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Maize (*Zea Mays L.*) Response to Deficit Irrigation Levels at Different Growth Stages on its Yield and Water Use Efficiency at Koka, Central Rift Valley of Ethiopia

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Abstract

Water scarcity is among the major limitations for crop production. Improving water use efficiency of irrigated crops through water management options is crucial in water scarce areas. Field experiment was carried out at Wondo Genet Agricultural Research Center Koka Research site, to investigate the effect of water stress at different growth stage on yield and water use efficiency of maize. one optimum irrigation and eight growth stage based deficit levels(100% ETC at all growth stages, 75% ETC at all growth stages, 50% ETC at all growth stages, 75% ETC at development growth stage, 50% ETC at development growth stage, 75% ETC at mid growth stage, 50% ETC at mid growth stage, 75% ETC at late growth stage and 50% ETC at late growth stage) were imposed on maize (Zea mays L.) variety Melkassa II as a treatment and laid out in randomized complete block design (RCBD) with three replications. Results indicated that the different levels of growth stage based deficit levels had significant ($p<0.01$) effect on crop yield, harvest index and water use efficiency. Grain yield reduced with increased stress, whereas water use efficiency was increased with stress level increased. The highest grain yield of 6.4 t/ha and WUE of 1.01 kg/m3 were obtained at 100% ETC and 50% ETC at all growth stages, respectively. Also, 75% ETC at development stage and late stage treatments showed no significant variation with 100% ETC in grain yield. Water use efficiency observed at 75% ETC all growth stages treatment was statistically similar with that of 50% ETC at all growth stages treatment. Grain yield obtained from 50% ETC at mid growth stage was similar with 50% ETC at all growth stages, and water use efficiency was the least and this shows that maize was sensitive to moisture stress at mid growth stage than development and late growth stages. Therefore, maize could be irrigated at 75% ETC at all growth stages and by stressing development or late growth stages up to 50% ETC to increase water use efficiency with a small grain yield reduction for stressed scenario and for non stressed scenario with 100% ETC at all growth stages.

Keywords: Deficit Irrigation, Growth Stage, Maize, Water Use Efficiency

Introduction

Water is a finite resource used by different sectors like agriculture, domestic, municipal and industry. The competition for this scarce resource is increasing from time to time due to increasing food demand from the highly consuming agricultural sector, which makes less water available for crop production (Ingle *et al.*, 2015; Pereira *et al.*, 2009) [10, 20].This competition for water from different sectors made water a very scarce resource. As water scarcity intensifies in many regions of the world, better management of water is becoming an issue of paramount importance (Lorite *et al.*, 2007) [16].

Under conditions of scarce water supply and drought, deficit irrigation can lead to greater economic gain by maximizing water use efficiency. The potential benefits of deficit irrigation are derived from three factors: Increased irrigation efficiency, reduced costs of irrigation and the opportunity costs of water (English *et al.*, 1990) [6]. The water saved by DI can be used to irrigate more land on the same farm or in the water user's community, which given the high opportunity cost of water, and may largely compensate for the economic loss due to yield reduction (Ali *et al.*, 2007) [3]. In other words, DI aims at stabilizing yields and at obtaining maximum WP rather than maximum yields (Kazemeini and Edalat, 2011) [14].

Growth stage based deficit irrigation is an important way of managing irrigation water by identifying the most sensitive growth stages to apply the required amount of water on these sensitive growth stages. In this practice full irrigation water is applied only in the sensitive growth stages and a certain level of deficit irrigation can be applied on the growth stages that are not sensitive to water stress. Worldwide these types of research are common to identify crops sensitive growth stages in water scare areas. For instance, Zhang *et al*. (2019) [24] try to identify response of maize yield components to growth stage-based deficit irrigation and reported that water deficit applied during the maturity stage had a larger impact on maize yield compared with water deficit applied during the vegetative stage. Jin *et al*. (2020) [12] also try to identify the responses of maize yield and water use to growth stage based deficit irrigation on the Loess Plateau in China and reported that when irrigation water is limited, high WUE can be achieved if it is applied at vegetative growth stages, while high yield can be achieved if more available water is applied at tasseling stage.

Maize is one of the cereal crops produced in the study area widely through rainfall. However, there were information gap on effect of deficit irrigation at different growth stages on yield and water use efficiency of maize at the study area. Therefore the study was conducted to assess the effects of deficit irrigation at different growth stage on yield and water productivity of maize.

Materials and Methods

Description of the experimental site

The study was conducted at Wondo Genet Agricultural Research Center, Koka research station, Ethiopia, 8^{O}34'36"to 8^{O}36'24' N and 39^{O}02'12" to 39^{O}10'48" E at mean altitude of 1602 m.a.s.l during 2020/2021 dry season to assess the effects of deficit irrigation at different growth stage on yield and water productivity of maize. Loam and clay loam soil textures were the dominant soils of the area with moisture content at field capacity and permanent wilting point of 34.0 and 17.1%, respectively. The pH of the soil was found to be 7.3. The bulk density was found to be 1.17g/cm^3 and the total volumetric available water in the root zone was 170 mm/m. The climate of the area is characterized as semi-arid with uni-modal low and erratic rainfall pattern with annual average of 831.1 mm. About 71.2% of the total rainfall of the area falls from June to September, which is the main cropping season for the area. The mean maximum temperature varies from 30.9 to 26.1 ^{O}C; while the mean minimum temperature varies from 11.0 to 15.5 ^{O}C (Table 1).

Table 1: Climatic data of the study area

Month	Tmax (^{o}c)	Tmin (^{o}c)	Relative humidity (%)	Wind speed (m/s)	Sunshine hour (%)	Rainfall (mm)
January	27.4	11.3	54	4.04	75	13.5
February	28.3	12.6	52	4.08	76	26.1
March	30.0	14.4	51	4.64	74	51.5
April	30.3	15.2	54	3.80	71	58.5
May	30.9	15.1	53	3.98	68	48.5
June	30.0	15.5	57	4.91	65	72.7
July	26.7	15.0	67	4.30	54	212.7
August	26.3	15.1	68	3.15	53	202.4
September	27.8	14.9	66	2.30	57	104.3
October	28.3	12.7	56	3.50	73	21.1
November	27.4	11.3	52	4.09	83	9.9
December	26.1	11.0	54	4.19	76	9.9

Source: Lome Woreda meteorological station

Experimental design and procedure

The experimental field was ploughed on 27thNovember, 2020 with tractor. Then, the land was leveled so that it is suitable for laying the experiment. After the land is leveled, ridge preparation had been done with each block. The plot size was 15.75 m^2, (4.20 m length and 3.75 m width) by taking into account land availability in the experimental site. There were twenty seven experimental units. The distance between each plot and replication were 2 m and 4 m, respectively. Furrow irrigation was used and Maize seed of Melkassa II variety were sown on the experimental field at 30 cm spaces and thinning activities were done after the plant is well established. Each plot had 5 ridges at 75 cm spaces and furrow length of 4.2 m. Once the layout was prepared, main canal outside the experimental field and field channels constructed for the conveyance of irrigation water. Prior to sowing seeds, each plot was irrigated as pre-irrigation to create favorable condition for seed germination.

The treatments include optimum irrigation and different level of stress at different growth stages (T_1:- Full irrigation of 100% ETc (control), T_2:- 75% ETc at dev't stage (25% deficit only at dev't stage), T_3:- 50% ETc at dev't stage (50% deficit only at dev't stage), T_4:- 75% ETc at mid stage (25% deficit only at mid stage), T_5:- 50% ETc at mid stage (50% deficit only at mid stage), T_6:- 75% ETc at late stage (25% deficit only at late stage), T_7:- 50% ETc at late stage (50% deficit only at late stage), T_8:- 75% ETc at all stage (25% deficit at all stage), and T_9:- 50% ETc at all stage (50% deficit at all stage)). Treatments were arranged in Randomized Completely Block Design (RCBD) with three replications, following the design by Gomez and Gomez (1984). Blocking was designed across the slope to check water flow condition and soil fertility effect in the experiment. Treatments were arranged in each of the three blocks randomly based on randomization using SAS (Statistical Analysis System 9.3) software for randomized completely block design.

Irrigation scheduling was done based on the metrological, soil and crop data using CROPWAT 8.0 irrigation software and the level of moisture depletion were monitored by soil moisture determination using gravimetric soil sampling. The irrigation scheduling was done based on the optimum irrigation treatment and other treatments were receiving lower water than the control treatment with their level of moisture stress. The control treatment (optimum irrigation) was irrigated based critical moisture deficit for the crop irrigating to refill soil to field capacity. However, stressed treatments were receiving lower amount based on the stress level with the same irrigation interval as control treatment. Regular agricultural management like weeding and hoeing in the study area was done uniformly for all plots during the experimental period.

Data collection and analysis

By harvesting the whole 3 entire ridges yield and yield components were measured by using sensitive balance after the maize was dried with sun. Moreover, based on the grain yield and the amount of irrigation used for each treatment, the water use efficiency was calculated using the following formula.

$$\text{Water use efficiency } (\text{kg/m}^3) = \frac{\text{grain yield } \left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Net irrigation water applied } \left(\frac{\text{m}^3}{\text{ha}}\right)}$$

The collected data were analyzed using the statistical analysis system (SAS) software version 9.3 procedure of the general linear model for the analysis of variance. Mean comparisons were carried out to estimate the differences between treatments using Fisher's least significant difference (LSD) at 5% probability level.

Results and Discussion

Cob weight with seed

Cob weight with seed was significantly affected ($p<0.01$) due to different level of growth stage based deficit levels. The highest cob weight with seed was obtained from the control treatment that gained 100% ETC at all growth stages and has no significance difference from treatments that received 75% ETC at development and late growth stages. The minimum cob weight with seed was obtained from the treatment that received 50% ETC at all growth stages and has no significance difference from treatments that received 50% ETC at mid growth stage. Cob weight with seed was reduced as stress level increased from 100% ETC to 50% ETC in the treatments that were stressed at different growth stages.

Maximum cob weight with seed of 253.2 gm was obtained from the control treatment that gained 100% ETC at all growth stages and which was statistically similar with that of treatments that received 75% ETC at development and late growth stages that obtained 247.8 and 246.4 gm, respectively. On the other hand, minimum cob weight with seed of 123.3 gm was obtained from the treatment that received 50% ETC at all growth stages and which was statistically similar with that of treatment that received 50% ETC at mid growth stages that obtained 129 gm (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 51% that stressed at all growth stages and 49% that stressed at mid growth stage in cob weight with seed.

The result showed that cob weight with seed was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase cob weight with seed become small. This might be due to the adverse effects of deficit soil moisture stress on plant growth, development and yield which lead to Loss of turgidity leading to cell enlargement and stunted growth. Similar studies also showed that cob weight with seed is affected due to growth stage based moisture stress in different crops. The result is in line with Meskelu *et al*. (2018) [18] and Jemal and Agegnehu (2020) [11] who reported that maximum cob weight with seed is obtained from conventional furrow irrigation methods that received more irrigation water. Yazar *et al*. (2012) reported that maximum mean maize grain weight per cob produced by complete irrigation which is agreed with the current finding. The study is also in line with Hanson *et al*. (2007) [7] who reported that irrigation frequencies increased cob weight with seed.

Cob weight without seed

Cob weight without seed was also significantly affected ($p<0.01$) due to different level of growth stage based deficit levels. The highest cob weight without seed was obtained from the control treatment that gained 100% ETC at all growth stages and has no significance difference from treatments that received 75% ETC at development and late growth stages. The minimum cob weight without seed was obtained from the treatment that received 50% ETC at all growth stages and has no significance difference from treatments that received 50% ETC at mid growth stage. Cob weight without seed was reduced as stress level increased from 100% ETC to 50% ETC in the treatments that were stressed at different growth stages.

Maximum cob weight without seed of 60.8 gm was obtained from the control treatment that gained 100% ETC at all growth stages and which was statistically similar with that of treatments that received 75% ETC at development and late growth stages that obtained 60 and 58.5 gm respectively. On the other hand, minimum cob weight without seed of 32.4 gm was obtained from the treatment that received 50% ETC at all growth stages and which was statistically similar with that of treatment that received 50% ETC at mid growth stages that obtained 34.7 gm (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 46.7% that stressed at all growth stages and 42.9% that stressed at mid growth stage in cob weight without seed.

The result showed that cob weight without seed was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase cob weight without seed also become small. This might be due to decrease in photosynthesis due to decreased diffusion of CO_2 with the closure of stomata to conserve water and reduced leaf area. Similar studies also showed that cob weight without seed is affected due to growth stage based moisture stress in different crops. The result is in line with Meskelu *et al*. (2018) [18] and Jemal and Agegnehu (2020) [11] who reported that maximum cob weight without seed is obtained from conventional furrow irrigation methods that received more irrigation water.

Thousand Seed weight

Growth stage based deficit irrigation significantly ($p<0.01$) affected thousand seed weight. The highest thousand seed weight was obtained from the control treatment that gained 100% ETC at all growth stages and has no significance difference from treatments that received 75% ETC at development and late growth stages. The minimum thousand seed weight was obtained from the treatment that received 50% ETC at all growth stages and has no significance difference from treatments that received 50% ETC at mid growth stage. Thousand seed weight was reduced as stress level increased from 100% ETC to 50% ETC in the treatments that were stressed at different growth stages.

Maximum thousand seed weight of 570 gm was obtained from the control treatment that gained 100% ETC at all growth stages and which was statistically similar with that of treatments that received 75% ETC at development and late growth stages that obtained 567.3 and 565 gm, respectively. On the other hand, minimum thousand seed weight of 353.2 gm was obtained from the treatment that received 50% ETC at all growth stages and which was statistically inferior from all other treatments (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 38% that stressed at all growth stages and 34.9% that stressed at mid growth stage in thousand seed weight.

Here the result showed that thousand seed weight was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increases thousand seed weight is small. This might be due to the adverse effects of deficit soil moisture stress on plant growth, development and yield which lead to Loss of turgidity leading to cell enlargement and stunted growth. Similar studies also showed that thousand seed weight is affected due to growth stage based moisture stress in different crops. The finding is agreed with the result of Mansouri-Far *et al*. (2010) [17] reported that when the amount of water decreased, both the 1000 grain weight and grain yield were decreased. Reduction of 1000 grains weight due to soil water deficits have also been reported by Cakir (2004) [5] and Karam *et al*. (2003) [13]. The result also supported by Hesamoddin *et al.* (2012) [8]. Which stated that, thousand seed weight is higher for full irrigation.

Grain yield

Growth stage based deficit irrigation highly significantly ($p<0.01$) affected grain yield. The highest grain yield was obtained from the control treatment that gained 100% ETC at all growth stages and has no significance difference from treatments that received 75% ETC at development and late growth stages. The minimum grain yield was obtained from the treatment that received 50% ETC at all growth stages and has no significance difference from treatments that received 50% ETC at mid growth stage. Grain yield was reduced as stress level increased from 100% ETC to 50% ETC in the treatments that were stressed at different growth stages.

Maximum grain yield of 6.4 t/ha was obtained from the control treatment that gained 100% ETC at all growth stages and which was statistically similar with that of treatments that received 75% ETC at development and late growth stages that obtained 6.1 and 6.2 t/ha, respectively. On the other hand, minimum grain yield of 3.9 t/ha was obtained from the treatment that received 50% ETC at all growth stages and which was statistically similar with that of treatment that received 50% ETC at mid growth stages that obtained 4.1 t/ha (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 39% that stressed at all growth stages and 35.9% that stressed at mid growth stage in grain yield.

The result showed that grain yield was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase grain yield become small. This might be due to the adverse effects of deficit soil moisture stress on plant growth, development and yield which lead to Loss of turgidity leading to cell enlargement and stunted growth, decrease in photosynthesis. Similar studies also showed that grain yield is affected due to growth stage based moisture stress in different crops. This finding is in line with Song *et al.* (2019) [21] who reported that the maximum LAI, canopy height, biomass, unit kernel weight, kernels per spike, and yield were highest in FullIRR treatment during all treatments, while water stress during different growth stages has different effects on those variables. Different researches conducted on maize (Admasu *et al*., 2019) [1] and wheat (Meskelu *et al*., 2017) [19] also showed that, as the moisture stress level increased the production of the crop will declined, which agreed with the current finding. Agyare *et al*. (2013) [2] also reported that moisture stress in the sensitive stages (tasseling and silking or grain filling) resulted in highest grain yield reduction which is in line with the current finding. Çakir (2004) [5] also reported that highest grain yield was obtained in the fully irrigated treatment and the treatment which allowed water stress during the vegetative growth stage and he also stated that even a single irrigation omission during one of the sensitive growth stages, caused up to 40% grain yield losses during dry years and Igbadun *et al*. (2008) [9] also reported that deficit irrigation at any crop growth stage of the maize crop led to decrease in grain yields and dry matter yields in which their findings are in line with the current findings.

Dry biomass

Growth stage based deficit irrigation highly significantly ($p<0.01$) affected dry biomass. The highest dry biomass was obtained from the control treatment that gained 100% ETC at all growth stages and has no significance difference from treatments that received 75% ETC at development and late growth stages. The minimum dry biomass was obtained from the treatment that received 50% ETC at all growth stages and has no significance difference from treatments that received 50% ETC at mid growth stage. Dry biomass was reduced as stress level increased from 100% ETC to 50% ETC in the treatments that were stressed at different growth stages.

Maximum dry biomass of 13.6 t/ha was obtained from the control treatment that gained 100% ETC at all growth stages and which was statistically similar with that of treatments that received 75% ETC at development and late growth stages that obtained 13.5 and 13.6 t/ha, respectively. On the other hand, minimum dry biomass of 9.1 t/ha was obtained from the treatment that received 50% ETC at all growth stages and which was statistically similar with that of treatment that received 50% ETC at mid growth stages that obtained 9.6 t/ha (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 33% that stressed at all growth stages and 29.4% that stressed at mid growth stage in dry biomass.

Here also the result showed that dry biomass was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase dry biomass also become small. This might be due decrease in photosynthesis due to decreased diffusion of CO_2 with the closure of stomata to conserve water and reduced leaf area. Similar studies also showed that dry biomass is affected due to growth stage based moisture stress in different crops. This finding is agreed with Admasu *et al.* (2019) [1] who reported that water supply reduced from 100 to 25% ETC the above ground dry biomass yield decreased by 44.6%. Kuscu and Demir (2012) [15] also reported that Moisture stress resulting from the limited water supply at vegetative and flowering stages affected crop canopy development which led to low dry matter yield which is agreed with the current finding. The findings were also agreed with the reports of Çakir (2004) [5] and Igbadun *et al*. (2008) [9] that the effect of the deficit irrigation on dry matter of the maize crop depends on the crop growth stage and the frequency of the deficit, irrespective of whether it was at one or more growth stages.

Harvesting index

Harvesting index was also highly significantly ($p<0.01$) affected due to different level of growth stage based moisture stresses. The highest harvesting index was obtained from the treatment that gained 50% ETC at development growth stages and has no significance difference from the control, treatments that received 75% ETC at development, mid, and late and all growth stages. The minimum harvesting index was obtained from the treatment that received 50% ETC at mid growth stages and has no significance difference from treatments that received 50% ETC at all growth stage.

Maximum harvesting index of 49% was obtained from the treatment that gained 50% ETC at development growth stages. On the other hand, minimum harvesting index of 42% was obtained from 50% ETC at mid growth stages (Table 2).

The result also showed that there is no clear trend or relationship between amount of water applied and harvesting index. Different studies also showed that harvesting index is affected due to growth stage based moisture stress in different crops. for instance, Admasu *et al.* (2019) [1] reported that highest harvesting index of maize was observed from100ETc and the lowest harvesting index was observed from 25% ETC where as Kuscu and Demir (2012) [15] reported that the highest harvest index was obtained from VF treatment (weekly irrigation in the vegetative and flowering stages) and the lowest values of harvest index were determined from control. However, Traore *et al*. (2000) [22] found that the harvest index was affected by water deficit only when stress was imposed during anthesis.

Water use efficiency

Water use efficiency of maize was also highly significantly ($p<0.01$) affected due to different level of growth stage based deficit levels. The highest water use efficiency was obtained from the treatment that gained 50% ETC at all growth stages and has no significance difference from treatment that received 75% ETC at all growth stages. The minimum Water use efficiency was obtained from the treatment that received 50% ETC at mid growth stages and statistically it was inferior from all other treatments.

Maximum Water use efficiency of 1.01 kg/m^3 was obtained from the treatment that gained 50% ETC at all growth stages and has no significance difference from treatment that received 75% ETC at all growth stages that obtained 0.95kg/m^3. On the other hand, minimum water use efficiency of 0.72 kg/m^3 was obtained from the treatment that received 50% ETC at mid growth stages and statistically it was inferior from all other treatments (Table 2).

The result showed that water use efficiency were higher for the treatments that received lower amount of irrigation water than the treatments that received higher amount of irrigation water even if their yield were lowered. Different researches conducted on maize (Yenesew *et al*., 2009) [23], maize (Admasu *et al*., 2019) [1] and wheat (Meskelu *et al*., 2017) [19] also showed that, as the moisture stress level increased the production of the crop will declined and the water use efficiency were increased, which agreed with the current finding. This shows that deficit irrigation to a certain level increases or improves water use efficiencies to without significant yield reduction.

From growth stage aspects WUE in a treatment that received 50% ETC at mid growth stages was smaller than from the other treatments. This might be due to the condition that the treatment gained unwanted amount of water at development and late growth stages that increase total amount of water and do not gained the required amount of water in its water sensitive growth stages that leads to yield reduction at mid growth stages. Ayas (2019) [4] reported that lowest value of WUE was obtained from the treatment that stressed at flowering and yield formation periods in tomato which is in line with the current finding.

Table 2: Effect of growth stage based deficit levels on yield component, yield, harvesting index and water use efficiency of maize

Treatments	cob weight with seed (gm)**	cob weight without seed (gm)**	thousand seed weight (gm)**	grain yield (t/ha)**	dry biomass (t/ha)**	Harvest index (%) **	water use efficiency (kg/M^3)**
100% Etc @ all	253.2a	60.8a	570.0a	6.4a	13.6a	47ab	0.88bc
75% Etc @ dev	247.8a	60.0a	567.3a	6.1ab	13.5a	45bc	0.88bc
50% Etc @ dev	220.0b	46.3cd	533.8b	5.8bc	11.9b	49a	0.87bc
75% Etc @ mid	175.2c	48.5bc	420.5d	5.2d	11.2b	46abc	0.82c
50% Etc @ mid	129.0d	34.7e	371.2e	4.1e	9.6c	42d	0.72d
75% Etc @ late	246.4a	58.5a	565.0a	6.0ab	13.6a	44cd	0.88bc
50% Etc @ late	227.5b	50.1b	541.2b	5.3cd	12.0b	44cd	0.85c
75% Etc @ all	176.7c	44.2d	448.9c	5.3d	11.4b	46abc	0.95ab
50% Etc @ all	123.3d	32.4e	353.2f	3.9e	9.1c	43d	1.01a
LSD (0.05)	17.0	3.4	17.2	0.4	0.9	2	0.08
CV (%)	4.9	4.1	2.0	4.7	4.2	3.0	5.2

Means followed by different letters in a column differ significantly and those followed by same letter are not significantly different at $p<0.05$ level of significance; ns: No significant at $p<0.05$; *significant at $p<0.05$; **significant at $p<0.01$.

Conclusion

The study was aimed to enhance the water productivity of irrigated maize in water scarce areas. An attempt was made to growth stages based moisture stress through reduction of irrigation water applied to the crop. The optimum irrigation water application was determined based on the CropWat model and the irrigation water applied to each stressed treatments was based on their stress levels. As a result, seasonal water demands for maize (*Zea mays*L.) Melkass II variety under the study area and for the specified planting date (during the dry season of the area), could be 726.3 mm net irrigation depth for non-stress scenario (100% ETC). Yet, for stressed scenario, the net irrigation depth reduced based on the moisture stress level until 382.6 mm for the least treatment that received 50% ETC at all growth stages. Reductions of irrigation water from 100% ETC to 50 ETC at all growth stages and mid growth stages have an effect on all the recorded yield and yield components. However, Reduction of irrigation water from 100% ETC to 50 ETC at development and late growth stage has no that much effect on the recorded yield and yield components as compared to mid growth stages. In conclusion, for non stressed condition, maize Melkassa II variety should be irrigated with net seasonal irrigation depth of 726.3 mm for optimum irrigation (100% ETC) at all growth stages to attain maximum grain yield and aboveground biomass and for water stressed area to enhance the water productivity, it could be irrigated to 75% of the full irrigation amount at all growth stages to improve the water productivity to 1.01 kg/m^3 with a compromise of yield reduction by 12.5%. The seasonal net irrigation water depth required for this case should be 554.5 mm and the grain yield obtained could be 5.6 t/ha. Since mid growth stage was sensitive to moisture stress, moisture stress at this stage should be avoided for maize Melkassa II variety. Rather for improving water productivity, it could be grown by stressing development or late growth stages up to 50% ET_C.

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