

Performance and yield of cowpea (*Vigna unguiculata* L. Walp) subjected to imposed water deficit

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Abstract

Growth performance, yield and yield component analysis studies of water-stressed irrigated cowpeas were conducted using cowpea cultivars: Ife Brown and TVx 3236 in order to determine the best phenological stage to stop irrigation. Water stress was imposed by stopping irrigation at seedling establishment, 50% vegetative growth, first flowering, 50% flowering, pod setting or 50% pod fill. The effect of cultivar was not significant in all parameters evaluated.

Cowpea seed yield progressively increased from 7 g/plant for plants that received 80-160 mm of water during the seedling establishment and early vegetative growth stages to 11-22 g/plant for crops that received 260-320 mm of water from planting till end of vegetative and early flowering stages. Seed yield was only 24-26 g/plant for cowpea irrigated from planting till end of flowering and pod filling stages. The phenological stage to stop irrigation and still obtain high yield in irrigated cowpea was at the end of the flowering stage. Irrigating beyond this stage increased total biomass but reduced seed yield by about 8 percent.

Introduction

Cowpea is an important food legume in the tropics and subtropics providing an inexpensive source of protein in many diets. In tropical West Africa, cowpea is usually planted towards the end of the rainy season, because better seed quality is obtained if maturation occurs during the dry period (Nangju et al. 1979). However, observations have shown that the total grain yields of cowpea planted towards the end of the rainy season is lower than yields from crops planted in the early or middle part of the rainy season (Ezedinma, 1966; Nangju et al, 1979). The reasons for the observed high grain yield in the early as compared to the late season's is not sufficiently clear. For example, Ezedinma (1966) attributed the higher grain yield in the early seasons to higher solar radiation and leaf area index for April and May plantings than for later plantings. Nangju et al. (1979) suggested that the differences in the yield in these seasons could be due to rainfall, since they observed a longer reproductive period in the first than in the second season owing to longer rains. Observations generally show that in tropical West Africa, photosynthetically active radiation is not limiting at any period for crop growth and development even though total radiation may be low at certain periods. Therefore, the low yields observed for late plantings might have been moisture stress induced.

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Consequently, adequate irrigation should provide enough soil moisture to enable irrigated cowpea to have sufficiently long reproductive period and produce yields comparable to early season cowpea. Fapohunda et al. (1984) found that cowpea grain and dry matter yields increased with increase in water use up to the point where applied water (450-500mm) matched the evapotranspiration values (461 mm) calculated from climatological data. Beyond this point, cowpea yields were depressed by over-irrigation.

Cowpea is a relatively drought tolerant crop, however, varying degrees of yield reductions have been reported on cowpea subjected to drought conditions during different growth stages. Several workers (Turk et al., 1980; Shouse et al., 1981; Labanauskas et al., 1981; Ziska and Hall, 1983) reported that cowpea had the ability to maintain seed yields when subjected to drought during the vegetative stage, but drought during flowering and pod filling substantially reduced yields. Most of these studies were conducted under simulated drought conditions imposed at a particular growth stage or combination of stages. It will be desirable to know the exact phenological stage to stop irrigation (started at planting), and still obtain good quality and high seed yields of cowpea. The growth stages requiring irrigation for dry matter production can then be compared with those for seed yields for better water management practices. The objective of this study therefore, was to find out the yield potential of irrigated cowpea in relation to the best phenological stage to stop irrigation for dry matter production and high seed yields.

Materials and Methods

The experiment was conducted at the Obafemi Awolowo University Teaching and Research Farm first as a preliminary study in the dry season (November to February) of 1984/85 and repeated in the dry season of 1985/86. The soil of the experimental site was Iwo loamy sand, an alfisol, Oxic Paleustalf (Harpstead, 1973). Table 1 shows some of the physical and chemical characteristics of the soil. The experiment was a randomized complete block design with four replicates. Fig. 1 shows the experimental plot layout and sprinkler head locations.

Irrigation water was delivered through an overhead sprinkler system consisting of 6 single-nozzled sprinklers, each with an effective wetting diameter of 20m and spaced 18.3m apart from along an irrigation pipe about 97.6m long. A pre-planting irrigation of 20mm was applied to the plots three days before planting. Subsequent irrigation applications were based on cowpea phenology as presented in Table 2. Water control on the different plots (treatments) was achieved by plugging the necessary sprinkler head or heads when no water was to be applied during a particular physiological growth stage or stages. The flow thus discontinued was usually diverted for use on adjacent irrigated fields to maintain fairly uniform nozzle pressures and application rates on the experimental plots during the growth period. Plots were irrigated under low wind speed conditions (0-5 m/s) both in the morning and in the evening for one hour each time. It had been established during the preliminary trials that the overhead sprinkler system, on the average, delivered 20mm of irrigation water in 2 hours. An irrigation frequency of 3 days was maintained on the plots throughout the growing season. Rainfall amounts were considered negligible since they were mere drizzles during the period.

Ife brown and TVx 3236 varieties of cowpea were planted at a spacing of 0.30m within and 0.60m between rows on a site that had just been ploughed and harrowed.

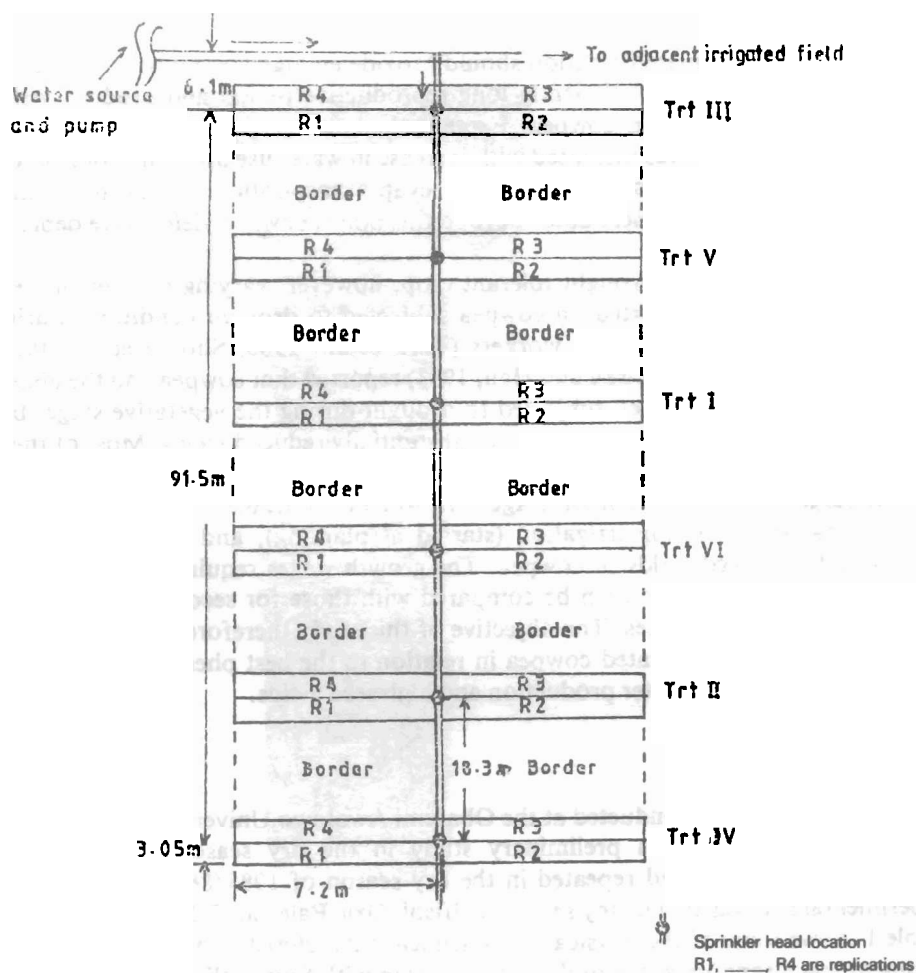


Figure 1. Experimental layout showing the treatments and sprinkler head locations

TABLE 1: SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF IWO LOAMY SAND.

<i>Soil properties</i>	<i>Value</i>
Sand (%)	82.3
Silt (%)	9.9
Clay (%)	7.8
Organic matter (%)	2.0
CEC (meq/100g)	4.9
pH	6.1
Exch. Sodium Percentage	2.34

A single plot consisted of 5 rows of cowpea, 24 plants per row giving a plot size of 3m by 7.2m. At planting, a single pre-emergence spray application of 3.0 kg a.i./ha. alachlor was done using a knapsack sprayer previously calibrated to deliver 250 litre/ha spray volume under a pressure of 2-3 kg/cm² to control weeds. There was no supplementary weed control and no fertilizer was applied. 500 g. a.i./ha monocrotophos was applied fortnightly beginning at flower initiation to control insect pests. During podding, benomyl at 3 g/l was added to the insecticide spray to control the attack of brown blotch (*Colletotrichum spp.*).

Dry matter (biomass) production was assessed at 20, 40, and 60 days after planting (d.a.p) by harvesting two randomly selected stands of cowpea at soil level. On each sampling date, harvested cowpea plants were separated into their different components before they were oven-dried at 80°C for 48 hours. Completely opened flowers were counted on the entire 24 plants of the middle row every other day beginning from the first appearance of an opened flower until no more flowers were observed. Pods were also counted every other day until no new pods were observed. Data on seed yield and 100 seed weight were obtained after shelling and adjusted to 10% moisture content. An analysis of variance was carried out on the data collected and means of factors with significant F-values were compared using the least significant difference (LSD) at 5% level of probability.

TABLE 2: COWPEA PHENOLOGY AND THE AMOUNT OF IRRIGATION WATER APPLIED

<i>Stages of Growth that received Irrigation</i>	<i>Amount of Irrigation Water applied (mm)</i>	<i>Growth Stages without Irrigation</i>
I. From planting till seedling establishment (0-12 d.a.p.*)	80	Vegetative growth, flowering, pod fill and reaping
II. From planting till 50% vegetative growth (0-24 d.a.p.)	160	Advanced vegetative growth, flowering, pod fill & ripening
III. From planting till end of vegetative growth (1st flower) (0-40 d.a.p.)	260	Flowering, pod fill and ripening
IV. From planting till 50% flowering (0-50 d.a.p.)	320	Advanced flowering, pod fill and ripening
V. From planting till end of flowering (incl. pod setting) (0-60 d.a.p.)	400	Pod fill and ripening
VI. From planting till 50% pod fill (0-73 d.a.p.)	480	Advanced pod fill and ripening

* d.a.p. = days after planting.

Results

Table 3 shows the mean survival percentage and dry matter yields of cowpea at different stages of growth. Both the survival and biomass of cowpea varied according to the extent of irrigation. For example, survival was 90% or more if irrigation was extended till end of flowering or longer; these survival values were significantly higher than in crops irrigated for shorter periods (Table 3). At 20 d.a.p., all treatments had generally low total biomass but slight biomass increases were recorded for treatments III and IV, which had received 120 mm, over treatment I which received only 80 mm. At 40 d.a.p., total biomass increased generally over those of 20 d.a.p. Cowpea that received irrigation up to the end of the vegetative growth stage had significantly higher biomass than those that received irrigation during the seedling establishment and up to 50% vegetative growth stages. At 60 d.a.p., total biomass was much higher than at 40 d.a.p. Total biomass in treatments that received irrigation up to the end of the vegetative growth stage and beyond were significantly higher than those that received irrigation for shorter periods.

The flowering periods were monitored in order to know if moisture stress had a direct relationship on the time of flowering, number of flowers produced, and the number of flowers successfully transformed to pods. Generally, most of the flowers and pods were produced in the second and third weeks of flowering; the first and last weeks producing only few flowers and pods. During the first week of flowering, the percentage of flowering plants and pods per plant were not significantly different among all treatments. However, the number of flowers per plant were significantly higher where irrigation period was short. For example, plants irrigated from planting till middle and end of the vegetative phases had higher number of flowers than those irrigated for longer periods (Table 4). During the second week, between 60 and 85% of cowpea plants flowered. Significantly more flowers were produced and transformed into pods in cowpea irrigated till end of the vegetative growth phase. In the third week, generally most of the flowers and pods were produced in cowpea irrigated beyond the end of vegetative phase; all plants irrigated beyond the end of the vegetative phase had flowered whereas plants where irrigation was limited to the end of vegetative phase or less had less than 100% flowering plants. As of the fourth week, all plants had flowered in all treatments. Significantly more total pods were produced when irrigation was extended till the end of vegetative phase or longer periods. The number of flowers produced in the fourth week were generally few but not significantly ($P < 0.05$) different among the treatments except where irrigation was stopped at about the end of flowering.

Table 5 shows the yield and yield components of cowpea irrigated to different phenological stages of growth. Although, days to first flower were significantly longer for cowpea irrigated to about 50% flowering stage or longer, their number of days to peak flower was significantly shorter. Also, in comparison to plants irrigated beyond the end of the vegetative phase, the total number of flowers, total pods and seed yield per plant, were significantly low for treatments whose irrigation was terminated at or before the end of vegetative growth (Table 5). The 100 seed weight as an index of the quality of the seeds were relatively high and fairly uniform even though significant differences were observed among some treatments.

TABLE 3: SURVIVAL AND DRY MATTER PRODUCTION OF COWPEA SUBJECTED TO IMPOSED WATER DEFICIT.

Stages of Growth that received Irrigation	Mean Survival (Z)	Mean Total Dry Matter (20 d.a.p) (g/plant)	Mean Dry Matter (40 d.a.p) (gram per plant)			Mean Dry Matter (60 d.a.p) (gram per plant)			
			Stem	Leaf	Total	Stem	Leaf	Pod	Total
I. From planting till seedling establishment (0-12 d.a.p*)	71	1.3	2.6	3.7	6.3	7.6	6.4	2.8	16.8
II. From planting till 50% vegetative growth (0-24 d.a.p)	68	1.3	1.7	3.5	5.2	5.8	5.7	3.5	15.0
III. From planting till end of vegetative growth (1st flower) (0.-40 d.a.p)	74	1.8	6.0	9.3	15.3	8.7	8.0	4.1	20.8
IV. From planting till 50% flowering (0.50 d.a.p.)	69	2.0	7.1	14.4	21.5	13.0	12.3	10.0	35.3
V. From planting till end of flowering (incl. pod setting) (0.60 d.a.p.)	90	2.1	8.0	18.0	26.0	23.0	16.4	13.0	52.4
VI. From planting till 50% pod fill (0-73 d.a.p)	96	2.4	9.9	22.1	32.0	39.0	21.8	18.7	79.5
LSD (0.05)	5	0.8	3.1	6.1	9.0	8.1	4.7	6.0	13.6

*d.a.p. = days after planting

Discussion

The performance of cowpea irrigated till varying phenological growth stages in this study can be explained by grouping them into three categories. The first category includes those that were irrigated for seedling establishment and 50% vegetative growth stages. This group can be described as the moisture-stressed group. They produced 60% flowers and pods, 25% seed yield of cowpea that received full irrigation (that is, until 50% pod filling stage). It is interesting to note that this group of moisture stressed cowpea plants could produce any seed at all. The fact that about 7 g/plant seed yield was produced by cowpea that received only 80-160 mm of irrigation (about 17-33% of that received by crops irrigated throughout) indicates that cowpea is a drought tolerant crop as previously observed by other workers (Nangju et al., 1979; Akingbohunge, 1982). Moisture stress at the early stages appeared to have induced early flowering and some yields.

The second group of cowpea plants are those whose performance can be compared to conventional late season (July-September) planting. This is the group that received about 260-320 mm of irrigation from planting till 50% flowering stage, and did not receive moisture during the latter part of flowering, pod filling and maturation stages. In this group, biomass production was intermediate. Flower and pod production of between 38-50 per plant and grain yield of between 11-22 g/plant in

TABLE 4: FLOWER POD PRODUCTION AND PERCENT OF FLOWERING COWPEA SUBJECTED TO IMPOSED WATER DEFICIT

Stages of Growth that received Irrigation	1st Week of Flowering			2nd Week of Flowering			3rd Week of Flowering			4th Week of Flowering		
	Flowers /plant ^b	Pods /plant ^b	F. Pl ^a (%)	Flowers /plant ^b	Pods /plant ^b	F. Pl (%)	Flowers /plant ^b	Pods /plant ^b	F. Pl (%)	Flowers /plant ^b	Pods /plant ^b	F. Pl (%)
I. From planting till seedling establishment (0-12 d.a.p*)	0.7	0.1	21.1	3.2	2.3	62.4	6.0	7.0	91.8	3.2	12.0	100
II. From planting till 50% vegetative growth (0-24 d.a.p)	1.0	0.4	28.0	4.5	3.4	73.2	7.3	10.3	96.0	2.5	14.5	100
III. From planting till end of vegetative growth (1st flower) (0-40 d.a.p)	1.2	0.4	26.0	11.9	8.6	83.0	4.0	13.6	94.3	3.1	17.2	100
IV. From planting till 50% flowering (0.50 d.a.p)	0.2	0.1	6.0	11.2	10.6	84.3	11.0	18.0	100.0	3.3	21.2	100
V. From planting till end of flowering (incl. pod setting) (0-60 d.a.p.)	0.2	0.1	7.4	6.4	5.8	76.8	7.3	12.4	100.0	7.5	19.5	100
VI. From planting till 50% pod fill (0-73 d.a.p)	0.2	0.1	9.0	5.0	5.0	69.6	10.4	10.6	100.0	5.6	21.0	100
LSD (0.05)	0.8	NS ^a	NS	4.5	5.2	NS	2.8	4.9	5.0	3.0	5.0	NS

*d.a.p = days after planting

^aF. Pl = percent Flowering Plants

^bEach datum is the mean for 24 plants.

^cNS = Not Significant at 5% level of probability

TABLE 5. MEANS OF YIELD AND YIELD COMPONENTS OF COWPEA SUBJECTED TO IMPOSED WATER DEFICIT.

Stages of Growth that received Irrigation	Days to first flower	Days to peak flower	Total No. of flowers per plant	Total No. of Pods per plant	Seed Yield (g/plant)	Weight of 100 seeds (g)
I. From planting till seedling establishment (0-12 d.a.p*)	41.0	56.0	14.1	14.0	5.6	13.5
III. From planting till end of vegetative growth (1st flower) (0-40 d.a.p)	41.0	52.0	20.8	18.1	11.6	12.8
IV. From planting till 50% flowering (0.50 d.a.p)	52.5	53.0	25.7	24.2	22.5	13.0
V. From planting till end of flowering (incl. pod setting) (0-60 d.a.p.)	43.5	53.0	26.7	25.7	26.2	12.4
VI. From planting till 50% pod fill (0-73 d.a.p)	42.5	53.0	21.2	21.0	24.0	11.3
LSD (0.05)	1.5	2.0	4.0	6.0	10.0	0.9

*d.a.p = days after planting

this group compare favourably with those reported for September conventional plantings by Akingbohunge (1982).

The performance of cowpea in the third category is comparable to the performance of first season planting of conventional rainfed cowpea. Here, moisture was supplied for all phases except during the advanced pod filling and ripening stages in order to ensure good properly filled pods. In this group, the dry matter yields for leaf and stem were higher than for the other two groups that received irrigation for shorter periods. Similarly, flower and pod production, and grain yields per plant were higher and the yields of the category compared favourably with those reported for May/June plantings in conventional rainfed cowpea (Akingbohunge, 1982).

Nangju et al (1979) obtained yields about 100% higher in the first season than in the second season owing to favourable climatic conditions in rainfed first season cowpea. In the results reported here, the yield of cowpea irrigated till end of vegetative period is about 44% of that of cowpea irrigated till end of flowering stage where maximum seed yield was obtained. The implication is that inadequate moisture limits yield in cowpea and there is a minimum moisture threshold for good seed yield.

From the foregoing, it is clear that the phenological stage to stop irrigation and still obtain good quality and high seed yields in irrigated cowpea is at the end of the flowering stage. Beyond this stage, there were actual reductions in total number of flowers (21%), pods (18%) and seed yield per plant (8%). These reductions were however not significant at 5% level of probability. Cowpea dry matter yield, on the other hand, continued to be significantly high ($P < 0.05$) even when irrigated during the pod filling stage:

Conclusions

The survival and dry matter of cowpea depend on the extent of irrigation. Hence, the more the number of phenological phases covered by irrigation, the higher the dry matter yield. However, irrigation beyond the pod setting stage merely produced dry matter at the expense of seed yield and seed weight.

Generally, most of the flowers and pods were produced in the second and third weeks of the flowering stage. Cowpea irrigated till the end of the vegetative growth stage or for shorter periods flowered earlier but reached peak flowering stage later than cowpea that was irrigated for longer periods. Seed production by cowpea whose irrigation was stopped at 12 days after planting indicates that cowpea is a drought tolerant crop. Premature termination of irrigation resulted in 50-75% yield reduction. Termination of irrigation at the 50% flowering or pod setting (end of flowering) phenological stage resulted in the highest total number of flowers per plant, total pod number and seed yield.

There was no apparent benefit in irrigating cowpea beyond pod setting (end of flowering) stage. Therefore, if seed production is the ultimate objective, irrigation should terminate at either 50% flowering or end of flowering since it is important that pods mature under dry conditions in order to avoid fungal attack.

References

- Akingbohunbe, A.E. (1982). Seasonal variation in cowpea crop performance at Ile-Ife, Nigeria and the relationship to insect damage. *Insect Sci. App.*, 3(4):287-296.
- Ezedinma, F.O.C. (1966). Some observations on the effect of time of planting on the cowpea (*Vigna unguiculata* (L) Walp.). *Tropical Agriculture (Trinidad)*, 43: 83-87.
- Fapohunda, H.O.; Aina, P.O. and Hossain, M.M. (1984). Water use — yield relations for cowpea and maize, *Agric. Water Manage.*, 9: 219-224.
- Harpstead, M.I. (1973). The classification of some Nigerian soils. *Soil Science*, 166: 437-443.
- Nangju, D.; Nwanze, K.F. and Singh, S.R. (1979). Planting date, insect damage and yield of cowpea in Western Nigeria. *Expl. Agric.*, 15: 289-298.
- Labanauskas, C.K.; Shouse, P. and Stolzy, L.H. (1981). Effect of water stress at various growth stages on seed yield and nutrient concentrations of field-grown cowpeas. *Soil Sci.*, 131(4): 249-256.
- Shouse, P.; Dasberg, S.; Jury, W.A. and Stolzy, L.H. (1981). Water deficit effects on water potential, yield and water use of cowpeas. *Agron. J.*, 73(2): 333-336.
- Turk, K.J.; Hall, A.E. and Asbell, C.W. (1980). Drought adaptation of cowpea. 1. Influence of drought on seed yield. *Agron. J.*, 72(3): 413-420.
- Ziska, L.H. and Hall, A.E. (1983). Seed yields and water use of cowpea (*Vigna unguiculata* (L.) Walp) subjected to planned-water-deficit irrigation. *Irrig. Sci.* 3: 237-243.