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Evaluation of Moisture Stress Effect at Different Growth Stage of Maize (*Zea mays* L.) Under Smallholder Farmer's Condition at Jimma, South Western Ethiopia

Addisu Asefa[1, *], Minda Taddese[1], Etefa Tilahun[1], Robel Admasu[2], Zelalem Tamiru[1]

[1]Jimma Agricultural Research Center, Jimma, Ethiopia

[2]Debrezeit Agricultural Research Center, Debrezeit, Ethiopia

Email address:
adisujarc2016@gmail.com (Addisu Asefa)

[*]Corresponding author

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Abstracts: The use of water management technologies improves water use efficiency since water is getting scarce which is driven particularly by increasing human population. A field experiment was conducted at Jimma zone, Dedo woreda, during the off-season for three consecutive years to evaluate moisture stress at different growth stage of maize. Over year analysis showed that the maximum mean yield of maize (9.87t/ha) was recorded from treatment irrigated at all growth stage. The minimum maize yield (7.91t/ha) was obtained from irrigating all sage except mid-season stage. However, irrigating all growth stage may results in minimum water use efficiency of 1.67Kg/m^3. From the current study, depriving irrigation at mid-season stage result in reduction of maize yield by 19.9% with improvement of water use efficiency by 53.29%. whereas, irrigating all stage except initial stage improve water use efficiency by 6.59% with only 0.9% yield penalty. Moreover, irrigating all growth stage except initial stage resulted in the highest marginal rate of return 51895.6% by improving water use efficiency. From this study, even though stress is imposed at initial stage of maize development, the effect is low because the plants are already well developed, and they can modify themselves to cope with stress compared to the case when stress is imposed at development and mid-season stages at study area.

Keywords: Moisture Stress, Growth Stage, Water Use Efficiency, Maize

1. Introduction

Water is the major yield limiting factor in agricultural system. In the present era of climate change and colossal population pressure, drought is becoming a critical problem, thus making the water a sparse resource in the world [3]. The sustainable use of water in agriculture has become a big concern. The adoption of strategies for saving irrigation water and maintaining acceptable yields may contribute to the preservation of this ever more restricted resource [11]. Water scarcity is the major threats to global food production constraints as well as in Ethiopia. Most farmers in Africa including Ethiopia lived in water limited areas [10] Water is a major constituent of living organism. It comprises about 80 - 90% of fresh weight of herbaceous plants and over 50% of woody plants. Water furnishes a suitable medium for many biochemical reactions. Also, sufficient water must be present in active crop root zone for germination, evapotranspiration, nutrient absorption by roots, root growth and soil microbiological and chemical processes that aid in the decomposition of organic matter and mineralization of nutrients [8]. Yields of several crops, including maize, appear to be increasing in sensitivity to water limitations despite improvements in germplasm, likely due to increases in planting density and other changes in crop management [6].

The use of water management technologies improves water use efficiency since water is getting scarcer and more valuable year by year.

Little information is available about the water use efficiency, growth, and yield of crop with on farm water management of water [7]. The research [1] showed that Maize is very sensitive to water stress. there is a significant yield and yield component reduction of maize under deficit irrigation. According to the author [5] the effective use of deficit irrigation requires a prior and precise knowledge of the crop critical stages, of which farmers are often unaware. This study aims to verify and demonstrate effect of water stress at different growth stage for maize production at framers field level.

2. Materials and Method

2.1. Description of the Experimental Area

The evaluation work was carried out at Jimma Zone, Dedo worada, Waro-kolobo kebele, southwest of Ethiopia for three consecutive years. The site was located at about 13 Km west of Jimma town, geographically 7° 37' 12" North Latitude and 36° 50' 24" East Longitude with an altitude of 1716 m.a. s. l. The site receives a mean annual rainfall of 1541 mm with an average minimum and maximum temperature of 11.5 and 25°C, respectively. The soil textural class of the study area is dominated with sandy clay loam.

***Table 1.** Treatment setting.*

Irrigate all growth stages (Check)	T1
Irrigate all stages except initial stage	T2
Irrigate all stages except d development	T3
Irrigate all stages except mid-season stage	T4

2.2. Experimental Materials, Design and Management

A field experiment was carried out in three consecutive seasons of 2017/18, 2018/19 and 2019/20. The treatments which are presented in Table 1 consisted of three soil moisture stress levels and a check which imposed at four growth stages. Each individual plot had area of 10mX10m = 100m^2, which consists of 14rows.

Maize variety BH 661 (Zea Mays L..) was used as seed source. The recommended spacing of 75 and 50cm between row and plant was employed. Diammoniumphosphate (DAP) fertilizer was applied at the rate of 69 kg/ha of P_2O_5 at planting by placing the fertilizer 6-8 cm away from the hole where the seeds were placed. Top-dressing was carried out at five weeks after planting with urea fertilizer. The total amount of nitrogen applied from the two fertilizer applications was 100 kg N/ha according to the recommended rate of fertilizers for the area [9]. All cultural practices were done to all treatments in accordance to the recommendation made for the area. Irrigation water was applied as per the treatment to refill the crop root zone depth close to field capacity.

***Table 2.** Long-term monthly climatic data of the study area.*

Month	T_{Max} (°C)	T_{Min} (°C)	RF (mm)	RH (%)	Ws (m/s)	U (hr)
Jan.	27.83	9.81	34.1	54.99	2.53	7.17
Feb.	27.64	10.93	47.4	52.71	2.88	7.11
Mar.	28.6	12.88	98.3	55.41	3.21	6.44
Apr.	26.65	13.62	126.8	60.25	3.11	6.17
May	26.71	13.8	184.7	64.67	3.03	6.16
Jun.	25.11	13.57	210.6	70.16	2.85	4.84
July	23.66	13.43	225.3	74.57	2.32	3.32
Aug.	23.8	13.51	220.1	74.05	2.21	3.78
Sept.	24.95	13.26	187.3	71.19	2.27	5.09
oct.	26.16	11.82	108.4	64.96	2.17	7.19
Nov	26.91	9.93	55.8	60.7	2.26	8.05
Dec.	27.36	9.03	30.8	57.34	2.33	8.04

T_{max}=maximum temperature, T_{min}=minimum temperature, RF=rainfall, RH=relative humidity, ws=wind speed and U=sunshine hours

3. Result and Discussion

From the results of three years data at Dedo woreda's waro kolobo kebeles, the maximum mean yield of maize (9.87t/ha) were recorded from treatment irrigated at all growth stage. The minimum maize yield (7.91 t/ha) was obtained from irrigating all sage except mid-season stage. When stress is imposed at initial stage of maize development, the effect is low because the plants are already well developed, and they can modify themselves to cope with stress compared to the case when stress is imposed at development and mid-season stages. Hence for maximum maize grain yield to be achieved moisture stress at development and mid-season stage must be avoided. From current study limiting irrigation during mid-season stage may decreases the yield by (19.9%), whereas, preventing irrigation at initial stage decrease the yield only by (0.9%). Therefore, it can be concluded that imposing moisture stress at initial stage was not significantly reduced the maize grain yield in case of Jimma zone, dedo woreda's. In agreement with this finding [3] concluded that imposing deficit irrigation during the late vegetative stage with no to-moderate stress at other stages appears to maximize yield of maize crop. According to the author [6] although yields have increased in absolute value under all levels of stress sensitivity of maize yields to drought stress associated with high vapor pressure deficits has increased.

The highest crop water use efficiency was obtained from treatment irrigating all stage except mid-season stage (2.56 Kg/m^3) followed by preventing irrigation at development growth stage (1.79Kg/m^3). while, the lowest crop water use efficiency was obtained from treatment received irrigation at all growth stage (1.67 Kg/m^3), (table 4). Depriving irrigation at mid-season stage result in improvement of water use efficiency by 53.29%. whereas, irrigating all stage except initial stage improve water use efficiency by 6.59%. From the result we can observe water use efficiency showed decreasing trend with increasing irrigation amount and reduction of maize yield which is in line with the research [2].

Table 3. *Water use efficiency and mean yield of maize.*

Treatments	2017/18	2018/19	2019/20	*Mean Yield (Ton /ha)*	Percentage of decrement
	Yield (Ton/ha)	Yield (Ton /ha)	Yield (Ton /ha)		
all stage	9.95	9.87	9.79	9.87	-
all expt initial	10.82	9.21	9.33	9.78	-0.9%
all stage expt dev	8.44	8.75	7.93	8.36	-15.3%
all stage expt mid	7.05	9.20	7.47	7.91	-19.9%

Table 4. *Mean yield and water use efficiency at different growth stage.*

Treatment	Mean yield ((kg /ha)	Mean depth of Irrigation (m^3)	WUE (Kg/m^3)	WUE Improvement (%)
all stage	9870	5901	1.67	
all expt initial	9780	5479	1.78	6.59
all stage expt dev	8360	4659.7	1.79	7.20
all stage expt mid	7910	3083.6	2.56	53.29

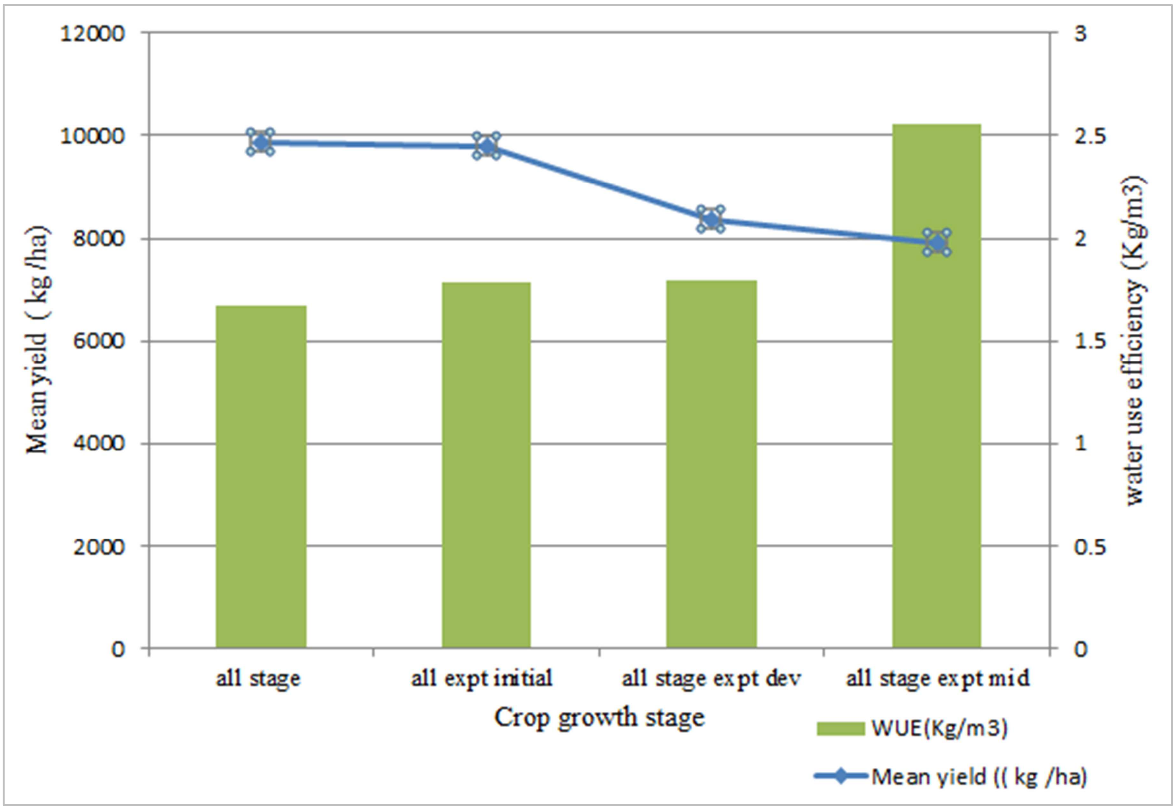

Figure 1. *Mean yield and water use efficiency of maize.*

3.1. Partial Budget Analysis

The partial budget analysis revealed that the highest MRR 51895.6% were obtained from irrigation of all stage except initial stage treatment. This showed that depriving irrigation at initial stage was the most economically with lower cost of production and higher benefit. Moreover, allowing irrigation at all stage resulted in minimum marginal rate of return (6298.1%) which increase cost of production.

Table 5. *Partial budget analysis.*

Treatment	All stage except mid	All stage except dev't	All except initial	All stage
GY	7910	8360	9780	9870
CLP	4000	4000	4000	4000
CF	5070	5070	5070	5070
DW	3083.6	4659.7	5479	5901
CIW	308.36	465.97	547.9	590.1
TVC	9378.36	9535.97	9617.9	9660.1
RFG	237300	250800	293400	296100
TR	237300	250800	293400	296100
NB	227922	241264	283782	286440
MC	-	157.6	81.9	42.2
MB	-	13342.4	42518.1	2657.8
MRR	-	8465.4	51895.6	6298.1

GY=grain yield in kg/ha, CLP=cost of land preparation, CF=cost of fertilizer, DW=depth of irrigation water (m^3), CIW=cost of irrigation water, TVC=total variable cost, RFG=revenue from gain, TR=total revenue, NB=net benefit, MC=marginal cost, mb=marginal benefit and MRR=marginal rate of return
NB: All costs are in Ethiopian birr

4. Conclusion

Irrigation water management in agriculture have significant impact on water saving and improving water use efficiency. Depriving irrigation water during specific growth stages of the growing season enables farmers to use scarce water resources in a manner that increases water use efficiency. However, these technologies need to be tested under different maize variety and environment. The current study revealed that when water stress is imposed at initial stage of maize development, the effect is low because the plants are already well developed, and they can modify themselves to cope with stress compared to the case when stress is imposed at development and mid-season stages at study area. The lowest water use efficiency was obtained from irrigation of all maize growth stage. The result also shows that, preventing irrigation at initial and development stages decrease mean yield of the maize (Table 3) since these periods coincide with the highest water requirement and the crop cannot withstand water deficit at these stages without significant penalty in yield. The partial budget analysis shows that application of water at all growth stage except initial stage resulted in higher marginal benefit with maximum marginal rate of return. Therefore under limited water resource condition withholding irrigation at initial stage may increase water use efficiency with insignificant yield penalty in the study area.

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