent to climbing beans is climbing ability. Climbing capacity in turn is closely related to a series of component traits including total plant height (PH) and internode length (IL), which together with the determinacy character help to make up what is known as growth habit in common beans (Debouck 1991). Climbing capacity in beans also depends on the variation in outgrowth of lateral branches and the degree of vine circumnutation (winding movements), which determines the ability or lack thereof of the plant to climb on staking material. Interaction of vegetative growth pattern with distribution of flowers and pods during reproductive growth can determine whether most of the seed production occurs along the entire length of the climbing bean or only in the lower or upper parts of the plant (Singh 1982). These traits permit the classification of common beans into 4 growth habits: type I growth habit characterized by plants

analyses of generation means for both PH and IL in the G2333 × G19839 and Tío Canela × G2333 populations when comparing the evaluation at 40 DAP versus the evaluation at 70 DAP. These 2 crosses have in common the Mesoamerican parent G2333, which suggests that the later manifestation of the effects of the dominance observed may be a characteristic of this material or the gene pool it belongs to. It is important to note that for the population BRB32 × MAC47, in contrast to the other 2 populations, no dominance was observed in IL, whereas partial dominance was evident for PH at both evaluation dates, although more significantly at 70 DAP as in the other populations. Our results agree with those of Detongnon's (1985) for determinate genotypes of common bean, which indicated that both additive and dominant effects are involved in the expression of PH and IL. Additive or additive–dominance effects have been more prevalent than other epistatic effects in generation means analysis conducted for common beans (Kornegay and Temple 1986; Sauter et al. 1990; Chung et al. 1991; Hanson et al. 1993; Park et al. 1994; Rainey and Griffiths 2005).

The comparison of means for the different generations in each of the 3 crosses, together with the analysis of frequency distributions, showed that mid-parent heterosis was highest in the cross G2333 × G19839, where the progenitors came from different gene pools (Andean and Mesoamerican). This was likely due to the greater genetic distance presumed to exist between G2333 and G19839 compared with the crosses carried out within the Andean (BRB32 × MAC47) and Mesoamerican (Tío Canela × G2333) gene pools. Transgressive segregation was not highly evident for either of the traits evaluated in the F₂ or BC₁ generations of any of the populations. However, more transgressive segregation was evident in the Andean intra–gene pool and the Mesoamerican × Andean inter–gene pool populations than in the Mesoamerican intra–gene pool population. The relationship between overdominance, complete, or partial dominance and patterns of heterosis as well as the existence of transgressive segregation for the 2 traits of PH and IL in climbing beans should be further studied.

For the 3 populations, additive effects were established as being of greater importance compared with dominance, especially in the first evaluation for both PH and IL. Similarly, in the second evaluation the additive model was more acceptable than the additive–dominance model for 2 of the 3 populations. In addition, in the evaluations where the additive–dominance model did give a better fit, the contribution of the additive effects to the SS_q of the model was greater than the contribution of the effects of dominance. These results agree with Hamad (1975) who found that for climbing snap beans most of the variation in PH was due to additive gene action and that the additive gene action was more important than the dominant gene action for this variable. Confirming this for all 3 populations and for all the traits measured, the additive variance had a value that was very close to that of genotypic variance (Table 4), highlighting the importance of additive effects in the expression of these traits results that agree with those of Ortíz de La Cruz (1989) who studied the inheritance of growth habit using diallelic crosses between

genotypes with type I, II, III, and IV growth habits and showed that additive factors predominated in the inheritance of most of the traits.

In our results, broad-sense and narrow-sense heritability values were high and suggested a large participation of the genetic effects on the phenotypic expression of the traits and that selection for the traits would be expected to be highly efficient. These results are similar to those reported by Ortega Ybarra (1968), who found that in 3 crosses between genotypes with bush (Goiano), prostrate (Costa Rica), and indeterminate (Mexico 50) growth habits, narrow-sense heritabilities for the length of the main stem ranged from 50% to 68%. Our results show similar values of heritability for PH and IL in the 2 evaluations, in contrast to Detongnon (1985), who suggested that heritability for PH was higher than for IL. This difference may have stemmed from the fact that all the parents in our study were indeterminate, whereas this previous author worked with beans of determinate growth habit. According to Bliss (1971), the genetic factors that control PH, duration of growth, and flowering time are complex and often affected by the environment. Although we preferred to carry out this trial in a single site where climbing beans are well adapted, it would be interesting to determine if generation means analysis results would be similar in additional environments because genotype × environment interactions have been observed for both PH and IL (Scully et al. 1991). To counteract the limitation of estimating heritabilities from generation means analysis, we have also studied the heritability of PH and IL for a recombinant inbred line population developed from the cross G2333 × G19839 grown over 4 contrasting environments (Checa et al. 2004).

The general results of this study are promising for climbing bean improvement because the additive fraction of genetic variance is useful in breeding self-pollinating crops such as common bean. The results suggest that given the similar inheritance of the PH and IL traits, these can be combined into a climbing ability score which will be useful for a rapid assessment of adaptation for climbing beans. Further crosses should be used to confirm the inheritance of climbing ability in different genetic backgrounds within each gene pool.

Acknowledgments

We are grateful to Yercil Viera for field trial management, to Steve Beebe, Daniel Debouck, and Andy Jarvis for helpful discussions and reviews of the manuscript and to Patricia Zamorano for formatting. This work was supported by Fontagro grant ATN/SF-7382-RG.

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Received February 1, 2006

Accepted July 6, 2006

Corresponding Editor: Reid Palmer