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Effect of intergenotypic competition on yield assessment at different spacings in cowpea (*Vigna unguiculata* L. Walp)

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Abstract

Study on the effect of intergenotypic competition at different spacings in cowpea (*Vigna unguiculata* L. Walp) revealed that the magnitude of competition effects depended not only on genotypes but also on spacings. All characters except pod length and seeds per pod were significantly influenced by the competition. Average competition effect was, in general, smaller and nonsignificant at wider spacings. An inverse relationship was found between competition effect and spacing i.e., the competition effect increased as the distance between plants decreased. Estimation of the average competition effects and expected bias in nonbordered single-row plots at different spacings suggests wider spacing as an efficient way of curtailing competition bias since most of the characters were free from competition bias at 20- and 40-cm spacings.

Key words : *Vigna unguiculata*, cowpea, genotypic, competition, spacing

Introduction

Competition among plants affects yield, stability and various estimates of genetic parameters due to compulsory sharing of environmental resources in response to density-induced shortages and suppresses yield of genetically identical plants evenly (autocompetition) and genetically different plants unevenly (allocompetition) [1-3]. Since it is encountered in plant breeding experiments causing significant bias in yield assessment of individual plants and their progenies in early generations, reliability of selection through various breeding methods is considerably reduced [4-10]. To avoid such bias, a general practice is to increase plant spacing in early generations and exclude border rows in yield evaluation trials. Therefore, the present study was designed to assess competitive ability of different plant types in cowpea and determine a reasonable spacing at which competition bias would effectively be reduced.

Materials and methods

Three cowpea genotypes IT82D-716, IT82E-18 and IT84E-124 representing different growth habits were included in the study. IT82E-716 is a semi-determinate type with erect and high branches whereas IT82E-18 is an indeterminate, semi-prostate type with semi-erect and high branches, and IT84E-124 is a determinate and bushy type with erect and low branches. Each genotype was grown as yield genotype under all possible combinations of genotypes i.e. p (p + 1)/2 (where p = number of genotypes). For genotype 1 as yield genotype, six possible combinations were 1-1-1, 1-1-2, 1-1-3, 2-1-2, 2-1-3 and 3-1-3. Thus, the competition test involved a total of 18 treatments. The experiment was conducted in a split-plot design with four spacings in main plots and 18 competition treatments in sub plots. The layout was based on alternate-row design of Hanson *et al.* [4] where competition treatments were obtained through random allocation of genotypes in rows till all the possible combinations are achieved. For example, the order of ... 213231... gives 2-1-3, 1-3-2, 3-2-3 and 2-3-1 combinations. Though the experiment was conducted in four replications, chances of a combination appearing more than once within a replication was not ruled out. In such cases, the mean was used in the analysis. Seeds were sown at 5-, 10-, 20- and 40- cm in rows spaced 40 cm apart. Each plot consisted of single row of 4 m length so that at maturity, at least five plants could randomly be selected. Three seeds per hill were sown and thinning to one plant per hill was done two weeks after germination. The recommended cultural practices were adopted to grow a successful crop. Observations recorded on each plant for days to 50% flowering, plant height, peduncle length, number of pods, pod length, seeds per pod, 100-seed weight and seed yield were subjected to analysis of variance for competition effect. The following model was developed to explain the competition effect:

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$$Y_{lijkm} = \mu + r_i + d_l + e_{li} + g_j + C_{ljk} + C_{ljm} + S_{ljkm} + d_{glj} + e_{lijkm}$$

Where Y_{lijkm} - value of j-th yield genotype bordered by k-th and m-th competing genotypes in i-th replication at l-th spacing, μ-population mean, r_i–i-th replication effect, d_l–l-th spacing effect, e_{li}–random error for spacing, g_j–j-th genotype effect, C_{ljk} and C_{ljm}–average competition effect of k-th and m-th genotypes on the performance of j-th genotype at l-th spacing, S_{ljkm}–joint competition affect of k-th and m-th genotypes on the performance of j-th genotype at l-th spacing, d_{glj}–interaction effect between l-th spacing and j-th genotype, and e_{lijkm} - random error.

The average adjusted competition effect ($C_{l,\ k}$) and expected yield bias (Δ_{lj}) in nonbordered single-row plots for different genotypes at l-th level of spacing were estimated by :

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

$$\Delta_{lj} = -2p\ C_{lj}/(p - 1)$$

The $C_{l.k}$ estimated the average increase or decrease in the mean performance of different genotypes when bordered by kth genotype at l-th spacing. A genotype was called aggressive or cooperative depending on whether the mean performance of different genotypes decreased or increased when bordered by it. The Δ_{lj} estimated the average expected bias in nonbordered single-row plot for j-th cultivar at l-th spacing. A positive estimate of Δ_{lj} indicated over-estimation and negative estimate indicates under-estimation.

Results and discussion

Analysis of variance for competition effects (Table 1) revealed that spacing had significant effect on days to

Table 1. Analysis of variance for intergenotypic competition effect at different spacings in cowpea trial

Source of variance	d.f.	Mean square							
		Days to 50% flowering	Plant height	Peduncle length	Pods per plant	Pod length	Seeds per pod	100-seed weight	Seed yield per plant
Replications	3	16.8	138.7	31.5	23.3	16.3	21.3	9.1	33.6
Spacings	3	73.3**	88.6	34.6*	75.9**	3.9	5.8	12.8*	133.0**
Main plot error	9	5.7	48.7	7.4	1.1	2.2	3.5	1.8	6.1
Genotypes (G)	2	347.0**	3449.3**	1841.4**	149.5**	284.3**	46.7**	104.5**	444.8**
Within genotype	15	4.8**	111.7**	43.9**	9.7**	2.1	5.6	13.3**	37.1**
Competition treatments	5	7.0**	83.8**	22.6**	9.1**	3.1	6.9	16.5**	15.0**
Genotype × Competition	10	3.7**	126.1**	54.6**	10.0**	1.6	4.9	11.7**	48.2**
Spacing × Competition	15	2.8**	60.9**	45.6**	6.5**	1.0	2.3	4.5**	25.8**
Sub plot error (adjusted)	204	0.7	6.6	3.6	0.8	1.0	3.5	1.1	2.4
At 5 cm spacing									
Average competition (C)	2	4.1**	83.3**	20.2**	4.4**	1.9	2.7	7.7**	29.7**
Specific competition (S)	3	7.9**	79.4**	14.5*	9.6**	3.8*	1.3	18.3**	1.2
G × C	4	1.2	71.9**	6.9	10.9	2.7	5.6**	5.6**	37.5**
G × S	6	5.7**	137.9**	82.0**	4.0**	1.9	2.7	7.7**	29.7**
At 10 cm spacing									
Average competition (C)	2	3.3**	35.7**	112.3**	12.7*	0.3	4.8	7.7**	37.2**
Specific competition (S)	3	8.5**	84.7**	56.9**	0.5	4.8*	5.4	18.1**	1.0
G × C	4	4.8**	81.0**	31.3**	11.7**	0.3	0.8	5.5**	22.9**
G × S	6	0.8	106.1**	64.0**	8.6**	2.2	3.1	15.5**	45.2**
At 20 cm spacing									
Average competition (C)	2	4.2**	57.5**	17.0*	0.4	1.9	4.2	3.9*	0.1
Specific competition (S)	3	5.4**	68.4**	27.7**	14.0**	3.8	4.5	19.2**	21.4**
G × C	4	5.3**	73.5**	18.5**	2.7*	0.4	2.3	2.7*	68.2**
G × S	6	1.0	126.7**	74.7**	15.2**	2.0	5.6	14.9**	12.4**
At 40 cm spacing									
Average competition (C)	2	0.4	1.4	9.4	0.1	1.3	3.4	2.3	4.9
Specific competition (S)	3	10.8**	133.9**	32.4**	14.8**	3.5	4.6	24.3**	20.2**
G × C	4	1.3	9.4	41.7**	0.8	1.0	3.1	8.8**	4.6
G × S	6	4.9**	179.9**	33.5**	15.9**	2.1	5.4	11.3**	71.7**

* and ** significant at 0.05 and 0.01 levels of probability

50% flowering, peduncle length, pods per plant, 100-seed weight and seed yield while competition treatments not only exerted significant effects but also interacted significantly with genotypes and spacings for all the characters studied except pod length and seeds per pod.Various components of competition, average, specific and their interaction with genotypes were significant for most of the traits at close spacings, viz., 5 and 10 cm. Though the average competition effect was nonsignificant for pods per plant and seed yield at 20 cm sacing, it was found significant for days to 50% flowering, plant height, peduncle length and 100-seed weight. The effects of average competition and its interaction with genotypes (G × C) were non-significant for all the characters at 40 cm spacing. Competition at narrow spacings might be attributed to the interference between plants whereas its absence at wider spacing might be attributed to the sufficient space available for each plant with no mutual shading. The result shows a tendency of high average competition effect (additive type) at close spacings whereas specific competition effect (nonadditive type) were more prominent at wider spacing. Significance of specific competition effects and its interaction with genotypes for most of the characters even at wider spacings indicates that certain combinations of genotypes caused competition even at wider spacings. A perusal of the results and growth habits of the genotypes used revealed that a semi-determinate type with erect and high branching represented by IT82D-716 remained competitive if flanked by IT82E-18, which is indeterminate and semi-prostrate type with semi-erect and high branching. To reduce the specific competition effect, it would be desirable to avoid such combinations while planning evaluation of single plant progenies in the segregating generations or in experiments where single row of a genotype is grown because of either large number of test genotypes or due to limited quantity of seeds such as in diallel experiments since spacing as a way to reduce it was found to be ineffective. These results were in agreement with the earlier findings in various crops [4-14].

The average competitive ability of k-th genotype at l-th spacing ($C_{l.k}$) (Table 2) showed that, on an average, the seed yield of different genotypes was depressed by 380 kg/ha when bordered by IT82D-716 at 5 cm spacing. This reduction was less at 10 cm spacing and became nonsignificant at 20 and 40 cm spacings. This indicates that IT82D-716 is an aggressive genotype at narrow spacings, causing significant yield loss to other genotypes when bordered by it. IT82E-18 as a border caused a yield advantage of 505 and 87.5 kg/ha on other genotypes at 5 and 10 cm spacings, respectively and nonsignificant effect at wider spacings and thus classified as cooperative genotype. IT84E-124 was depressive at 5 cm spacings and thus classified as cooperative genotype. IT84E- 124 was depressive at 5 cm spacing and cooperative at 10 cm spacing because of its growth habit. This confirms that genotypes with different growth habits should be evaluated in different yield trials to keep competition at low level.

Among the yield components, pods per plant and 100-seed weight were significantly influenced by competition at narrow spacings and nonsignificant at wider spacings whereas pon length and seeds per pod remained uninfluenced by competition. IT82D-716 was aggressive regarding plant height, pods per plant and 100-seed weight over the spacings with a tendency that the wider the spacing, the smaller was the competition effect. IT82E-18 was cooperative with regard to most of the characters over the spacings whereas IT84E-124 was aggressive regarding days to 50% flowering and plant height, and cooperative with regard to the remaining traits. However, the magnitudes of average competition effects, though statistically significant, were small enough to be of any practical consequence and hence not reported here.

Table 2. Average competition effect of different genotypes and average expected bias at different spacings for seed yield in cowpea

		Average competition effect		Nature of interaction	Average expected bias		
Spacing	Genotype	g per row	kg per ha		g per plant	g per row	Nature of bias
5 cm	IT82D-716	−60.8**	−380.0**	Depressive	3.89**	311.2**	Over-estimated
	IT82E-18	80.8**	505.0**	Cooperative	−7.53**	−600.4	Under-estimated
	IT84E-124	−20.0**	−125.0**	Depressive	−1.36**	−108.8**	Under-estimated
10 cm	UT82D-716	−46.0**	−287.5**	Depressive	4.56**	182.4**	Over-estimated
	IT82E-18	14.0*	87.5*	Cooperative	−1.16*	−46.4*	Under-estimated
	IT84E-124	32.0**	200.0**	Cooperative	−1.46*	−58.4*	Under-estimated
20 cm	IT82D-716	1.2	7.5	Nonsignificant	7.18**	143.6**	Over-estimated
	IT82E-18	0.0	0.0	Nonsignificant	−8.9**	−178.0**	Under-estimated
	IT84E-124	−1.2	−7.5	Nonsignificant	2.3	46.0	Nonsignificant
40 cm	IT82D-716	−4.2	−26.25	Nonsignificant	−2.25	−22.5	Nonsignificant
	IT82E-18	1.5	9.38	Nonsignificant	−1.16	−16.1	Nonsignificant
	IT84E-124	2.7	16.9	Nonsignificant	1.4	14.2	Nonsignificant

The average expected bias of different genotypes (Table 2) in a nonbordered single-row plot showed that at narrow spacings, IT82D-716, an aggressive competitor, was over-estimated in single-row plots, whereas IT84E-124 and IT82E-18 were under-estimated because of their poor competitive ability. Since genotypes reacted differently to competition, it caused considerable changes in the relative performance and ranking of genotypes at narrow spacings. The yield of IT82D-716 was low in pure stand but high under competition with other genotypes. The reverse was true of IT82E-18. As a result, an aggressive genotype like IT82D-716 would be picked up as an outstanding genotype in the nonbordered single-row plots whereas IT82E-18 and IT84E-124 might be discarded. Therefore, selection of genotypes from single-row at narrow spacing without considering competition effects would lead to erroneous results. The expected biases, however, were small in magnitude and non-significant at 20 and 40 cm spacings, suggesting wider spacing as an effective means of reducing the competition bias.

Our results suggest that the nonbordered single-row plots with normal spacing reduced the accuracy of the yield assessment of cowpea lines. Therefore, measures like wider spacing should be taken to minimize competition bias in single-row plots. Earlier studies [8, 12-14] also suggested wider spacing as an efficient mean to reduce intergenotypic competition effect in spring wheat and other crops. The results of this experiment suggest that individual plant progenies in segregating generations should be evaluated at 40 cm spacing at which competition biases were nonsignificant.

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