YIELD COMPONENT COMPARISON OF TEN CULTIVARS OF BUSH BEANS (PHASEOLUS VULGARIS L) GROWN UNDER HEAT STRESS

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SUMMARY

Ten cultivars of bush bean (*Phaseolus vulgaris* L) were compared on the basis of their yield components under conditions of heat stress. A growth bench was used to provide a climatic model with a 33/23°C day/night temperature. Primary data included number of branches, nodes, racemes, flowers pods and seeds. The main components of yield were branches per plant, pod number, seeds per pod and pod size. Seeds per pod is a promising component for improvement because it was not involved in compensatory relationships and accounted for 17.1% of the total yield diversity.

INTRODUCTION

An earlier study (Eaton and Herath 1979) considered the effects of heat and population stress in bush bean *Phaseolus vulgaris* L. Branching was considerably reduced under the effect of population stress. Appadurai *et al* (1967), Camacho *et al* (1968), Hodgson and Blackman (1956), Mack and Hatch (1968) and Mathews (1933) have reported on the effect of spacing on beans. The effect of spacing on yield component compensation has also been investigated by some of these workers in addition to the work of Adams (1967) on the field bean and that of Goulden (1976) on navy beans. Heat and population stress and their effects on yield component compensation have also been reported (Herath and Eaton, (1979). Ormrod *et al* (1967) and Stobbe *et al* (1966) investigating the effect of temperature on embryo sac development in Phaseolus, found that high temperatures adversely affected seed formation. Since seed number per pod is an important component of yield, these findings are significant. Miladinovic and Gorokalo (1976) have reported on the effect of agro-ecological conditions on variability of yield components, and Tomar *et al*, (1972) have reported the effects of the environment on character correlation and heritability in green gram (*Vigna radiata*).

The present study was designed to investigate the effects of heat stress applied at ciritcal stages of growth, namely, the seedling, pre-flowering and pod-set stages of bush bean on yield component compensation, with a temperature regime similar to the conditions that prevail in a dry lowland tropical climate, identified as DL 1 by Panabokke, (1979). These conditions give adequate assimilation of dry matter to produce satisfactory crops. With the limitation on land resources in the highlands, bush bean cultivation has gradually been spreading to the plains where marginal conditions prevail, during the cool season from December to February. In this region, (DL 1) day temperatures often reach 33°–34°C and night temperatures too remain relatively high (23°–25°C). However, these regimes of temperature are frequently modulated by cloud cover and prevailing winds, and do not often remain the same throughout. The fluctuation often occurs more during the day than in the night.

MATERIALS & METHODS

The experiment was designed to test for heat stress at different periods during growth. Ten of the most heat tolerant cultivars of the previous study were tested on the growth bench. Two bush bean cultivars Contender and Top Crop were also included among the ten as they were considered relatively heat tolerant under dry zone conditions in Sri Lanka. While maintaining a constant night temperature of 23°C throughout the experiment, the day temperature was varied to give 33°C during the heat stress treatment which lasted six days from the 6th, 12th, 18th, 24th and 30th–36th day after planting. These coincided with the seedling, pre-bloom and pod-set stages. Spacing was kept constant at 10x10 inches between individual units. Dry matter accumulation rates were recorded on the 12th, 18th, 30th and 44th days after planting and leaf area was determined on the last three dates. Relative photosynthetic efficiency was determined at first flowering on the 24th day after planting. The method adopted was removing one square centimeter discs from the first fully expanded leaf of each treatment. These samples were taken at 0500 hours before lights on the growth bench went on and the second set of samples was taken at 1400 hours on the same day. The difference in weight of the two discs was measured as the amount of photosynthates assimilated. The two discs for each treatment were removed from the same position on either side of the midrib of the same leaf. The ratio of the leaf area to dry weight of whole plants was determined and harvest index was computed as the ratio of total dry weight of pods to the dry weight of plant residue at harvest. The cultivars were Kinghorn Wax (KHW), Slim Green (SG), Top Notch Golden Wax (TNGW), Early Wax (EW), Miami (MIA), Resistant Kinghorn Wax (RKHW), Contender (CON), Dwarf Green Tender Crop (DGTC), Top Crop Stringless (TCS), and Improved Tender Green (ITG), all arranged in 4 randomised complete blocks.

Recorded on each plant were branching (main stem counted as a branch), node number (N), raceme number (R), flower number (F), pod-set (P), seed number (S) and pod weight (G).

Yield components computed were branches per plant (B), nodes per branch (N/B), racemes per node (R/N), flowers per raceme (F/R), pods harvested per flower cluster (P/F), seeds per pod harvested (S/P), and pod enlargement per seed (G/S). The data were analysed as in previous studies (Herath and Eaton (1979); Huxley *et al.* (1979). Each ratio was first expressed as a natural logarithm. Taking each dependent variable one after another, the preceding independent variable was orthogonalized by a modified Gram-Schmidt method (Bock 1975). Each independent variable was then transformed and finally had means of zero, variance of unity for any one dependent variable, and were zero correlated. In the regression analysis an increment in R-squared measured the independent contribution of each independent variable included in succession. For orthogonal independent variables these contributions could react directly as the squares of the entries in a simple correlation matrix. The means for each log ratio (Table 1) then became the intercepts of the equations in which these variables were taken as dependent (Table 2).

A one-way analysis of variance tested for cultivar differences in each yield component was also carried out

RESULTS

There was considerable compensation among yield components (Table 2). These compensations were indicated by significant negative values of the regression coefficients along the diagonal (Table 2). The intensity of these compensations was indicated by the magnitude of the coefficients of determination (Table 2). Thus, there was a tendency for plants with greater branch number (B) to have decreased (N/B). Similarly F/R compensated strongly for R/N while P/F compensated for F/R (Table 2). There was a positive association between yield (G) and pod enlargement per seed (G/S). While these findings are very similar to those of the previous study, the present study did not detect a correlation between S/P and G/S.

The mean contribution to yield of each independent variable taken in succession (Table 2) was as follows:– Branch number (B) accounted for 16.0% of the variability in yield. Given the number of flowers per plant, 11.3% of the remaining variability in yield was accounted for by pod set (P/F) (Table 2.) Seed number accounted for 17.1% and after seed number was fixed the remaining 54.0% of the variability in yield was accounted for by pod enlargement per seed (G/S). While G/S was the major component of yield, it in turn was mainly predicted from N/B (negatively), R/N (negatively) and P/F (positively) (Table 2).

R/N was a significant component of P/F while S/P had no significant predictors. The component compensation found in the present experiment indicates that cultivars achieve similar overall yield by quite different means.

The present experiment suggests the selection of cultivars or parents with branching, pod set, seed numbers, and pod enlargement in the upper range, of their respective distributions, Furthermore, experiments to investigate practical methods of increasing one or more of these attributes in existing cultivars could be undertaken. Of special interest would be G/S because of the importance of its contribution to yield and S/P because of its independence from its own components. This independence indicates that levels of S/P were not limited by any other factor under the conditions of the present experiment. The ability to set pods with larger seed numbers has thus been added to pod set itself as an important component of stress adaptation in the cultivars studied.

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Table 1 Means of yield components in ten bean cultivars grown under heat stress applied at particular stages of growth, 1979

Cultivar	*KHW*	*SG*	*TNGW*	*EW*	*MIA*	*RKHW*	*CON*	*DGTC*	*TCS*	*ITG*
Arithmetic Means of Varieties										
B	5.3 ab	6.8 ab	7.3 a	7.0 a	6.0ab	6.3 ab	5.0 ab	5.0 ab	5.3 ab	4.5 b
N	14.0 bc	18.0 a	16.0 abc	17.1 ab	15.0 abc	15.0 abc	15.0 abc	13.0 c	14.5 bc	13.3 c
R	8.3 abc	12.3 a	11.3 ab	12.5 a	9.8 abc	9.8 abc	9.3 abc	9.0 abc	7.3 c	7.0 c
F	44.5 b	78.0 a	66.5 ab	78.5 a	70.8 ab	59.8 ab	56.0 ab	52.8 b	46.0 b	47.3 b
P	11.3 ab	18.3 a	18.0 a	14.8 a	16.0 ab	15.0 ab	10.8 b	13.3 ab	12.3 ab	13.3 ab
S	46.3 b	79.3 a	66.8 ab	55.0 ab	69.3 ab	64.8 ab	53.3 ab	54.0 ab	53.0 ab	53.8 ab
G	52.8 bc	62.0 abc	76.3 ab	50.8 c	54.7 c	61.9 abc	77.6 a	42.9 c	65.2 abc	58.7 abc
Geometric Means of Components										
E	5.2 ab	6.7 a	7.2 a	6.8 a	5.2 ab	5.9 ab	6.2 ab	4.9 ab	5.1 ab	4.5
N/B	2.7	2.7	2.2	2.5	2.9	2.5	2.4	2.6	2.8	2.9 b
R/N	0.6	0.7	0.7	0.7	0.6	0.7	0.7	.07	0.5	0.5
F/R	5.5	6.6	5.6	6.3	6.5	6.1	6.1	6.0	6.3	6.7
P/F	0.3	0.2	0.3	0.2	0.3	0.3	02	0.3	0.3	0.3
S/P	3.9	4.4	3.8	3.8	4.3	4.4	5.0	4.1	4.3	4.
G/S	1.2 ab	0.8 c	1.1 ab	0.9 bc	0.8 c	1.0 bc	1.5 a	0.8 c	1.2 ab	1.1
G	50.4 ab	61.3 ab	75.9 a	49.7 ab	53.6 ab	61.4 ab	77.1 a	42.0 b	65.0 ab	581 ab .0ab
Standard Orthogonal Variables										
B	–0.44 ab	0.7 4a	1,04 a	0.77 a	–0.39 a	0.14 ab	0.40ab	–0.64 ab	–0.52 ab	–
N/B	–0.3	1.2	–0.3	0.6	0.4	–0.1	–0.4	–0.9	0.1	-1.10 b
R/N	–0.2	0.1	0.2	0.5	0.1	0.2	0.2	0.4	–0.7	–0.2
F/R	–0.8	0.5	–0.3	0.5	0.3	0.1	0.0	0.0	–0.3	0.4
P/F	–0.4	0.2	0.7	0.7	0.6	0.2	–1.2	0.2	0.0	0.2
S/P	–0.8	0.4	–0.4	–0.9	0.3	0.4	1.0	0.0	0.0	–0.4
G/S	0.1 abc	0.6 bc	0.8 ab	–0.4 bc	–0.7 bc	–0.1 abc	1.3 a	–1.3 c	0.7 ab	.01
G	0.2	0.4	0.4	0.3	–0.9	0.8	–0.2	–.03	–.02	0.4 ab 0.3

B— branch number, including main stem; N–node number; R–raceme number; F–flower number; P–pods harvested; S–seed number in pods harvested; G–yield total weight (g) of pods harvested.

The cultivars were Kinghorn Wax (KHW), Slim Green (SG), Top Notch Golden Wax (TNGW), Early Wax (EW), Miami (MIA), Resistant Kinghorn Wax (RKHW), Contender, (CON), Dwarf Green Tender Crop (DGTC), Top Crop Stringless (TGS), and Improved Tender Green (ITG).

Table 2 Regressions of untransformed yield components (log ratios) on independent standard transformed residuals, logarithmic scales (cultivar comparisons, 1979).

		Independent variable						
	Mean	*B*	*N/B*	*R/N*	*F/R*	*P/F*	*S/P*	*G/S*
		Regression coefficients						
B	1.742							
N/B	0.962	-0.130**						
R/N	-0.485	0.070	-0.016					
F/R	1.819	-0.023	0.011	-0.095**				
P/F	-1.418	-0.009	-0.019	-0.110**	-0.102*			
S/P	1.433	0.024	0.023	0.004	-0.017	-0.045		
G/S	0.015	-0.004	-0.078*	-0.078*	-0.051	-0.087*	-0.033	
G	4.069	0.103*	0.017	-0.029	0.001	0.087*	0.107**	0.190**
		Total Coeficients of determination (%)						
N/B	65.3	65.3**						
R/N	7.7	7.3	0.4					
F/R	25.0	1.4	0.3	23.2**				
P/F	32.4	0.1	0.5	17.1**	14.7*			
S/P	14.7	2.4	2.4	0.1	1.2	8.7		
G/S	39.6	0.0	10.3*	10.2*	4.3	12.8*	1.9	
G	100.0	16.0*	0.4	1.3	0.0	11.3*	17.1**	54.0**

B—branch number, including main stem; N—node number; R—raceme number; F—flower number; P—pods harvested; S—seed number in pods harvested; G—Yield total weight (g) of pods harvested.

*—p—5%, **—p—1%

Negative signs on significant regression coefficients indicate compensation of one component by another. The coefficients of determination measure increments in the variability of a single yield component, taken as a dependent variable, accounted for after including each preceding yield component sequentially in a stepwise multiple regression.