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interaction of cowpea maturity with degree of waterlogging in the post-rice environment

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Abstract

Cowpea [*Vigna unguiculata* (L.) Walp] is grown widely as an inexpensive source of protein in tropical regions. Production is often limited by either waterlogged or dry soils in the wet–dry transition period following rice because periodically saturated soils are followed by progressively severe drought. An optimum fit of cultivar phenology to these situations is crucial to higher, stable yields. The responses of a set of diverse cowpea cultivars differing in maturity were compared under a line-source moisture gradient applied during the vegetative stage on an isohyperthermic, clayey, Typic Tropudalf with a fluctuating shallow water table, during two dry seasons in the Philippines. In 1986–87, in saturated soil, the mean yields of the medium-maturing grain (460 kg ha^{-1}) and dual-purpose (460 kg ha^{-1}) types exceeded yield of the early-maturing grain (250 kg ha^{-1}) and vegetable (210 kg ha^{-1}) types, with a similar ranking (920, 730, 470, and 390 kg ha^{-1}) without irrigation. In 1988, the medium-maturing cultivar group had a mean yield 985 kg ha^{-1} in saturated soil and 1389 kg ha^{-1} in unirrigated, again exceeding the early-maturity group with yields of 544 and 985 kg ha^{-1}, respectively. Saturated soil reduced seed yields by 10 to 71% in 1986–87 and 10 to 42% in 1988. Pods per plant, seeds per pod, and individual seed mass of the cultivars were reduced 13 to 32%, 12 to 19%, and 3 to 12%, respectively. The results suggest that the best medium-maturing cultivars had superior adaptation to that of the best early-maturing cultivars in a post-rice environment with prolonged high rainfall and a high water table. Contrasting results are [illegible]pected in post-rice niches with a deep water table and limited soil water reserves.

Keywords: Cowpea; Post-rice environment; Seed yield; Yield components; Waterlogging

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1. Introduction

Grain legumes, including cowpeas [*Vigna unguiculata* (L.) Walp.], are inexpensive sources of protein in tropical Asia. In monomodal tropical monsoonal climates cowpeas are widely grown in rice lands during the wet–dry transition period after the rice harvest (Rachie and Roberts, 1974). Waterlogging is a serious constraint during the onset of the dry season (Lantican, 1982; Zandstra, 1982), especially where the water table remains near the soil surface for a period following crop establishment. Cowpeas grown on such lands encounter excess moisture during the vegetative stage and drought during the reproductive stage (Del Rosario and Pandey, 1985; Pandey et al., 1986).

Cowpea cultivars in the tropics differ widely in growth duration, varying from early and extra-early maturing (50–60 days), to medium (60–75 days) and

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late (> 75 days) maturity. The recent development of early- and synchronous-maturing cultivars by the International Institute of Tropical Agriculture (IITA) enhanced the crop intensification potential (Singh and Singh, 1983; Singh et al., 1983). Hall and Patel (1985) noted that short-duration cultivars are needed where the average period of water supply is short but reasonably reliable. In contrast, relatively long-duration cultivars are required where the average period of water supply is longer and less reliable.

Excess moisture and drought are two of the most important factors responsible for the low yields (Rachie, 1985). Variation in root and nodule growth and function have been attributed to reduced oxygen supply during flooding (Sprent, 1971; Minchin and Pate, 1975; Hong et al., 1977). Flooding of determinate cowpea cultivars had the most severe effects on seed yield during the vegetative stage (Minchin et al., 1978; Wien et al., 1979a). However, cowpeas as a species are more waterlogging tolerant (Minchin and Summerfield, 1976; IRRI, 1984) as well as more drought resistant (Wien et al., 1979b; Turk et al., 1980; Pandey et al., 1984) than other major grain legumes.

Most previous research on cowpea response to drought and flooding was on plants grown on freely drained sandy soils. In fine-textured soils with low saturated hydraulic conductivity, high water-holding capacity, and high capillary movement from the water table, cultivar response to excess and dry soil moisture regimes may be expected to differ from that observed on coarse textured soils (Hartman and De Boodt, 1973; Summerfield and Lawn, 1987).

Cultivar differences in response to both saturated and dry soil moisture regimes during the vegetative stage are not fully understood. Classifying the response to alternating excess moisture and drought stress during the vegetative and reproductive stages, and identifying cultivars that can withstand such dual stress, may facilitate the development of more productive and stable cropping systems.

Field studies were conducted to determine the responses of 24 diverse cowpea cultivars, grouped into 4 maturity × use groups, to varying intensities of waterlogging stress at the vegetative stage of growth. Yield and yield component responses in relation to the hydrological environment are discussed in this paper. Growth and plant water relations of a selected subset of these cultivars are reported in a companion paper (Timsin et al., 1994).

2. Materials and methods

2.1. Experimental details

Two field experiments on the adaptation of cowpe cultivars to varying moisture regimes were conducte at the experimental farm of the International Ric Research Institute (IRRI) (14°11′N, 121°15′E, 23 m elevation), Los Baños, Laguna, Philippines in 19 87 and 1988 dry seasons (DS). The 1986–87 expe ment evaluated the response of 24 cultivars to saturate (MR1), wet (MR2) and unirrigated (MR3) soil moisture regimes. The maturity of the early-maturing grai and vegetable-type cultivars ranged from 58 to 68 days and that of medium-maturing grain and dual-purpos types from 67 to 78 days, in MR3 (Table 3). Based o relative performance in 1986–87, two medium-maturing cultivars (TVX1948-012F and TVX3871-02F and two early-maturing cultivars (IT82D-889 an CES41-6) were selected for further study in the 198 dry season. The cultivar TVX3871-02F had a below average performance in 1986–87 and was intentionall chosen in 1988 for comparing with TVX1948-012 which performed best in 1986–87. In both years a line source sprinkler system (Hanks et al., 1976) was use to create the range of moisture regimes during the vegetative stage. No irrigation water was applied durin the reproductive stage in either year.

The soil was an isohyperthermic, clayey Typic Tro pudalf of the Philippine soil series Mahaas clay, with a fluctuating shallow water table (between 52 and 13 cm from the soil surface). The soil profile characteristics of the experimental site are presented in Table 1

2.2. Crop establishment and management

Each year, prior to experimentation, a uniform rainfed crop of lowland rice was grown on the field. The rice stubble was cut just above ground level immediately after harvest. Shallow furrows were made 0.5 m apart and 3–5 cm deep with minimal tillage. Fertilize was applied at the rate of 30–13–25 N–P–K kg ha^{-1} in the furrows. Seeds were treated with the fungicide Brassicol (Pentachloronitrobenzene) at the recom-

Table 1
Soil physical and chemical properties of the experimental site

Soil depth (cm)	Bulk density (g/cm^3)	Saturated hydraulic conductivity (cm/day)	Organic C (%)	Total N (%)	Olsen avail. P (ppm)[a]	Exch. K (meq/100 g)	P.S.D. (%)[b]		
							Sand	Silt	Clay
0–10	1.13	1.4	0.76	0.08	7.6	1.2	20	36	43
10–20	1.20	2.2	0.42	0.05	5.7	0.7	25	34	41
20–40	1.23	5.6	0.28	0.04	8.7	0.4	26	33	41
40–60	0.98	2.8	0.15	0.02	7.5	0.5	30	36	34
60–80	0.91	12.9	0.16	0.02	8.1	0.6	40	30	30
80–100	0.93	59.7	0.10	0.02	7.6	0.7	41	33	26

[a] Olsen extraction method (Olsen et al., 1954).
D. = Particle size distribution.

mended rate, and were sown in the furrows on 9 December in 1986–87 and on 9 February in 1988. One week after emergence plants were thinned to a 50- to 60-mm intra-row spacing, with an aim of having a density of 200 000 plants ha^{-1} at harvest. Stand establishment was uniform in both experiments. Monocrotophos (dimethyl phosphate ester with (E)-3-hydroxy-N-methyl Crotonamide) was used for insect control and was applied at approximately 15-d intervals. Decis [(S)-a-Cyano-M-phenoxybenzyl (IR,3R)-3(2-dibromovinyl)-2,2 dimethyl cyclo-propane-carboxylate, a.i. 2.5 EC] was sprayed fortnightly at the rate of 480 ml ha^{-1} to control thrips (*Megalurothrips sjostedti*) and pod borers (*Maruca testulalis*). Weeds were controlled with butachlor [N-(butoxy-methyl)-2-chloro 2^1,6^1-diethyl-acetanilide] at 1.2 kg a.i. ha^{-1} before emergence, followed by two handweedings at 20 and 35 d er emergence (DAE). Each 6.0×15.0-m plot of a cultivar was subdivided into three subplots (6.0×5.0 m) representing three, and into five subplots (6.0×3.0 m) representing five, moisture regimes in 1986–87 and 1988, respectively. The subplot closest to the line source was designated as 'MR (moisture regime) 1' or 'saturated' while the farthest from the line source was 'MR3' or 'unirrigated' in 1986–87 and 'MR5' or 'unirrigated' in 1988. Cultivars were the vertical factor while the moisture regimes were the horizontal factor of a strip-plot design with 4 replications. The statistical analysis as proposed by Hanks et al. (1980) was used.

2.3. Water application procedure

Water applied by the line-source sprinkler system decreased linearly with increasing distance from the line. Irrigations were scheduled every 2–3 days so that the plots near the line were maintained at or near full saturation, as measured with tensiometers. Water application was measured in catch-cans placed in the center of each of the water regime subplots in both years. Irrigation was applied in the late night or early morning hours when wind speeds were insignificant. Evaporation was determined daily by a Class A evaporation pan (data from the nearby agrometeorological station of the IRRI Climate Unit).

2.4. Soil moisture measurements

Soil moisture determinations were obtained with observation wells, tensiometers and neutron probes in the 1988 experiment. Aluminum access tubes, 58 mm in diameter and 1.0 m long, were placed in the center of each water regime of each cultivar in two replications to monitor the soil moisture, using a neutron probe (Campbell Nuclear Pacific Hydroprobe Model 503). The seasonal variation in air-filled porosity for 0–10 cm depth was determined from moisture content, bulk density, and particle density data. Air-filled porosity (%) was calculated as % total porosity minus % water content (v/v), where total porosity is $[1-BD/PD]$, and BD is bulk density and PD is particle density (assumed to be 2.65 g cm^{-3}). Tensiometers were installed at 10 and 40 cm soil depths and observation wells (4.8 cm×150 cm perforated PVC pipes) were installed to 150 cm depth in fully saturated, wet and unirrigated treatments in two replications to monitor the seasonal variation in the soil matric potential and free water table depth, respectively.

2.5. Yield and yield components

Seed yield was obtained from two 4-m long rows in 1986–87, and from four 3-m long rows in 1988 experiment. Pods were harvested when 95% of them were mature. Early-maturing cultivars were harvested in one to two pickings while the medium-maturing ones were harvested in two to three pickings. Pods were threshed and seeds were dried in an oven at 70°C for 48 h and all yields adjusted to 14% moisture content. A subsample of plants in a 1.0-m row segment was harvested for analysis of yield components in the 1988 experiment.

3. Results

3.1. Crop environment

Agrometeorological conditions contrasted between the two experiments. For more than two weeks after planting in the 1986–87 experiment, there was abu dant rainfall at the test site (Table 2 and Fig. 1). Rai fall plus irrigation water fostered an environment excess moisture during the vegetative stage. Daily ave age maximum and minimum temperatures during tl vegetative stage were 29.9°C and 21.9°C respective (average for December 9, 1986 to January 15, 1987 and during the reproductive stage were 29.5°C ar 21.0°C respectively (average for January 16 to Febr ary 28, 1987).

Table 2
Rainfall and irrigation data for 1986–87 and 1988 post-rice dry season experiments

Date	Rainfall (cm)	Irrigation water (cm)				
		MR1	MR2	MR3	MR4	MR5
1986–87						
9–26 Dec.	7.96					
26		0.73	0.49	0.00		
28	0.08					
29	0.04	1.66	0.82	0.00		
31	0.92					
2 Jan		0.83	0.46	0.00		
4		1.15	0.49	0.00		
6	0.07					
7	3.04	0.76	0.48	0.00		
8	1.57					
12	0.12					
13	0.21					
14		2.63	0.99	0.00		
17		2.56	0.64	0.00		
Total	14.09	10.32	4.37	0.00		
1988						
9–23 Feb	1.32					
24	0.36	2.30	2.00	1.47	0.90	0.34
28	0.58	1.89	1.38	0.89	0.45	0.15
1 Mar	0.00	4.02	3.33	2.26	1.12	0.28
4	0.00	4.47	3.85	2.65	1.28	0.29
7	0.00	3.48	2.89	1.76	0.88	0.13
11	0.16	2.77	2.22	1.57	0.73	0.10
	0.00	2.88	2.38	1.73	0.86	0.17
23	0.34	1.80	1.29	0.65	0.00	0.00
Total	2.76	23.61	19.34	12.98	6.22	1.46

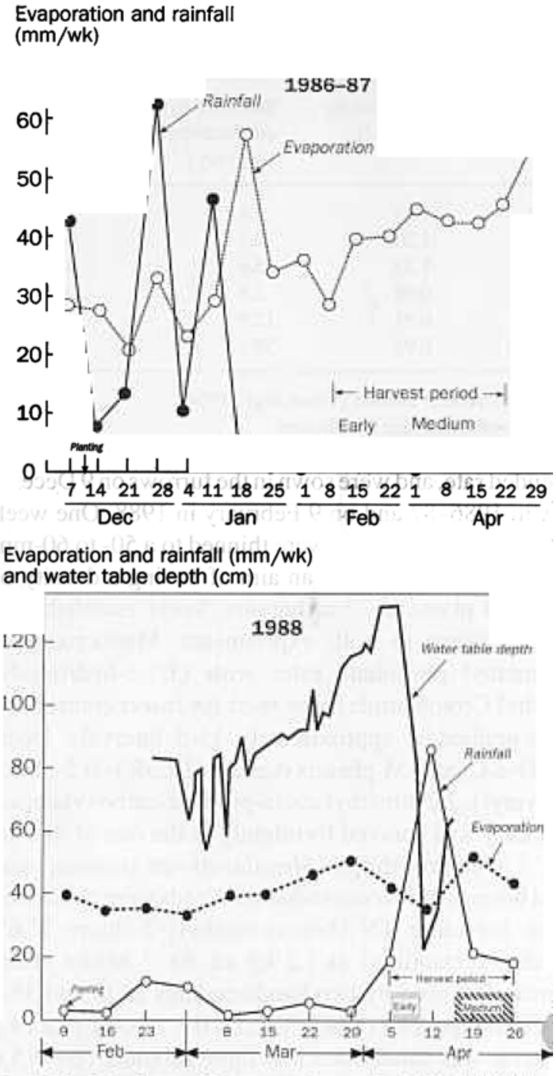


Fig. 1. Variation in weekly evaporation and rainfall (1986–87 a 1988) and water table depth (1988) during the growing seasons.

During the 1988 experiment, there was little rainfa for five weeks after planting (Table 2 and Fig. 1). Th

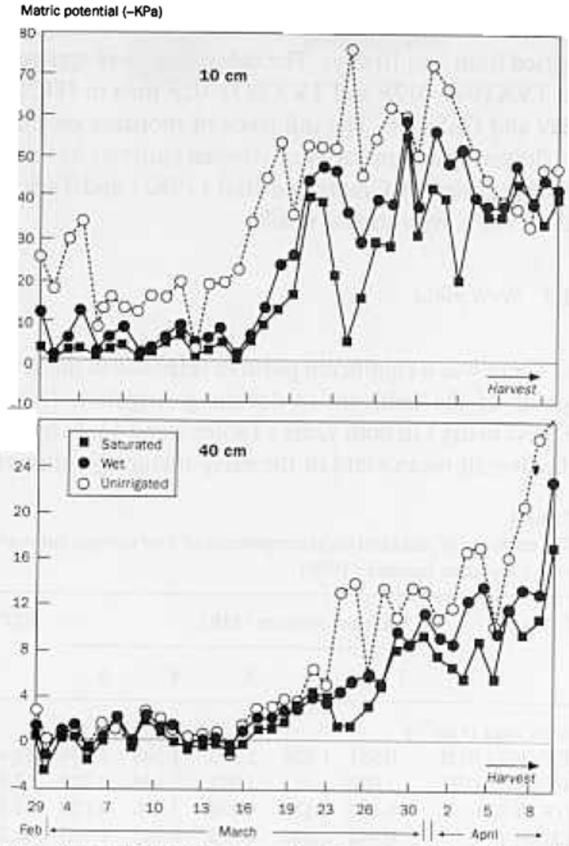


Fig. 2. Seasonal fluctuations in soil matric potential (– kPa) at 10 and 40 cm soil depths under three soil moisture regimes (1988).

was coupled with high pan evaporation and a fluctuating shallow water table (0.52 to 1.32 m). There was a substantial rainfall event on April 11 which brought [illegible]il moisture to the saturated condition after prolonged drought. However, at this time, the early-maturing cultivars were harvested, and the medium-maturing cultivars were in the physiologically mature stage. Hence, this rainfall did not appear to influence the reproductive stage performance. Daily average maximum and minimum temperatures throughout the growth were higher than in the first experiment [32.9°C and 23.6°C, respectively during the vegetative stage (average for February 9 to March 15) and 32.9°C and 23.5°C respectively during the reproductive stage (average for March 16 to April 15)].

Applied water during the vegetative stage maintained the surface soil at a saturated condition ($\geqslant -10$ kPa) for 35 days from planting. Subsequently, the soil moisture potential in the unirrigated treatment deviated markedly. During the reproductive stage, when there was no rain or irrigation, soil moisture potential in the 10 cm depth decreased in all the treatments, reaching the limit of the instrument capacity in the unirrigated regime. In the 40 cm depth, the matric potential was similar among treatments until 42 days after planting (Fig. 2).

Air filled porosity was 24 to 26% for both moisture regimes on February 18 (Fig. 3). The – 10 kPa saturated condition shown in the figure is an estimate based on the general soil properties and moisture release curve data. When the irrigation was started on February 24, there was a sudden drop of air-filled porosity which continued to decline until March 4, since by that time a large amount of water had been added in the saturated treatment. Differences among treatments in air-filled porosity were evident from 19 days after planting (March 1). Cultivars in the fully saturated plots experienced most severe anaerobiosis at 23 days after plant-

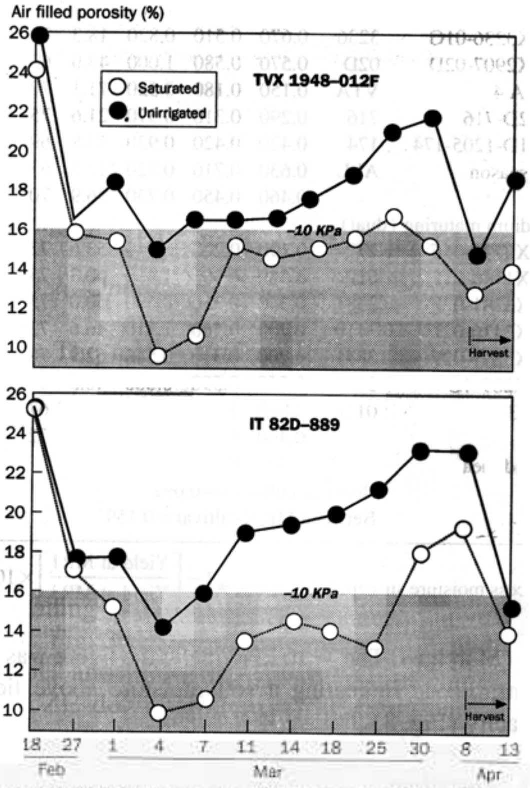


Fig. 3. Seasonal fluctuations in air filled porosity (%) at 10 cm soil depth in the saturated and unirrigated treatments grown with two cowpea cultivars (1988). The – 10 kPa line is the estimated field capacity; shaded area indicates saturation.

Table 3
Mean seed yield (t ha^{-1}) response of 24 cowpea cultivars to three moisture regimes (MR) (1986–87)

Cultivars	Code	Mean seed yield (t ha^{-1})			ESI[a] (%)	Maturity (MR3) (days)
		MR1	MR2	MR3		
Early maturing (grain)						
IT82E-18	IT18	0.140	0.160	0.440	68.2	65
IT82E-16	IT16	0.170	0.190	0.190	10.5	62
IT82D-889	889	0.360	0.460	0.500	28.0	58
CES 41-6	CES	0.270	0.500	0.570	52.6	58
IT82D-892	892	0.310	0.440	0.640	51.6	60
$\bar{X}$		0.250	0.350	0.470	46.8	61
Early maturing (vegetable)						
IT81D-1228-10	IT10	0.320	0.430	0.500	36.0	66
IT81D-1228-13	IT13	0.160	0.260	0.290	44.8	67
IT81D-1228-15	IT15	0.170	0.100	0.390	56.4	66
Farve 13	FRV	0.150	0.200	0.230	34.8	68
LBBS 1	LB	0.170	0.400	0.370	54.0	65
BS6	BS6	0.260	0.440	0.570	54.4	60
$\bar{X}$		0.210	0.310	0.390	46.2	65
Medium maturing (grain)						
TVX3236-01G	3236	0.670	0.510	0.820	18.3	72
TVX2907-02D	02D	0.570	0.580	1.000	43.0	68
VITA 4	VTA	0.150	0.180	0.520	71.1	70
IT82D-716	716	0.290	0.310	0.370	21.6	75
IT81D-1205-174	174	0.420	0.420	0.930	54.8	69
All season	ALL	0.630	0.710	0.720	12.5	67
$\bar{X}$		0.460	0.450	0.730	36.9	70
Medium maturing (dual)						
TVX2724-01F	2724	0.190	0.200	0.410	53.6	73
TVX1948-01F	01F	0.560	0.900	1.410	60.3	75
TVX3381-02F	3381	0.340	0.350	0.680	50.0	75
TVX3410-02J	3410	0.700	0.760	1.310	46.6	72
TVX3871-02F	3871	0.200	0.310	0.540	62.9	78
TVX289-4G	289	0.350	0.590	0.680	48.5	67
TVX1948-012F	012F	0.860	1.420	1.440	40.3	67
$\bar{X}$		0.460	0.650	0.920	50.0	72
Grand mean		0.350	0.450	0.650	46.2	
S.E.	Between cultivars = 0.092 Between MR × cultivar = 0.159					

[a]Excess moisture susceptibility index = $-\left[\frac{\text{Yield at MR1}}{\text{Yield at MR3}}\right]\times 100$.

ing (March 4). The −10 kPa line in the figure was an arbitrary one indicating a soil moisture above field capacity (Fig. 3).

3.2. Phenology

Increased water application significantly delayed flowering and maturity of all cowpea cultivars. The delay in maturity was greater than that in flowering a varied from 3 to 10 days. The delay was more appare in TVX1948-012F and TVX3871-02F than in IT82 889 and CES41-6. The influence of moisture on ti to flowering and maturity of cowpea cultivars has al been reported by Grantz and Hall (1982) and Turk al. (1980), with similar results.

3.3. Seed yield

There was a significant positive response in the se yields of the cultivars to declining irrigation (fr excess to dry) in both years (Tables 3 and 4). In M the overall mean yield of the early-maturing cultiva

Table 4
The response of yield and yield components of four cowpea cultiv to five moisture regimes (1988)

Cultivars	Moisture regimes[a] (MR)				
		2	3	4	5
Seed yield (t ha^{-1})					
TVX1948-012F	0.951	1.026	1.192	1.288	1.549
TVX3871-02F	1.020	1.047	1.071	1.140	1.229
IT82D-889	0.647	0.678	0.736	1.000	1.028
CES41-6	0.441	0.640	0.572	0.642	0.763
S.E.	Between MR = 0.053 Between cultivar = 0.077				
Pods/Plant					
TVX1948-012F	17.0	17.0	17.5	17.5	23.8
TVX3871-02F	18.1	18.6	21.8	23.0	24.1
IT82D-889	13.5	12.9	15.7	15.6	19.9
CES41-6	16.8	15.5	14.9	17.0	19.4
S.E.	Between cultivars = 0.8 Between MR × cultivar = 2.0				
Seeds/Pod					
TVX1948-012F	13.5	14.0	14.5	14.5	15.3
TVX3871-02F	13.0	14.0	14.0	14.5	15.3
IT82D-889	10.5	11.0	12.3	13.0	11.9
CES41-6	9.5	10.5	10.5	11.0	11.5
S.E.	Between cultivars = 0.2 Between MR × cultivar = 0.5				
Seed mass (mg)					
TVX1948-012F	128	132	139	144	146
TVX3871-02F	146	147	148	149	151
IT82D-889	134	137	139	135	146
CES41-6	152	161	161	154	158
S.E.	Between cultivars = 3 Between MR × cultivar = 6				

[a]Excess moisture susceptibility index = $1-\left[\frac{\text{Yield at MR1}}{\text{Yield at MR5}}\right]\times 10$

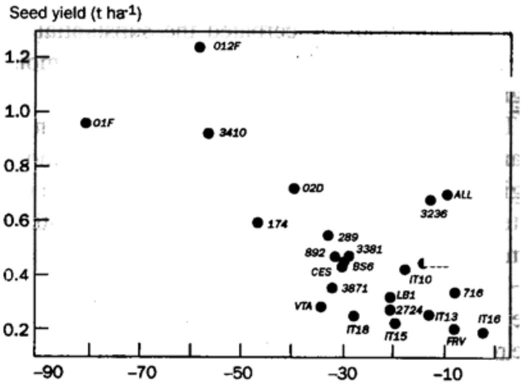
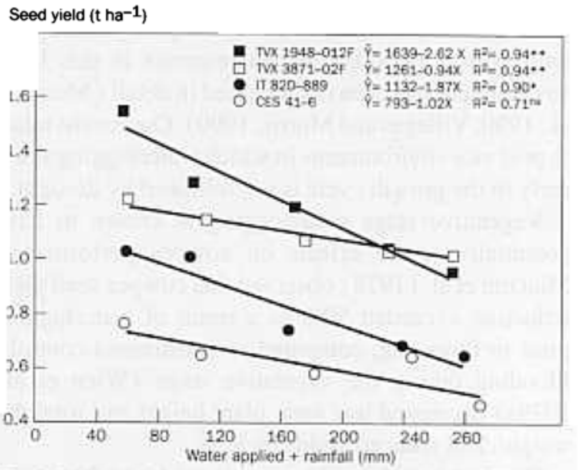


Fig. 4. Relationship between cultivar grand means (average over water levels) and linear regression coefficients (unit response per cm of total water received) for seed yield (1986–87).



ig. 5. Relationship between seed yield and water applied plus rain- ll for four cowpea cultivars (1988).

(grain and vegetable types inclusive) of 230 kg ha^{-1} was one-half that of the medium-maturing grain and dual-purpose types as a group (Table 3). In MR3, the yield of the early groups (430 kg ha^{-1}) was 52% of the medium groups (825 kg ha^{-1}). In 1988, the mean yield of the early cultivars (765 kg ha^{-1}) was 64% of the medium cultivars (1187 kg ha^{-1}) in MR1 and 985 and 1389 kg ha^{-1} in MR5, respectively for the early and medium-maturing cultivar groups. The yield difference between the MR1 and MR5 treatments for the early-maturing grain type cultivars (42.1%) was similar to that for the medium-maturing grain types (36.8%) (Table 3). Seed yields of the two early cultivars, IT82D-889 and CES41-6, were reduced by 28.0 and 52.6% respectively in 1986–87 and by 37.1 and 42.2% respectively in 1988 in MR1 compared with MR5.

Cultivars occupying positional coordinates in the left half of the seed yield graph in Fig. 4 exhibited a greater reduction in seed yield than cultivars falling in the right half. On this basis, the former may be characterized as more sensitive to excess moisture and the latter as less sensitive. Medium-maturing cultivars such as TVX1948-012F, TVX3410-02J, TVX1948-01F, and IT81D-1205-174 tended to greater sensitivity to excess

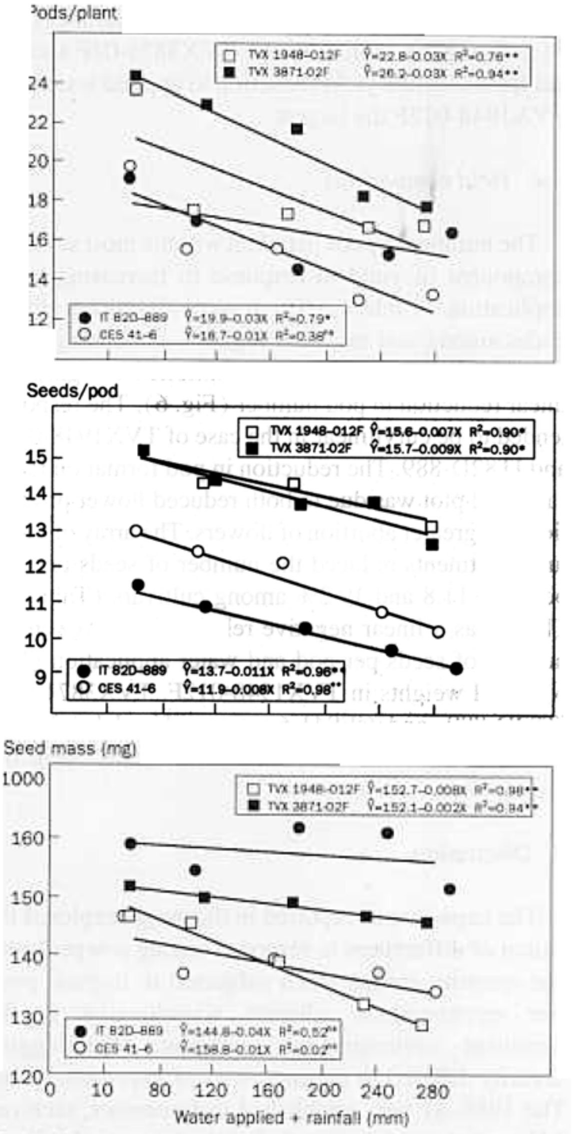


Fig. 6. Relationship between yield components and water applied plus rainfall for four cowpea cultivars (1988).

water, yet performed well under low moisture. However, a few cultivars (IT82E-16, IT81D-1228-13, IT82D-716 and Farve 13) had relatively low yield reduction due to excess moisture but did not respond to the low moisture. Cultivars TVX3236-01G, All Season and TVX2907-02D differed substantially in their regression coefficients, but had mean productivities that were quite similar (Fig. 4), indicating a general adaptability.

Seed yields in all four cultivars examined in 1988 exhibited a negative linear relationship with the total amount of water applied (irrigation plus rainfall) (Fig. 5). Among the four cultivars, TVX3871-02F showed the least absolute yield reduction to applied water, and TVX1948-012F the largest.

3.4. Yield components

The number of pods per plant was the most sensitive component of yield in response to increasing water application (Table 4). There were significant differences among soil moisture regimes and among cultivars. Three of four cultivars exhibited a significant linear reduction in pod number (Fig. 6). The response tended to be curvilinear in the case of TVX1948-012F and IT82D-889. The reduction in pod formation in the saturated plot was due to both reduced flower production and greater abortion of flowers. The array of moisture treatments reduced the number of seeds per pod between 11.8 and 19.2% among cultivars (Table 4). There was a linear negative relationship between the number of seeds per pod and water application (Fig. 6). Seed weights in TVX1948-012F, TVX3871-02F, IT82D-889, and CES41-6 were reduced by 3–12% among cultivars in MR1 compared with MR5 (Fig. 6).

4. Discussion

The experiments reported in this paper explored the extent of differences in response among cowpea cultivar maturity groups when subjected to tropical post-rice environments wherein waterlogging is the dominant environmental constraint. Waterlogging severity differed in the two years of experimentation. The 1986–87 test, established in December, received 141 mm of precipitation during the first month of crop growth, with three rains exceeding 10 mm. Line-source water applications exacerbated the substantial wate excess. Low grain yields were observed in all moistur regimes, including the driest.

The 1988 test was sown later in the dry season (February) to provide greater control of the moistur regimes. Natural precipitation was low, but the unirrigated regime still experienced water excess in the roo zone. Moisture potential reached a moderate leve (-80 kPa) in the surface soil, but remained high a the 40 cm depth, due to the influence of free water i the root zone, which fluctuated from 52 to 132 cm dept (Fig. 2). This was sufficient to depress grain yields Yields increased as less water was applied.

The line-source treatments in both years did no result in either an optimum moisture regime, or 'drought-stressed' regime in which soil water extraction exhausted the profile storage capacity during th crop growth period. Cowpea response in this latte environment has been documented in detail (Morris e al., 1990; Villegas and Morris, 1990). Our results relat to post-rice environments in which waterlogging stres early in the growth cycle is not followed by drought.

Vegetative stage waterlogging is known to hav potentially severe effects on cowpea performance Minchin et al. (1978) observed that cowpea seed yiel reduction exceeded 50% as a result of waterloggin prior to flowering, compared to nonstressed controls Flooding during the vegetative stage (Wien et al 1979a) decreased leaf area, plant height and total dr weight, and reduced yields by 91%.

Our first years' results provide evidence that majo differences occur in the productivity of individual cultivars and cultivar groups in waterlogged environments. Yields ranged from 140 to 860 kg ha^{-1} unde the most severe stress, and from 190 to 1440 kg ha^{-} with less severe stress.

Cultivar performance was examined in terms of tw dominant components: yield potential and sensitivit to waterlogging. Yield potential of all cultivars in early maturing grain and vegetable-type groups was low i all moisture regimes. Low yield potential was observe in the early cultivars IT82D-889 and CES41-6 whic have an outstanding record for yield and wide adaptation in national and international trials in South-Eas Asia (IRRI, 1989). Performance of the medium-maturing cultivars, both grain and dual-purpose types, wa clearly superior to that of the early-maturing grain an vegetable types in terms of yield potential. Three of th four highest yielding cultivars were from the group of dual-purpose types.

In the second year, the superiority of the medium-maturing group over the entire range of unfavorable environments was confirmed. With regard to cultivars within the two groups, it was generally observed that the best medium-maturity cultivars outperformed the best early-maturity cultivars. In comparing lines of lower yield potential this judgement does not necessarily apply.

In terms of waterlogging tolerance, as evaluated by an excess moisture susceptibility index, the distinction between cultivar groups was not clear. No consistent superiority was observed by either group. Therefore, the superiority of the best medium-maturing cultivars under the conditions of these tests was concluded to depend on superiority in yield potential rather than lesser sensitivity to waterlogging.

The factors underlying the differences in yielding ability of cultivars from the early and medium maturity groups were investigated in a companion paper (Timsina et al., 1994). Ecologically, a cultivar maturing in 70–75 days may experience a natural advantage in this set of environments, as opposed to one of 50–55 days maturity. Anaerobiotic conditions are most pronounced during the early growth period, and are relieved as the dry season proceeds. When rainfall ceases, root zone air-filled porosity improves and the water table declines. Early-maturing cultivars tended to complete their growth cycle before sufficient recovery from the early stress occurs. Later maturity enabled prolonged recovery under more advantageous conditions. The best medium-maturing cultivars were consistently superior in the expression of yield.

Cowpea cultivars in these tests experienced significant waterlogging stress. Caution must be exercised in extrapolating these results from the hydrological domain under which the trials were conducted. In most post-rice environments, temporary waterlogging is followed by rapid and deep retreat of the water table. The crop is more reliant on the limited reservoir of available soil water stored in the root zone, typically 150 to 200 mm (Morris et al., 1990). Terminal water stress is progressive and extreme. Early maturity to avoid terminal drought stress would be advantageous in these situations. Thus, we hypothesize that the early and medium maturity types may be superior in contrasting post-rice niches. The existence of a distinct maturity × niche interaction suggests the need to elucidate selection criteria further to identify superior cultivars for each niche, and to clarify the appropriate domains for the new cultivars of both types that emerge from cowpea improvement programs.

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