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Full Length Research Paper

Optimizing Water Management for Enhanced Yield and Water Use Efficiency in *Corchorus olitorius*

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Yield and water use efficiency of *Corchorus olitorius* was investigated under field conditions using three irrigation water management strategies replicated three times in a typical sandy loamy soil at the teaching and research farm of the Federal University of Technology, Akure, Nigeria. The experiment was performed during the dry season of 1999 and early rainy season of 2000. The biomass yield at maturity (7 WAP) in 1999 was 5.22 t.ha^{-1} for crop at full irrigation (one pan evaporation, EP), 4.14 t.ha^{-1} at medium level irrigation (¾ EP) and 1.96 t.ha^{-1} at low level irrigation (½ EP). The biomass yields in 2000 were 7.27 t.ha^{-1} (1 EP), 5.89 t.ha^{-1} (¾ EP) and 3.66 t.ha^{-1} (½ EP) respectively. The differences in above ground biomass among irrigation treatments were highly significant ($P = 0.05$). The water use efficiencies for biomass yield at 49 days after planting in 1999 were 0.70 kgm^{-3} of water at 1 EP, 0.59 kgm $^{-3}$ of water at ¾ EP, and 0.15 kgm^{-3} of water at ½ EP; whereas, WUE values in 2000 were 0.58 kgm^{-3}, 0.54 kgm^{-3} and 0.19 kgm^{-3} for irrigation treatments 1 EP, ¾ EP and ½ EP respectively. Results showed a significant decrease in water WUE with decreasing water application for biomass production. Higher biomass yield and WUE of C. olitorius can be achieved when the crop is grown at full irrigation (1 EP)

Key words: Irrigation, biomass yield, pan evaporation, water use efficiency (WUE), jute mallow.

INTRODUCTION

Jute mallow (*Corchorus olitorius)* is noted for its important contribution to diet by supplying nutrients and rendering food more palatable (Grubben, 1997) . *C. olitorius* is reported to be demulcent, deobstruent, diuretic, lactagogue, purgative, and tonic. The crop is a folk remedy for aches and pains, dysentery, enteritis, fever, dysentery, pectoral pains, and tumors (Duke and Wain, 1981; Negm et al., 1980). Ayurvedics use the leaves for ascites, pain, piles, and tumors (Okoegwale and Olumese, 2001). Elsewhere the leaves are used for cystitis, dysuria, fever, and gonorrhea (Smith, 1985). The cold infusion is said to restore the appetite and strength. Despite the nutritional quality of this crop, its production is limited to the rainy season due to scarcity of water supply during the off season. *C. olitorius* is susceptible to moisture stress owing to its shallow rooting depth which can be prevented by using irrigation (Fasinmirin, 2000). Taylor and Klepper (1990) reported that N fertilizer significantly increased the seed yield of *C. olitorius* and that yield was also enhanced when irrigation was used in conjunction with rainfall to reduce soil moisture stress. When evaporation rates are high, frequent irrigations are required to maintain plant available water at levels necessary to maximize growth and yield (Connor et al., 1985; Whitfield et al., 1986).

The question of when to irrigate can be approached in three broad ways: using plant indicators, soil indicators and water balance techniques (Phene et al., 1992). Research result from varying environmental conditions present recommendations for the schedule of irrigation using the water balance technique and in combination with analysis of historical climate data from a region (Phene et al., 1992).The range of number of irrigation required can be identified using such date and information (Perrier, 1988) . The objective of this study was to investigate the effect of different irrigation strategies on yield and water

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Table 1. Details of irrigation treatments

Code	Treatment definition	Depth of water for each application(mm)			
		1999		2000	
		March	April	Sept.	Oct.
A	Irrigation at full level (that is. 100% Pan evaporation, 1Ep)	8.4	9.6	12.2	10.2
B	Irrigation at medium level that is at 75% Pan evaporation (3/4Ep)	6.3	7.2	9.2	7.7
C	Irrigation at low level that is, at 50% Pan evaporation (½Ep)	4.2	4.8	6.1	5.1

*Ep – pan evaporation

Table 2. Climate parameters during experiment.

Climatic Parameters	March	April	September	October
Mean air temperature (^oC)	36.3	36.1	31.1	30.5
Rainfall (mm)	-	71.1	130.8	117.8
Wind speed (m/s)	0.049	0.056	0.71	0.72
Sunshine hours (hr)	6.5	6.2	6.6	7.4
Mean relative humidity (%)	73	78.7	87.7	84.5

use efficiency of *C. olitorius.*

MATERIALS AND METHODS

Field experiments were conducted on sandy clay loam soil at the irrigation research farm of the Department of Agricultural Engineering, Federal University of Technology, Akure between March and April, 1999 and between September and October 2000. *C. olitorius* seed was soaked in warm water to break its dormancy and later broadcast on the field on 7th March, 1999 and 1st September, 2000. Thinning was carried out manually at 2 weeks after planting to attain a spacing of 15 x 30 cm.

Rainfalls, pan evaporation (Ep) and temperature details were measured at a weather station situated near the experimental site. Detail of the three irrigation treatments which were replicated three times is shown in Table 1. The irrigation treatments were full irriga-tion (one pan evaporation, EP), irrigation at medium level (¾ EP) and low irrigation (½ EP). This values of pan evaporation were used for estimating the amount of irrigation water to be applied for the corresponding months of March and April (1999) and of September and October (2000). Irrigation intervals were based on moisture storage condition as monitored by the soil moisture content mea-surement. Irrigations were carried out on 2nd, 7th,9th, 14th, 16th , 21st, 23rd, 28th, 37th and 40th days after planting (DAP) during the 1999 experiment. Similarly, irrigations were applied on 1st, 12th, 26th, 32nd, 34th, 40th, 42nd, 44th, and 45th DAP during the 2000 experiment.

Soil moisture contents at depths 10, 20, 30, 40 and 50 cm were determined on weekly basis using the gravimetric method. Crop water use (CWU) from sowing to harvest was estimated using soil water balance equation (Hillel, 1999).

$$CWU = I + P \pm s \pm D \pm R$$

1 = Irrigation

Where:

CWU - Crop water use (mm)
I - Irrigation (mm)
P - Precipitation (mm)
s - Change in soil moisture storage (mm)
D - Drainage (mm)
R - Runoff (mm)

Drainage (D) and Run-off (R) were assumed negligible due to sparse rainfall and the little quantity of water applied.

The water use efficiency on fresh was determined on fresh weight basis from the relationship below:

$$WUE = \frac{M_b}{C_w} kg/m^3$$

2

Where:

WUE = water use efficiency in kg/m^3,
M_b = sum of fresh weight of leaves, stems and roots in kg,
C_w = cumulative amount of water used (m^3)

Plants were harvested on 4th April, 1999 and 22nd October, 2000 when the leafy part of the plant had reached maturity. Four ran-domly selected crops were carefully uprooted and gently washed to remove soil particles from the roots. The roots and leaves were cut off from the stem to measure individual weights. The above ground biomass was expressed on dry weight basis.

The water use efficiency (WUE) was determined on fresh weight basis on the 28th and 49th days after planting (DAP). WUE is the ratio of the total biomass to the cumulative water use. Data col-lected were subjected to analysis of variance (ANOVA) and treat-ment means were separated using LSD using MS excel Software package.

RESULTS AND DISCUSSION

Climatic condition during experiment

The climatic condition during experiment is presented in Table 2. There was no rainfall in the month of March and therefore the crop depended absolutely on inherent soil moisture and irrigation water applied. The 2000 experi-ment falls within the 2nd peak of rainfall but there were occasional dry days when supplemental irrigations were carried out. Sunshine hours were however higher during

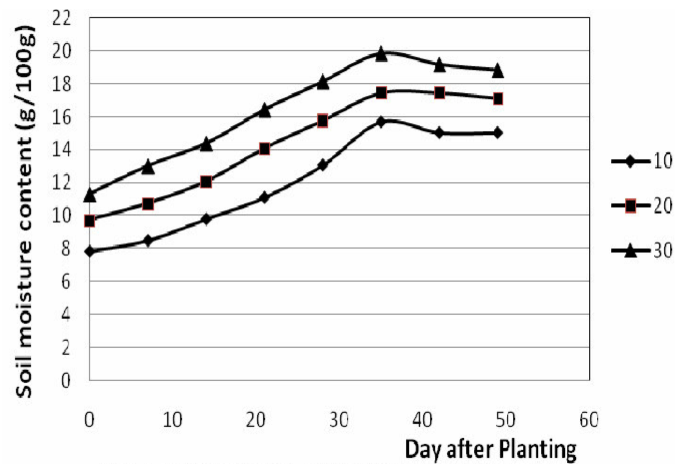

Figure 1. Soil moisture content under full irrigation treatment uring the March and A pril 1999 experiment.

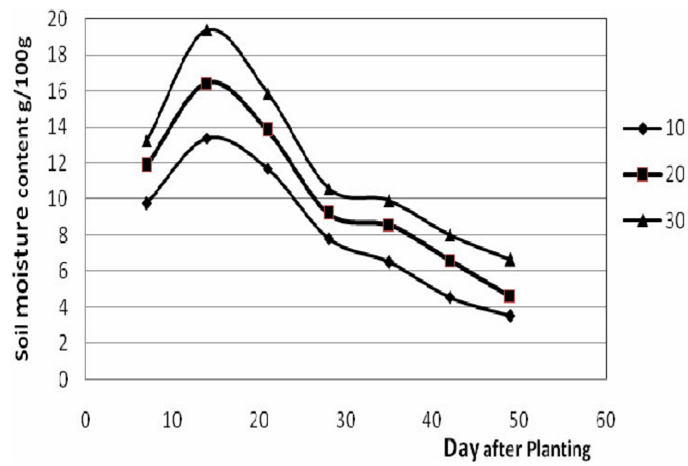

Figure 2. Soil moisture content between Sept and Oct. under full irrigation treatment during the 1999 experiment

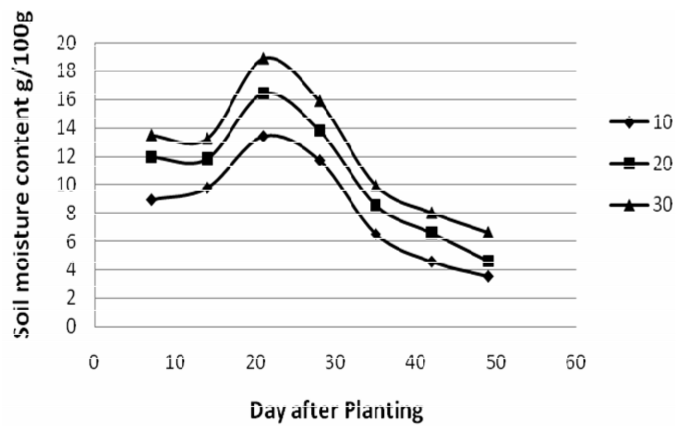

Figure 3. Soil moisture content between March and April under medium irrigation treatmet during the 2000 experiment

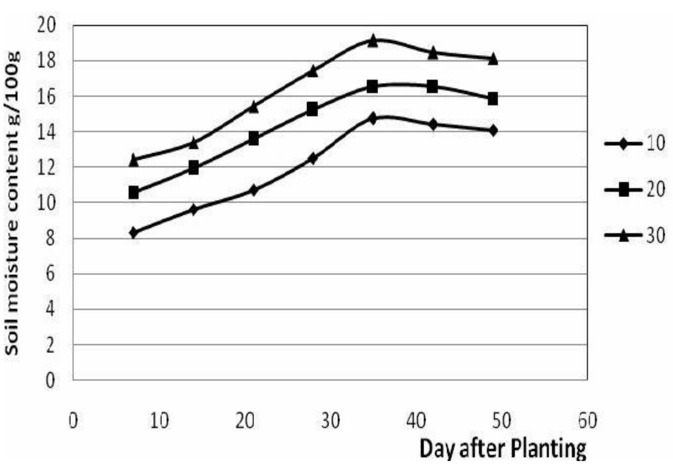

Figure 4. Soil moisture content between Sept. and Oct. under medium irrigation treatment during the 2000 experiment

2000 comparatively with 1999 experiment.

Soil moisture content

The soil moisture content in the various treatments from 0 – 49 DAP is presented in Figure 1 - 4. Soil moisture regime reflected the amount of water applied that is soil moisture was highest in full irrigation treatment comparatively with ¾ and ½ EP. At 10 cm soil depth, the moisture content decreased from 8.5 g/100g during 7 DAP to 15.03 g/100g during 42 DAP in the full irrigation treatment in 1999. Similar trend were observed at depths 20 and 30 cm but the highest soil moisture content was 19.86 g/100g at depth 30 cm in the full irrigation treatment. The soil moisture content during the 2000 experiment was significantly higher than the 1999 observations. This must have been caused by higher intensity of precipitation at the early stage of crop development. Soil moisture content increased at the on-set of rainfall in April, 1999. This same trend of moisture increase was observed in September (2^{nd} peak of rainfall in the year). It is however reduced drastically at crop maturity when the dry season sets in.

Evapotranspiration

The crop evapotranspiration (ET) expressed on function of days after planting is presented in Figures 5 and 6. The highest and lowest ET values under full irrigation treatment during the 1999 and 2000 experiments were 7.1 and 2.1 $mm.day^{-1}$ respectively. Also, the highest and lowest ET values under full irrigation during the 2000 experiment were 11.8 and 2.0 $mm.day^{-1}$. The evapo-transpiration at full irrigation is about 21 percent higher than ET at medium irrigation and about 45% higher than the ET at low irrigation treatment. It was observed that significant proportion of total water applied was con-

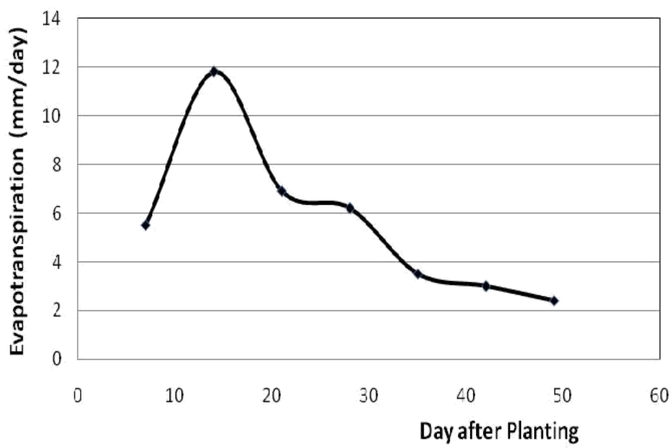

Figure 5. Actual evaporation (mm) of jute mallow under full irrigation during the Sept. and Oct. experiment.

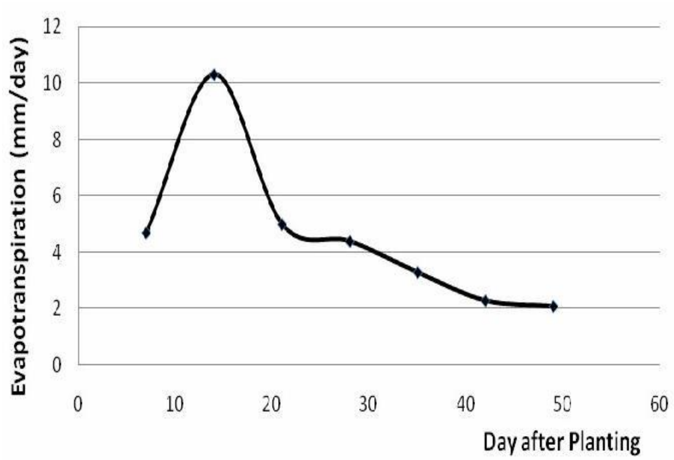

Figure 6. Actual evapotranspiration (mm) of jute mallow under medium irrigation during the Sept. and Oct. experiment of 2000

was consumed at the fruiting stage of the crop during the 1999 experiment while ET was highest at the vegetative stage of the crop irrespective of the irrigation treatment during the 2000 experiment. The difference in ET in April, September and October were not significant at P = 0.05. This is an indication that *C. olitorius* respond quickly to water application and increased its evapotranspiration rate during the rainy period

Water use efficiency

The variations of water use efficiency of *C. olitorius* dur-ing its growth are presented in Table 3 and 4. The water use efficiency increased significantly with increases in irrigation water application. The highest and lowest values of water use efficiency (WUE) at 4 WAP during 1999 were 0.22 and 0.06 kg.m $^{-3}$ of water under treatments 1 and ½ EP. At 7 WAP, the water use efficiency was high-

Table 3. Water use efficiency (kg.m^{-3}) at 4 WAP

Year	1 EP	¾ EP	½ EP
1999	0.22	0.18	0.06
2000	0.20	0.14	0.06

Table 4. Water use efficiency (kg.m^{3}) at 7 WAP

Year	1 EP	¾ EP	½ EP
1999	0.70	0.59	0.15
2000	0.58	0.54	0.19

highest (0.70 kg.m^{-3}) in irrigation treatment 1 EP and lowest (0.15 kg.m^{-3}) in treatment ½ EP. Similar trend was observed at 4 WAP during 2000, where the highest and lowest values of WUE were obtained in treatments 1 and ½ EP respectively. At the 7 WAP during 2000 experiment, the highest WUE (0.58 kg.m^{-3}) occurred in treatment 1 EP and lowest was 0.19 kg.m^{-3} in treatment ½ EP. The high value of WUE observed in irrigation treat-ment ¾ EP during 2000 may be due to the accumulated moisture in soil from rainfalls.

The data analysis indicates that the WUE increased with increased water application. The relative increase in the yield of biomass per unit increase in water application was high under full irrigation (EP) when compared with values under low irrigation application. This observation is similar to the findings of Sharma et al. (1990) in crop response to water application.

Plant height

The plant height is significantly higher in plots that received full irrigation treatment than under medium and low irrigation treatments (Table 5). In 1999, the mean plant height under full, medium and low irrigation treat-ments was 49.6, 43.5 and 33.9 cm at 4 WAP. Similarly, plant height was 93.9, 80.2 and 63.9 cm under 1, ¾ and ½ EP respectively at the 7 WAP. Similarly, the plant height during 2000 averaged 53.3, 45.8 and 37.0 cm under 1, ¾ and ½ EP treatments during the 4 WAP and 102.7, 97.2 and 81.3 cm respectively at the 7WAP. The crops under full irrigation treatment were in a state of water comfort and the relatively low growth in ½ EP may be as a result of moisture stress on the crop.

Number of leaves

There were significant differences in the number of leaves with respect to the level of water application (Table 5). Irrigation treatment at 1 EP gave the highest leaf number at the 4 and 7 WAP. The crop under this treatment benefited from increased soil moisture content. Plots under 1 and ¾ EP treatments produced more

Table 5. Effects of Irrigation treatments on Plant height and leaf number (1999 trial)

Treatments	Plant Height (cm) 4 WAP	6WAP	7WAP	Leaf Number/Plant 4WAP	6WAP	7WAP
1EP	49.0(±5.86)	77.1 (±8.89)	93.9 (±5.65)	24.1 (±2.32)	40.4 (±5.37)	54.0 (±7.04)
¾ EP	42.4(±4.22)	70.6 (±4.86)	80.2 (±4.90)	22.5(±2.40)	35.7(± 6.80)	47.8 (±5.25)
½ EP	33.7(±3.47)	57.8 (±1.04)	63.9 (±2.98)	19.2 (±1.98)	28.1 (±4.20)	38.5(±1.32)

Table 6. Leaf area and leaf area Index (LAI) of *C. olitorius* under varying Irrigation treatments (1999 trial)

	Leaf area (Cm^2)	LAI (Cm^2)	Leaf area (Cm^2)	LAI (Cm^2)	Leaf area (Cm^2)	LAI (Cm^2)	Leaf area (Cm^2)	LAI (Cm^2)
Treatments	(4WAP)	(4WAP)	(5 WAP)	(5WAP)	(6WAP)	(6WAP)	(7WAP)	(7WAP)
1EP	140.7	0.016	384.0	0.045	543.6	0.063	7.243	0.084
¾ EP	126.2	0.015	273.9	0.033	445.7	0.053	543.7	0.065
½ EP	78.7	0.008	177.5	0.019	279.6	0.030	321.2	0.034

Table 7. Effect of Irrigation treatments on above ground biomass of *C. olitorius*.

Treatments	Biomass yield ton ha^{-1} 1999	2000
1EP	5.22 ± 0.6	7.27 ± 0.7
¾ EP	4.14 ± 0.3	5.89 ± 0.5
½ EP	1.96 ± 0.2	3.66 ± 0.5

leaves and luxuriant growth when compared with irriga-tion treatment ½ EP. This is due to adequate soil availa-ble for root extraction. The observation agrees with that of Yayock et al. (1988). The relatively low supply of wa-ter in ½ EP resulted in poor leaf formation and stunted growth. In 2000, the means of leaf number per sampled plot were 19, 17, and 15 at 4 WAP and 54, 53 and 37 at 7 WAP in treatments 1, ¾ and ½ EP respectively. Lower leaf production under 1 EP during 2000 when compared to 1999 result may be due to increased susceptibility of soil to water logging which reduces aeration within the soil (Jensen et al., 1990). Sharma et al (1990) also stated that crop growth and yield were improved when appli-cation of water can be controlled to what the plant actually need.

Leaf area and the leaf area index (LAI)

The values of leaf area and leaf area index (LAI) of *C. olitorius* during the 4th, 5th, 6th and 7th WAP are presented in Table 6. No significant difference was observed in LAI between 1 and ¾ EP at 4 WAP during 1999 at P = 0.05. However, the difference in LAI becomes significant during the 5th, 6th and 7th WAP in ¾ EP. The ¾ EP produced broad leaves comparatively with other treatments. Leave formation and growth during 2000 were enhanced by irrigation used in conjunction with rainfall to limit soil moisture depletion (Whitfield et al., 1986). The lower leaf formation during 1999 may be due to little rainfall bet-ween March and April with accompanying increase in water stress.

Biomass yield

The values of biomass yield in the various treatments are shown in Table 7. Biomass yield was increased by irriga-tion application in 2000. In contrast, the yield response to irrigation application was lower in treatment ½ EP, especially in 1999. The lower response appears to be due to low rainfall between March–April 1999, with con-sequent increase soil moisture stress. The above ground biomass for the three irrigation treatments differed signi-ficantly for both trials (1999 and 2000). The mean of above ground biomass are 5.22 tonha^{-1} in treatment 1 EP, 4.14tonha^{-1} in ¾ EP and 1.96tonha^{-1} under ½ EP. The total yields in 2000 were with the averaged 6.02, 5.89 and 5.76tonha^{-1} in treatment 1, ¾ and ½ EP res-pectively. The crop response to water available moisture was enhanced in 2000 due to supplemental irrigation carried out at the onset of dry season.

Conclusion

Effect of variable water application on *C. olitorius* has been investigated. *C . olitorius* was found to be very sen-sitive to water stress but have the tendency to quickly re-gain its viability and grow well when supplied with water through irrigation, especially during the dry season. The water use efficiency of *C. olitorius* was highest during the 1999 experiment which was carried out during the dry period. Above ground biomass increased with amount of water application when grown under irrigated condition.

Owing to its economic importance, *C. olitorius* constitute a viable option for dry season farming or urban agricul-ture.

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