Table 4. Mean seed yield (Mg/ha) of 24 cowpea cultivars in three water table sites (1986–1987 DS and 1987 wet season).

	Dry Season (1986-87)			Wet Season (1987)			
Cultivars	SWT	MWT	DWT	SWT	MWT	DWT	Mean
Early Maturing (Grain)							
IT82E-18	0.17	1.19	1.15	0.14	0.34	0.41	0.57
IT82E-16	0.57	0.60	0.89	0.33	0.61	0.82	0.64
IT82D-889	1.29	1.05	1.36	0.36	0.52	0.57	0.86
CES41-6	0.82	1.18	1.01	0.39	0.58	0.63	0.77
IT82D-892	1.02	1.18	1.47	0.56	0.62	0.73	0.93
$\bar{X}$	0.77	1.04	1.18	0.36	0.53	0.63	0.75
Early Maturing (Vegetable)							
IT81D-1228-10	0.54	0.51	1.09	0.31	0.68	0.96	0.68
IT81D-1228-13	0.18	1.17	1.17	0.11	0.29	0.38	0.55
IT81D-1288-15	0.59	0.77	0.92	0.19	0.30	0.34	0.52
Farve 13	0.16	0.19	0.58	0.17	0.38	0.30	0.30
LBBS 1	0.11	0.61	1.06	0.11	0.34	0.24	0.41
BS6 1	1.20	1.40	2.20	0.31	0.31	0.52	0.99
$\bar{X}$	0.46	0.78	1.17	0.20	0.38	0.46	0.57
Medium Maturing (Grain)							
TVX3236-01G	2.26	2.73	2.10	0.77	1.01	1.47	1.72
TVX2907-02D	0.41	1.88	1.35	0.38	0.79	1.25	1.01
Vita 4	0.12	1.40	1.42	0.20	0.63	0.58	0.73
IT82D-716	1.25	2.03	1.54	0.50	0.82	0.95	1.18
IT82D-1205-174	0.81	1.58	1.93	0.42	0.69	0.99	1.07
All Season	1.52	1.91	2.13	0.61	0.90	0.91	1.33
$\bar{X}$	1.06	1.92	1.75	0.48	0.81	1.03	1.17
Medium Maturing (Dual)							
TVX2724-01F	0.19	0.57	0.19	0.22	0.39	0.69	0.38
TVX1948-01F	1.33	2.39	2.31	0.54	0.65	1.16	1.40
TVX3381-02F	1.63	2.77	2.19	0.46	0.58	0.65	1.38
TVX3410-02J	2.04	2.44	2.26	0.59	0.74	0.70	1.46
TVX3871-02F	0.37	1.34	1.31	0.22	0.42	0.51	0.70
TVX289-4G	1.88	2.07	1.65	0.44	0.57	0.66	1.21
TVX1948-012F	1.49	2.57	1.78	0.66	0.75	1.19	1.41
$\bar{X}$	1.28	2.02	1.67	0.45	0.59	0.79	1.13
Grand mean	0.91	1.48	1.46	0.37	0.58	0.73	0.92

SE: Between Cultivars† = 0.15
Between WT × Cultivars‡ = 0.33

† Between cultivars within a water depth regime.
‡ Between any combination of cultivar by water depth regime.

In the 1986-1987 DS experiment, seed yields of most of the medium-maturing cultivars were highest in the MWT site, whereas that of the early maturing types were highest in DWT site (Table 4). At the SWT site, most of the cultivars had poor plant vigor, greater senescence and wilting, and lesser recovery, because of the continuous high water table during crop growth. This reduced the mean seed yields of early maturing cultivars (grain and vegetable type together) by 48.7% in SWT compared to DWT. However, performance of the medium-maturing cultivars (grain and dual type together) was superior (mean yield reduction of 40.1%) to the early maturing cultivars in the SWT site. Seed yields of all cultivars in the 1987 WS experiment (Table 4) were much lower than in the dry season (59.1 and 61.0% reductions for early and medium-maturing cultivars). All cultivars except Farve 13, LBBS1, Vita 4, and TVX3410-02J produced their highest seed yields in the DWT site. A shallow water table reduced the seed yields of all cultivars as compared to the DWT site, with mean yield reductions of about 50%. In the SWT site intense rainfall plus the unusually high water table caused poor plant vigor, more wilting, less recovery and less survival of the plants.

In the 1987-1988 dry season experiment, seed yields of all cultivars were also significantly affected by water table depths (Table 6). The shallow water table regime significantly reduced the seed yields of all cultivars. The reductions were greatest with cultivars BS6, and IT82D-892, both early maturing types. Medium-maturing cultivars performed best in MWT site, whereas the early maturing ones were clearly superior in DWT site.

Although there were some discrepancies, the general trend for the dry-season experiments was that the medium-maturing cultivars exhibited best performance under MWT conditions, whereas the early maturing types had best performance in DWT conditions. In the wet season, all other cultivars except TVX 3410-02J did best under DWT conditions. The superior performance of early maturing cultivars under DWT conditions in the dry season may have been due to the shorter period of terminal drought stress to which they were subjected, as compared to the cultivars in the medium group. Water stress influenced the growth of the medium maturing cultivars during a greater proportion of the total life cycle. There were seed yield reductions in all cultivars under SWT conditions in both dry and wet seasons, with relatively lower reductions among the medium-maturing types.

Yield Components

The number of pods per plant was the yield component most sensitive to water table depth (Tables 5 and 6). In

Table 5. Yield components of 24 cowpea cultivars in three water table sites (1987 wet season)

	Pods/plant			Seeds/pod			1000 seed wt (g)		
Cultivars	SWT	MWT	DWT	SWT	MWT	DWT	SWT	MWT	DWT
Early Maturing (Grain)									
IT82E-18	1.9	5.7	6.1	7.1	10.7	11.7	123	126	126
IT82E-16	2.5	4.3	3.9	9.7	12.2	13.1	116	122	124
IT82D-889	3.0	6.0	6.8	8.9	10.9	10.3	101	115	124
CES41-6	2.8	4.5	6.7	8.7	10.7	11.0	115	116	115
IT82D-892	2.3	3.9	4.7	8.3	10.8	12.0	111	131	119
Early Maturing (Vegetable)									
IT81D-1228-10	2.3	4.0	4.5	8.1	11.1	11.6	107	112	109
IT81D-1228-13	1.7	4.3	6.3	7.3	11.5	11.4	89	98	109
IT81D-1228-15	3.5	5.1	6.8	7.4	10.0	9.2	101	117	112
Farve 13	2.6	4.2	4.1	8.6	10.9	11.7	124	120	121
LBBS 1	2.7	5.9	6.5	7.9	9.4	9.4	101	116	112
BS6	2.4	2.8	3.6	9.2	10.3	10.8	120	144	157
Medium Maturing (Grain)									
TVX3236-01G	4.7	8.1	7.1	10.0	10.1	11.5	90	103	100
TVX2907-02D	3.7	6.1	7.7	9.8	13.2	12.7	114	124	121
Vita 4	3.6	6.3	6.5	12.6	13.7	13.1	84	92	91
IT82D-716	3.2	6.9	5.7	6.4	9.7	9.8	97	115	114
IT82D-1205-174	3.5	5.9	7.0	9.9	10.6	10.1	143	152	145
All Season	2.7	5.0	5.0	7.5	9.8	12.2	159	158	171
Medium Maturing (Dual)									
TVX2724-01F	2.0	4.7	6.6	6.6	11.5	11.9	107	113	117
TVX1948-01F	1.8	5.6	5.8	10.0	12.9	12.1	100	108	110
TVX3381-02F	2.2	5.1	6.1	8.6	12.1	12.8	118	129	128
TVX3410-02J	1.9	5.4	5.3	8.1	11.7	11.7	102	123	121
TVX3871-02F	2.1	4.9	4.4	6.6	11.2	13.2	98	112	115
TVX289-4G	2.9	5.5	5.5	9.8	10.5	11.1	121	126	122
TVX1948-012F	1.7	5.2	6.0	11.0	12.6	14.0	98	104	110
SE: Between Cultivars† =		0.6			0.6			3	
Between WT × Cultivars‡ =		0.9			0.9			4	

† Between cultivars within a water depth regime.
‡ Between any combination of cultivar by water depth regime.

the wet season, most of the cultivars produced a significantly higher number of pods per plant in the DWT site. On the contrary, in the dry season, the medium-maturing cultivars produced the highest number of pods in the MWT site, while the early maturing ones had highest pods in DWT site. In the SWT site, all the cultivars produced significantly lower number of pods per plant in both seasons. Polthanee (1989) also reported a significant reduction in the number of pods per plant in mungbean due to flooding. The additional ethylene present in flooded plants may result in the premature abscission of flowers and pods in legume crops exposed to flooded soil (Cannell et al., 1979).

The number of seeds per pod was less sensitive to water table depth than were pod number in both experiments (Tables 5 and 6). In the wet season, most cultivars had more seeds per pod in DWT and less seeds in SWT sites. In the dry season, the medium-maturing cultivars had highest number of seeds per pod in the MWT site, while the early maturing ones had highest seeds in the DWT site. In SWT site, all the cultivars produced a significantly lower number of seeds per pod in both seasons.

One thousand seed weight was also significantly influenced by water table depth in both experiments (Tables 5 and 6). Most cultivars had highest seed weights either in the MWT or in the DWT site. The cultivars had least seed weights in the SWT site.

DISCUSSION

The experiments reported in this paper explored the extent of differences in the response of cowpea cultivars when evaluated under conditions judged representative of a particular segment of tropical environments with a shallow water table. Waterlogging is a serious constraint to upland crop performance in the post-rice period since the water table may remain near the soil surface for a substantial period following crop establishment. Likewise waterlogging is a serious constraint in pre-rice crop performance. The water table rises to near or above the soil surface during the reproductive growth of the upland crop.

This research was concerned with the extent to which cultivar maturity influences the productivity and stability of tropical cowpea cultivation under contrasting water table regimes. The dry season and wet season results provided evidence that major differences occur in the productivity of individual cultivars, and of cultivar groups, under different water table regimes. Yield ranged from 0.11 to 2.26 Mg ha^{-1} under the shallow water table regime, and from 0.19 to 2.73 Mg ha^{-1} under the medium water table regime. The early maturing grain and vegetable-type cultivars responded similarly (Table 4). Yield potential of all cultivars in both of these groups, as compared to the cultivars in medium-maturing group, was low in the SWT regime, suggesting generally poor

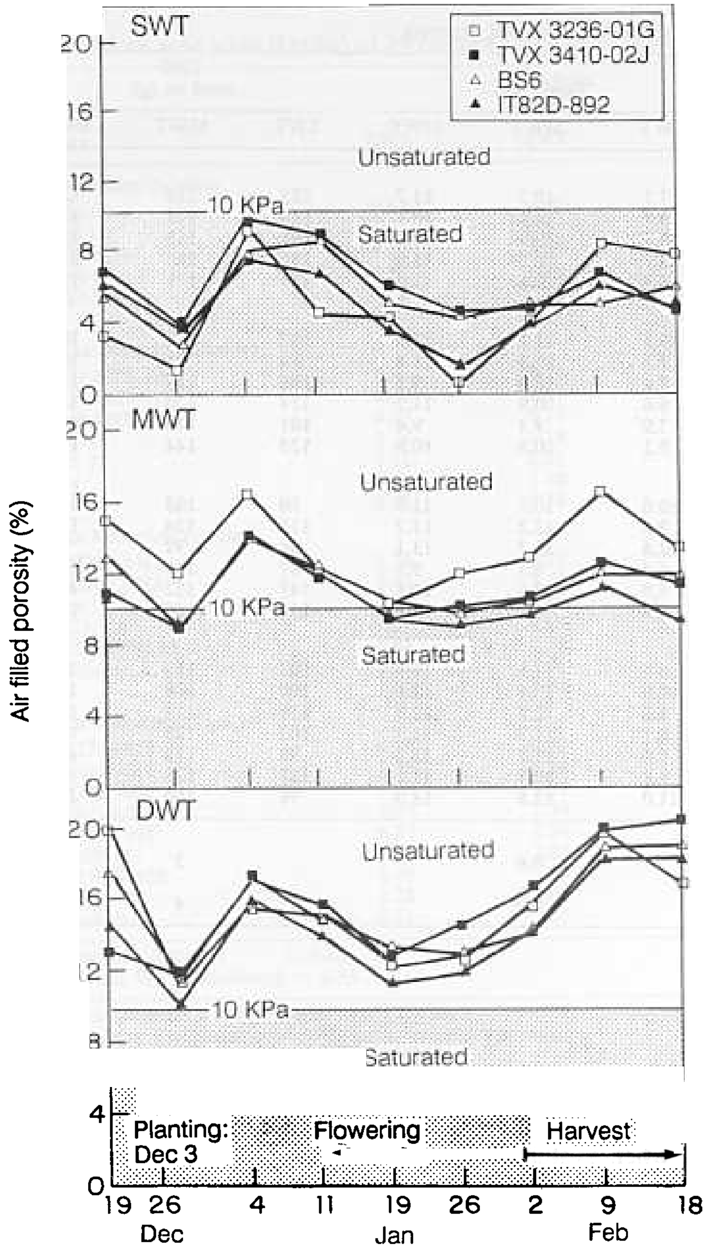

Fig. 5. Seasonal fluctuation in air-filled porosity at the 0.2-m soil depth in three water table sites (1987-1988 dry season).

adaptation. The clear superiority of the medium-maturing entries under the entire range of water table regimes was confirmed.

Poor performance of cowpea compared to soybean under a high water table was previously observed by Wien et al. (1979) and Hulugalle and Lal (1986) in Nigeria. The former authors attributed this to nodulation failure at SWT, whereas the latter authors reported that cowpea roots did not grow in the saturated soil zone immediately above the water table. The development of adventitious roots under a high water table, to facilitate the pumping of O_2 to the main root system, has been reported for cowpeas and several other crops (Kawase, 1981), needs more investigation.

Improved photosynthesis, and consequently higher seed yield in soybean, have been observed when cultivated in

Table 6. Effect of water table depth on yield and yield components of four cowpea cultivars. 1987-1988 dry season.

Cultivars	Water Table Depth (WT) SWT	MWT	DWT
	— Seed Yield (Mg/ha) —		
TVX3236-01G	1.34	2.60	1.80
TVX3410-02J	0.95	2.29	1.49
BS6	0.16	0.34	0.75
IT82D-892	0.44	0.64	1.40
SE : Between Cultivars† =	.07		
Between WT × Cultivars‡ =	15		
	— Pods/plant —		
TVX3236-01G	8.5	11.7	10.2
TVX3410-02J	9.9	13.1	11.0
BS6	2.8	5.1	6.4
IT82D-892	5.2	5.7	9.0
SE : Between Cultivars† =			
Between WT × Cultivars‡ =			
	— Seeds/pod —		
TVX3236-01G	11.4	12.5	10.6
TVX3410-02J	12.5	13.5	13.0
BS6	10.4	12.2	12.7
IT82D-892	10.4	10.9	12.3
SE : Between Cultivars† =	0.6		
Between WT × Cultivars‡ =	0.7		
	— 1000-seed weight (g) —		
TVX3236-01G	129.8	142.3	138.8
TVX3410-02J	148.7	161.9	160.7
BS6	197.1	204.4	206.9
IT82D-892	151.6	186.0	186.5
SE: Between Cultivars† =	1.8		
Between WT × Cultivars‡ =	3.9		

† Between cultivars within a water depth regime.
‡ Between any combinations of cultivar by water depth regime.

a saturated zone of soil 3 to 15 cm above a perched water table throughout crop life (Troedson et al. 1985; Summerfield and Lawn, 1987). Such results require careful manipulation and control of the water table. In the shallow water table conditions observed in this study, the medium-maturing cultivars as a group performed better than others. The responses suggest that if the field water table can be controlled different drainage management designs may be optimal for medium-maturing types as compared to early maturing types. The depth to which the ground water table needs to be lowered to minimize damage to the root system and optimizing performance, appears to differ among cultivars. Raised beds are a viable management alternative for partially alleviating shallow water table stresses. This practice has been used by farmers in some areas in the humid regions of Asia. Our results indicate that a cowpea cultivar interaction with bed height may be anticipated.

The studies confirmed the hypothesis that a strong interaction exists between the soil water table depth regime and maturity class in cowpea. Maximum yields were associated with different water table depth regimes in different maturity classes. This interaction was observed in both the wet and dry seasons, when other agrometeorological and soil moisture parameters differed substantially.

One implication of the water table by maturity interaction is the need to consider the identification of cowpea genotypes unique to production areas with differing water table dynamics. However, examination of absolute yields in all water table depth regimes reveals that cultivars in the medium maturity groups were consistently superior (Table 4). Cultivars such as TVX3236-01G and TVX3410-02J were top-ranked in all regimes in both seasons.

The extrapolation domain of these trials is limited to situations in which a water table is present within the crop root zone for at least a portion of the growth period. Within these limits the cultivars that are most successful when challenged with an array of water table regimes are genotypes from the medium maturing classes. However, an adaptive advantage of early maturity has been observed in freely drained soils, with terminal drought stress in the post-rice season that is more severe than that observed here (Timsina, 1989).

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