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Response of Maize (*Zea Mays L.*) To Soil Moisture Stress Condition at Different Growth Stages, Central Rift Valley of Ethiopia

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Abstract

Water resources availability is a crucial limiting factor for crop production in arid and semi-arid area. Consuming these limited resources carefully and efficiently is unquestionable. The planning of irrigation permitting to the water stress tolerance and water use efficiency of crops remains the only way to guarantee the continuity of production in an arid area. Considering this an experiment has been conducted in Melkassa Agricultural Research Center where shortage of moisture is a problem. The experiment was laid out in RCBD with three replications having 15 experimental treatments. The treatments had four crop growing seasons or stages (Initial, Development, midseason and late season stages. Melkassa II maize variety was used for seed materials. Water stress had significant different effect on grain yield, above ground dry biomass, plant height and water productivity ($P<0.05$). Lower grain yield of maize cultivar was obtained from moisture stress treatment that irrigated only at initial stages (2.09 ton/ha) and higher grain yield was obtained from non-stressed treatment at all growth stages (6.19ton/ha). Maximum above ground dry biomass was gained from non-stressed treatment (9.67ton/ha) were as irrigating only at initial stage produces lower yield of biomass (3.06 ton/ha). Higher water productivity was obtained from treatment irrigated only at initial growth stage ($2.15kg/m^3$).The lower water productivity of the study was obtained from treatment irrigated at all growth stages ($0.82kg/m^3$). The result revealed that there was no significant ($p>0.05$) difference in grain yield among treatments stressed only at initial stage, late stage and non-stressed. However, stressing of maize at development and mid-season crop growth stage led to significant reduction of grain yield, above ground dry biomass and plant height. Therefore, stressing maize at combination of development stages and mid stages was more sensitive with significant yield penalty.

Keywords: Grain yield • Growth Stage • Maize • Melkassa • Soil Moisture Stress• Water Productivity

Introduction

Irrigated agriculture is the main user of the available water resources. About 70% of the total water withdrawals and 60-80% of total consumptive water use are consumed in irrigation [1]. The irrigated area should be increased by more than 20% and the irrigated crop yield should be increased by 40% in 2025 to secure the food for 8 billion people [2]. Agricultural production will be too increased, to sustain the rapidly growing world population. Water resources availability is a crucial limiting factor for crop production in arid and semi-arid area. Using this limited resource economically and efficiently is unquestionable. The planning of irrigation according to the water stress tolerance and water use efficiency of crops remains the only way to guarantee the continuity of production in an arid area [3]. Agricultural research has focused primarily on maximizing total Production in past year. Know a days the focus has shifted to the limiting factors in production system such as availability of land and water resources [4].

Water is one of the most important factors that determine the distribution of species around the world. Maize is a multipurpose crop, which can supply food, feed and fuel in relatively large quantities as compared to other cereal crops. Maize is very sensitive to water stress. Water stress can effect growth, development and physiological processes of maize plants, which reduce biomass and yield [5]. Proper growth and development of maize needs adequate soil moisture in the root zone. In addition to adequate soil moisture proper irrigation scheduling is needed for effective use of available water in optimizing maize production. According to Shaozhong and Minggang moisture stress at milking stage of maize affect grain yield. Adequate and limited soil water supplies affect grain yields of maize during total and individual growth stages. Flowering stages were more sensitive to soil water deficit. The aim of this research was to identify maize growth stages that sensitive to soil moisture stress, to determine critical time for irrigation application for limited water resources and to determine productivity of water for major crops under stressed condition.

Materials and Methods

Description of the Study Area

The study was conducted at Melkassa Agricultural Research Center, Central Rift Valley of Ethiopia in two consecutive years 2018, 2019 and 2020. It is geographically located between the latitude of 8˚24' to 8˚26' N, the longitude of 39˚19' to 39˚19' E and the mean altitude of the area is 1550 m.a.s.l. The climate of the area is characterized as semi-arid with a uni-modal low and erratic rainfall pattern with annual average of 824.9 mm. About 67.4% of the total rainfall of the area occurs from June to September. The mean maximum temperature varies from 26.3 to 31.0˚C while the mean minimum temperature varies from 10.4 to 16.4˚C.

Experimental Design and Procedure

The experiment was laid out in randomized complete block design (RCBD) with three replications having 15 treatments. The experimental plots had 5.5 m*4.5 m, 0.25 m, 0.75 m dimensions, intra plant and inter row spacing, respectively. Exponential plot had 5 numbers of ridges and the data was collected from the three central rows to avoid border effect. Melkassa II variety of maize was used for seed material. The treatments had four crop growing seasons or stages (Initial, Development, midseason and late season). The irrigation amount for each growing season was computed with the aid of CROPWAT 8.0 model. Irrigation water was applied as per the treatment to refill the crop root zone depth close to field capacity. The amount of irrigation water to be applied at each irrigation application had been measured using Parshall flume. Soil moisture content before irrigation had been monitored

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gravimetrically at different depth interval up to maximum root depth to determine optimal irrigation scheduling. (Table 1)

Irrigation Water Schedule

The actual volume of water that can be obtained from the soil profile depends on the depth of the root system. The total available water (TAW), stored in a unit volume of soil, is approximated by taking the difference between the water content at field capacity (FC) and at permanent wilting point (PWP).

The TAW is expresses as:

TAW = (FC – PWP)* BD*Dz)/100

Where; FC and PWP in % on weight basis, BD is the bulk density of the soil in g/cm^3, and Dz is the maximum effective root zone depth in mm.

The bulk density, BD, is the mass of a soil in a unit volume for undisturbed soil condition and is expressed on dry weight basis of the soil as:

BD = Ms/ Vt

Where Ms is the weight of oven dry soil (gm.), and Vt is the total volume of the same soil (cm^3).

For maximum crop production, the irrigation schedule was fixed based on readily available soil water (RAW). The RAW is the amount of water that crops can extract from the root zone without experiencing any water stress. The RAW was computed from the expression:

RAW = p*TAW

Where; RAW in mm, p is in fraction for allowable/permissible soil moisture depletion for no stress and TAW is total available water in mm.

The depth of irrigation supplied at any time was obtained from a simplified water balance equation which is expressed as:

IRn = Etc. – Pe

Where IRn is the net irrigation depth (mm), Etc. is the crop water requirement (mm) and Pe is the effective rainfall (mm) which is a part of rainfall that enters in to the soil and makes available for crop production.

The effective rainfall was estimated using dependable rain (FAO/AGLW formula) method as given by as.

Pe = 0.6 *P -10 for month ≤ 70 mm Pe = 0.8

*P - 24 for month ≥ 70 mm

Where Pe is the effective rainfall (mm) and P is total rainfall (mm).

The gross irrigation requirement was obtained from the expression: IRg =IRn/Ea

Where; Ig is the gross irrigation depth (mm); Ea is the field application efficiency (%)

In furrow irrigation, knowing the application efficiency of the furrows (60%), the time required to deliver the desired depth of water into each furrow was calculated using the equation:

T = (d x W x L)/ (6xQ)

where; d = gross depth of water applied (cm), W and L = width and length (m) of the experimental plot,

T= application time (min) and Q is flow rate (discharge) (l/s).

Soil moisture depletion at any soil moisture level was observed with the following expression as:

SMD= (FC- MC) x Dzr

Where, SMD = soil moisture depletion (mm), FC = volumetric soil moisture content at field capacity (mm), MC = volumetric moisture content at time of irrigation (mm), and Dzr = Depth of effective root zone (mm).

Water Productivity (WP)

Water productivity was determined by dividing grain yield by total applied irrigation water and is expressed as follows:

CWP =(Y/ET)

Where WP water productivity (kg/m^3), Yield (kg/ha) and total water received (m^3/ha) from planting to harvest. But water applied before planting is not included in the total.

Data Analysis

The collected data were statistically analyzed using the statistical analysis system (SAS) software version 9.0 using the general linear programming procedure (GLM). Mean separation using the least significant difference (LSD) at 5% probability level was employed to compare the differences among the treatments mean.

Result and Discussion

Soil of experimental site and applied irrigation water

The physical properties of the experimental soil texture, bulk density field capacity, permanent wilting point and total available water were determined. The soil textural class was clay loam within the soil profile considered. The values of FC, PWP, and TAW were 34.26%, 18.25% and 176.1 mm/m, respectively, while the average bulk density was 1.10 g/cm^3. The average

Table 1. Treatments and treatments combinations.

Treatments	Treatments Combinations	Descriptions
T1	IDMdMt	Irrigated all growth stages as control (no stress)
T2	DMdMt	Holding water during initial stage
T3	IMdMt	Holding water during development stage
T4	IDMt	Holding water during mid-stage
T5	IDMd	Holding water during maturity stage
T6	MdMt	Holding water during initial and development stages
T7	DMt	Holding water during initial and mid stages
T8	DMd	Holding water during initial and maturity stages
T9	IMt	Holding water during development and mid stages
T10	IMd	Holding water during development and maturity stages
T11	ID	Holding water during mid and maturity stages
T12	Mt	Holding water during all growth stages except maturity stage
T13	Md	Holding water during all growth stages except mid stage
T14	D	Holding water during all growth stages except development stage
T15	I	Holding water during all growth stages except initial stage

applied net irrigation water requirement for each treatment for three years in (mm) was shown in the following figure 1. The total crop evapotranspiration (Etc.) of growing season was 544.68 mm per season. Treatment which receives irrigation at all growing stages was gained 544.7 mm net irrigation equal to evapotranspiration. Other treatments receive less than total net irrigation. (Figure 1)

Effect of Soil Moisture Stress on Maize and Water Productivity

Grain Yield: Over years mean result on grain yield of maize indicated that moisture stress during different growth stages had significant ($p<0.05$) effect on maize grain yield (Table 2). Higher moisture stress resulted in low productivity of maize. Lower grain yield of maize cultivar was obtained from treatment that only irrigated at initial stage (2.09 ton/ha). On other hand higher grain yield was gained from no moisture stress at all growth stages (6.19ton/ha). Irrigating maize at all stages except initial stage produces grain yield which was not significantly different from control treatment (5.9 ton/ha). The result in agreement with result of Agyare that reported yields of treatments exposed to water stress were lower than unstressed treatment. Moisture Stress at flowering and pollination could result in unfilled kernels on the cob which reduce grain yield [6]. Yield is most sensitive to water stress during flowering and pollination, followed by grain filling, and finally vegetative growth stages.

Above Ground Dry Biomass: Gained above ground biomass of maize was shown in table 2. Moisture stress at different growth stages had a significant ($p<0.05$) influence on above ground dry biomass of maize. Maximum above ground dry biomass was obtained from non-stressed treatment (9.67ton/ha). Irrigating at initial stage only produces lower yield of biomass (3.06 ton/ha) [6]. Stated that combined stress imposing at different Growth stages significantly reduced the above ground dry biomass of maize. Water stress at time of initial stages does not reduce above ground dry biomass of maize. It has different effect on other treatments. (Table 2)

Plant Height: The three years over year statistical analysis showed that plant height had affected by the application of different moisture stress on the growth stages($p<0.05$). Maximum plant height was gained from non- stressed treatment (227.93 cm) flowed by stressing maize in the initial stages (222.43 cm) were as the smallest plant height was obtained from stressing all stages except initial stages [7]. Stated that from non-stress treatment gave tallest plant height but the smallest plant height due to water stress was obtained

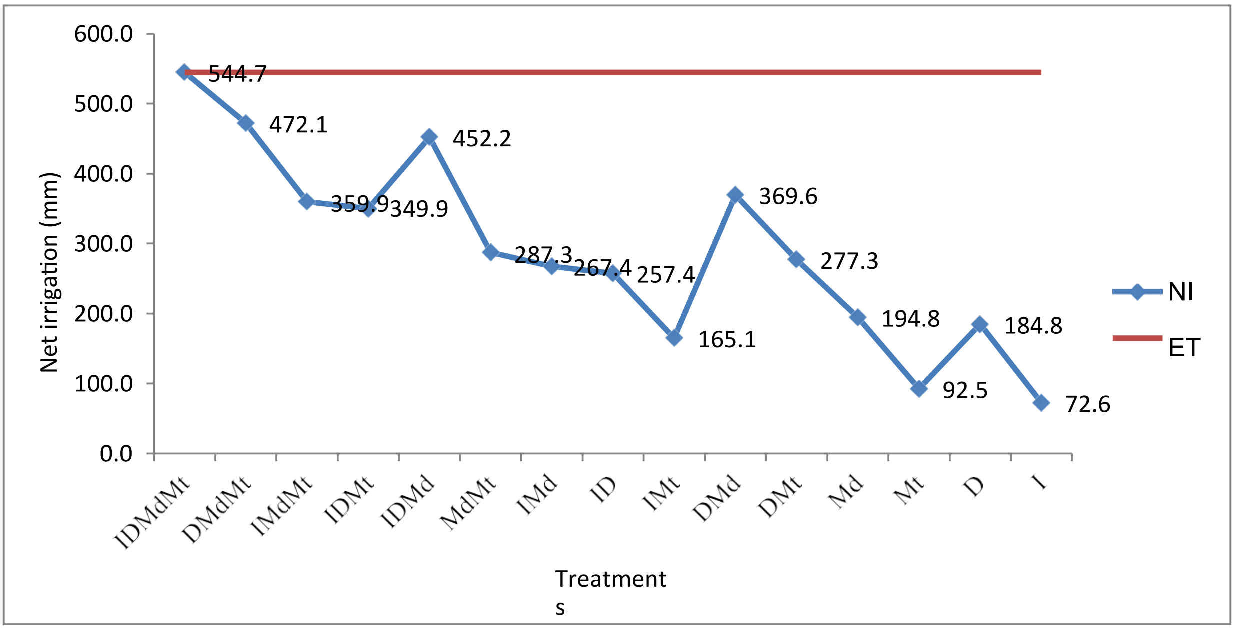

Figure 1: Average crop water requirements and irrigation depth per treatments for each growth period.

Table 2. Effect water stress on grain yield, biomass, plant height and water productivity.

Treatment	Grain Yield(ton /ha)	Biomass(ton /ha)	Plant Height(cm)	Water Productivity(kg /m^3)
IDMdMt	6.19^{a}	9.67^{a}	227.93^{a}	0.82^{e}
DMdMt	5.9^{ab}	8.28^{b}	222.43^{ab}	0.95^{de}
IMdMt	5.6abc	7.75^{b}	219.4^{abc}	1.12^{cde}
IDMt	5.68^{abc}	6.81^{c}	216.6^{abcd}	1.27^{bcde}
IDMd	5.89^{ab}	6.74^{cd}	212.73^{abcde}	1.24^{bcde}
MdMt	4.65^{cdef}	6.74^{cd}	208.8^{abcde}	1.09^{cde}
IMd	3.47^{gh}	5.92^{cde}	202.53^{bcde}	1.4^{bcd}
ID	5.23^{abcde}	5.88^{de}	198.73^{cde}	1.52^{bc}
IMt	4.35^{efg}	5.75^{ef}	198.37^{cde}	1.44^{bc}
DMd	5.55^{abcd}	5.11^{ef}	198.27^{cde}	1.25^{bcde}
DMt	3.58^{fgh}	5.08^{ef}	195.73^{de}	1.29^{bcde}
Md	4.54^{defg}	4.96^{f}	192.93^{e}	1.53^{bc}
Mt	3.58^{fgh}	4.03^{g}	192.53^{e}	1.43^{bc}
D	4.96	3.79^{gh}	153.33^{f}	1.69^{ab}
I	2.09	3.06^{h}	151.97^{f}	2.15^{a}
LSD0.05	0.53	0.43	11.3	0.23

from three growth stages (initial, development and mid). Considering the result as moisture stress increases plant height was decrease. Water productivity: The water productivity was significantly affected by moisture stress at different growth stage ($p<0.05$). Higher water productivity was gained from irrigating at initial growth stages because application of water was maximum (2.15 kg/m^3).The lowest water productivity of the study was obtained by irrigating all growth stages (0.82 kg/m^3). The study was in line with result of which stated that stressing maize with three growth stages (mid, development and late season) can increase water use efficiency and more increase at initial stage [6,8].

Conclusion and Recommendation

The results of the study revealed that soil moisture stress imposed at some growth stages enhance water productivity of maize without significantly reducing grain yield. Stressing maize at development and mid- season crop growth stage while irrigating the rest of growth stages lead to wastage of water decreasing the water productivity in relation with the yield recorded. To enhance maize productivity in water limited areas, application of the available irrigation water at grain filling stage is very important. Moisture availability at development stage has great influence on water productivity. Keeping optimal moisture at development and grain filling stage while holding irrigation at initial and late stage results in higher water saving with not significant yield penalties. Stressing maize at initial stage but irrigating all other stages produces maximum yield next to non-stressed treatment. However, combined stress of maize at development and mid-season crop growth stages lead to reduction of grain yield, above ground dry biomass and plant biomass. Lower water productivity was obtained from non-stress treatment in this study. In general, it can be concluded that the critical sensitive stages are the combined development and mid-season stages. Moreover, to enhance the water productivity without affecting the maize grain yield, irrigation could be hold at initial and late season stage.

References

1. Ray, Huffaker, Joel Hamilton. “Irrigation of Agricultural Crops, Second Edition: Section I: Background”. *Agronomy Monographs* 30 (2007):1-21.
2. Lascano Robert J, Sojka RE. “Irrigation of Agricultural Crops, Second Edition: Principles of Irrigation”. *Agronomy Monographs* 30 (2007): 664.
3. Bassou, Bouazzama, Xanthoulis B, Bouaziz A and Mailhol C. “Effect of water stress on growth, water consumption and yield of silage maize under flood irrigation in a semi-arid climate of Tadla (Morocco)”. *Biotechnol Agron Soc Environ* 16 (2012): 468-477.
4. Geerts S and Raes D. “Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas, Agricultural Water Management”. 96 (2009): 1275-1284.
5. Jose Payero O, Tarkalson D, Irmak S, and Petersen J, et al. “Effect of Irrigation Amounts Applied with Sub surface Drip Irrigation on Corn Evapotranspiration, Yield, Water Use Efficiency, and Dry Matter Production in A Semiarid Climate”. *Agric Water Manage* 95 (2008): 895-908.
6. Robel, Admasu, Tadesse M and Shimbir T. “Effect of Growth Stage Moisture Stress on Maize (*Zea Mays L.*) Yield and Water Use Efficiency at West Wellaga, Ethiopia”. *J biol agric healthc* 7 *(2017)*:23.
7. Meskelu E, Mohammed M and Hordofa T. “Response of Maize (*Zea mays L.)* For Moisture Stress Condition at Different Growth Stages”. *Int J Life Sci Res* 1 (2014) : 2-21.
8. Pereira LS, Oweis T, Zairi A. “Irrigation management under water scarcity”. *Agric water manag* 57 (2002):175-206.

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