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EFFECT OF INTERGENOTYPIC COMPETITION ON YIELD ASSESSMENT IN COWPEA TRIALS

SHIV KUMAR* AND S. N. MISHRA

Department of Plant Breeding, G. B. Pant University of Agriculture and Technology Pantnagar 263145

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ABSTRACT

Study on the effect of intergenotypic competition in cowpea revealed significant differences among cultivars for their competitive ability. Competition caused significant changes in the relative performance of cultivars with regard to the characters studied except pod length and number of seeds per pod. For seed yield, the average competition was the major source of bias in single-row plots. Estimates of the average competition effects and average expected bias for seed yield indicated that an aggressive competitor was overestimated in competition, whereas a poor competitor was underestimated. Negative correlation between yielding and competing abilities of cultivars suggest the need for bordered plots in yield evaluation trials of cowpea. Since pod length and number of seeds per pod were unaffected by competition, they could be better selection criteria for yield in single-row plots.

Key words: Border effect, cowpea, intergenotypic competition.

Intergenotypic competition has been recognized as one of the major sources of bias in the yield assessment of different crops, causing considerable changes in performance and ranking of cultivars [1–8]. To avoid such bias, a general practice is to exclude the border rows of multi row plots in a yield trial. However, where only limited amount of seed is available, e.g. in the early generations of a breeding programme, and where a large number of lines have to be accommodated in replicated yield trials, then single-row plots are often used. In such situations, yield of a cultivar in single-row plots could well be confounded with border effects generated from the flanking rows of other cultivars, thereby decreasing reliability of selection. The present study aims to determine the effect of intergenotypic competition in single-row plots for various characters in cowpea.

*Present address: Plant Breeding, Directorate of Rice Research, Rajendranagar, Hyderabad 500030.

MATERIALS AND METHODS

Three cowpea (*Vigna unguiculata* L. Walp.) cultivars IT82D-716, IT82E-18 and IT84E-124 differing in growth habit, seed colour, seed shape, flower colour, stem length, days to maturity, and seed yield (Table 1) were taken for this study. Each cultivar was used as a yield genotype under all possible combinations of genotypes for p(p+1)/2 (where p = number of cultivars) or six competing conditions. For cultivar 1 as yield genotype, the six possible combinations were 1-1-1, 1-1-2, 1-1-3, 2-1-2, 2-1-3, and 3-1-3. Thus, a competition test involved 18 treatments. The layout of the experiment was based on alternate-row design of Hanson et al. [1] where competition treatments were obtained by random allocation of the cultivars in rows. For example, the order of . . .21323. . . gives 2-1-3, 1-3-2 and 3-2-3 combinations. The experiment was conducted in a randomized complete block design with four replications over three growing seasons (summer 1987, rainy 1987, and summer 1988). Plot size was a single-row of 2 m length. The distance between plants was 10 cm in rows spaced 40 cm apart. Three seeds per hill were sown, and thinning to one plant per hill was done two weeks after emergence. Observations recorded on each plant for eight quantitative traits (Table 2) were subjected to analysis of variance for competition effect following the model proposed by Hanson et al. [1]:

$$Y_{ijkm} = U + r_i + g_j + C_{jk} + C_{jm} + S_{jkm} + e_{ijkm}$$

where y_{ijkm} — value of j-th yield genotype bordered by k-th and m-th competing genotypes in i-th replication, U—population mean, r_i — i-th replication effect, g_j — j-th genotype effect C_{jk} and C_{jm} — average competition effects of k-th and m-th genotypes on the performance of j-th genotype, respectively, S_{jkm} — joint competition effect of k-th and m-th genotypes on the performance of j-th genotype, and e_{ijkm} — random error.

The average adjusted competition effect ($C_{.k}$) and the average expected yield bias (Δ_j) in nonbordered single-row plots for different cultivars were estimated following Hanson et al. [1].

$$C_{.k} = Y_{..k.}/rp^2 - Y_{....}/rp^3$$

$$\Delta_j = -2pC_{jj}/(p-1)$$

The $C_{.k}$ estimates the average increase or decrease in the mean performance of different cultivars when bordered by k-th cultivar. A cultivar is called aggressive or cooperative depending on whether the mean performance of different cultivars is decreased or increased. The Δ_j estimates the average expected yield bias in nonbordered single-row plot for j-th cultivar. A positive estimate of Δ_j indicates over-estimation and a negative estimate indicates underestimation.

The mean performance of cultivars under competition with other cultivars (allocompetition) was compared with their pure stand performance (autocompetition). Correlation coefficient was estimated between autocompetition and allocompetition.

RESULTS AND DISCUSSION

Analysis of variance for competition effects (Table 2) revealed that the variances due to average (C) and specific (S) competition and their interactions with genotypes were highly significant in different seasons for all characters studied except pod length and number of seed per pod. The magnitude of average competition was higher than that of specific competition for days to 50% flower, stem length, 100-seed weight, and seed yield, indicating that additive type of competition effect was the major source of bias in the estimation of these traits. For peduncle length and pods per plant, the relatively high specific competition effect suggested that certain combinations of competing genotypes were the principle source of bias for these traits. Therefore, the effect of total competition on peduncle length and pods per plant could be reduced to a certain level by avoiding such combinations while evaluating lines. A few discrepancies for competition effects were observed from season to season, suggesting influence of environmental conditions in the genotypic response to competition. This is in conformity with the observation of Hanson et al. [1] that the degree of competition between two cultivars is influenced by seasonal variations.

Table 1. Origin and important morphological and agronomic characteristics of cowpea genotypes

Character	IT82D-716	IT82E-18	IT84E-124
Origin	IITA, Nigeria	IITA, Nigeria	IITA, Nigeria
Growth habit	Semideterminate	Indeterminate, semiprostrate	Determinate, bushy
Branching habit	Erect, high branching	Semierect, high branching	Erect, low branching
Seed colour	Creamy white	Dark brown	Brown
Seed shape	Rhomboid	Ovoid	Kidney
Flower colour	Creamy white	Light violet	Yellowish white
Days to 50% flower	65 ± 5	60 ± 5	55 ± 5
Days to maturity	80 ± 5	75 ± 5	70 ± 5
Stem length (cm)	60 ± 5	80 ± 5	45 ± 5
100-seed weight (g)	14	15	16
Pods/plant	13	16	10
Pod length (cm)	13	16	16
Seeds/pod	11	12	10
Seed yield (kg/ha)	1300	1820	1470

Table 2. Analysis of variance (mean squares) for competition effects in cowpea

Source	d.f.	Season	Days to 50% flower	Stem length	Ped-uncle length	Pods per plant	Pod length	Seeds per pod	100-seed weight	Yield per plant
Average competition adjusted (C)	2	Summer, 87	21.0**	1776.4**	3.0	25.8**	1.2	2.4	3.5*	30.6**
		Rainy, 87	21.8**	386.5**	34.3**	34.2**	1.2	3.2	13.3**	15.0**
		Summer, 88	2.1**	66.5**	50.3**	0.2	0.1	4.3	8.7**	31.9**
Specific competition (S)	3	Summer, 87	2.3	673.7**	24.4**	45.8**	2.7	1.5	11.0**	3.4
		Rainy, 87	17.3**	365.4**	35.8**	68.7**	1.2	1.2	7.7**	27.2**
		Summer, 88	0.4	27.4*	5.9	1.7	0.6	0.9	0.7	3.6
Genotypes x C	4	Summer, 87	1.9	868.4**	24.3**	7.5	0.9	0.6	5.1**	2.0
		Rainy, 87	3.0	709.8**	9.7*	28.0**	0.8	4.7	9.5**	20.7**
		Summer, 88	4.2**	42.2**	7.4	2.4	0.3	0.9	4.9*	2.9
Genotypes x S	6	Summer, 87	7.9**	507.8**	12.4**	56.1**	2.8*	4.6	3.3	22.1**
		Rainy, 87	1.3	432.2**	47.8**	72.0**	3.4	2.5	12.1**	49.0**
		Summer, 88	2.9**	112.6**	25.5**	3.9*	0.6	2.4	10.5**	22.6**
Error (adjusted)	51	Summer, 87	1.1	10.5	3.7	4.0	1.1	1.9	1.1	4.0
		Rainy, 87	1.4	5.7	3.7	2.3	2.4	2.4	0.7	2.5
		Summer, 88	0.4	6.7	3.5	1.3	1.4	1.8	1.5	3.0

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

The average competitive ability of k-th cultivar (C_k) estimates the average increase or decrease in the mean performance of other cultivars when bordered by it. The results in Table 3 show that, on an average, the seed yield of different cultivars was decreased by 150 to 252.5 kg/ha and increased by 22.5 to 172.5 kg/ha when bordered by IT82D-716 and IT82E-18, respectively. This indicates that IT82D-716 is an aggressive and IT82E-18 is a poor competitor. Among yield components, pods/plant and 100-seed weight were significantly influenced by competition whereas pod length and seeds per pod remained unaffected. However, the magnitudes of average competition effects, though statistically significant, were so small that they were of no practical importance and hence not reported here.

The average expected yield bias, Δ_j's, in nonbordered single-row plots for different cultivars is given in Table 4. It was found that IT82D-716, an aggressive competitor, was overestimated in single-row plots, whereas IT82E-18 and IT84E-124 were underestimated because of their poor competitive ability. Since cultivars reacted differently to competition effects, the competition caused considerable changes in the relative performance and ranking of cultivars as shown in Table 5. The yield of IT82D-716 was low in pure stand but high under competition with other cultivars. The reverse was true for IT82E-18. As a result, an aggressive cultivar like IT82D-716 would be picked up as an outstanding genotype in

Table 3. Average competitive effect of k-th cultivar ($C_{.k}$) in cowpea

K-th cultivar	Season	$C_{.k}$ value for seed yield			Nature of interaction
		g/plant	g/row	kg/ha	
IT82D-716	Summer, 87	–0.96	–19.20	–240.00	Depressive
	Rainy, 87	–0.60	–12.00	150.00	Depressive
	Summer, 88	–1.01	–20.20	–252.50	Depressive
IT82E-18	Summer, 87	0.09	1.80	22.50	Cooperative
	Rainy, 87	0.69	13.80	172.50	Cooperative
	Summer, 88	0.14	2.80	35.00	Cooperative
IT84E-124	Summer, 87	0.88	17.60	220.00	Cooperative
	Rainy, 87	–0.09	–1.80	–22.50	Depressive
	Summer, 88	0.86	17.20	215.00	Cooperative

the nonbordered single- row plots whereas IT82E-18 and IT84E-124 might be discarded. Therefore, selection of cultivars from single-row trials without considering intergenotypic competition effects would lead to erroneous results. Correlation coefficient between auto-competition (pure stand) and allo-competition was high and significantly negative (–0.96), suggesting negative association between yielding and competing abilities of cultivars. The implications of negative correlation between yielding and competing ability in plant breeding have been discussed by Fasoula [9].

Table 4. Average expected bias (Δ_j) for seed yield in cowpea

Cultivar	Season	Average expected yield bias (Δ_j)			Nature of bias
		g/plant	g/row	g/2 rows	
IT82D-716	Summer, 87	3.27	65.40	32.70	Overestimated
	Rainy, 87	0.08	1.60	0.80	Overestimated
	Summer, 88	3.07	61.40	30.70	Overestimated
IT82E-18	Summer, 87	–0.93	–18.60	–9.30	Underestimated
	Rainy, 87	–6.78	–135.60	–67.80	Underestimated
	Summer, 88	–1.23	–24.60	–12.30	Underestimated
IT84E-124	Summer, 87	–2.49	–49.80	–24.90	Underestimated
	Rainy, 87	–1.32	–26.40	–13.20	Underestimated
	Summer, 88	–2.46	–49.20	–24.60	Underestimated

Our results suggest that nonbordered single-row plots with normal spacing reduced the accuracy of the yield assessment of cowpea lines. Therefore, measures should be taken to minimize competitional bias in single-row plots. The double-row plot trial reduced the

Table 5. Cultivar performance under competition and pure stand

Cultivar	Seed yield (% of overall mean)					
	summer, 1987		rainy, 1987		summer, 1988	
	auto	allo	auto	allo	auto	allo
IT82D-716	93.70	106.60	88.20	107.30	91.50	111.30
IT84E-124	94.70	103.70	56.60	120.40	100.50	95.70
IT82E-18	111.60	89.80	155.20	72.30	108.00	93.00
SE ±	1.07	1.06	6.23	2.99	0.90	1.14

Auto — auto-competition; allo — allo-competition.

expected yield bias by half (Table 4). In the quantitative genetic studies such as diallel and triple-test cross involving single plant progenies, the number of replications can be reduced accordingly without sacrificing much precision because variance due to replications accounted for a very small proportion (1–10%) of the total variance compared to competition variance (27–42%) in this experiment. Lin and Torrie [4] in soybean and Bradshaw [8] in swedes also suggested a double-row plot for yield assessment. Another alternative approach would be to separate single-row plots by a row spacing that eliminates intergenotypic competition as was also suggested by Kramer et al. [10] in spring wheat. However, a preliminary investigation is needed to see the differential response of cultivars to the available free space in this approach. Other possible solution to minimize the competition effects could be to evaluate the yield performance of cultivars with different growth habits in separate trials because there seemed to be a positive association between competitive ability for seed yield and growth habit of a cultivar. In general, a tall cultivar has an advantage in competing for available light and a late maturing cultivar is able to extract nutrients from the soil after the root system of an early maturing cultivar no longer functions. In the present study, IT82D-716 (the best competitor) was the tallest and late maturing cultivar (Table 1), hence it might have exploited the available resources more efficiently in competition. Covariate adjustment for competition effect is the other approach to correct single-row plot yields [11]. Since number of seeds per pod has been reported to be positively associated with yield per plant in earlier studies [12], it is suggested that number of seeds per pod along with pod length could be a reliable selection criterion for seed yield in single-row plots as there traits were unaffected by competition in this study.

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