academicresearchJournals

Vol. 7(5), pp. 289-296, July 2019
DOI: 10.14662/ARJASR2019.100

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Determination of Optimal Irrigation Scheduling and Water Productivity for Wheat (*Triticum aestevum L.*) at Kulumsa, Arsi Zone, Ethiopia

Samuel Lindi[1], Bakasho Iticha[1], Mehiret Hone[1], Kassu Tadese[1] and Wubengida Admasu[1]

[1]Kulumsa Agricultural Research Center, P.O.Box 884, Asella, Ethiopia
Corresponding author's email: samuellindi5@gmail.com

Accepted 31 July 2019

The study was conducted at Kulumsa Agricultural Research Center, Arsi zone, Ethiopia, for Two consecutive years (2015/16 and 2016/17) based on the objective to evaluate the response of crop to irrigation regime (when and how much) and determine the crop water requirement and water productivity of wheat. The experiment was arranged in a Randomized Complete Block Design (RCBD) with three replications. Five level of irrigation scheduling were arranged for the study based on their level of soil moisture depletion (60%, 80%, 100%, 120% and 140% of Allowable Soil Moisture Depletion Level (ASMDL)). The study result revealed that, the variation of soil moisture depletion level from 60% to 140% of the FAO recommendation had no effect on plant heights, Hectoliter weight, total kernel weight and harvesting index. Grain yield, above ground biological yield and water productivity of wheat had statistically significant difference at ($P<0.05$) level. Maximum wheat grain yield of 4,959 kg/ha was obtained at 60% of ASMDL. The maximum grain yield obtained at 60% of ASMDL was statistically similar with control 100% ASMDL treatment and the minimum grain yield of 3,823 kg/ha recorded at 140% of ASMDL. Maximum above ground biological yield of 10,734kg/ha was obtained at 60% of ASMDL, however this result was statistically similar with control treatment. The minimum above ground biological yield of 8,555kg/ha was recorded at 120% of ASMDL. Maximum water productivity of 1.17kg/m^3 was obtained at 60% of ASMDL which was statistically similar with control treatment and the minimum water productivity of 0.98kg/m^3 was recorded at 140% of ASMDL. Since the grain yield and water productivity of 60% of ASMDL and 100% of ASMDL were not significantly different to each other, the control treatment (100% of ASMDL) had recorded longer irrigation interval when compared to 60% of ASMDL. Therefore, irrigation scheme could be used FAO 33 ASMDL recommendation for wheat production at the study area in similar agro-ecology and soil type.

Keywords: irrigation scheduling, wheat, soil moisture depletion, water productivity

Cite this article as: Samuel L., Bakasho I., Mehiret H., Kassu T., Wubengida A. (2019). Determination of Optimal Irrigation Scheduling and Water Productivity for Wheat (*Triticum aestevum* L.) at Kulumsa, Arsi Zone, Ethiopia. Acad. Res. J. Agri. Sci. Res. 7(5): 289-296

INTRODUCTION

Water is essential for crop production and best use of the available water must be made for efficient crop production and high yields. This requires a proper understanding of the effect of rainfall and irrigation on crop growth and yield under different growing conditions (FAO, 1986). Irrigation can be defined as replenishment of soil water storage in plant root zone through methods other than natural precipitation. Irrigation is seen to have found its roots in the history of mankind since earliest beginning. It helps reduce the uncertainties, particularly the climatic uncertainties in agriculture practices. The problem of irrigation consists of when to irrigate, and how much to irrigate.

Crop water requirements (CWR) encompass the total amount of water used in evapotranspiration. FAO (1986) defined crop water requirements as 'the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease free, growing in large fields under non restricting soil conditions, including soil water and fertility, and achieving full production potential under the given growing environment'. The irrigation water requirement represents the difference between the crop water requirement and effective precipitation. The irrigation water requirement also includes additional water for leaching of salts and water to compensate for non-uniformity of water application. For the calculations of the Crop Water Requirements (CWR), the crop coefficient approach is used (Allen et al., 1998).

Water shortage in the country demands to develop new technologies and methods of irrigation that can be help full to utilize this precious input in an effective way. In addition there is also a need to carry out practices of irrigation water management to achieve high water use efficiency.

Wheat (Triticum aestivum L.) is one of the most important staple food crops in the world. Ethiopia is the major producer of wheat in Eastern Africa accounting for over 70% of the total wheat area in the region (Gebre-Mariam, 1991). The two major species of wheat grown in Ethiopia are tetraploid durum and hexaploid bread wheat (Tesemma and Jemal, 1982). Annual crops are moderately to highly sensitive to water stress and the inadequate supply of irrigation water influences the growth and yield (Mishra et al., 1995; Alderfasi and Nielsen, 2001). Under semi-arid conditions, water resources are usually scarce and hence a limiting factor for crop production. Soil moisture deficit (SMD) at a particular magnitude may occur either continuously over the total growing period of the crop or it may occur during any individual growth period. However, different crops have different requirements and respond differently to SMD under different climatic conditions. Therefore, information on optimal irrigation management and the adverse effects of soil moisture depletion levels at different growth stages of bread wheat and yield performance is essential for decision making in irrigation management. Research results have confirmed that some deficit irrigation is successful in increasing the water use efficiency for various crops without causing severe yield reduction (Geerts and Dirk, 2009).

The subsequent irrigations are provided with an interval of 30 – 35 days. This water shortage stresses re-scheduling of irrigation which should not affect grain yield significantly but can reduce the water applied to the crop. Water requirements of wheat vary from 180 to 420mm (Balasubramaniyan & Palaniappan, 2001). Thus, there is sufficient room to carry out research to find out what minimum amount of water should be applied to have maximum yield per millimeter of water applied. Study of soil moisture contents and the patterns of moisture depletion as the crop grows could help to sort out a suitable irrigation schedule for this objective. A lot of scientific work in this respect has been documented. Mohamed (1994) reported that irrigation at 60% ASMD gave the highest grain yield and harvest index in wheat while WUE was the highest with 85% ASMD. Ahmad et al. (1996) observed that increasing SMD from 50% to 75% markedly reduced total yield. Karim et al. (1997) observed that irrigation at 35% available soil moisture depletion (ASMD) gave highest yield (4.71 t ha-1) with the application of 120 kg N while irrigation at 65% ASMD produced satisfactory yield (4.13 t ha-1) with highest WUE (196.5 kg ha-1cm-1) with application of 80 kg N. Similarly, Aydin et al. (2000) reported that irrigation at 66% ASMD was the most effective in terms of grain yield in wheat. Tahmasabi and Fardad (2000) applied irrigation at 10, 25, 50 and 75% soil moisture depletion and observed that grain yields were 3384, 3050, 3094 and 2273 kg ha-1, while water use efficiency was 1.13, 1.05, 0.82 and 0.86 kg m-3, respectively. Narang et al. (2000) found that yield of all wheat cultivars studied decreased with increasing levels of SMD. Water use efficiency was highest with 60% ASMD.

Water is needed to carry out normal physiological activities of the plant. However, the actual water requirement is the quantity of water required to meet the demands of evapotranspiration and the metabolic activities of the plant i.e., consumptive use (CU). Since the water used in actual metabolic processes is insignificant (about 1%), water requirement is usually equal to evapotranspiration or consumptive use. Therefore, the objective of the study were to evaluate the response of crop to irrigation regime (when and how much) and determine the crop water requirement of wheat crop for highest water productivity.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Kulumsa Agricultural Research Center, Tiyo district of Arsi Zone Oromia regional state, Ethiopia. The study area lies between 8°00'59''North latitude, 39°09'25''East longitude and situated to an elevation of 2200m a.s.l. The area is characterized by Uni-modal rainfall pattern with mean annual rainfall of 809.15mm. The climate of the study area is described with maximum and minimum air temperature of 23.08^{0}C and 9.90 ^{0}C, respectively. The soil of the study area is clay loam type, at the experimental site it has a field capacity of 33.60%, wilting point of 21.8 % and the total available water was about 11.80% while, the bulk density is 1.25g/cm. The summarized climate information of the study area is shown in the Table 1.

Table 1: Long term climatic data of KARC Catchment (1979-2009)

Year	RF (mm)	Max T (^{o}c)	Min T (^{o}c)	RH (%)	WS (m/s)	SS (hr)	ETo (mm)
Jan	17.09	23.36	8.21	56.49	4.96	8.18	191.36
Feb	37.66	24.37	9.35	52.89	5.23	8.35	173.18
Mar	79.53	25.07	10.33	50.73	4.36	7.65	182.63
Apr	84.15	24.41	11.50	58.35	4.18	7.23	161.08
May	88.13	24.80	11.16	57.26	4.74	7.28	179.89
Jun	87.04	23.50	10.64	80.58	4.71	6.53	133.03
Jul	124.22	21.16	10.64	76.41	4.84	4.94	128.55
Aug	131.07	20.94	10.38	77.37	3.87	4.96	105.58
Sep	97.86	21.51	9.94	75.38	2.87	5.57	99.01
Oct	42.09	22.75	10.17	60.91	4.98	7.65	192.32
Nov	10.16	22.56	8.70	53.98	5.71	8.75	198.98
Dec	10.15	22.53	7.71	54.23	6.11	9.00	179.27
Total	**809.15**						**1924.87**
Average		**23.08**	**9.90**	**62.88**	**4.71**	**7.17**	

Experimental Design and Management Practice

Wheat *(Triticum aestevum L.)* king bird variety was sown to the experimental plot and it was well-watered to have suitable germination and favorable plant stand. The experimental plot size was 4.0m wide and 4.50m long. The distances between each ridge was 0.40m, while the wheat was sown in double row with 0.20m row spacing. The distances between plots and between replications were 1m and 1.5m, respectively. Sowing was performed by hand drill along the furrow right and left side to make the seed rate uniform. Wheat was fertilized with the recommended rate of 150kg/ha DAP at planting and 100kg/ha Urea was applied half during planting the rest at tillering stage.

Furrow irrigation method was used and the amount of water applied was measured using Parshall flume. Irrigation scheduling was done based on soil water depletion replenishments using the CROPWAT 8.0 software program. Crop water requirement was calculated using CROPWAT 8.0 software computed program based on the FAO Penman equation. Soil water level was monitored by using the gravimetric soil moisture content determination method. Before irrigation and 24hrs after irrigation soil samples were taken from well irrigated plots to check the moisture content at management allowable depletion level and to check the moisture content to field capacity level respectively. The regular agricultural crop management operations were followed.

This experiment was conducted for two consecutive years (2015/16 to 20116/17) during the off season. The irrigation treatments included five levels of soil water depletions depending on FAO 33 soil moisture depletion levels such as: Available Soil Moisture Depletion Level (ASMDL) of 60%, 80%, 100%, 120 % and 140%. Irrigation scheduling was based on the percentage depletion of available soil water in the root zone. The experimental treatments were laid out in Randomized Complete Block Design (RCBD) with three replications, in which the soil moisture depletion levels were randomly assigned to the experimental plots. With the aid of the CROPWAT software, the crop water requirement of wheat was calculated for the various growth stages. The treatment setup is described as follow in Table 2.

Table 2: Treatment setting for field experiment

Treatment	Description
T1= ASMD1	60% of ASMDL
T2= ASMD2	80% of ASMDL
T3= ASMD3	ASMDL*
T4= ASMD4	120% of ASMDL
T5= ASMD5	140% of ASMDL

*ASMD is available soil moisture depletion level according to FAO (33)

Data Collection and Statistical Analysis

Data collection

Cropwat software input data: daily climatic data, soil physical properties: texture, field capacity, permanent wilting point and available water as well as the infiltration capacity of the soils were collected for software inputs. Other inputs required by the model include the crop type, information on growth stages and their periods up to maturity, effective rooting depth and days to maturity were obtained from FAO Irrigation and Drainage Paper 2005. The summarized crop water requirement of wheat for the study area is shown in the Table 3. Agronomic data wheat yield and yield components that include plant height, hectoliter weight (HLW), total kernel weight (TKW), harvesting index (HI) above ground biological yield and grain yield were collected for analysis.

Estimation of water productivity was carried out as a ratio of total bulb yield to the total water applied (Central Statistics, 2011). The effect of water stress on crop yield performance was quantified by yield response factors (Ky) formula.

$$\text{Water Productivity}\left(\frac{\text{kg}}{\text{m3}}\right) = \frac{\text{Total Bulb Yield(kg)}}{\text{Crop Water Use (m3)}}$$

The yield response factor (Ky) was estimated from the relationship (Simonne EH., 2010).

$$K_y = \frac{\left[1-\left(\frac{Y_a}{Y_m}\right)\right]}{\left[1-\left(\frac{ET_a}{ET_m}\right)\right]}$$

Where: K_y=Yield response factor, Y_a=Actual harvested yield, Y_m=Maximum harvested yield, ET_a=Actual Evapo-transpiration, ET_m=Maximum Evapo-transpiration

Statistical Data Analysis

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

RESULT AND DISCUSSION

Crop Water Requirement of Onion

The average of 31 years rainfall pattern data indicated that irrigation practice during off season starting from November to April very critical in the study area. This indicates the average rainfall obtained during the experimental year is low. The result showed the crop water requirement of onion in the study area is

Table 3: Crop water requirement and net irrigation of wheat at Kulumsa Research Center

Growing stage	Growing Date (day)	ETc (mm/d)	Net IR (mm)	CWR (mm)
Initial	30	1.62	48.90	75.23
Development	30	4.50	135.00	207.69
Mid	40	4.35	174.00	267.69
Late	20	3.38	67.60	104.00
Total	**110**		**425.50**	**654.62**

654.62mm and the net irrigation requirement is 425.50mm (Table 3).

CropWat 8.0 software model and FAO irrigation and drainage paper 33, Penman Monthez equation has been used to calculate the optimal irrigation of wheat and Available soil moisture depletion level (ASMDL). Then, two years field experiment was implemented to analyze the effect of different ASMDL levels on the yield of wheat and water productivity.

The statistical analysis of variance of plant height, HLW, TKW and HI showed that there were no significant differences among ASLDL at $P<0.05$ level. However, grain yield, above ground biological yield and water productivity of the wheat crop affected significantly by soil moisture depletion level at ($p<0.05$) level. The data on Table 4 provide analysis of variation for plant height, HLW, TKW, HI grain yield, above ground biological yield and water productivity.

Plant Height

The soil moisture depletion levels were not significantly affected the plant height of wheat. The statistical analysis of variance show that, there was no significant difference between treatment at ($p<0.05$) level. Maximum plant height (70.67cm) was obtained from treatment received 60% of ASMDL and the minimum (64.17cm) was from 80% of ASMDL (Table 4). However, the maximum plant height was obtained at 60% of ASMDL,

Hectoliter Weight

The analysis of variance revealed that, the depletion levels in soil moisture had no significant influence on hector liter weight of wheat crop at ($p<0.05$) level (Table 4). The minimum and maximum hector liter weight of wheat ranges from 230.57 to 232.03kg/hl, respectively.

Total Kernel Weight

The variation in soil moisture depletion levels had no significant effect on total kernel weight of wheat at ($p<0.05$) level (Table 4). The maximum total kernel weight (42.83g) was obtained from treatment received 60% of ASMDL and the minimum (38.04g) was from 80% of ASMDL (Table 4). Though, treatment 60% of ASMDL had statistically similar total kernel weight with all treatments except 80% of ASMDL.

Harvesting Index

The analysis of variance revealed that soil moisture depletion stress at different level of wheat had no significant ($p<0.05$) influence on harvesting index (Table 4). However, mean harvesting index varies from 40 to 46.6%. This might be as the amount of irrigation amount reduced due to soil moisture depletion at different level, both grain yield and aboveground biomass production reduced similarly and vice versa. This is in line with former report of Elias *et al*. (2017) who reported different levels of moisture stress had no influence on harvesting index. Khakwani *et al.* (2011) also reported a similar finding due to moisture stress, despite different wheat varieties showed different harvesting index.

Above Ground Biological Yield

Different levels of ASMDL were significantly influence above ground biomass yield of wheat at ($p<0.05$) level. The highest above ground biological yield (10,734kg/ha) of wheat was recorded from the 60% of ASMDL treatment and this treatment was statistically difference from all treatments except treatment received 100% of ASMDL FAO ($p=0.55$). The lowest above ground biological yield (8,554kg/ha) of wheat was obtained from treatment received 120% of ASMDL and this treatment was statistically similar with treatment received 80% and 120% of ASMDL (Table 4). Narang et al. 2000 found that yield of all wheat cultivars studied decreased with increasing levels of soil moisture depletion level. R. K. Panda et al (2005) reported that above ground dry matter also followed a similar trend as that of grain yield. It was observed that, when the irrigation was scheduled at a depletion level of less than or equal to 45% MAD, there was no significant change in the plant above ground dry matter yield. However, a reduction in the above ground dry matter yield was noticed when the irrigation was scheduled at 60% to 75% MAD because soil moisture was depleted sufficiently and affected the root water extraction. Similar trend was observed during all the three experiments for wheat crop. This finding is also in line with FAO which recommend 60% depletion level for production of grass species (FAO 1998). This might be due to the optimum depletion level lemongrass required is 60% of TAW both for optimum water and air circulation in the root depth. This could be as soil gets dried beyond 60% the crop experience stress in the growing season due to photosynthesis interruption due to shortage of water supply (Makino A., 2011).

Grain Yield

The analysis of variance revealed that different soil moisture depletion level influence grain yield of wheat at ($P<0.05$) (Table 4). Maximum grain yield of 4,959kg/ha was obtained due to 60% of ASMDL treatment. However, the highest grain yield obtained at 60% of ASMDL treatment was statistically similar with grain yield obtained when moisture depletion imposed 100% of ASMDL FAO (p=0.55). On the other hand, minimum grain yield of 3,823 kg/ha was obtained when soil moisture depletion 140% of ASMDL. However, the minimum grain yield obtained when at 140% of ASMDL was statistically similar with 80% and 120% of ASMDL treatments.

The result indicated that 60% of ASMDL has increased the grain yield and water use efficiency of wheat grain yield on a clay loam textured soil. However, the reduction of soil moisture depletion level below the recommended FAO value (100% of ASMDL) by 40%, increase the frequency of irrigation number. Therefore the adoption of FAO 33 recommendation of allowable soil moisture depletion level is better in terms of longer irrigation interval, which minimizes irrigation frequency to save labor conception in comparison with 60% of ASMDL treatments.

Table 4: Statistical ANOVA table of PH, HLW, TKW, HI, GY AGY and WP

Treatments	PH (cm)	HLW (kg/hl)	TKW (gm)	HI (%)	GY (kg/ha)*	ABY (kg/ha)*	WP (kg/m^3)**
T1	71.67	232.03	42.83a	46.21	4,959a	10,734a	1.17a
T2	64.17	231.91	38.04b	44.10	3,945bc	8,750b	0.93bc
T3	70.00	231.18	39.29ab	48.05	4,800ab	9,950ab	1.12ab
T4	65.67	231.50	39.51ab	44.29	3,929bc	8,554b	0.92bc
T5	68.83	230.57	40.13ab	43.89	3,823c	8,668b	0.89c
$LSD_{0.05}$	**ns**	**ns**	**ns**	**ns**	**9.47**	**16.11**	**0.22**
CV (%)	**9.87**	**3.34**	**7.61**	**8.51**	**18.42**	**14.33**	**18.42**

Note: Means followed by the same letters in a column are not significantly different from each other at a 5% probability level.

Water Productivity

Water productivity result showed that, there was significance difference at $P<0.05$ level. The highest water productivity of wheat grain yield was observed at 60% of ASMDL treatment (Table 5). The maximum water productivity 1.17kg/m^3 was recorded at 60% of ASMDL depleted from the soil. This treatment was not statistically different from 100% of ASMDL treatment. Contrary to this, the minimum water productivity of 0.89kg/m^3 was recorded when wheat irrigated after 140% of the ASMDL from the soil. The minimum water productivity obtained at 140% of ASMDL was statistically similar with 80% and 120% of ASMDL treatments. The study showed that irrigating wheat at 60% of ASMDL depletion from the soil improved water productivity by 3% than the 100% ASMDL depleted from the soil treatment. Improving water productivity is an increasing concern through different irrigation practice to enhance yield of crop per irrigation water used.

Different studies on different crops revealed that water productivity improved based on different irrigation practice like determining the optimum soil moisture depletion level before. The results obtained from this experiment (60% of ASMDL) were no statistical difference from the recommended ASMDL of FAO 33. Among all treatments Treatment (60% of ASMDL) performed high water productivity. As there is no significance yield reduction between 60% and 100% of ASMDL treatments, it is better to select the efficient water saving application in order to improve water productivity. Therefore, 100% of ASMDL is the best water productivity application without significant yield reduction.

Table 5: The amount of water applied, grain yield obtained and yield reduction observed due to different soil moisture depletion level on wheat crop.

Treatments	Water Applied (mm)	Grain yield (kg/ha)	Yield Reduction (%)	WP (kg/m^3)
T1	425.50	4,959	-	1.17
T2	425.50	3,945	17.83	0.93
T3	425.50	4,800	-	1.12
T4	425.50	3,929	18.14	0.92
T5	425.50	3,823	20.36	0.89

CONCLUSION AND RECOMMENDATION

Water is essential for crop production and best use of the available water must be made for efficient crop production and high yields. This requires a proper understanding of the effect of water-rainfall and irrigation- on crop growth and yield under different growing conditions (FAO, 1986). Soil water monitoring is important for proper irrigbation water management and scheduling. The determination of optimal irrigation scheduling for water productivity of wheat was conducted at Kulumsa Agricultural Research Center, Arsi zone, Ethiopia based on the objective to evaluate the response of crop to irrigation regime (when and how much) and determine the crop water requirement of wheat. Five level of irrigation scheduling were arranged for the study based on their level of soil moisture depletion (60%, 80%, 100%, 120% and 140% ASMDL of FAO recommendation). Variation on the level ASMDL had significant effect on wheat grain yield, above ground biological yield and water productivity, in contrary to this, no significant effect were obtained on plant heights, HLW, TKW, and HI at ($p<0.05$). Maximum grain yield and water productivity of 4,959kg/ha and 1.17kg/m^3 were obtained at 60% of ASMDL respectively. The minimum grain yield and water productivity of 3,823kg/ha and 0.89 kg/m^3 were recorded at 140% of ASMDL respectively. Since the water productivity of 60% of ASMDL had not statistically different from FAO 33 recommendation (100% of ASMDL), the adoption of FAO 33 recommendation of allowable soil moisture depletion level is better in terms of longer irrigation interval, which minimizes irrigation frequency to save labor consumption when comparison with 60% of ASMDL treatments. Therefore, it is fair to recommend the FAO 33 depletion ($p=0.55$) for wheat production at the study area in similar agro-ecology and soil type.

ACKNOWLEDGMENT

The authors are grateful to Ethiopian Institute of Agricultural Research, for providing funds for the experiment and technical support. The authors also very grateful to Kulumsa Agricultural Research Center, Technical Assistant’s: Mr. Mengistu M., Alemayehu W., Dawit T. and all staff of natural resources management research process for giving us support in field management, suggestion and technical guidance during the experiment.

REFERENCES

Ahmad, A.T., K.W. Khalil, F.A. Bouthaina, El–Ghany and S.Y. Awadalla, 1996. Ameliorating the properties of virgin sandy soil and its impact on wheat production. Desert Ins. Bull., (Egypt) 46: 319–39

Alderfasi, A.A. and D.C. Nielsen. 2001. Use of crop water stress index for monitoring water status and scheduling irrigation in wheat. Agricultural Water Manamgement 47 (1): 69–75.

Allen, G.R., Pereira, S.L., Raes, D. and Smith, M., 1998. Crop Evapotranspiration – guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper No 56, Rome.

Aydin, M., M. Kalayci and H. Ekiz, 2000. Effect of irrigation applied depending on soil moisture on some wheat cultivars. Orta Anadolu'da hububat tarmnn sorunlar ve cozum yollar Sempozyumu, Konya, Turkey, 8–11 (Haziran 1999–2000, 196–202)

Balasubramaniyan, P. and S.P. Palaniappan, 2001. Principles and Practices of Agronomy. Agrobios, Jodhpur, India.

Doorenbos, J., and Kassam, A.H., 1979. Yield response to water. FAO Irrigation and Drainage Paper 33. FAO, Rome.

Elias Meskelu, Abraham Woldemichael and Tilahun Hordofa. 2017. Effect of Moisture Stress on Yield and Water Use Efficiency of Irrigated Wheat (Triticum aestivum L.) at Melkassa, Ethiopia. Acad. Res. J. Agri.

Sci. Res. 5(2): 90-97.
FAO (Food and Agricultural Organization) (1998) Crop Evapotranspiration: guideline for computing crop water requirements. Irrigation and drainage paper No. 56, FAO, Rome.
Gebre-Mariam, H. 1991. Wheat production and research in Ethiopia, pp. 1–15. In H. GebreMaariam, G, D.G. Tanner and M. Hulluku. (eds.) Wheat Research in Ethiopia, 2nd edition: A Historical Perspective. IAR/ CIMMYT, Addis Ababa, Ethiopia.
Geerts, S. and R. Dirk. 2009. Deficit irrigation as an on farm strategy to maximize crop
productivity in dry area. Agricultural Water Management 96: 1275–1284.
Karam, F., R. Kabalan., J. Breidi., Y. Rouphael. and T. Oweis. 2009. Yield and water function of two durum wheat cultivars growing under different irrigation and nitrogen regimes. Agricultural Water Management 96(4): 603–615.
Karim, A.J.M.S., K. Egashira and M.J. Abedin, 1997. Interaction effects of irrigation and nitrogen fertilization on yield and water use of wheat grown in a clay terrace soil in Bangladesh. Bull. Inst. Tropical Agric., 20: 17–26
Khakwani, A. A., Dennett, M. D. and Munir, M. 2011. Drought tolerance screening of wheat varieties by inducing water stress conditions. Songklanakarin J. Sci. Technol. 33 (2): 135- 142.
Makino A (2011) Photosynthesis, grain yield and nitrogen utilization in rice and wheat. Plant physiology American Society of Plant Biologiest 155: 125-129.
Mishra, H.S., T.R. Rathore and V.S. Tomar. 1995. Water Use efficiency of irrigated wheat in the Tarai region of India. Irrigation Science 16: 75–80.
Mohamed, K.A., 1994. The effect of foliage spray of wheat with Zn, Cu, Fe and urea on yield, water use efficiency and nutrients uptake at different levels of soil salinity. Assiut J. Agric. Sci., 25: 179–89.
Narang RS, Gill SM, Gosal KS, Mahal SS (2000) Irrigation and N –fertilizer requirements for maximum yield potential of wheat. J Res Punjab Agric 37: 20-27
Penman, H. L. 1971: "Potential Crop Production". p89-99. Edited by P. F. Wareing and J. P. Cooper. Heinemann, London.
R. K. Panda, S. K. Behera and P. S. Kashyap (2003) Effective Management of Irrigation Water for Wheat Crop Under Stressed Conditions Using Simulation Modeling Seventh International Water Technology Conference Egypt 1-3
Simonne EH, Dukes MD (2010) Principles and practices of irrigation management for vegetables UF. University of Florida. pp: 17-23.
Tahmasabi, R. and H. Fardad, 2000. Effect of irrigation starting with different readily available soil water on winter wheat yield in Karaj area. Iranian J. Agric. Sci., 31: 111–8
Tesemma, T. and M. Jemal. 1982. Review of wheat breading in Ethiopia. Ethiopian Journal of Agricultural Sciences