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Effects of Irrigation Scheduling and Soil Management on Maize (*Zea mays* L.) Yield in Guinea Savannah Zone of Nigeria

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Abstract**—**The main objective of any irrigation program is the development of an efficient water management system to sustain crop growth and development and avoid physiological water stress in the growing plants. Field experiment to evaluate the effects of some soil moisture conservation practices on yield and water use efficiency (WUE) of maize was carried out in three locations (i.e. Mubi and Yola in the northern Guinea Savannah and Ganye in the southern Guinea Savannah of Adamawa State, Nigeria) during the dry seasons of 2013 and 2014. The experiment consisted of three different irrigation levels (7, 10 and 12 day irrigation intervals), two levels of mulch (mulch and un-mulched) and two tillage practices (no tillage and minimum tillage) arranged in a randomized complete block design with split-split plot arrangement and replicated three times. The Blaney-Criddle method was used for measuring crop evapotranspiration. The results indicated that seven-day irrigation intervals and mulched treatment were found to have significant effect ($P>0.05$) on grain yield and water use efficiency in all the locations. The main effect of tillage was non-significant ($P<0.05$) on grain yield and WUE. The interaction effects of irrigation and mulch were significant ($P>0.05$) on grain yield and WUE at Mubi and Yola. Generally, higher grain yield and WUE were recorded on mulched and seven-day irrigation intervals, whereas lower values were recorded on un-mulched with 12-day irrigation intervals. Tillage exerts little influence on the yield and WUE. Results from Ganye were found to be generally higher than those recorded in Mubi and Yola; it also showed that an irrigation interval of 10 days with mulching could be adopted for the Ganye area, while seven days interval is more appropriate for Mubi and Yola.

Keywords**—**Irrigation, maize, mulching, tillage, guinea savannah.

I. Introduction

THE most critical issue facing agriculture is the need to meet with the food demands and an ever increasing population in the face of limited water and land resources. Irrigated agriculture is expected to produce much more food in the future while using less water than it uses today. In the years to come, about 80% of the food production that will be required to feed the ever increasing population will depend on irrigation agriculture [1]. The main goal of any irrigation farming is efficient water management to sustain crop growth and development to avoid water stress in the plants. Improper irrigation scheduling could lead to unpleasant results like under-irrigation or ill-timed irrigations which would lead to water stress in plants with the consequent lower yields while, over-irrigation may result in the waste of water, energy, and reduced soil quality and drainage problems.

Enhancing water use efficiency and its sustainability is the major challenge in water management in agriculture. Some of the ways of realizing this include (i) improvement in crop water productivity through efficient irrigation, (ii) reduction in water losses through soil and (iii) improving soil moisture retention capability through better and sustainable soil and water management practices [2].

Mulching has much beneficial importance to crops in terms of improvement of soil properties that relate to better crop performance. Reference [3] reported that the addition of mulch resulted in significant increase in soil water contents and reduced runoff. The increase in soil water was effective in ensuring better germination and higher yield. Nutrients were available to plant roots in presence of moisture, leading to higher grain yield. It was also reported that mulch increases the soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield [4]. In another research it was reported that mulching increases soil water and reduce soil temperature significantly but, tillage did not influence them as significantly as mulch, [5] and [6]. Conservation of soil water is an important management objective for crop production in the semi-arid tropics where droughts are persistent [7].

Maize (*Zea mays* L.) or corn is the most important and widely grown cereal crop in the world due to its high yield and moderate water requirement. Maize is a major and most dominant cereal crop in Nigeria. Development of improved varieties in the seventies led to maize cultivation extending to the northern parts of the country and gradually replacing sorghum and to some extent millet, which is the traditional cereal crop of the savannah. The Guinea Savannah zone is characterized by low rainfall, high temperature, high evapotranspiration and long dry season. The utilization of the long dry months for the production of non-perishable crops (such as maize) will boost the economic status of the farmers around the riverside and Fadama areas of Adamawa State; consequently, creating more employment, increasing income and optimizing the utilization of farms and farm resources [8].

The present study involved the use of soil moisture conservation practices (mulching and tillage) and irrigation

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schedules to assess their impacts on grain yield and water use efficiency of maize in northern and southern Guinea Savannah ecological zones of Adamawa State.

II. Materials and Methods

Experiments were conducted during the 2013 and 2014 dry season (November to April) in three locations in Adamawa State: (i) Mubi, 10^{o}N, 13^{o}30'E and situated at 305 m above sea level in the Northern Guinea Savannah zone, with an average annual rainfall of 1,050 mm. The soils of the area are underlain by hard crystalline cratonic basement complex (ii) Yola situated at 9^{o}16'N, 12^{o}35'E and 152 m above sea level in the Northern Guinea Savannah zone also, with average annual rainfall of 900 mm. The soils of the area are underlain by cretaceous continental deposits and (iii) Ganye located at 8^{o}N, 11^{o}E, and 152 m above sea level in the Southern Guinea Savannah, with average annual rainfall of about 1,300 mm. The soils of the area are underlain by hard crystalline cratonic basement complex [9].

The mean monthly temperature and rainfall of the three experimental sites where presented in Tables I and II. The mean monthly temperatures for Mubi are 25.9 and 25.1, Yola 29.6 and 29.0, and Ganye 27.3 and 27.1^{o}C in 2013 and 2014, respectively (Table I). This indicated a slight rise in temperature from 2013 to 2014. The years 2013 and 2014 were characterized by different rainfall patterns. Total seasonal rainfall for 2013 was higher than that received in 2014 at Mubi and Ganye, while in Yola it was much more in 2014 (Table II).

TABLE I
MEAN MONTHLY TEMPERATURE DATA (^{o}C) FOR THE THREE LOCATIONS IN 2013 AND 2014 [10]

		Month												
Location	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Mubi	2013	24.60	25.70	26.40	29.30	27.20	25.20	23.80	23.60	23.90	24.30	25.00	21.70	25.10
	2014	23.50	25.50	27.10	28.50	28.80	24.80	24.00	26.10	26.70	25.60	24.50	25.10	25.90
Yola	2013	27.00	27.00	32.00	34.00	33.00	31.50	28.00	27.00	27.00	29.30	27.00	25.50	29.00
	2014	28.00	27.00	35.00	34.00	33.70	31.00	28.00	26.00	28.00	29.00	27.00	28.50	29.60
Ganye	2013	26.50	26.80	28.10	33.70	29.80	27.80	25.80	25.00	24.50	27.00	26.90	23.50	27.10
	2014	25.70	26.00	29.80	32.70	28.90	27.60	26.70	25.80	26.70	26.20	26.10	24.80	27.30

TABLE II
MEAN MONTHLY RAINFALL DATA (MM) FOR THE THREE LOCATIONS IN 2013 AND 2014 [10]

		Month									
Location	Year	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mubi	2013	0.00	63.90	44.50	146.70	155.80	413.60	188.40	119.60	0.00	0.00	1132.50
	2014	0.00	52.60	98.90	96.50	274.70	235.90	146.50	73.60	5.10	0.00	983.80
Yola	2013	0.00	28.30	68.60	40.40	146.70	227.20	155.20	71.25	0.00	0.00	737.65
	2014	0.00	28.20	101.10	210.90	462.20	200.80	183.40	77.30	0.00	0.00	1263.90
Ganye	2013	0.00	52.50	85.50	371.50	222.30	438.60	335.00	88.50	0.00	0.00	1593.90
	2014	8.50	84.30	110.00	120.10	249.70	314.00	327.40	148.40	0.00	0.00	1362.40

Soil composite samples were taken from the experimental sites and analyzed using the routine soil analysis procedures as described in [11]. The experimental farms were prepared into check basin plots for irrigation as commonly practiced by farmers in the study area. Twelve treatments replicated three times in a randomized complete block design (RCBD), separated in split-split plot arrangements were used in conducting the experiment. The treatment variables were three frequencies of irrigation (seven, 10 and 12 day intervals of irrigation), two levels of mulch (mulched and un-mulched plots) and two tillage practices (no- tillage and minimum tillage plots). Thirty-six check basin plots were laid down for each experimental site with each plots measuring 3 m x 3 m. A seven-day interval was considered conventional practice for the farmers of the region.

The no-tillage plots were cleared of weeds using atrazine-metalchlor herbicide at a rate of 5 liters/ha after the initial wetting before planting. Minimum tillage plots were prepared by tilling the soil lightly to a depth of approximately 5 cm with local hand hoe. Maize seeds variety Oba 98 was sown by putting two seeds per hole with an interplant spacing of 25 cm and row spacing of 60 cm apart.

Dry rice (*Oryza sativa* L.) straw mostly abandon by farmers after harvest to decay or partially used as animal feed was used as mulching material and applied to mulch treated plots after sowing at the rate of 5.4 kg mulch/plot corresponding to 6,000 kg/ha. NPK fertilizers were applied at the rate of 100 kg N, 50 kg P_20_5 and 50 kg K_20 per hectare. Half of the N dose and full of P_20_5 and K_20 were applied at the time of planting using NPK 15:15:15 fertilizer. The remaining half dose of N was applied four weeks after planting by sides' placements using urea (46% N) fertilizer.

Uniform initial irrigation scheduling was adopted until the maize crop reached the knee-high stage (30 days after planting). The irrigation scheduling was then separated to seven, 10 and 12 days up to maturity period. The water flow rate was obtained by using velocity-bucket method. The flow rate was estimated at 2.5 liters per second. One basin was opened at a time to allow the water to enter the basin and the average time allowed to pond the basin was recorded to be 3 minutes. The average depth of water applied to each irrigation regime was estimated at 70mm. all necessary cultural management practices were maintained to harvest.

Maize yield was measured at harvest using a quadrat of each treatment for three replicates [12]. Potential evapotranspiration (ETcrop) was estimated using the "Blaney-Criddle" method in which ETcrop is expressed as a function of daily mean temperature, daily proportion of annual daylight hours and a crop coefficient [13].

- $ET_0 = p\ (0.46T_{mean}+8)$
- ET_0 = Reference crop evapotranspiration (mm/day)
- T mean= Mean daily temperature (^{0}C)
- P = Mean Daily percentage of annual day time hours

This empirical method of estimating evapotranspiration was adopted because of its simplicity and lack of enough meteorological data for all the experimental sites.

$$ETcrop = ET_0 \times Kc,$$

Kc is the crop coefficient updated for maize grain was adopted from [14].

Water use efficiency was estimated on basis of grain yield for each treatment using the ratio of yield obtained per crop consumptive use. As expressed in [15]:

- WUE= Y/ETcrop
- WUE= Water Use Efficiency
- Y = Maize yield (kg)
- ET = Evapotranspiration (mm)

A. Data Analysis

Data collected were subjected to analysis of variance usin g generalized models. Treatment means were then compared by Duncan at 5 % level of probability using GenStat [16].

III. Results and Discussion

The initial soil test of the soils of the experimental plots (Table III) indicated that the general soil textural classes in all the three sites were clay loam, soil moisture contents at field capacity were moderate, but slightly higher in Ganye than in Mubi and Yola and moderate soil bulk density. The chemical properties of the soils following critical values of soil nutrients showed that the pH in all the locations were moderately acidic. The total nitrogen, available phosphorus, calcium, magnesium, potassium and sodium were generally moderate and sodium was all over low in all locations, while organic matter was low in Mubi and Yola and medium in Ganye as described in [17].

A. Effects of Irrigation Interval, Mulch and Tillage on Grain Yield

The result on grain yield in indicated that irrigation interval and mulch significantly (P>0.05) influenced grain yield in all locations (Table IV). The seven-day irrigation interval treatments produced the highest grain yield, while the 12-day irrigation interval produced the least grain yield in all locations. Increasing maize grain yield with increase in irrigation water supplied was reported [18]. The main effect of mulch treatments were also significant (P<0.05) at the two locations (i.e. Mubi and Yola) with mulched plots having the maximum yield and minimum with un-mulched treatments this was in tandem with [19], who reported that the grain yield increases of maize crops were generally credited to increased water content in the soil due to reduced evaporation. In Ganye, mulch main effect and tillage treatments were non-significant on grain yield in all the locations.

TABLE III
Soil Physicochemical Properties of the Experimental Sites (0-20cm)

Soil Properties	Mubi	Yola	Ganye
Physical Properties			
Sand (g kg^{-1})	401.00	302.00	303.00
Silt (g kg^{-1})	302.00	305.00	351.00
Clay (g kg^{-1})	297.00	388.00	346.00
Textural Class	CL	CL	CL
Soil Moisture at Field capacity (%)	18.50	17.75	19.20
Bulk Density (g/cm^3)	1.54	1.50	1.50
Chemical Properties			
pH (Water)	6.05	6.10	6.00
pH 1N KCl	5.70	5.90	5.50
Total N (g kg^{-1})	1.20	1.10	1.80
Available P(mg kg^{-1})	7.13	6.19	7.70
Organic Matter (%)	1.70	1.75	2.85
Exchangeable Cations (cmol kg^{-1})			
Calcium	9.50	8.70	10.20
Magnesium	2.60	2.20	2.40
Potassium	0.45	0.38	0.54
Sodium	0.18	0.21	0.19
Electrical Conductivity (ds/m)	1.82	1.70	1.63

TABLE IV
Main effect of the Treatments on Grain Yield (kg/ha) in the Three Locations

Treatments	Mubi	Yola	Ganye
Irrigation (I)			
7-day interval	2755.0a	2521.2a	3340.1a
10-day interval	2651.1b	2433.4b	2959.3b
12-day interval	2516.1c	2283.4c	2672.0c
SE	14.98	25.1	57.2
Mulch (M)			
Un-mulched	2578.4b	2349.6b	2953.1
Mulched	2703.1a	2475.7a	3027.1
SE	12.23	20.5	NS
Tillage (T)			
Zero-Tillage	2635.3	2396.4	2979.3
Minimum Tillage	2646.1	2428.6	3001.2
SE	NS	NS	NS
Interaction			
I x M	*	*	NS
I x T	NS	NS	NS
M x T	NS	NS	NS
I x M x T	NS	NS	NS

Significant interaction between irrigation and mulch was recorded in Mubi and Yola (Table V). This variation may be attributed largely to improved soil moisture retention and fertility by the possible decomposition of the mulch. The interactive effect between irrigation and mulch on maize grain yield was also reported to be significant [20]. Mulch was shown to increase the soil moisture and nutrients availability to plant roots, in turn, leading to higher grain yield [4]. It was further asserted that the effect of mulch on grain yield was observed and that yield increase of corn resulting from application of rice straw mulch, was resulted predominantly from increased water storage and reduced maximum soil temperature compared to bare soil [21].

TABLE V
INTERACTION OF EFFECT IRRIGATION INTERVAL AND MULCH ON GRAIN YIELD (KG/HA) IN MUBI AND YOLA

Treatments	Mubi	Yola
I_1M_0	2659.9c	2441.3c
I_2M_0	2551.7d	2324.2d
I_3M_0	2523.4d	2282.3d
I_1M_1	2850.1a	2600.4a
I_2M_1	2750.5b	2542.2bc
I_3M_1	2508.6d	2285.3d
SE	21.19	35.4

I_1 = seven-day irrigation interval, I_2 = 10-day irrigation interval, I_3 = 12-day irrigation interval, M_0 = Un-mulched, M_1 = Mulched, SE = Standard Error. Means with in columns for each treatment followed by the same letter are not significantly different at α = 0.05.

B. Effect Treatments on Water Use Efficiency (WUE)

The results on water use efficiency were generally higher for the seven-day irrigation interval and mulched treatments, while the least was recorded with the 12-day irrigation interval and un-mulched plots. Tillage was non-significant on WUE (Table VI).

TABLE VI
MAIN EFFECT OF THE TREATMENTS ON WATER USE EFFICIENCY (KG/HA/MM) IN THE THREE LOCATIONS

Treatments	Mubi	Yola	Ganye
	Irrigation (I)		
7-day interval	3.77a	3.45a	4.57a
10-day interval	3.63b	3.33b	4.05b
12-day interval	3.44c	3.12c	3.66c
SE	0.21	0.034	0.078
	Mulch (M)		
Un-mulched	3.53b	3.21b	4.04
Mulched	3.70a	3.39a	4.14
SE	0.017	0.028	NS
Tillage (T)			
Zero-Tillage	3.61	3.28	4.08
Minimum Tillage	3.62	3.32	4.11
SE	NS	NS	NS
	Interaction		
I x M	*	*	NS
I x T	NS	NS	NS
M x T	NS	NS	NS
I x M x T	NS	NS	NS

The WUE was higher at Ganye followed by Mubi and then Yola, but significant difference between the mulch treatments were only recorded in Mubi and Yola, where mulched plots produced higher WUE than un-mulched plots. This was in line with the report that straw mulching reduced soil evaporation by 43 mm for maize and WUE was improved by over 10% [21]; although, our own improvement on WUE by mulching was not up to 10%, but about 4-5% was recorded in Yola and Mubi, respectively.

TABLE VII
INTERACTION OF EFFECT IRRIGATION INTERVAL AND MULCH ON WATER USE EFFICIENCY (KG/HA/MM) IN MUBI AND YOLA

Treatments	Mubi	Yola
I_1M_0	3.64c	3.34c
I_2M_0	3.49d	3.18d
I_3M_0	3.45d	3.12d
I_1M_1	3.9a	3.56a
I_2M_1	3.76b	3.48bc
I_3M_1	3.43d	3.13d
SE	0.029	0.048

I_1 = 7 days irrigation interval, I_2 = 10 days irrigation interval, I_3 = 12 days irrigation interval, M_0 = Un-mulched, M_1 = Mulched, SE = Standard Error. Means with in columns for each treatment followed by the same letter are not significantly different at α = 0.05.

The interaction between irrigation intervals and mulch on WUE was higher with seven-day irrigation interval and mulched treatment, while the minimum was with 12-day irrigation interval with both mulched and un-mulched treatments (Table VII). This could be due to what was reported that mulching materials on the soil surface act as a shade, serve as a barrier against moisture loss from the soil and that by reducing the irrigation depth and application of mulch, the evaporation losses reduced so that WUE was increased [20]. This may be attributed to the higher grain yield recorded and lower atmospheric temperature of the area, which is a major factor in the determination of the evapotranspiration using Blaney-Criddle empirical formula.

IV. CONCLUSION

The results obtained suggested that seven-day irrigation interval and mulching produced higher grain yield and WUE at all the locations, and therefore, it could be adopted as good water management practices for maize production under irrigation in Adamawa State. At Ganye in the Southern Guinea Savannah, the 10-day irrigation interval with mulch can equally produce relatively good grain yield and water use efficiency; it may be preferable as it saves irrigation water, energy and cost, therefore recommended for the area.

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