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# COMBINING ABILITIES OF SOME COMMON BEAN (*Phaseolus vulgaris* L.) CULTIVARS HAVING DIFFERENT MECHANISMS OF RESISTANCE TO BEAN GOLDEN MOSAIC VIRUS (BGMV)*

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## ABSTRACT

Adequate knowledge of combining ability and inheritance of has not been available for resistance to bean golden mosaic virus (BGMV) parental genotypes of common bean (*Phaseolus vulgaris* L.). An 8 x 8 complete diallel cross, including 28 crosses, their 28 reciprocals, and 8 parents was evaluated in the $F_1$, and $F_2$ generations, at Viclos (Tucuman), Argentina in 1990. Data were recorded on leaf yellowing (mosaic), number of pods and seeds/plant, seed weight and seed yield. Mean square values due to general combining ability (GCA) were highly significant and were larger than the estimates for specific combining ability (SCA) for all characters in the $F_1$ and $F_2$. Porrillo Sintetico proved to be one of the best parents for increased yield of the susceptible cultivar Alubia Cerrillos. However, Royal Red contributed to lower mosaic expression. Pinto 114, Great Northern and Red Mexican 36 significantly increased the number of pods and seeds per plant, as well.

## INTRODUCTION

Bean golden mosaic virus (BGMV) is one of the most destructive and widespread problems for the production of the common bean (*Phaeolus vulgaris* L.) in Argentina, Brazil, Dominican Republic, El Salvador, Guatemala, Honduras, and Mexico (Gamez, 1971; Costa 1976; Galvez and Morales, 1989). Complete crop failures are

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common, especially in Argentina and Brazil, where farmers grow susceptible cultivars, and the incidence of the virus and the whitefly (*Bemisia tabaci*) vector is high due to favorable environmental conditions (e.g., relatively high temperature and dry weather). Also, most farmers cannot afford agro-chemicals and do not follow cultural control practices.

Among the control strategies available, the use of resistant cultivars is crucial in order to reduce damage due to BGMV, to minimize production costs, avoid pollution, and to stabilize yield. Recently, new mechanisms of BGMV resistance have been identified in different bean genotypes which possess seed colors other than black (Morales and Niessen, 1989).

Knowledge about the combining ability of parental genotypes selected for resistance to BGMV, as well as relevant information on the genetic control of the mechanisms linked to virus resistance are important for the success of a resistance breeding program. An assay carried out in greenhouse at CIAT - Colombia, showed a predominance of additive effects in genetic control of this feature and made evident the possibility of selection for BGMV resistance (Morales and Singh, 1991).

This study was conducted to estimate the combining ability of parental cultivars possessing different mechanisms of BGMV resistance, such as low symptom expression, resistance to dwarfing and to plant, pod and seed malformation under Argentinan field conditions.

## MATERIALS AND METHODS

One susceptible and seven resistant genotypes were selected as parents in this study. Of the resistant parents, six (Redlands Green Leaf C, Red Mex. 36, Royal Red, Pinto UI 114, Great Northern 31, Porrillo Sintético) were identified by Morales and Niessen (1989). PVA 1111 is the most widely grown large-seeded red cultivar in Argentina. The susceptible parent, Alubia Cerrillos, is likewise the most extensively grown large-seeded white cultivar in Argentina. The eight parents possess different growth habits, seed characteristics, rate of maturity, and belong to different races of common bean according to Singh *et al.*, 1989 (Table I). These genotypes were crossed in all possible combinations by hand emasculation and pollination at CIAT-Palmira, Colombia in 1988-1989. An average of 200 flower buds were hybridized for each cross combination. A part of the $F_1$ hybrid seed was grown in 1989 to produce selfed ($F_2$) seed.

The eight parents, 28 $F_1$, and 28 reciprocal $F_1$ populations were grown in one experiment. In another trial the same eight parents were evaluated along with 28 $F_2$, and 28 reciprocal $F_2$ populations. Both trials were grown simultaneously in adjacent plots under BGMV pressure, in Viclos, Argentina, during the 1990 cropping season. In both cases, a randomized complete block design with two replications was used.

Table I - Main traits of the common bean utilized in the BGMV study.

| Identification | No. CIAT | Origin | Race | Habit | Seed Weight | Seed Color | Seed Shape |
|---|---|---|---|---|---|---|---|
| 1. Alubia Cerrillos | G7930 | Argentina | New Granada | I | 49 | White | Wide |
| 2. Redlands Green Leaf C. | G5646 | EE.UU. | New Granada | I | 34 | Brown | Wide, Kidney |
| 3. Red Mexican 36 | G6385 | EE.UU. | Durango | III | 35 | Red | Rombóide |
| 4. Royal Red. | G6724 | EE.UU. | New Granada | I | 52 | Red | Wide, Kidney |
| 5. Pinto UI 114 | G8086 | EE.UU. | Durango | III | 37 | Pinto | Rombóide |
| 6. Great Northern 31 | G5710 | EE.UU. | Durango | III | 40 | White | Rombóide |
| 7. Porrillo Sintético | G4495 | El Salvador | Middle-America | II | 18 | Black | Wide, Kidney Small |
| 8. PVA 1111 | | CIAT | New Granada | I | 41 | Red | Wide, cilin. |

a. I - determinate; II - indeterminate erect; III = indeterminate vine.

For the $F_1$ populations, each plot consisted of a single row, 5 m long. for the $F_2$, a plot consisted of four rows, 7 m long. The space between rows was 60 cm. An average of 15 seeds were sown per meter of row length. Plots were kept free from other fungal and bacterial diseases, weeds, and insects. Standard agronomic practices were followed to assure good crop development. Data were recorded using a scale from 1 to 9 (1: immune, and 9: highly susceptible, according to van Schoonhoven and Pastor Corrales, 1989). At maturity, the plants were harvested, the number of pods were counted and then threshed to count the number of seeds. Seed yield and weight of 100 seeds were recorded in g/plant which was adjusted to 14% moisture by weight. Data were analyzed using Griffing's (1956) Method 1, Model I, in which parents are considered to be a fixed set of genotypes.

## RESULTS AND DISCUSSION

Porrillo Sintético demonstrated the highest level of resistance ot mosaic followed by Great Northern 31 and Royal Red. PVA 1111 had the highest average numbers of pods, followed by Porrillo Sintético and Redlands Green Leaf C (Table II). For the number of seeds per plant, the order was as follows: Porrilo Sintético, PVA 1111, and Redlands Green Leaf C. Red Mexican 36 and Pinto UI 114 produced an average of 18.9 and 17.6 seeds per plant, respectively whereas Alubia, the susceptible control, produced an average of 9 seeds per plant. PVA 1111, Porrillo Sintético, and Redlands Greenleaf C, had the highest yield (seed weight per plant).

Table II - Means of five traits in two experiments of diallel crosses.

| Treatment | BGMV | | Pods/plant | | Seed/plant | | 100 Seed weight (g) | | Seed yield (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1[1/] | 8.9 | | 4.2 | | 9.0 | | 27.8 | | 2.5 | |
| 2 | 7.5 | | 6.0 | | 20.3 | | 27.8 | | 5.7 | |
| 3 | 6.6 | | 5.4 | | 18.9 | | 25.2 | | 4.8 | |
| 4 | 6.0 | | 4.6 | | 11.5 | | 29.6 | | 3.4 | |
| 5 | 6.4 | | 5.5 | | 17.6 | | 22.5 | | 4.0 | |
| 6 | 5.5 | | 4.6 | | 13.6 | | 30.6 | | 4.1 | |
| 7 | 5.3 | | 10.8 | | 53.2 | | 19.7 | | 9.4 | |
| 8 | 6.6 | | 11.7 | | 41.3 | | 23.6 | | 9.8 | |
| | $F_1$[2/] | $F_2$[2/] | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ |
| 12[3/] | 6.5 | 7.3 | 8.4 | 6.6 | 25.1 | 21.6 | 28.3 | 24.5 | 7.1 | 5.5 |
| 13 | 6.9 | 6.5 | 9.6 | 8.3 | 30.0 | 30.5 | 32.2 | 24.7 | 9.8 | 7.5 |
| 14 | 6.1 | 6.3 | 8.0 | 8.4 | 31.4 | 24.9 | 30.5 | 24.0 | 9.6 | 5.9 |
| 15 | 7.0 | 7.2 | 11.4 | 10.0 | 38.4 | 35.5 | 29.0 | 20.5 | 11.1 | 7.1 |
| 16 | 6.6 | 6.9 | 8.5 | 11.4 | 25.2 | 35.8 | 31.0 | 23.7 | 7.8 | 8.5 |
| 17 | 6.7 | 7.3 | 9.7 | 11.8 | 40.1 | 50.8 | 26.2 | 21.5 | 10.5 | 10.9 |
| 18 | 6.8 | 6.6 | 8.2 | 10.4 | 28.5 | 38.5 | 24.6 | 25.3 | 7.0 | 9.7 |
| 23 | 6.1 | 6.7 | 10.6 | 8.2 | 33.8 | 31.1 | 24.1 | 19.8 | 8.2 | 6.1 |
| 24 | 7.1 | 6.6 | 10.0 | 10.3 | 24.8 | 31.6 | 29.9 | 27.8 | 7.4 | 8.8 |
| 25 | 6.1 | 7.1 | 9.3 | 7.5 | 33.9 | 28.3 | 22.5 | 23.0 | 7.7 | 6.4 |
| 26 | 6.3 | 6.7 | 12.3 | 11.2 | 40.9 | 40.7 | 21.6 | 23.1 | 9.0 | 9.4 |
| 27 | 6.3 | 6.7 | 12.7 | 11.3 | 49.9 | 48.4 | 22.5 | 23.1 | 10.9 | 10.5 |
| 28 | 6.1 | 6.1 | 12.9 | 9.0 | 48.0 | 33.7 | 22.7 | 21.4 | 10.7 | 9.5 |
| 34 | 6.3 | 6.2 | 8.8 | 9.6 | 22.5 | 33.2 | 25.4 | 22.5 | 5.8 | 7.5 |
| 35 | 5.8 | 6.5 | 11.6 | 7.2 | 29.8 | 29.4 | 24.4 | 20.9 | 7.5 | 6.2 |
| 36 | 5.8 | 6.6 | 8.8 | 8.7 | 29.1 | 27.5 | 23.7 | 24.4 | 6.9 | 6.7 |
| 37 | 6.5 | 6.1 | 13.8 | 9.6 | 54.4 | 33.5 | 21.3 | 22.7 | 11.6 | 7.7 |
| 38 | 5.8 | 5.8 | 11.4 | 8.8 | 38.0 | 40.3 | 24.6 | 18.0 | 9.1 | 7.7 |

Continued

Table II - Continued

| Treatment | BGMV | | Pods/plant | | Seed/plant | | 100 Seed weight (g) | | Seed yield (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $F_1$[2/] | $F_2$[2/] | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ |
| 45 | 6.8 | 6.7 | 11.6 | 9.9 | 31.0 | 28.9 | 27.7 | 25.9 | 8.9 | 7.5 |
| 46 | 7.4 | 6.2 | 12.5 | 12.1 | 33.1 | 32.7 | 29.4 | 23.1 | 9.8 | 8.7 |
| 47 | 5.9 | 6.2 | 11.7 | 10.9 | 47.7 | 40.0 | 25.4 | 20.0 | 11.3 | 8.0 |
| 48 | 6.6 | 6.2 | 9.2 | 8.6 | 33.8 | 30.0 | 28.7 | 29.3 | 9.7 | 8.7 |
| 56 | 6.9 | 5.8 | 5.4 | 6.2 | 17.6 | 19.0 | 23.9 | 30.5 | 4.2 | 4.2 |
| 57 | 5.7 | 5.6 | 9.0 | 13.4 | 31.2 | 48.0 | 21.9 | 18.3 | 6.8 | 7.8 |
| 58 | 6.4 | 6.2 | 10.7 | 11.0 | 32.4 | 37.3 | 27.4 | 23.6 | 9.0 | 8.8 |
| 67 | 6.5 | 5.6 | 10.9 | 13.0 | 32.3 | 49.9 | 21.9 | 18.0 | 7.1 | 9.0 |
| 68 | 7.3 | 6.5 | 10.7 | 10.3 | 38.5 | 36.5 | 26.1 | 23.0 | 10.1 | 8.4 |
| 78 | 6.7 | 6.6 | 7.9 | 13.0 | 33.9 | 56.4 | 26.2 | 20.0 | 8.9 | 11.2 |

[1/]Parents presented in Table I.

[2/]$F_1$ and $F_2$ generations.

[3/]Crosses represented by the mean of crosses and reciprocal crosses.

It is apparent from this study that all of the BGMV-resistant parental lines selected, significantly increased the levels of resistance observed in the $F_1$ and $F_2$ progenies obtained from their crosses with the BGMV-susceptible cultivar Alubia Cerrillo (Table II).

The different growing conditions in Argentina might have affected the adaptation of most of the parental lines. Cultivars Pinto UI 114, Red Mexican 36, and Great Northern 31 belong to the race Durango of Middle american domestication center (Singh *et al.*, 1989). They are better adapted to the relatively warmer and longer days and cooler nights of the Mexican highlands and north western USA. These conditions are quite different from the much warmer conditions occurring in Argentina. These differences are especially significant during the early stages of plant growth and development when common beans are more susceptible to BGMV (Morales and Singh, 1991). On the other hand, Porrillo Sintético is well known for its good adaptive abilities and for its resistance to BGMV in several Latin American countries (Morales and Niessen, 1989). PVA 1111 reconfirms its good performance in Argentina.

The reciprocal effects were not significant for all traits in both generations. Mean squares of GCA were highly significant and larger then the values for SCA for all five traits in both $F_1$ and $F_2$ (Table III).

Table III - Mean squares analysis of BGMV, number of pods, number of seeds/plant, 100-seed weight, and seed yield, obtained in a 8x8 complete diallel cross in the $F_1$ and $F_2$ generation of common bean (*Phaseolus vulgaris*) evaluated at Viclos, Argentina in 1990.

| | | Mean squares | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BGMV x $10^3$ | | Number of pods x $10^3$ | | Number of seeds x $10^3$ | | 100-seed weight x $10^3$ | | Seed yield x $10^3$ | |
| Variation sources | GL | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ |
| Blocks | 1 | 280** | 130** | 1 | 1770** | 1 | 2180** | 37420 | 123280** | 4160 | 66000** |
| Treatments | 63 | 30 | 20** | 300** | 210** | 1530** | 1490** | 17620** | 29250** | 10730** | 7200** |
| General comb. ability (GCA) | 7 | 80** | 110** | 630** | 890** | 5740** | 7980** | 78750** | 146050** | 28520** | 28370** |
| Specific comb. ability (SCA) | 28 | 40** | 20** | 470** | 230** | 1800** | 1230** | 16760** | 26270** | 15240** | 8350** |
| Reciprocal | 28 | 5 | 1 | 40 | 30 | 200 | 120 | 3190 | 3040 | 1780 | 780 |
| Mistake | 63 | 20 | 2 | 110 | 70 | 590 | 360 | 9440 | 9380 | 5230 | 2000 |

*, ** - Significant level; P = 0.05 and P = 0.01, respectively.

Relatively larger mean square values of GCA compared to that of SCA may indicate that the additive genetic variance is more important than nonadditive gene action in the inheritance of resistance to BGMV as well as seed yield and its components. These results agree with those of Morales and Singh (1991) who studied resistance to BGMV and with Nienhuis and Singh (1988a, 1988b) who studied seed yield and its components. Thus, parental performance should prove to be a reliable selection criteria for predicting the performance of their hybrid populations and derived recombinant lines.

Although the mean square values of GCA were larger than that for SCA in both $F_1$ and $F_2$ and, as expected, they increased from $F_1$ to $F_2$ for most traits, the SCA values, in spite of their reduction from the $F_1$ to $F_2$ due to inbreeding, were still significant in the $F_1$ as well as in the $F_2$ for seed yield and its components. These results are contrary to those reported by Nienhuis and Singh (1988b) for optimum growing conditions, but similar to those reported by Kornegay and Temple (1986) under leafhopper pressure.

Porrillo Sintético ($F_1$ and $F_2$), PVA 1111 ($F_2$), and Red Mexican 36 ($F_2$) gave significant and negative GCA values for BGMV reaction (Table IV). On the other hand, Alubia Cerrillos ($F_1$ and $F_2$) and Redlands Green Leaf C ($F_2$) had significant positive values for this trait. Porrillo Sintético and PVA 1111 had positive and significant GCA values for the number of pods and seeds, and yield in $F_1$ and $F_2$. GCA values for the number of pods were significant and negative for Red Mexican 36 ($F_2$), Royal Red ($F_2$), Pinto UI 114 ($F_1$ and $F_2$), and Great Northern 31 ($F_1$ and $F_2$). For 100-seed weight, Alubia Cerrillos ($F_1$) and Royal Red ($F_1$ and $F_2$) had positive GCA values and Porrillo Sintético ($F_1$ and $F_2$) and Red Mexican 36 ($F_1$) registered negative GCA values.

Table IV - Estimates of general combining ability for mosaic, number of pods, number of seeds, 100-seed weight, and grain yield in $F_1$ and $F_2$ generations. Viclos, Argentina, 1990.

| Parents | BGMV | | Number of pods per plant | | Number of seeds per plant | | 100-seed weight | | Grain yield (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ | $F_1$ | $F_2$ |
| Alubia Cerrillos | 0.11** | 0.12** | -0.06 | -0.05 | -0.24 | -0.19 | 1.65** | 0.53 | -0.07 | 0.53 |
| Redlands Green Leaf C. | 0.00 | 0.06** | -0.05 | -0.07 | -0.26 | -0.18 | 0.31 | 0.69 | -0.75 | -0.31 |
| Red Mexican 96 | 0.001 | -0.05** | -0.01 | -0.14** | -0.01 | -0.09 | -1.06* | -0.51 | -0.23 | -0.52* |
| Royal Red | -0.02 | 0.00 | 0.02 | -0.10* | -0.09 | -0.44** | 1.98** | 3.96** | -0.34 | 0.18 |
| Pinto UI 114 | -0.02 | -0.02 | -0.18** | -0.13** | -0.33* | -0.19 | -0.28 | -0.39 | -0.93* | -0.65** |
| Great Northern 31 | -0.006 | -0.03 | -0.14* | -0.03 | -0.39** | -0.38** | 0.75 | -0.89 | -0.95* | -0.98** |
| Porrillo Sintético | -0.08** | -0.05** | 0.16** | 0.29** | 0.69** | 1.04** | -2.93** | -3.79** | 0.82* | 1.32** |
| PVA 1111 | -0.01 | -0.05* | 0.24** | 0.23** | 0.62** | 0.44** | 0.41 | 0.36 | 1.75** | 1.62** |

*, ** - Significant at 5% and 1% probability levels, respectively.

Because it is one of the best parents for most BGMV resistance traits, the small-seeded cultivar Porrillo Sintético showed be used in crosses with parents with positive GCA values for 100-seed weight or some form of backcross program should be used in order to recover desirable seed size.

## RESUMO

O presente trabalho teve como finalidade obter informações sobre o controle genético da tolerância ao vírus do mosaico dourado (BGMV) do feijoeiro (*Phaseolus vulgaris* L.) e outras características através das estimativas da capacidade geral e específica de combinação, da herdabilidade e da correlação entre os caracteres. Para isso foi realizado um cruzamento dialelo envolvendo 8 progenitores. Os 28 híbridos e seus recíprocos juntamente com os pais foram avaliados nas gerações $F_1$ e $F_2$ na localidade de Vielos, Tucuman Argentina em 1990. Para todos os caracteres os quadrados médios devido a capacidade geral de combinação foram altamente significativas e superiores aos obtidos para a capacidade específica de combinação em $F_1$ e $F_2$ "Porrillo Sintético" mostrou ser o progenitor mais apropriado para aumentar o rendimento da cultivar suscetível "Alubia Cerrillos". Contudo, "Royal Red" contribuiu para a menor expressão dos sintomas de mosaico. Pinto UI 114, Great Northern e Red Mexican 36 contribuiram para aumentar o número de vagens e de sementes nos cruzamentos que participara.

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