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Variation in reproductive efficiency and yield of cowpea under high temperature conditions in a Sahelian environment

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Summary

Fifteen cultivars differing in plant type and maturity were evaluated for their reproductive efficiency and yield at the ICRISAT Sahelian Center in Niger in 1988 1989 and 1990 Flowers and pods were used to determine the reproductive efficiency and yield differences were assessed by using crop growth rate and partitioning Significant differences among cultivars were observed for their ability to flower and set pods under high temperature conditions The pattern of flowering and pod set showed that flowers formed in the first 10 days after initial flowering had the highest percentage pod set Potential pod set ranged from 5 to 81% TN88 63 the most widely adapted cultivar in the Sahel averaged 59% pod set followed by A73-2-1 with 56% There was considerable variation among cultivars in the duration of the reproductive period, crop growth rate and partitioning Crop growth rate was largely responsible for differences in yield among cultivars

Introduction

The cowpea (*Vigna unguiculata* (L) Walp) production area in the Sahel is characterized by a short rainy-season which averages 94 days (Sivakumar 1990) Flowering and pod filling stages coincide with the period with increased frequency of prolonged dry spells and rising temperature These factors have interactive and adverse effects on plant growth and development In this paper emphasis is on high temperature the detrimental effects of which are apparent with or without drought

Heat stress impairs reproductive processes and the yield of cowpea (Turk et al 1980, Warrag & Hall 1984b, Nielsen & Hall 1985) The level of tolerance to high temperature in cowpea varies among genotypes (Warrag & Hall 1983, Nielsen & Hall, 1985, Patel & Hall, 1990) These authors considered heat tolerant cultivars to be those that were able to flower and set pods under high temperature conditions

Achievement of high seed yield in cowpea is dependent on both the number of flowers and the proportion that develops into mature pods These factors are therefore relevant in evaluating different cultivars but limited information is available on the reproductive efficiency of popular Sahelian cultivars growing under high temperature field conditions

The objective of this study was therefore, to determine the variation in the reproductive efficiency and yield of a selected set of cowpea cultivars growing under high temperature conditions

Materials and methods

Fifteen cowpea cultivars were selected for this study based on their variability for growth habit, maturity and method of breeding (Table 1) The cultivars were grown at the ICRISAT Sahelian Center (ISC) research farm near Niamey in Niger during the hottest months in 1988 1989 and 1990

The soil type was sandy (Siliceous isohyperthermic Psammentic paleustaf) Field sowing was done in the first week of February of each year The experimental design was a randomized complete block design with four replications Plots consisted of 4 rows of 4 5 m long with inter and intra row spacing of 0 75 and 0 30 m In each year the field was fertilized with 18 kg ha^{-1} of P_2O_5 in the form of single superphosphate before sowing The crop was adequately watered by giving an equivalent of 30 to 40 mm of rainfall every week using an over head sprinkler irrigation and was regularly sprayed with insecticide to control flowering and post flowering insect pests

Mean daily maximum (T_{max}) and minimum (T_{min}) air temperatures during the experiments are presented in Table 2 These were taken from a weather station situated less than 500 m from the experimental plots

Flower and pod production were noted every day from the appearance of the first flower The number of flowers that had opened each morning were recorded on 10 tagged plants in each plot Pod counts started when the first visible pod was noticed until there were no more flowers or new pods The 10 plants were harvested separately and yield components determined Total flowers total pods and mature pods were used to determine reproductive efficiency The two centre rows were used to estimate shoot and grain yield

Since cowpea is an indeterminate crop yield differences among cultivars were also analyzed using the model

$$Y = C^*d^*p$$

where Y is the yield of grain C is the mean crop growth rate (CGR) d is the duration from flowering to maturity and p is the fraction of crop growth partitioned to Y This model was used by Williams & Saxena (1991) in the assessment of yield variation in chickpea

Table 1 Maturity growth habit and developmental breeding method of 15 cultivars

Cultivars	Maturity	growth habit	breeding method
TN88 63	M*	S	PLR
TN5 78	M	SS	PLR
TN27 80	M	S	PLR
Dan Ila	M	SS	LR
Tera local	M	S	LR
Sadore local	L	S	LR
A73 1 2	E	SS	H
B99 2 1	E	SS	H
58 57	L	S	PLR
Suvita 2	M	SS	PLR
Kvx61 74	E	SE	H
Kvx100 2	ME	SS	H
Tvx3236	ME	SS	H
IT83D328 4 1	E	SE	H
IT84E1 108	E	E	H

*E = Early M = medium ME = medium early L = late S = spreading SS = Semi spreading SE = Semi erect E = erect PLR = purified land race H = Hybridization and selection L = local land race

Results

Daily mean (± se) T_{max}/T_{min} during flowering were 41 3 ± 0 29/28 0 ± 0 31°C in 1988 41 6 ± 0 29/24 2 ± 0 42°C in 1989 and 41 3 ± 0 27/27 3 ± 0 37°C in 1990 Significant differences were observed among cultivars for the characters measured (Table 3) Year effects were significant for all the characters In both years IT84E1 108 and IT83D328-4 1 were the earliest to flower These cultivars mature in about 60 days during the normal cropping season

Table 2 Mean monthly minimum and maximum daily air temperature during February through May

Month	1988		1989		1990	
	Min	Max	Min	Max	Min	Max
February	19 0	35 9	16 4	32 6	19 7	33 3
March	24 7	39 8	22 0	38 4	20 2	38 5
April	27 5	41 5	24 5	41 9	28 4	41 5
May	28 4	42 0	26 9	41 3	25 4	39 5

Table 3 Variation in days to flower flowers and pod production and pod set of 15 cultivars in three seasons

	Days to flower			Flowers plant			Total pods plant			Mature pods plant			Potential pod set ( )			Actual pods set ( )		
	1988	1989	1990	1988	1989	1990	1988	1989	1990	1988	1989	1990	1988	1989	1990	1988	1989	1990
2 A73 1 2	57	54	56	61	30	62		9	43	21	17	36	43			38	63	58
3 Kvx 61 74	57	58	56	117	64	134		6	59	20	21	50	23			20	34	36
4 Tvx 3236	57	58	59	28	44	87		3	59	10	22	51	38			38	50	58
5 IT84E 1 108	42	44	45	34	19	54		2	26	7	11	22	23	65	47	33	61	41
6 TN88 63	60	58	60	46	27	98		9	53	21	16	41	55	68	54	48	62	42
7 58-57	54	62	62	58	29	102		9	78	16	9	24	32	43	27	28	40	23
8 IT83D328 4 1	48	50	51	135	31	163		3	55	8	10	36	5	47	35	5	35	23
9 TN5 78	57	57	59	37	33	88		2	31	16	12	25	50	68	34	48	37	27
10 B99 2 1	56	56	57	70	48	113		3	59	21	22	54	32	49	54	30	47	48
11 Kvx100 2	56	56	55	43	33	90		1	52	15	14	42	42	63	57	40	42	46
12 TN27 80	50	55	54	76	39	82		4	42	25	14	33	45	63	51	38	36	41
13 Dan Ila	57	54	52	78	41	71		3	37	23	16	27	33	81	52	28	39	40
14 Sidore Local	58	56	54	59	54	92		1	40	31	21	29	57	60	46	55	30	33
15 Tera Local	57	58	59	37	42	98		4	42	18	18	34	52					
SE	1.9	0.6	2.0	23.0	8.2	19		4.1	12.1	5.7	3.7	10.4	5					

The total number of flowers and pods plant[1] differed significantly among cultivars in each year with significantly ($p < 0.05$) greater numbers of flowers produced in 1990 than in 1988 and 1989 (Table 3). Cultivars which produced the highest number of flowers in 1988 maintained their rank in 1990. Kvx 61–74 and IT83D328-4-1 produced the highest number of flowers each averaging 104 and 109 flowers plant[1]. IT84E1-108 produced the lowest number of flowers.

The total number of pods formed did not follow the trend of flower production. The potential pod set ranged from 5 to 57% in 1988, 41–81% in 1989, and 27 to 68% in 1990. The actual pod set indicated considerable variation among cultivars with regard to pod abscission. TN88-63 had the highest average pod set of 59% over the three years followed by A73-2-1 which averaged 56%. IT83D328-4-1 produced the highest number of flowers but set very few pods.

The distribution of flower production and pod retention in a 25 day period beginning with the first flower was examined in three contrasting cultivars (IT84E1-108, IT83D328-4-1 and TN88-63). The pattern of flowering was monomodal in the three cultivars (Table 4). Flowers were produced at a more rapid rate in the first 15 days after the first flower than later in the flowering period. Newly formed pods followed a similar trend whereby the highest pod set was from those flowers formed in

Table 4 Mean number over three years of flowers pods and pod set of three cowpea cultivars

Days from first flower	Cultivars								
	IT84E1-108			IT83D328 4 1			TN88-63		
	Flowers no	Pod no	Pod set (%)	Flower no	Pod no	Pod set (%)	Flower no	Pod no	Pod set (%)
5	100	25	34	104	48	41	118	69	51
10	189	79	48	315	133	48	234	189	65
15	216	112	44	431	181	45	377	165	60
20	236	92	35	600	136	22	255	137	42
25	133	45	25	483	105	0	241	114	43

Table 5. Shoot dry weight and grain yield (kg ha^{-1}) of 15 cultivars

Cultivars	Shoot dry weight			Grain yield		
	1988	1989	1990	1988	1989	1990
1. Suvita 2	960	1355	4540	470	530	1640
2. A73-1-2	780	2040	3330	550	480	1010
3. Kvx 61-74	480	2690	3770	750	610	1200
4. Tvx 3236	910	1975	3270	540	460	1320
5. IT84E1-108	720	650	1600	125	240	570
6. TN88-63	1550	1440	4530	710	525	1265
7. 58-57	1040	925	3770	750	300	650
8. IT83D328-4-1	590	1270	3885	–	320	710
9. TN5-78	960	1350	2120	700	630	1000
10. B99-2-1	1610	2430	4370	680	690	930
11. Kux100-2	1430	1560	3700	980	670	1270
12. TN27-80	1260	1210	2470	570	810	1080
13. Dan Ila	1450	2050	2510	1010	990	1150
14. Sadore local	1590	2510	3085	960	860	780
15. Tera local	2130	1870	3560	950	630	680
SE	225	393	896	134	145	213

the first 10 days. The three cultivars attained a peak in pod set within 15 days after the initial flower.

Shoot dry weight and grain yield were in general greater in 1990 than in 1988 and 1989 (Table 5). The two early maturing cultivars were the lowest yielders. B99-2-1 produced the highest shoot dry matter followed by Tera Local, Sadore Local and Kvx 61-74.

Table 6. Duration of reproductive growth, Crop Growth Rate (CGR) and partitioning factors (P) of 15 cultivars grown during the hot dry season

Cultivars	Duration of reproductive growth (d)			Crop growth rate kg ha^{-1} day^{-1}			Grain growth rate relative to crop growth rate (P)		
	1988	1989	1990	1988	1989	1990	1988	1989	1990
1. Suvita 2	28	27	30	20.24	22.73	72.54	0.82	0.88	0.84
2. A73-1-2	32	30	25	18.38	29.77	53.97	0.95	0.54	0.77
3. Kvx 61-74	30	27	28	30.86	38.88	55.11	0.81	0.54	0.79
4. Tvx 3236	30	25	26	19.43	29.23	54.32	0.92	0.65	0.95
5. IT84E1-108	25	29	32	14.72	12.52	28.25	0.39	0.66	0.64
6. TN88-63	35	25	38	30.65	23.78	59.56	0.69	0.87	0.56
7. 58-57	26	24	36	27.21	14.23	40.02	1.09	0.87	0.48
8. IT83D328-4-	36	32	38	8.65	19.47	46.17	–	0.51	0.49
9. TN5-78	27	26	27	23.40	23.87	36.94	1.13	1.00	1.05
10. B99-2-1	32	30	42	32.00	36.48	53.52	0.65	0.62	0.41
11. Kux100-2	27	26	26	24.74	27.21	61.03	1.07	0.93	0.80
12. TN27-80	31	27	24	26.72	30.63	45.20	0.68	0.98	0.98
13. Dan Ila	31	28	28	34.37	38.11	51.54	0.96	0.95	0.87
14. Sadore local	29	27	27	35.23	40.58	47.66	0.94	0.78	0.61
15. Tera local	30	28	35	43.45	29.35	44.99	0.76	0.75	0.43
SE	2.7	1.9	1.9	5.23	6.30	12.76	0.07	0.08	0.10

Crop growth rate and partitioning

There was considerable variation in the duration of reproductive growth, crop growth rate, and partitioning among cultivars (Table 6). Variation in partitioning reflected cultivar differences in the timing of establishment of reproductive sinks.

Relationship between grain yield and other traits

Significant positive linear correlations were observed between grain yield and other traits (Table 7). The consistently high correlation between shoot dry matter and pods plant^{-1} with grain yield indicated that seed yield resulted from a high shoot dry matter and pods plant^{-1}. Flowers plant^{-1} were significantly related to seed yield only in 1989. Crop growth rate was an important source of yield variation among cultivars. The correlation between seed yield and harvest index was generally low compared to similar studies in cereals. There was no direct association between reproductive growth duration and grain yield despite the considerable range amongst genotypes for these traits. Partitioning was consistent among cultivars but it accounted for a small proportion of the variation in seed yield.

Table 7. Relationship between seed yield and other characters (n = 60)

Character	Year 1988	1989	1990
	r	r	r
Shoot weight	0.79	0.72	0.58
Total flowers	0.02	0.67	− 0.13
Total pods	0.72	0.72	0.71
Mature pods	0.55	0.71	0.64
Peduncles	0.73	0.45	0.52
Branches	0.56	0.20	0.15
Seeds pod^{-1}	0.63	0.59	0.33
Harvest index	0.57	0.44	0.47
Reproductive duration	− 0.10	− 0.07	− 0.27
Crop growth rate	0.92	0.91	0.78
Grain growth rate	0.66	0.42	0.46

Discussion

Patterns of flower and pod production varied among cultivars and reproductive efficiency ranged from low to moderate levels. The pattern in pod retention indicated that the flowers produced in the first 10 days after the initial flowering were the ones most likely to be retained to produce ripe pods. This effect may be explained by assuming that early flowers have the first share of a limited supply of nutrients for their development and therefore having a greater chance of survival. The high flower and pod abscission rate in all cultivars might be attributed to the variation in environmental factors including, heat, wind and humidity.

Warrag & Hall (1984b) reported that high night temperatures cause substantial flower abscission and that extremely high day air temperatures could enhance it. In their study, total flower abscission occurred within 48 h at 33/30° C day/night temperature. Under such conditions a heat tolerant cultivar gave a pod set of 39%. On the other hand the pod set was 70% at much cooler temperatures (22° C at night) which is considered to be normal for cowpea growing under favourable conditions. The day/night temperatures during flowering in the present study appeared supra optimal. Therefore, cultivars having a podset of 45% and above would be considered tolerant to heat during flowering. Most of the Sahelian cultivars and lines derived from them appeared to be tolerant. Among the breeding lines from IITA, only Tvx 3236 would be classified as heat tolerant which is in agreement with the classification of Patel & Hall (1990).

The level of pod set and seed yield obtained in this sample of cultivars suggests that high temperature during flowering may not have been limiting, a reflection of heat tolerance among the cultivars studied.

A number of studies have examined yield component relationship in cowpea (Imirie & Butler, 1983; Kahn & Stoffella, 1985). Flower numbers fluctuated more widely than pods indicating that flower number may not be directly related to yield. Pod number was the single component most consistently associated with yield. The low correlation between seed yield and harvest index may be partly due to the difficulty of determining harvest index since in indeterminate grain legumes like the cow pea, considerable foliage is lost by the time the final seed is harvested

Although reproductive efficiency is a major component of total grain yield other factors are also important For example crop growth rate during the reproductive period was an important source of variation in seed yield indicating that cultivars with high yield had high crop growth rates during the reproductive period Most of the cultivars had relatively high partitioning rates which reflected high crop growth rates While this is desirable for grain production high partitioning rates may be detrimental to fodder production Fodder is a highly valued product in the Sahel Therefore there is need to select for different types of cowpea genotypes those for fodder on the one hand and those for seed yield on the other

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