EARLY GENERATION YIELD TESTING IN BEANS IN MONOCULTURE AND INTERCROPPED WITH MAIZE

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SUMMARY

As part of an effort to evaluate different breeding methods, two trials were planted at CIAT (3° 31' N, mean temp. 24°C) with families of beans in F_3 and F_4 generations, from single plant selections made in the F_2 (F_2 progeny method). The value of early generation yield testing was examined, particularly with regard to the performance of the materials in different cropping systems. These included sole cropping (monoculture) and intercropping with three maize genotypes varying in height from tall to short.

Families had been separated on the basis of growth habit in the F_2. These differences were maintained in F_3 and F_4, as shown by differences in main stem node number, days to flowering, and specific leaf weight (leaf dry weight/100 cm^2). Specific leaf weight was also affected by the cropping system, an effect of shading by the maize. Bean yield was lowest with the tall maize (La Posta) and highest in sole cropping. The best combined yields of beans and maize were obtained in both generations with climbing beans (type IV) with La Posta (tall) or Suwan-1 (intermediate). Correlation coefficients between sole cropping and intercropping were generally higher for bush beans (types I, II and III) than for climbers (type IV). Bean and maize yields were negatively correlated in F_3 and F_4, with an average regression slope of -1, indicating that one kilo of maize was lost for every extra kilo of bean. Since the price ratio of the two crops is approximately 3:1 in Latin America, this regression slope is favourable for intercropping. The regressions among bean families from F_3 to F_4 were positive and significant both in sole cropping and intercropping. Two families of climbers (type IV) and one family of types II/III could be selected as exceptionally promising in both generations,

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in sole cropping and intercropping. It was concluded that the method of yield testing progenies from F_2 single plants in two generations gave highly promising selections for yield and yield stability in different seasons and cropping systems.

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In many parts of the world, particularly in tropical countries, it is important to increase food production by intensifying the use of land and achieving greater efficiency of production. Traditional intercropping offers a number of advantages in terms of increased total production, reduced risk, and increased net income (Francis, 1978; Francis and Sanders, 1978). To fully exploit the advantages of intercropping it is possible that plant breeding should be directed to selecting genotypes particularly suited to these cropping systems (Francis, 1980; Davis and García, 1983). At least it would be desirable to have a greater understanding of the morphological features of the plant which are related to its ability to yield efficiently when intercropped. In beans (Phaseolus vulgaris L.), there is great variability available for growth habit (CIAT, 1979) and crosses frequently have to be made between genotypes of different growth habits, in order to obtain suitable disease resistances for example. If selection is carried out in such populations in parallel in sole cropping and intercropped with maize, the selection pressure on plant characteristics may be different. The results of studies on advanced lines of beans grown in different cropping systems at CIAT indicate that selection in sole cropping will tend to lead towards bush plant types with 14 or less nodes on the main stem, and with little or no ability to respond to a climbing stimulus, such as a bamboo stake or a maize plant (Davis et al., 1983). These plants will have a relatively high harvest index in sole cropping but tend to suffer a large reduction in harvest index when faced with competition from intercropped maize. Selection in inter - cropping with maize, on the other hand, will tend to lead to vigorous climbing types which respond greatly to a climbing stimulus by putting on extra main stem nodes. They have a relatively low harvest index in sole cropping but suffer much less reduction in their harvest index in the face of competition

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from maize. They are also the highest yielding types when planted in monoculture with artificial supports (stakes or trellis) and are, therefore, suited for agricultural systems designed to produce maximum yield. Even among climbing beans there are large differences in their ability to compete with maize, leading to large interactions between cultivars and cropping systems (Laing et al., 1983).

In order to find out whether these conclusions, largely based on studies with finished varieties, are borne out in an actual selection programme, a trial was designed to follow the progress of early generation hybrid materials of beans in several different cropping systems. The present paper reports results of early generation yield trials in the F_3 and F_4 generations.

MATERIALS AND METHODS

Two trials were planted at CIAT, Palmira, Colombia (1,001 m. altitude, 3° 31' N, 1000 mm. per year rainfall). The soil is a fertile alluvial type, pH 6.9. Fertilizer was applied at a rate of 200 kg/ha 10-30-10 at planting. The first trial consisted of F_3 generation progenies from single plants selected in the F_2, and was planted in March 1982. The second trial included F_4 bulks from the same materials and had the same experimental design. The breeding method used is the F_2 progeny method described by Lupton and Whitehouse (1957).

The design was nested with two replications and bean growth habits forming the main plots. Growth habits included were: I (determinate bush, erect plants); II/III (indeterminate bush, erect or prostrate plants); IV (indeterminate climber). There were four sub-plots for each growth habit, consisting of bean monoculture (with a trellis for type IV growth habit only), and intercropping with three maize genotypes provided by the CIMMYT maize program: Población 30 (2.5 m. tall, 92 days to maturity), Suwan-1 (2.8 m. tall, 103 days to maturity) and La Posta (3.0 m. tall, 115 days to maturity). Maize and beans were planted simultaneously in the intercropping treatments. Within each sub-plot were 10 families of beans (each family was from a different cross), and within each family were 5 progenies from single plant selections made in F_2. The total number of genotypes tested was 150 (3 growth habits x 10 families x 5 progenies). The seed harvested from the F_3 trial of growth habits II/III and IV was planted again in the same design, differing only in the randomization. The materials of growth habit I were replaced by other materials in F_4 so that direct comparison between the two generations can only be made for two of the three growth habits.

Planting was on beds 1 m. apart, with 2 plants of maize 50 cm. apart in the centre of the bed (40,000 pl/ha) and beans in two rows 30 cm. apart, on either side of the maize (density 120,000 pl/ha). Since the bean seed originated from single plants, small plots of 1 m^2 were used per progeny, grouped together in families on beds 7 m.long (5 m. of experimental plot, and 1 m. of border at either end).

Irrigation was provided twice, as needed, and diseases and pests were controlled as far as possible.

Days to flowering was taken as the number of days to opening of the first flower on 50% of the plants. Leaf dry weight and leaf area were measured two weeks after flowering. In beans, leaf area consisted of a sample of six leaves, two from the upper portion of the plant, two from the middle, and two from the bottom. For maize, leaf area was measured on the flag leaf. Main stem node number was counted at maturity. Yield was corrected to 14% humidity for beans, and 15% for maize.

RESULTS AND DISCUSSION

The number of nodes on the main stem in F_3 and F_4 bean families reflected closely the selection which had been made in F_2 to divide the plants into different habit groups (Table 1). Habit I had an average of 9.5 nodes, habits II/III 14.9 nodes, habit IV 25.6 nodes. An important purpose of using the F_2 progeny method (Lupton and Whitehouse, 1957) is to separate genetic variability, and hence reduce interplant competition, in the early generations. Possibly as a result of increased self-shading when plants have many nodes, specific leaf weight (leaf dry weight/100 cm^2) was lowest in growth habit IV (climbing) and highest in growth habit I (determinate bush). Bean yield was also highest in growth habit IV and lowest in growth habit I.

For maize, of the three genotypes La Posta was the tallest (mean height 3.04 m.), Suwan-1 intermediate (2.80 m.) and Población 30 shortest (2.57 m.). Initial growth rate was fastest in Población 30, so that at 30 days this was the tallest maize, but by 65 days the position was reversed. Intercropping reduced the height of all maize genotypes by 10-40 cm. The area of the flag leaf was also reduced 20-25% by competition. Yield was highest in La Posta, intermediate in Suwan-1, and lowest in Población 30. Inter - cropping reduced yield least in La Posta (tall, competitive plant) and most in Población 30 (short, non-competitive plant). Maize yield reductions were greatest with growth habit IV (climbing) beans (12-33% reduction). Land equivalent ratio was 1.25 on average, with a tendency to be slightly higher with Type I beans, and slightly lower with growth habit IV beans. This is due to greater yield reduction of the maize with growth habit IV beans..

For beans, intercropping with maize did not affect days to flowering, but reduced the specific leaf weight by 20%, a direct effect of shading by the maize. Yield was reduced most by intercropping with La Posta (60% reduction) and least by Población 30 (50% reduction).

The interaction of growth habits x cropping systems (Table 2) was significant for bean yield, but not for maize. There was a trend for bean yield to increase from the bottom left corner of the table (growth habit I with La Posta) towards the top right corner (growth habit IV with Población 30). For maize the reverse trend occurred, with yields lowest in the top right corner.

This is a reflection of the negative correlation between bean and maize family yields, both in F_3 and F_4 (Figures 1 and 2). The slope of the re - gression was -0.79 in F_3 and -1.21 in F_4 , averaging -1.00 over the two generations. This indicates that approximately one kilo of maize is lost for every additional kilo of beans. At a price ratio of 3:1 for beans: maize, common in Latin America, this regression is favourable economically. It is very noticeable in both generations how the growth habits of beans are grouped, with type I families occupying the portion of the graph with low bean yields and high maize yields. Growth habit IV families had high bean yields and lower maize yields, with growth habit II/III families intermediate.

The relationship between bean yields in F_3 and F_4 is shown in Figures 3 and 4, for sole cropping and intercropping respectively. In both cropping systems the relationship was positive and highly significant, although the distribution of points within growth habit II/III did not follow the regression slope very convincingly. In both cropping systems, two families of growth habit IV and one of growth habit II/III stood out as being exceptionally high yielding in both generations. These were families 1 and 2 of growth habit IV, and family 7 of growth habits II/III.

Since beans are grown in a range of cropping systems, particularly in the tropics, it is considered important that early generation testing of families should be carried out in a number of different systems. The yield trial in F_3 and F_4 provided valuable information for selecting families with good performance when intercropped and in sole cropping. Stability of yield across seasons can also be selected for with this method. The best families can return to single plant selection in the F_5 or F_6 generations.

REFERENCES

1. CIAT (1979). Centro Internacional de Agricultura Tropical. Bean Program 1979 Annual Report. Cali, Colombia. 1980. 109p.

2. Davis, J.H.C. and García, S. (1983). Competitive ability and growth habit of indeterminate beans and maize for intercropping. Field Crops Research 6, 59-75.

3. Davis, J.H.C., Beuningen, L., Ortíz, M.V. and Pino, C. (1983). Selecting beans (Phaseolus vulgaris L.) for tolerance to competition from maize when intercropped. Submitted to Crop Science.

4. Francis,C.A. (1980). Development of plant genotypes for multiple cropping systems. In K.J. Frey (ed.), Plant Breeding Symposium II, Iowa State Univ.Press, Ames, Iowa, Ch. 7.

5. ___________ and Sanders, J.H. (1978). Economic analyses of bean and maize systems: monoculture versus associated cropping. Field Crops Res., 1,319-335.

6. ___________ (1978). Multiple cropping potentials of beans and maize. Hort. Science 13,12-17

7. Laing, D.R., Jones, P.G. and Davis, J.H.C. (1983). Crop Case Study: Common Beans (Phaseolus vulgaris L.). Submitted for publication in "The Physiology of Tropical Field Crops", eds. P.R. Goldsworthy and N. Fischer, John Wiley and Son Publishers.

8. Lupton, F.G.H. and Whitehouse, R.N.H. (1957). Studies on the breeding of self-pollinating cereals. I. Selection methods in breeding for yield. Euphytica 6,169-184.

Table 1. Mean characteristics of the bean progenies of different growth habits.

Character	Trial	Habit I	Habit II/III	Habit IV
Main stem node number	F_3	9.5	16.0	25.0
	F_4	9.5	13.8	26.2
Days to flowering	F_3	34.0	38.0	38.0
	F_4	34.9	37.4	35.3
Leaf dry weight/100 cm^2 (g.)	F_3	29.5	26.5	23.0
	F_4	29.7	25.0	23.5
Yield (kg/ha)	F_3	944	1497	2338
	F_4	581	589	925

Table 2. Mean yields (kg/ha) of beans and maize, combining different bean growth habits with different maize genotypes.

Bean Growth Habit		I		II/III		IV	
Maize genotype	Trial	Bean yield	Maize yield	Bean yield	Maize yield	Bean yield	Maize yield
Población 30	F_3	700	3192	1168	2639	1686	2105
	F_4	470	3954	438	4226	748	3366
Suwan-1	F_3	505	4219	1113	2948	1389	3040
	F_4	345	5189	347	5032	596	4958
La Posta	F_3	698	3693	951	4659	1387	4066
	F_4	323	4408	347	4278	567	4144

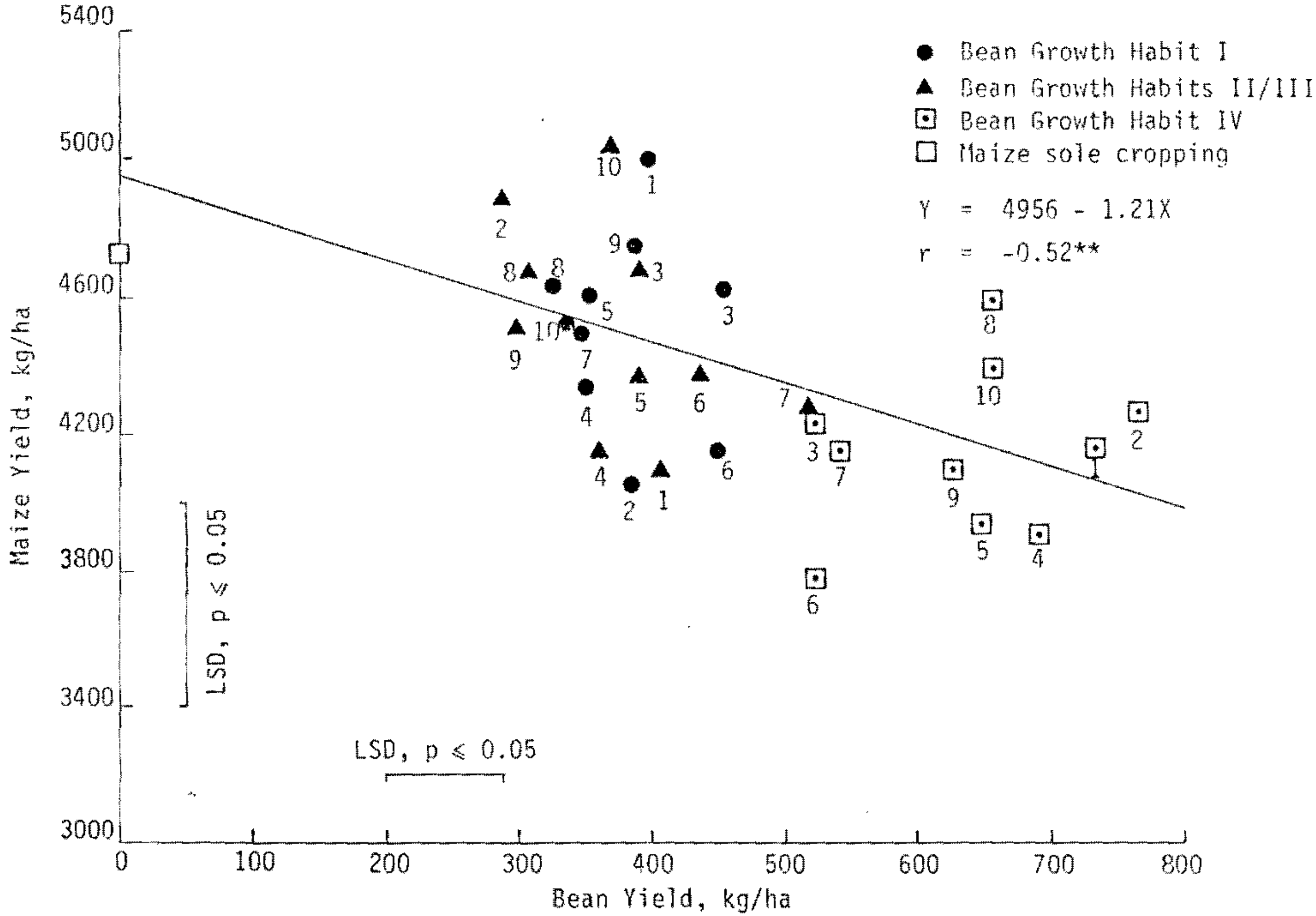

Figure 2. Mean yields of beans and maize (kg/ha) for F_4 families (numbered 1 to 10) of beans intercropped with maize (mean of 3 genotypes).

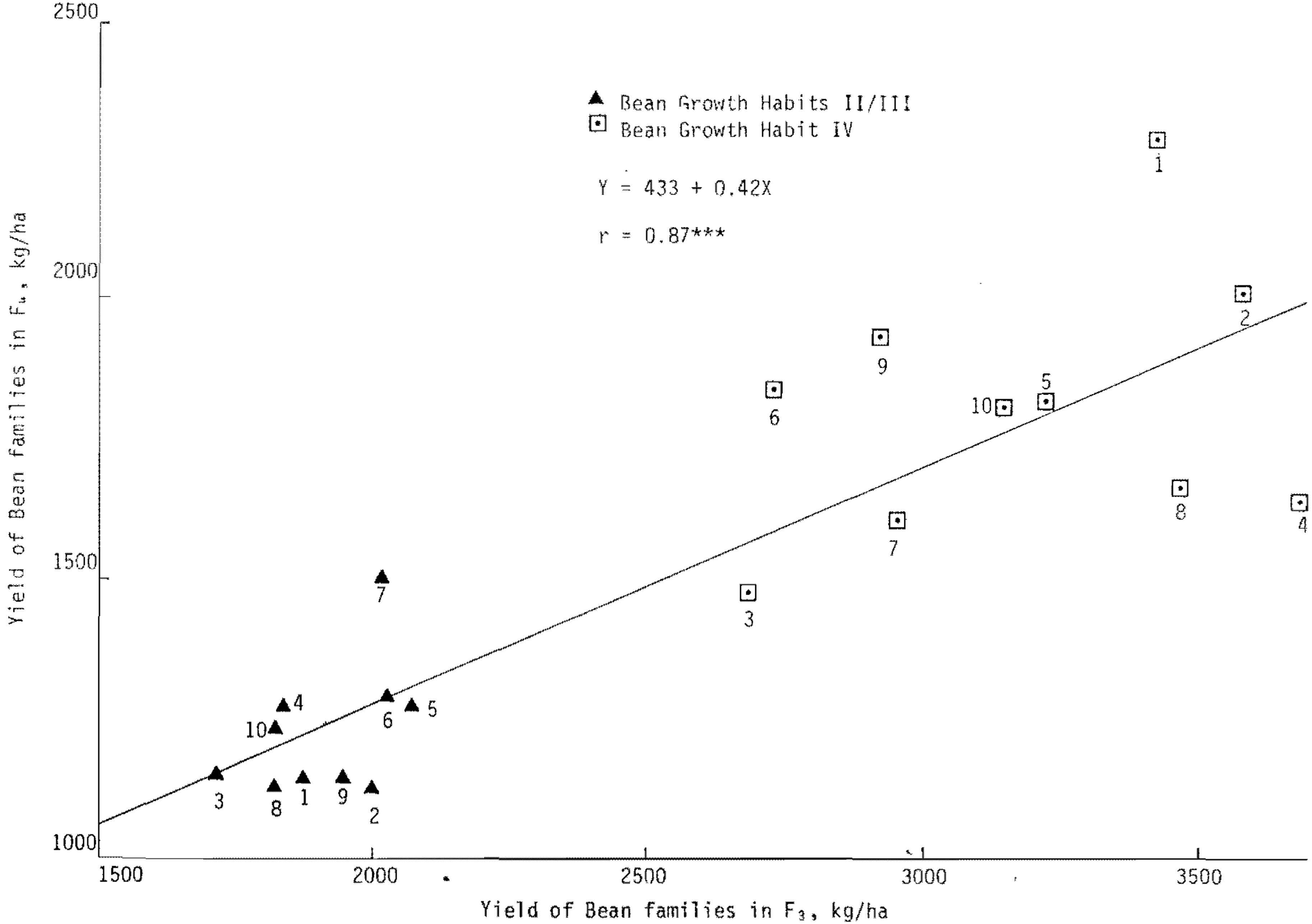

Figure 3. Mean yields of bean families (numbered 1 to 10) of growth habits II/III and IV in sole cropping, in F_3 and F_4 generations.

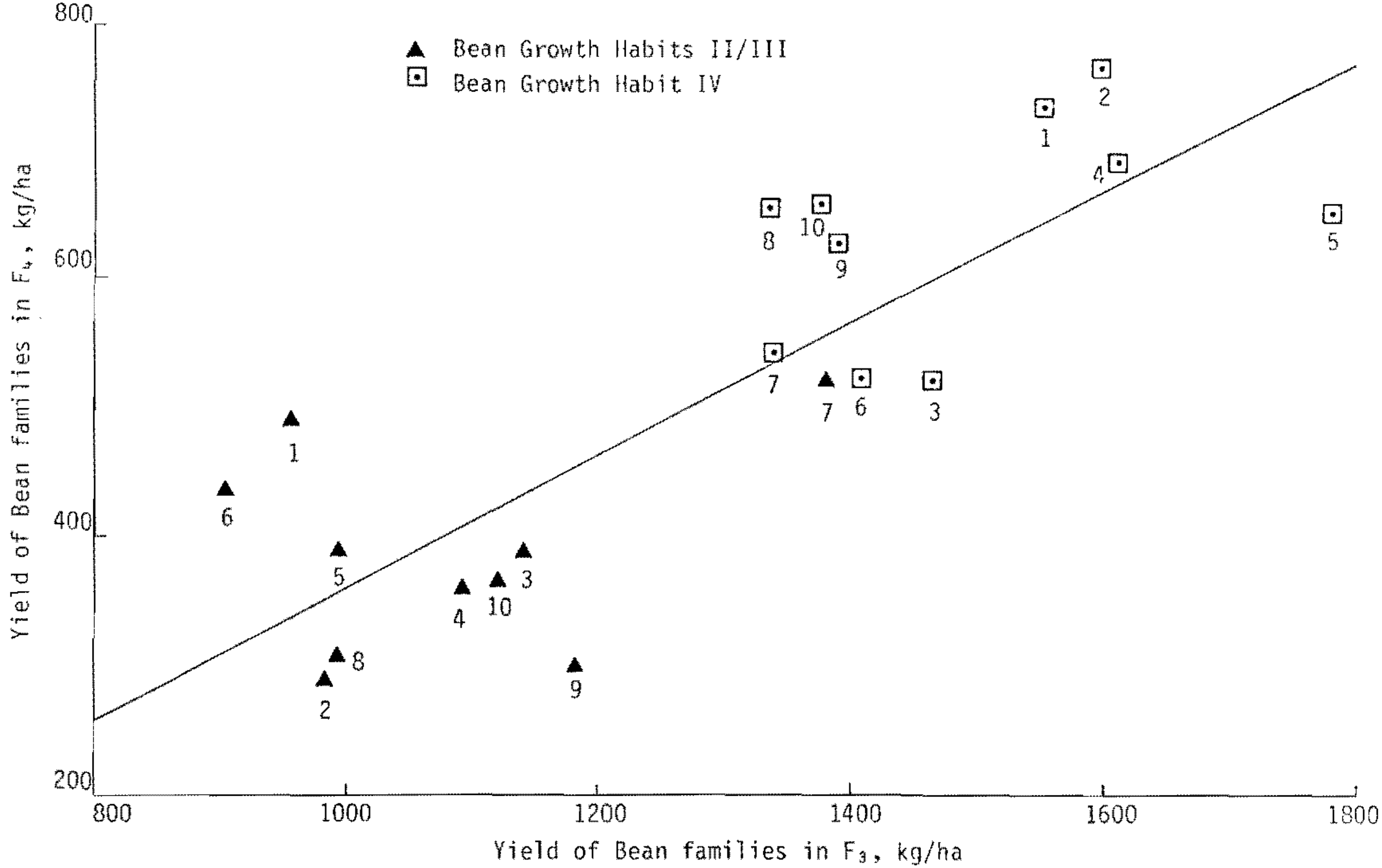

Figure 4. Mean yields of bean families (numbered 1 to 10) of growth habits II/III and IV intercropped with maize, in F_3 and F_4 generations.