OPEN ACCESS Freely available online

ISSN: 2168-9881
Agrotechnology

Research Article

Effects of Growth Stage Based Deficit Irrigation on maize (*Zea mays* L.): Growth Parameters at Koka, Central Rift Valley of Ethiopia

Ayele Debebe[1,2*]

[1]*Wondo Genet Agricultural Research Center, Shashemene, Ethiopia;* [2]*Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia*

ABSTRACT

Deficit irrigation is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop. Field experiment was carried out at Wondo Genet Agricultural Research Center Koka Research site, to investigate the effect of growth stage based deficit irrigation on maize growth parameters. One optimum irrigation and eight growth stage based deficit levels 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 ($p<0.01$) effects on maize growth parameters. Growth parameters reduced with increased stress. Plant height, ear height, leaf length, leaf width, cob length, cob diameter and leaf area index were shortened from 193.5 cm to 161.9 cm, 92.3 cm to 77.9 cm, 77.6 cm to 62.1 cm, 9.3 cm to 7.5 cm, 17.4 cm to 11.7 cm, 16.2 cm to 12.6 cm^2, and 252.2 cm^2 to 163 cm^2, respectively, due to reduction of irrigation water from 100% ETC (Ethereum Classic Coin) to 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 growth parameters of maize. 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 growth parameters of maize as compared to mid 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 for stressed scenario and for non-stressed scenario with 100% ETC at all growth stages.

Keywords: Deficit irrigation, Growth stage, Maize

INTRODUCTION

Agriculture is the main stay of Ethiopian economy and it depends on rainfall. Over 95% of the agricultural production depends on rainfall [1]. Almost 80%-85% of the population, 40%-48% of the country's GDP and 90% of export directly depend on rain fed agriculture [2].

Agricultural production can be increased by either expanding the irrigated-cropped area or by raising the crop productivity [3]. However, as the population growth increased irrigated crop area will not increase and it is not the exact option to increase agricultural production rather raising crop productivity is the best option to increase agricultural production.

Due to lack of water storage and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one crop per year and hence there are frequent crop failures due to dry spells and droughts which have resulted in a chronic food shortage. However, to ensure food security irrigation has its own share. Nata, et al. and Abraham, et al. listed out the benefits of irrigation that includes; increase food production in arid and semi-arid regions, enhances food production, promotes economic growth and sustainable development, create employment opportunities, and improve living conditions of small-scale farmers [4,5].

Deficit irrigation is an optimization strategy in which irrigation is applied during drought-sensitive growth stages of a crop.

Correspondence to: Ayele Debebe, Wondo Genet Agricultural Research Center, Shashemene, Ethiopia, E-mail: ayedebebe12@gmail.com

Received: 02-Nov-2023, Manuscript No. AGT-23-23725; **Editor assigned:** 06-Nov-2023, PreQC No. AGT-23-23725; **Reviewed:** 20-Nov-2023, QC No. AGT-23-23725; **Revised:** 27-Nov-2023, Manuscript No. AGT-23-23725; **Published:** 04-Dec-2023, DOI:10.35248/2168-9891.23.12.354

Citation: Debebe A (2023) Effects of Growth Stage Based Deficit Irrigation on maize (*Zea mays* L.): Growth Parameters at Koka, Central Rift Valley of Ethiopia. Agrotechnology. 12:354.

Outside these periods, irrigation is limited or even unnecessary if rainfall provides a minimum supply of water. Water restriction is limited to drought-tolerant phonological stages, often the vegetative stages and the late ripening period. Total irrigation application is therefore not proportional to irrigation requirements throughout the crop cycle. While this inevitably results in plant drought stress and consequently in production loss, deficit irrigation maximizes water use efficiency [6]. In other words, deficit irrigation aims at stabilizing yields and at obtaining maximum water use efficiency rather than maximum yields.

Now a day's competitions for irrigation water are common in different parts of the country including the study area. So, to minimize this competition exploring options that can solve these problems are needed and growth stage based deficit irrigation is an option. Therefore, the study was conducted to investigate the effects of growth stage based deficit irrigation on growth parameters of maize.

MATERIALS AND METHODS

Description of the experimental site

The trial was conducted at Wondo Genet Agricultural Research Center, Koka research station, Ethiopia, 8°34'36" to 8°6'24' N and 39°02'12" to 39°10'48" E at mean altitude of 1602 m.a.s.l during 2020/2021 dry season to assess the effects of growth stage based deficit irrigation on growth parameters 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 be1.17 g/cm3 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°C to 26.1°C; while the mean minimum temperature varies from 11.0°C to 15.5°C (Table 1).

Experimental design and procedure

The experimental field was ploughed on 27th November, 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. Prior to sowingseeds, each plot was irrigated as pre- irrigation to create favorable condition for seed germination. 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.

The treatments include optimum irrigation and different level of stress at different growth stages (T1: Full irrigation of 100% ETc (control), T2: 75% ETc at dev't stage (25% deficit only at

Month	T max (oc)	T min (oc)	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	14.4	51	4.64	74	51.5
April	30.3	15.2	54	3.8	71	58.5
May	30.9	15.1	53	3.98	68	48.5
June	30	15.5	57	4.91	65	72.7
July	26.7	15	67	4.3	54	212.7
August	26.3	15.1	68	3.15	53	202.4
September	27.8	14.9	66	2.3	57	104.3
October	28.3	12.7	56	3.5	73	21.1
November	27.4	11.3	52	4.09	83	9.9
December	26.1	11	54	4.19	76	9.9
Source: Lome Woreda meteorological station.						

Table 1: Climatic data of the study area.

dev't stage), T3: 50% ETc at dev't stage (50% deficit only at dev't stage), T4: 75% ETc at mid stage (25% deficit only at mid stage), T5: 50% ETc at mid stage (50% deficit only at mid stage), T6: 75% ETc at late stage (25% deficit only at late stage), T7: 50% ETc at late stage (50% deficit only at late stage), T8: 75% ETc at all stage (25% deficit at all stage), and T9: 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 [7]. 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

Ten plants were selected randomly and plant height, ear height, leaf length and width, cob length and cob diameter were measured by using tape meter. 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

Plant height

Plant height was significantly affected ($p<0.01$) due to different level of moisture stress at different growth stages. The highest plant height 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 plant height was obtained from the treatment that received 50% ETC at all growth stages and it was statistically inferior from all other treatments. Plant height was reduced as stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at all growth stages and mid growth stage. However, plant height was not reduced as the stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at development and late growth stages.

Maximum plant height of 193.5 cm 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 192.1 cm and 191.1 cm, respectively. On the other hand, minimum plant height of 161.9 cm obtained from the treatment that received 50% ETC at all growth stages (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 16.3% that stressed at all growth stages and 12.1% that stressed at mid growth stage in plant height.

The result showed that plant height was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase plant height become shortest. 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 due to decreased diffusion of CO_2 with the closure of stomata to conserve water and reduced leaf area. Similar studies also showed that plant height is affected due to growth stage based moisture stress in different crops. This finding is in line with the results reported by Çakir R, et al., Karasu, et al. and Kuscu, et al [8-10].

Ear height

Growth stage based deficit irrigation were significantly affected ($p<0.01$) ear height. The highest ear height 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 and 50% ETC at development stage. The minimum ear height was obtained from the treatment that received 50% ETC at mid growth stages and has no significant difference from treatments that received 75% and 50% ETC at all growth stages. Ear height was reduced as stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at all growth stages, development and mid growth stage. However, plant height was not reduced as the stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at late growth stages.

Maximum ear height of 92.3 cm 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 and 50% ETC at development stage that obtained 91.1 cm, 90.8 cm and 88.1 cm, respectively. On the other hand, minimum ear height of 75.8 cm obtained from the treatment that received 50% ETC at mid growth stage and which was statistically similar with that of treatments that received 75% and 50% ETC at all growth stages that obtained 78.6 cm and 77.9 cm, respectively (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 15.6% that stressed at all growth stages and 14.8% that stressed at mid growth stage in ear height.

The result showed that ear height was also directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase ear height become shortest. 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 ear height is affected due to growth stage based moisture stress in different crops. This finding is in line with Sohail, et al [11]. who reported highest ear height was recorded from full irrigation and lowest ear height was recorded from deficit irrigation (one irrigation missing at six leaves stage). Water stress in vegetative stage produced stunted maize plant due to high evapotranspiration rate and low photosynthetic rate, so ear was produced near the ground surface. Gonzalez et al. reported the same result that deficiency of water before reproductive stage produce ear at low height from the ground [12].

Leaf length

Leaf length was significantly affected (p<0.01) due to different level of growth stage based moisture stresses. The highest leaf length 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 leaf length was obtained from the treatment that received 50% ETC at mid growth stage and has no significance difference from treatments that received 50% ETC at all growth stages. Leaf length was reduced as stress level increased from 100% ETC to 50% ETC in the treatments that were stressed at different growth stages.

Maximum leaf length of 77.6 cm 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 75.8 cm and 77.3 cm, respectively. On the other hand, minimum leaf length of 60.2 cm was obtained from the treatment that received 50% ETC at mid growth stage and which was statistically similar with that of treatments that received 50%ETC at all growth stages that obtained 62.1 cm (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 20% that stressed at all growth stages and 22.4% that stressed at mid growth stage in leaf length.

The result showed that leaf length was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase leaf length become shortest. 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 leaf length is affected due to growth stage based moisture stress in different crops. This finding is in line with the results reported by Abrecht et al. who reported that, water stress delays leaf tip emergence and reduces leaf expansion in maize [13]. Also Hussain, et al. reported that plant water stress also retards leaf expansion and thus reduced leaf area, which is more important for decrease in crop growth [14].

Leaf width

Leaf width was also significantly affected (p<0.01) due to different level of growth stage based moisture stresses. The highest leaf width was obtained from the control treatment that gained 100% ETC at all growth stages and has no significance difference from treatments that received 75% and 50% ETC at development and late growth stages. The minimum leaf width 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. Leaf width was reduced as stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at all growth stages and mid growth stage. However, leaf width was not reduced as the stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at development and late growth stages.

Maximum leaf width of 9.3 cm 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 and 50% ETC at development and late growth stages that obtained 9.3 cm, 9.3 cm, 9.2 cm` and 9.1 cm, respectively. On the other hand, minimum leaf width of 7.5 cm was obtained from the treatment that received 50% ETC at all growth stages and which was statistically similar with that of treatments that received 50% ETC at mid growth stage that obtained 7.7 cm (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 19.4% that stressed at all growth stages and 17.2% that stressed at mid growth stage in leaf width.

The result showed that leaf width was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase leaf width become narrow. 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 due to decreased diffusion of CO_2 with the closure of stomata to conserve water and reduced leaf area. Similar studies also showed that leaf width is affected due to growth stage based moisture stress in different crops. This finding is in line with the results reported by Hussain et al. who reported that plant water stress also retards leaf expansion and thus reduced leaf area, which is more important for decrease in crop growth [14]. Traoré et al. and Abrecht et al. also reported that, water stress delays leaf tip emergence and reduces leaf expansion in maize, due to this leaf width of maize is reduced as moisture stress increases which is agreed with the current findings [13,15].

Leaf area index

Leaf area index was also significantly affected (p<0.001) due to different level of growth stage based deficit levels. The highest leaf area index was obtained from the control treatment that gained 100% ETC at all growth stages and this has no significance difference from treatments that received 75% ETC at development and late growth stages. On the other hand, the minimum leaf area index 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. Leaf area index was reduced as stress level increased from 100% ETC to 50% ETC in the treatments that were stressed at different growth stages.

Maximum leaf area index of 252.2 cm^2 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 245.6 cm^2 and 251.3 cm^2, respectively. On the other hand, minimum leaf area index of 161.3 cm^2 was obtained from the treatment that received 50% ETC at mid growth stage and which was statistically similar with that of treatments that received 50% ETC at all growth stages (163 cm^2) (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 35.4% that stressed at all growth stages and 36% that stressed at mid growth stage in leaf area index.

The result showed that leaf area index was also directly associated with the amount of irrigation water applied and inversely with the stress level. Similar studies also showed that leaf area index is affected due to growth stage based moisture stress in different crops. This finding is in line with Sohail et al. (2019) who reported highest leaf area index was recorded from full irrigation and lowest leaf area index was recorded from deficit irrigation (one irrigation missing at twelve leaves stage). Water stress in vegetative stage decreased leaf area index due to more transpiration from plant canopy and evaporation from the soil surface. Tari, et al and Lopez et al. investigated that leaf area index is decreased by water stress in vegetative stages [16,17].

Cob length

Growth stage based deficit irrigation significantly affected ($p<0.01$) cob length of maize. The highest cob length was obtained from the control treatment that gained 100% ETC at all growth stages and has no significance difference from treatments that received 75% and 50% ETC at development and late growth stages and 75% ETC at mid growth stage. The minimum cob length 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 length was reduced as stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at all growth stages and mid growth stage. However, cob length was not reduced as the stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at development and late growth stages.

Maximum cob length of 17.4 cm 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% and 50% ETC at development and late growth stages and 75% ETC at mid growth stage that obtained 16.9 cm, 16.8 cm, 16.5 cm, 16.4 cm and 16.3 cm, respectively. On the other hand, minimum cob length of 11.7 cm was obtained from the treatment that received 50% ETC at all growth stages and which was statistically similar with that of treatments that received 50%ETC at mid growth stage that obtained 12.7 cm (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 32.8% that stressed at all growth stages and 27% that stressed at mid growth stage in cob length.

Here also the result showed that cob length was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase cob length become shortest. Similar studies also showed that cob length is affected due to growth stage based moisture stress in different crops. This finding is in line with Sohail, et al. who reported highest ear length was recorded from full irrigation and lowest ear length was recorded from deficit irrigation (one irrigation missing at grain filling stage). Ear length was decreased when plant not receiving enough water in reproductive stage. Li et al., Mohammadi et al., and Ha BM reported that water stress in reproductive stage decreased ear length of maize due to low photosynthetic rate and high evapotranspiration rate [18-20].

Cob width

Growth stage based deficit irrigation were also significantly affected ($p<0.01$) cob width. The highest cob width was obtained from the control treatment that gained 100% ETC at all growth stages and has no significance difference from treatments that received 75% and 50% ETC at development and late growth stage. The minimum cob length 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 width was reduced as stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at all growth stages and mid growth stage. However, cob width was not reduced as the stress level increased from 100% ETC to 50% ETC on the treatments that were stressed at development and late growth stages.

Maximum cob width of 16.2 cm 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% at development and late growth stages and 50% ETC at development and late growth stages that obtained 16 cm, 15.7cm, 15.7 cm and 15.7 cm, respectively. On the other hand, minimum cob width of 12.6 cm was obtained from the treatment that received 50% ETC at all growth stages and which was statistically similar with that of treatments that received 50%ETC at mid growth stage that obtained 13.2 cm (Table 2). The decrease in irrigation level from 100% ETC to 50% ETC leads to a decrease of 22.2% that stressed at all growth stages and 18.5% that stressed at mid growth stage in cob width.

The result showed that cob width was directly associated with the amount of irrigation water applied and inversely with the stress level. When the stress level increase cob width become narrow. 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 width is affected due to growth stage based moisture stress in different crops. This finding is also in line with Sohail, et al. who reported highest ear diameter was recorded from full irrigation and lowest ear diameter was recorded from deficit irrigation (one irrigation missing at grain filling stage).

Treatments	Plant	Ear	Leaf	Leaf width	Leaf area	Cob length	Cob width
100% Etc @	193.5a	92.3a	77.6a	9.3a	252.2a	17.4a	16.2a
75% Etc @	184.7cd	85.6b	75.8ab	9.3a	245.6ab	16.9ab	16.0a
50% Etc @	185.9bc	85.4b	68.3d	9.2ab	218.9cd	16.5ab	15.7ab
75% Etc @	180.1d	83.8b	68.9cd	8.3c	199.9e	16.3ab	14.3c
50% Etc @	169.9e	75.8c	60.2e	7.7d	161.3f	12.7d	13.2d
75% Etc @	191.1ab	90.8a	77.3a	9.3a	251.3a	16.2b	15.7ab
50% Etc @	185.2cd	88.1ab	72.8bc	9.1ab	231.7bc	16.1b	15.7ab
75% Etc @	173.2e	78.6c	68.3d	8.8b	209.5de	14.0c	14.9bc
50% Etc @	161.9f	77.9c	62.1e	7.5d	163.0f	11.7d	12.6d
LSD(0.05)	5.5	4.3	4.1	0.4	16	1.2	0.9
CV (%)	1.8	3	3.3	2.7	4.3	4.9	3.4

Note: Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at $p<0.05$ level of significance. NS: Non-significant at $p<0.05$.

Table 2: Effect of growth stage based deficit levels on growth parameters of maize.

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 experiment showed that growth stage based moisture stress affects crop growth parameters like plant height, ear height, leaf length, leaf width, cob length, cob diameter and leaf area index. Plant height, ear height, leaf length, leaf width, cob length, cob diameter and leaf area index were shortened from 193.5 cm to 161.9 cm, 92.3 cm to 77.9 cm, 77.6 cm to 62.1 cm, 9.3 cm to 7.5 cm, 17.4 cm to 11.7 cm, 16.2 cm to 12.6 cm, and 252.2 cm^2 to 163 cm^2, respectively, due to reduction of irrigation water from 100%ETC to 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 growth parameters of maize. 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 growth parameters of maize 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 better grown maize. Since mid-growth stage was sensitive to moisture stress, moisture stress at this stage should be avoided for maize Melkassa II variety. However, late and development stages are not that much sensitive to moisture stress and under water scarce area maize can be grown by reducing irrigation water up to 50% ETC.

ACKNOWLEDGEMENT

The author is grateful to Ethiopian Institute of Agricultural Research, soil and water Research Directorate, for providing funds for the experiment. The author is also thankful to Remeto Elemo for his field assistance in the field experimentation.

REFERENCES

1. IFAD (International Fund for Agricultural Development). Special Country Programme, Phase II (SCP II). Ethiopia IFAD. 2005.
2. Food and Agriculture Organization Aquastat. AQUASTAT-FAO's Global Information System on Water and Agriculture. 2001.
3. Qureshi SK, Hussain Z. An assessment of warabandi (irrigation rotation) in Pakistan: A preliminary analysis. Pak Dev Rev. 1994;33(4):845-855.
4. Nata T, Asmelash B. Recharging Practices for the enhancement of hand dug wells discharge in Debre Kidane watershed, North Ethiopia. 4th International Work Shop on Water Management and Irrigation: Focus on groundwater. Mekelle University, Mekelle, Ethiopia. 2007.
5. Gebrehiwot AB, Tadesse N, Bheemalingeswara K, Haileselassie M. Suitability of groundwater quality for irrigation: a case study on hand dug wells in Hantebet catchment, Tigray, northern Ethiopia. Am J Sci. 2011;7(8):191-199.
6. English MJ, Musick, JT, Murtz, VV. Deficit irrigation. In Hoffman GJ, Howell TA, Solomon KH (Eds.), Management of farm irrigation systems. St. Joseph, MI: ASAE. 1990.
7. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John wiley & sons. 1984.
8. Cakir R. Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Res. 2004;89(1):1-6.
9. Karasu A, Kuşçu H, Öz M, Bayram G. The effect of different irrigation water levels on grain yield, yield components and some quality parameters of silage maize (*Zea mays indentata Sturt.*) in Marmara Region of Turkey. Not Bot Horti Agrobo. 2015;43(1): 138-145.
10. Kuşçu H, Demir AO. Responses of maize to full and limited irrigation at different plant growth stages. Bursa Uludağ Üniv Ziraat Fak Derg. 2012;26(2):15-28.
11. Sohail A, Anwar S, Khan MO, Nawaz S, Shah FA, Ali I, et al. 71. Response of planting methods and deficit irrigation on growth and yield attributes of maize under semi-arid conditions. Pure Appl Biol. 2019;8(1):706-717.
12. Gonzalez MG, Ramos TB, Carlesso R, Paredes P, Petry MT, Martins JD, et al. Modelling soil water dynamics of full and deficit drip irrigated maize cultivated under a rain shelter. Biosyst Eng. 2015;132:1-1328.

13. Abrecht DG, Carberry PS. The influence of water deficit prior to tassel initiation on maize growth, development and yield. Field Crops Res. 1993;31(1-2):55-69.
14. Hussain B, Dawar K, Khan I, Abbas A. Effect of various levels of NP fertilizers on maize (*Zea Mays L.*) under different moisture conditions. Int J Agri. R. 2014;5(4):54-66.
15. Traore SB, Carlson RE, Pilcher CD, Rice ME. Bt and non-Bt maize growth and development as affected by temperature and drought stress. J Agron. 2000;92(5):1027-1035.
16. Tari AF. The effects of different deficit irrigation strategies on yield, quality, and water-use efficiencies of wheat under semi-arid conditions. Agric Water Manag. 2016;167:1-0.
17. Lopez JR, Winter JM, Elliott J, Ruane AC, Porter C, Hoogenboom G. Integrating growth stage deficit irrigation into a process based crop model. Agric For Meteorol. 2017;243:84-92.
18. Li X, Kang S, Zhang X, Li F, Lu H. Deficit irrigation provokes more pronounced responses of maize photosynthesis and water productivity to elevated CO_2. Agric Water Manag. 2018;195:71-83.
19. Mohammadi SA, Khazaei HR, Nezami A. Effects N management on maize grain yield and its component under deficit irrigation. Iran J Field Crops Res. 2017;15(1):61-73.
20. Ha BM. A review of growth stage deficit irrigation affecting sticky maize production. GeoSci Eng. 2017;63(2):13-18.