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Pigeonpea Genotype Evaluation for Intercropping

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Abstract

Three years' data are presented from a wide range of pigeonpea genotypes intercropped with sorghum. The relative importance of a number of plant characters as possible determinants of yield in intercropping is examined. The extent to which intercrop performance of a given genotype can be predicted from its sole-crop performance is considered.

Intercropping research has mainly emphasized the identification of compatible crops and optimum plant populations and spatial arrangements; relatively little attention has been paid to identifying suitable genotypes. The improvement of crop genotypes has mostly been based on testing and selection under sole cropping, irrespective of the cropping system in which the genotypes are finally to be grown. Such an approach is questionable, particularly in the case of intercropping where the competition of an associated crop can alter genotype behavior.

Some studies have indicated that the intercrop performance of the dominant species can be highly correlated with sole-crop performance (Baker 1974; Francis et al. 1976); for the less competitive or dominated species, intercrop yields have been poorly correlated with sole-crop yields (Wein and Smithson 1979; Francis et al. 1976). This suggests that higher yielding genotypes in sole cropping are not necessarily the higher yielders in intercropping and it emphasizes the need for selecting genotypes specifically for intercropping. However, Francis et al. (1978a, 1978b) have emphasized the advantages of sole-crop selection because of higher yields and greater yield differences, and for convenience in handling. Wein and Smithson (1979) suggested that early generations of cowpea for intercropping with maize could be screened under sole cropping for characters such as disease and insect resistances, plant vigor, etc., but later generations should be tested with maize.

Pigeonpea is intercropped with diverse crops, but sorghum/pigeonpea is especially important in rainfed areas of India, where sorghum is the staple food. Thus a series of experiments was established to:

- Explore the scope for selecting pigeonpea genotypes suitable for intercropping with sorghum,

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- examine to what extent selection under sole cropping is valid for intercropping, and
- identify plant characters associated with good intercropping performance.

Materials and Methods

Pigeonpea genotypes of contrasting growth patterns were evaluated during 1977-79 in sole cropping and intercropping with a standard sorghum cv CSH-6. The 1977 experiment was flat-planted on a medium Vertisol and included 17 pigeonpea genotypes in main plots, divided into two subplots for sole cropping and intercropping. Intercropping was in a standard row arrangement of 1 pigeonpea:2 sorghum at optimum sole-crop populations of both crops. The 1978 experiment was on a Vertisol on a 150-cm broadbed-and-furrow system. A single row of pigeonpea was planted in the center of the bed, and in intercropping one row of sorghum was added on either side at 45 cm. The design was the same as in the previous year, but a few genotypes were changed, and the total was increased to 19. In 1979, both a Vertisol and an Alfisol experiment were conducted on broadbeds. The layout was slightly modified, the sole and intercropping systems being in main plots and the genotypes in subplots. The Vertisol experiment contained 16 genotypes; the Alfisol, 12, of which eight were medium-maturing and common to both trials and the remaining four were early (140-160 days) and well adapted to Alfisols. All experiments had four replicates, except the Alfisol experiment in 1979, which had three.

All experiments were planted during the fourth week of June, and both crops were sown at the same time. In 1977, pigeonpea was thinned to 29.5 cm in rows, which gave a population of 25 000 plants per ha; however a population of 40 000 plants per ha was used in later years. Sorghum was thinned to a stand of 167 000 plants per ha in sole and the same population was maintained in intercropping by adjusting within-row spacing. The trials were fertilized basally with 52 kg P_2O_5/ha and sorghum was later topdressed at 80 kg N/ha. Sorghum was harvested 100 to 105 days after sowing. The area was kept weed-free by hand weeding, and Thiodan(0.35%) was sprayed on pigeonpea two or three times at podding stage to control *Heliothis* borer. Harvest areas were not less than 20 m^2.

Besides yield and yield components, a number of plant characters were measured on pigeonpea in sole cropping. These included branch number, branch length, angle of branch, canopy width at different heights, and light interception just before active growth and at full canopy spread

Results and Discussion

Grain Yield

Grain yield of sorghum and pigeonpea genotypes in each of the 3 years' experiments are presented in Tables 1 and 2. Sorghum yields were good in 1977 and 1978 (Table 1), and exceptionally good in 1979 (Table 2) as a

Table 1. Yield and land equivalents of pigeonpea genotypes during 1977 and 1978.[a]

1977						
	Yield (kg/ha)		Land Equivalents			
Genotype	Sole	Intercrop	LEP	LES	LER	Residuals
ICP-185-9	1699	850	0.51	0.96	1.47	140
ICP-6982-6	1525	842	0.57	0.99	1.56	116
ICP-1-6	1428	740	0.52	0.92	1.44	51
ICP-2223-3	1407	815	0.58	0.91	1.50	128
ICP-1	1389	757	0.57	0.85	1.43	101
ICP-2223-1	1376	885	0.63	0.84	1.48	234
ICP-830-2	1323	799	0.63	0.98	1.62	77
ICP-3156-2	1296	619	0.60	0.85	1.45	- 35
ICP-1951-1	1264	585	0.46	1.00	1.46	-145
ICP-3048-10	1226	619	0.50	0.95	1.45	- 84
ICP-3198-12	1222	512	0.42	0.82	1.24	-123
HY 3C-E-20	1185	463	0.36	0.88	1.25	-207
HY 3C-E-12	1169	503	0.43	0.84	1.27	-144
ICP-2037-7	1148	661	0.59	0.99	1.58	- 64
ICP-185-8	1106	718	0.66	0.81	1.47	86
ICP-1196-2	1063	530	0.49	0.92	1.42	-158
ICP-1900-11	1058	720	0.73	0.93	1.66	27
Mean	1287	683	0.54	0.91	1.46	0
LSD(0.05) main effect of genotypes						
Systems		74				

1978						
	Yield (kg/ha)		Land Equivalents			
Genotype	Sole	Intercrop	LEP	LES	Total	Residuals
ICP-6982-6	1973	1625	0.82	0.90	1.72	156
ICP-2223-1	1904	1579	0.83	0.96	1.79	195
ICP-2223-3	1848	1610	0.87	0.94	1.81	200
HY 3C	1810	1300	0.72	0.89	1.61	-179
ICPL-76	1808	1368	0.76	1.00	1.76	35
ICPL-6	1768	1300	0.74	0.96	1.70	- 80
C-11	1761	1489	0.85	0.95	1.80	91
LRG 30	1758	1538	0.88	0.96	1.84	162
74240-F5M	1743	1464	0.84	1.02	1.86	172
ICPL-78	1735	1452	0.84	0.95	1.79	53
AS 71-37	1708	1392	0.82	0.95	1.77	- 3
ICP-1	1660	1243	0.75	0.97	1.72	-128
ICPL-79	1655	1358	0.82	0.94	1.76	- 49
BDN-1	1610	1381	0.86	0.92	1.78	- 53
ICP-185-9	1582	1331	0.84	1.00	1.84	7
ICPL-75	1581	1165	0.74	0.97	1.71	-200
ICPL-77	1463	1391	0.95	0.88	1.83	-104
ICPL-80	1432	1050	0.73	1.04	1.77	-216
74252-F4M	1430	1307	0.91	0.97	1.88	- 57
Mean	1696	1386	0.82	0.95	1.78	0
LSD(0.05) main effect of genotypes		243				
Systems		50				

a. Sorghum yield as sole crop was 3952 kg/ha in 1977 and 4588 kg/ha in 1978.

Table 2. Yield and land equivalents of pigeonpea genotypes during 1979.[a]

Genotype	Vertisols Yield (kg/ha) Sole	Vertisols Yield (kg/ha) Intercrop	Land Equivalents LEP	Land Equivalents LES	Land Equivalents Total	Residual
ICP 185-9	1648	882	0.54	0.84	1.38	54
BDN-1	1502	886	0.59	0.98	1.57	249
HY 4	1376	629	0.46	0.88	1.34	-143
ICP-1	1330	730	0.55	0.97	1.52	75
ICP-6982-6	1307	988	0.76	0.85	1.61	172
IGDT-1	1286	508	0.40	0.96	1.36	-154
C-11 (H)	1285	825	0.64	0.97	1.61	176
ICPL-77	1270	401	0.32	0.91	1.23	-331
C-11	1270	914	0.72	0.91	1.63	188
ICP-2223-3	1224	880	0.72	0.95	1.67	207
ICP-1-6	1220	780	0.64	0.90	1.54	29
LRG 30	1142	911	0.79	0.87	1.66	122
ICPL-76	1140	686	0.60	0.96	1.56	21
IGDT-2	948	624	0.66	0.94	1.60	- 67
HY 3C	666	448	0.67	0.98	1.65	-189
ICP-7035	431	303	0.69	0.92	1.61	-412
Mean	1190	712	0.61	0.92	1.53	0
LSD (0.05) Genotypes within a system		545				
Across systems		660				

Genotype	Alfisols Yield (kg/ha) Sole	Alfisols Yield (kg/ha) Intercrop	Land Equivalents LEP	Land Equivalents LES	Land Equivalents Total
AS 71-37	2095	1119	0.53	0.97	1.50
BDN-1	2067	780	0.38	0.97	1.35
HY 4	1697	587	0.35	0.77	1.12
IGDT 2	1642	922	0.56	0.80	1.36
ICP-185-9	1594	951	0.60	0.76	1.36
ICP-2223-3	1580	785	0.50	0.86	1.36
C-11	1454	1062	0.73	0.81	1.54
ICP-6982-6	1347	1097	0.81	0.85	1.66
ICP-1	1222	775	0.63	0.86	1.49
T-21	818	461	0.56	0.93	1.49
Pusa Ageti	810	497	0.61	0.88	1.49
DL 74-1	778	312	0.40	0.85	1.25
Mean	1425	779	0.55	0.86	1.41
LSD (0.05) Genotypes within a system		320			
Across systems		354			

a. Sole crop of sorghum yielded 5752 kg/ha on Vertisol and 6342 kg/ha on Alfisol.

result of well-distributed rainfall July to September. Although "full" yield of sorghum was not always obtained in intercropping, the presence of pigeonpea did not cause statistically significant reductions in sorghum yield, even when pigeonpea growth was excellent and yields as high as 1500 to 2000 kg/ha were obtained. The mean relative yield (land equivalent ratio or LER) of sorghum in intercropping was highest in the wet year of 1978 (0.95) and lowest on the Alfisol in 1979 (0.86). Sorghum yield with the different pigeonpea genotypes varied from 76 to 100% of the sole-crop yield and, though not statistically significant, there was evidence of a negative correlation between sorghum yield and pigeonpea yield. Thus it seem likely that the lower sorghum yields with certain genotypes could have been due to greater pigeonpea competition.

Pigeonpea yield was quite good with all except the very compact (HY-3A, ICP-7035) and early genotypes (T-21, Pusa Ageti, DL 74-1). Yields were generally better in the high-rainfall season of 1978. Intercropping reduced pigeonpea yield significantly, but the degree of yield reduction varied among genotypes and also between seasons. In 1977, yields for different genotypes ranged from 1058 to 1700 kg in sole and 436 to 885 kg in intercropping. The genotype x system interaction was not significant, but intercropping yields as a proportion of sole yields varied from 36 to 73%. Taking ICP-1 as a check genotype that was common throughout all four trials, four genotypes yielded higher than this in sole cropping, while five yielded higher in intercropping; only three were above ICP-1 in both the systems. In the 1978 experiment, yields varied between 830 and 1970 kg/ha in sole crop and 790 and 1625 kg in intercropping; the interaction of genotype x system was again not significant. The relative yield of pigeonpea in intercropping was higher compared with the previous year and the range for different genotypes was much less (73 to 95%); these high relative yields were no doubt due to the better moisture conditions in the early part of the postrainy season. In sole cropping, 11 genotypes yielded higher than ICP-1 but in intercropping five others were also higher yielding.

The system x genotype interaction was significant in both the trials of 1979, suggesting differences in the behavior of genotypes in sole and intercropping. In the Vertisol trial, three genotypes gave higher yields than ICP-1 in sole cropping; only two of these maintained superiority in intercropping, but six others were also higher yielding than ICP-1 in intercropping. In the Alfisol trial, except for the early cultivars, all the medium ones outyielded the check, although the relative order of these genotypes was different in sole cropping and intercropping. The relative yields in intercropping varied widely in 1979 (0.32 to 0.72).

Considering the performance over three seasons, the genotypes ICP-185-9, ICP-6982-6, ICP-1-6, and ICP-2233-3 had high yield potential over the ICP-1 check and over the well-proven cultivars C-11 and BDN-1. The genotype ICP-185-9 was top in sole cropping in 2 years but did not rank so high in intercropping; the genotypes ICP-6982-6, ICP-1-6, and ICP-2233-3 were particularly promising for intercropping. The total land equivalent ratios of the medium-duration genotypes generally showed a similar order in 1977 and 1979 and varied within 1.23 and 1.67, primarily depending on the contribution of pigeonpea. They were very high in 1978, ranging from 1.61 to 1.88, because of high pigeonpea contribution.

Relationship between Intercrop and Sole-crop Performance

Regressing the pigeonpea yields in intercropping on the yields in sole cropping showed that intercrop performance was to some extent a reflection of sole-crop performance. However, sole-crop yields accounted for only 40% of variation in intercrop yields in 1977, 51% in 1978, 42% in Vertisols 1979 and 46% in Alfisols 1979, so considerable variation in intercrop yield remained unexplained. This suggests that specific plant characters might be associated with intercrop performance. The correlation between the rank orders of the genotypes in sole and intercropping was significant only in 1977 and 1978 ($r = 0.67^{**}$) suggesting that, especially in a dry year such as 1979, the best genotypes in sole cropping are not always the best in intercropping.

The land equivalent ratios of pigeonpea in intercropping showed no relationship with sole-crop yields, indicating that the proportion of sole-crop yield that a genotype produces in intercropping is not dependent on the level of its sole-crop yield. This may indicate that intercropping performance is at least partly dependent on some plant characters not associated with sole-crop yield. For example, all the four top yielders in 1977 had an average LER of 0.55 but the lowest yielder, ICP-1900-11, which was more compact initially and spread later, gave the highest LER of 0.73; however, compactness per se did not favor high LERs because the two selections of HY3C which did not spread at all gave poor LERs. Such a clear distinction was not apparent in 1978 because of less variation in LERs, but a similar pattern could still be seen. The very compact HY-3C gave the lowest LER of this season and the semispreading 74252-F4M and ICPL-77 gave the highest LERs. Genotypes like ICP-6982-6, C-11, and LEG-30, which are highly spreading and bear long fruiting branches, gave intermediate values. In the experiments of 1979, the average LER value of compact (HY-4, HY-3, and ICP-7035) and determinate (IGDT-1 and IGDT-2) genotypes was much lower than that of the spreading genotypes (ICP-6982-6, C-11, and LRG-30). The drastic change in LER of ICPL-77 between 1978 and 1979 was due to segregation of the material.

Identification of Plant Characters

The identification of plant characters associated with good intercropping performance could be useful for selecting genotypes while evaluating under sole cropping and for identifying appropriate breeding parents. Thus the characters measured in the sole crops of the three Vertisol experiments were correlated with pigeonpea yield. Few correlations between individual characters and intercrop pigeonpea yield were significant in 1978, probably because of the good growing conditions and high correlation with sole-crop yield. In the other experiments, some of the characters correlated with intercrop yield were: branch number (primary, secondary at final harvest or total number at sorghum harvest), primary branch length, and light interception. Multiple correlations showed that the 40 to 51% variation in intercrop yield that could be accounted for in terms of sole-crop yield could be increased to 66 to 88% with the inclusion of primary or secondary branches and height or harvest index. The number and length of branches and the canopy spread, as indicated by light interception and canopy width, seemed important in determining the land equivalent ratio (relative yield) of pigeonpea. All these relationships suggest that genotypes that produce more and longer branches and spread well are better suited to intercropping.

It was mentioned earlier that there was some eivdence of a negative relationship between intercrop sorghum yield and intercrop pigeonpea yield, suggesting that the decreases in sorghum yield might be due to greater pigeonpea competition. Thus it might be important to ensure that pigeonpea genotypes selected for higher yields in intercropping do not offset their advantages by producing greater decreases in sorghum yield. Tables 1 and 2 give, for each genotype in the Vertisol experiments, the residuals of the linear regression line of pigeonpea intercrop yield on sorghum intercrop yield. A positive residual indicates that a genotype lies above this line, i.e., it has a higher yield than expected for a given decrease in sorghum yield. This could be a parameter to consider in identifying intercropping genotypes; thus, purely as an example, the two highest yielders in sole cropping in Table 2, ICP-185-9 and BDN-1, gave very similar yields in intercropping but the higher positive residual of BDN-1 (due to less reduction in sorghum yield) might make it the better overall prospect.

Efficiency of Selection under Sole Cropping

Using the data presented here, and additional data from the ICRISAT pigeonpea breeding program, Green et al.(1980) have indicated that selection under sole cropping at selection pressures of 20% and 33% are only 41% and 55% effective, respectively, i.e., only 41% and 55% of the genotypes identified in sole cropping were those identified in intercropping. Even with a low selection pressure of 50%, only 65% efficiency was achieved with the present data. Bearing in mind that these efficiencies do not take into account any effects on the yield of the other crop, the case for selecting actually in the intercropping situation needs to be given due consideration; it should also be appreciated that using an "additional" sorghum intercrop as described here, means that no greater land areas are required for selecting in intercropping compared with sole cropping. Perhaps a suitable compromise would be selection in sole cropping in the early generations but in intercropping from, say, the F_3 generation.

References

BAKER, E.F.I. 1974. Research on mixed cropping with cereals in Nigerian farming systems--a system for improvement. Pages 287-301 *in* Proceedings, International Workshop on Farming Systems. ICRISAT, 18-21 Nov 1974, Hyderabad, India.

FRANCIS, C.A., FLOR, C.A., and TEMPLE, S.R. 1976. Adapting varieties for intercropping systems in the tropics. Pages 235-253 *in* Multiple cropping, eds. R.I. Papendick, P.A. Sanchez, and G.B. Triplett. ASA Special Publication No.27, Madison, Wis, USA.

FRANCIS, C.A., PRAGER, M., LAING, D.R., and FLOR, C.A. 1978a. Genotype x environment interactions in bush bean cultivars in monoculture and associated with maize. Crop Science 18: 237-242.

FRANCIS, C.A., PRAGER, M., and LAING, D.R. 1978b. Genotype x environment interactions in climbing bean cultivars in monoculture and associated with maize. Crop Science 18: 242-246.

GREEN, J.M., SHARMA, D., REDDY, L.J., SAXENA, K.B., GUPTA, S.C., JAIN, K.C., REDDY, B.V.S., and RAO, M.R. 1980. Breeding methodologies and progress in the ICRISAT breeding program. Volume 1, these Proceedings.

WEIN, H.C., and SMITHSON, J.B. 1979. The evaluation of genotypes for intercropping. Presented at the International Workshop on Intercropping. ICRISAT, 10-13 Jan 1979, Hyderabad, India. Proceedings in preparation.