Hot pepper response to deficit Irrigation levels at different growth stages on yield and water productivity

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Abstract

This study examines the effects of deficit irrigation on yield and water use of hot pepper under fully irrigated field conditions during the 2018 to 2020 growing season. The design of the experiment was split plot design with three replications. The treatments have four crop growing seasons or stages (Initial, Development, mid-season and late season stages) and three deficit irrigation levels for each growing stages (100 % Etc, 75% Etc, and 50 % Etc levels), in which the growing stages arranged as a main plot and the deficit level laid as sub-plot. In this finding the deficit at initial crop growth stage with 100%ETc irrigation water application result in the highest marketable yield (7881kg/ha) and the lowest have been recorded with deficit at 50%ETc during the late-crop growth stage (3478kg/ha). The highest WUE was recorded for initial crop growth stage and 100%ETc treatments (1.755kg/m3) while the lowest one was obtained from late-crop stage and 100%ETc treatment (0.842kg/m3). The yield response factor (ky), which is the slope of the relative ET deficit versus relative yield reduction relation, for pepper was found to be 1.24 whole growing season. This study revealed that not only identify the crop growth stage determinant in loss of yield due to deficit irrigation technique but also the possibility to produce extra yield from 25%ETc irrigation water saved at initial growth stage, up to 33% additional production as well as the highest water productivity.

Key words: Hot Pepper, deficit irrigation, water use efficiency, yield response factor,

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INTRODUCTION

Water has to be treated as a scarce resource, with a far stronger focus on managing demand. The demand for fresh water is constantly increasing among all water users. Water scarcity is one of the leading challenges of the twenty-first century, and it is expected to intensify as a result of climate change. Water scarcity can be a result of lack of regular supply or adequate infrastructure[1]. As agriculture is the largest user of freshwater resources, water-saving technologies and use of alternative types of water can have a considerable impact on sustainable water management which is essential to resilient food systems.

Irrigation in Ethiopia consumes a large amount of water extracted from various sources. Hence, efficient water use and management are currently the major concerns in the country. Irrigation water is generally limited or mismanaged in all irrigation schemes, and is among the major challenges constraining agricultural production in Ethiopia [2]. Smallholder irrigation schemes in Ethiopia are generally characterized by poor on-farm water management practices and hence poor performance[3]

Deficit irrigation is a water management strategy that concentrates the application of limited seasonal water supplies on moisture-sensitive crop growth stages to maximize the productivity of applied water[4]. Crops are different in their response to water stress at a given growth stage. In this method, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season[5].

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The production of pepper in Ethiopia have been diversified with a range of varieties grown and scale of production from home garden and near settlement areas to large scale peasant and commercial farms[6].

Hot pepper (capsicum) is one of the major high value vegetable crops (also used as spice) produced in Ethiopia and the country is one of a few developing countries that have been producing paprika and capsicum oleoresins for domestic and export market. Because of its wide use in Ethiopian diet, the hot pepper is an important traditional crop mainly valued for its pungency and color in the form of karia (green pod) and berbere (dry pod in ground powder)[7-9].

Hot pepper planting is confined to warm and semi-arid countries where water is often a limiting factor for production. This necessitates the optimization of water management for pepper production because it is considered one of the most susceptible horticultural plants to water stress. Where the benefit from saving water outweighs the decrease in the total fresh mass of fruit, deficit irrigation could be feasible irrigation strategy for hot pepper production[10].

In the fact that the amount of water available for agriculture is generally limited overall the world and especially In Ethiopia, knowledge about the relationship between yield and quality of the product and irrigation regimes is important to maximize the benefit of the available water supply.

Therefore, the objectives of this study are: (i) to investigate the effect of water stress at different growth stage on yield and water productivity of hot pepper (Melka Awaze) and to identify the most sensitive growth stage to deficit irrigation.

MATERIALS AND METHODS

The study was carried out in Amibara district of Afar region, Ethiopia at Werer Agricultural research Center from 2018 to 2020 cool season. The design of the experiment was split plot design with three replications. The treatments have four crop growing seasons or stages (Initial, Development, mid-season and late season stages) and three deficit irrigation levels for each growing stages (100 % Etc, 75% Etc, and 50 % Etc levels), in which the growing stages arranged as a main plot and the deficit level laid as sub-plot.

The individual plot size, inter row and intra row spacing will have appropriate dimensions which may vary depending on the type of crops. The irrigation amount of 100 % Etc for each growing season has been computed from soil and climate parameters of the experimental site. The amount of irrigation water to be applied at each irrigation application treatments have been measured using Parshall flume.

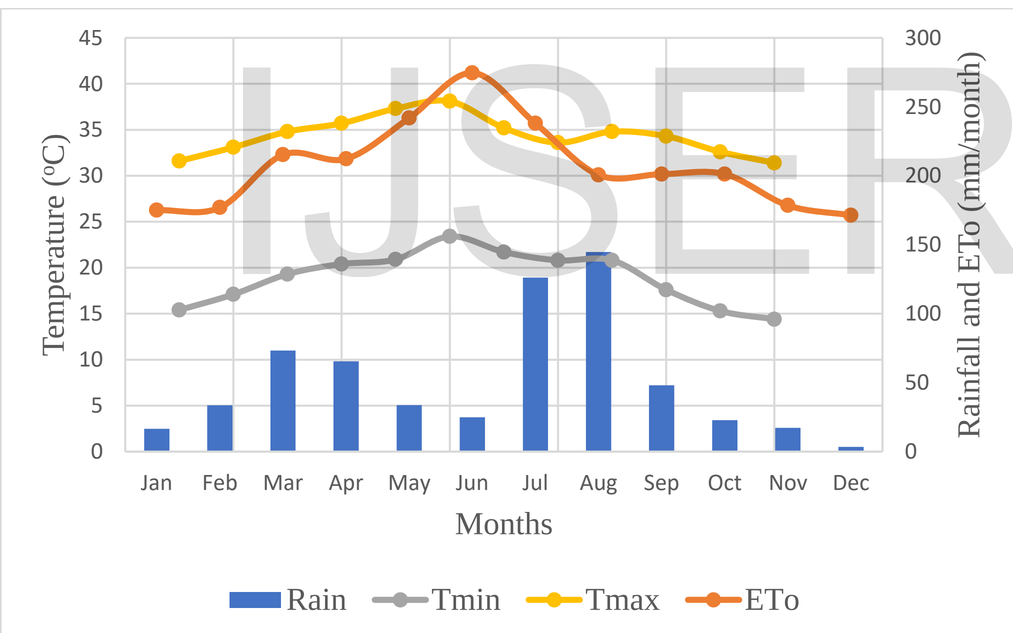

Figure 1. Climate of the study area (1965-2019).

Soil of study area

Table 1. Soil Moisture characteristics

Parameters	Dark Vertisol
FC(W/W%)	46
PWP(W/W %)	30.4
TAW(W/W%)	15.6
BD	1.17
TAW(mm/m)	182.52

Water productivity (WP)

Water productivity will be estimated as a ratio of aboveground dry matter at maturity or grain yield to the total Etc through the growing season and it will be calculate using the following equation [11].

$$CWP = (Y/ET)$$

Where, CWP is crop water productivity (kg/m^3), Y crop yield (kg/ha) and ET is the seasonal crop water consumption by evapotranspiration (m^3/ha).

Yield response factor (Ky)

The relationship between the evapotranspiration deficit [1 – (ETa/ETc)] and yield depression [1 – (Ya/Ym)] is always linear. The slope of this linear relationship is always called yield response factor or crop response factor (Ky) [12]. The Ky is the yield response factor that is defined as the decrease in yield per unit decrease in ET [13]. This relationship is expressed by the following equation:

$$[1 - (Ya/Ym)] = Ky\,[1 - (ETa/ETm)]$$

Where, Ym ($kg\ ha^{-1}$) and Ya ($kg\ ha^{-1}$) are the maximum (from a fully irrigated treatment) and actual yields, respectively. The ETm ($m^3\ ha^{-1}$) and ETa ($m^3\ ha^{-1}$) are the maximum (from a fully irrigated treatment) and actual evapotranspiration, respectively, while Ky is the yield response factor.

Data Analysis

Stand count was counted during the first harvest. Fruit yield (green pod) was harvested at appropriate maturity time and weight was taken for each treatment. Harvested pods were categorized as marketable and non-marketable fruits depending up on visible damages, spots and discoloration due to biotic and abiotic stresses. Yield and yield components data and water

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productivity data were subjected to statistical analysis using Genstat 18th Edition and least significance difference (LSD) was used to compare treatment means when there was statistically significant difference (P<0.05).

RESULT AND DISCUSSION

Stand Count (SC):

The analysis of variance revealed that the means of stand count in interaction between the growth stage and irrigation level statistically at (P<0.05) significant. The largest plant population was recorded in the treatment Late growth stage and 75% ETc application of water (16345 plant /ha) and the lowest at mid growth stage with 100%ETc irrigation water application (12146plant/ha).

Table 2.Summary of result

GS*IL	SC	MY	UMY	TY	WUE
INTI 100%ETC	15443ab	7881a	193.1ef	8075a	1.755a
INTI 75%ETC	14179abcd	6306bc	346.7bc	6653bc	1.464ab
INTI 50%ETC	14097bcd	5192cde	230def	5422cde	1.209bc
DEV 100%ETC	14972ab	7425ab	331bcd	7756ab	1.686a
DEV 75%ETC	12732cd	6048cd	239.2def	7756ab	1.484ab
DEV 50%ETC	14770abc	4377efg	242.6cdef	4620ef	1.193bc
MID 100%ETC	12146d	4419efg	178ef	4597ef	0.999cd
MID 75%ETC	16206ab	4872def	269.2cde	5141def	1.214bc
MID 50%ETC	15593ab	4435efg	388.6b	4824ef	1.247bc
LATE 100%ETC	15051ab	3697fg	178ef	3875f	0.842d
LATE 75%ETC	16345a	4059efg	143.6f	4202ef	0.992cd
LATE 50%ETC	14097bcd	3478g	527.6a	4006f	1.035cd
l.s.d.	2202.21	1265.7	104.683	1293.54	0.3
CV %	8.4	14.4	24.3	13.8	13.9

ETc= Crop Evapotranspiration, GS= growth stage, IL= Irrigation level, SC= Stand count, MY= Marketable Yield, UMY= Unmarketable Yield, TY= Total yield, WUE= Water use Efficiency; Letters indicate significant differences at *P<0.05.

Marketable Yield (MY)

The analysis of variance on marketable yield revealed that there were highly significant differences ($P<0.05$) between treatment means of factors interaction effect. In this finding the deficit at initial crop growth stage with 100%ETc irrigation water application result in the highest marketable yield (7881kg/ha) and the lowest have been recorded with deficit at 50%ETc during the late-crop growth stage (3478kg/ha). This result is in conformity with the work of [14] and[15].

Unmarketable Yield (UMY)

In this study, the analysis of variance shows significant difference on the interaction effect of growth stages and irrigation level factors at ($p<0.05$) significance interval. Application of irrigation water at 50%ETc in the Late-crop growth stage produce highest unmarketable yield(527.6kg/ha) and the treatment Late-crop growth stage in combination with 75% ETc irrigation water application produced the lowest unmarketable yield(143.6kg/ha).

Total Yield (TY)

Total yield data in table 2 indicated significantly influenced ($P<0.05$) by the interaction effect of irrigation level and growth stage. Significantly higher total yield (8075kg.ha-1) was produced at initial growth stage and 100% ETc whereas significantly lower total yield (3875Kg.ha-1) was obtained at late growth stage with 100% Etc irrigation level of Melka Awaze variety.

Average fruit length (AFL) and Average Fruit diameter (AFD)

Fruit length and fruit diameter are a quality measuring parameter in hot pepper production. In this experiment the average fruit length was not differ significantly between the treatment means in both growth stage and irrigation separately nor in their interaction effect at ($p<0.05$) significance interval. The average fruit diameter differs significantly at($p<0.05$) due to the irrigation level factor with the highest mean value 1.265cm applied irrigation water 75%ETc and the lowest 1.096cm diameter treatment irrigation water applied 50%ETc observed. This could be due to lack of water shortage. There was also no significance variation ($p<0.05$) observed between treatment means due to crop growth stage and interaction effect in the study area.

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Table 3. Average fruit diameter and Average Fruit length

AFD		AFL
GS	Mean	Mean
DEV	1.18	7.6
INTI	1.22	8.04
LATE	1.19	7.59
MID	1.23	7.61
l.s.d.	NS	NS
CV %	12.1	5.9
IL		
100%ETC	1.247a	7.78
75%ETC	1.265a	7.7
50%ETC	1.096b	7.65
l.s.d.	0.126	NS
CV %	12.1	5.9

AFD= Average Fruit Diameter, AFL= Average Fruit Length Letters indicate significant differences at *P<0.05

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Yield response factor (Ky)

The yield response factor (ky), which is the slope of the relative ET deficit versus relative yield reduction relation, for pepper was found to be 1.24 whole growing season (Figure 2).

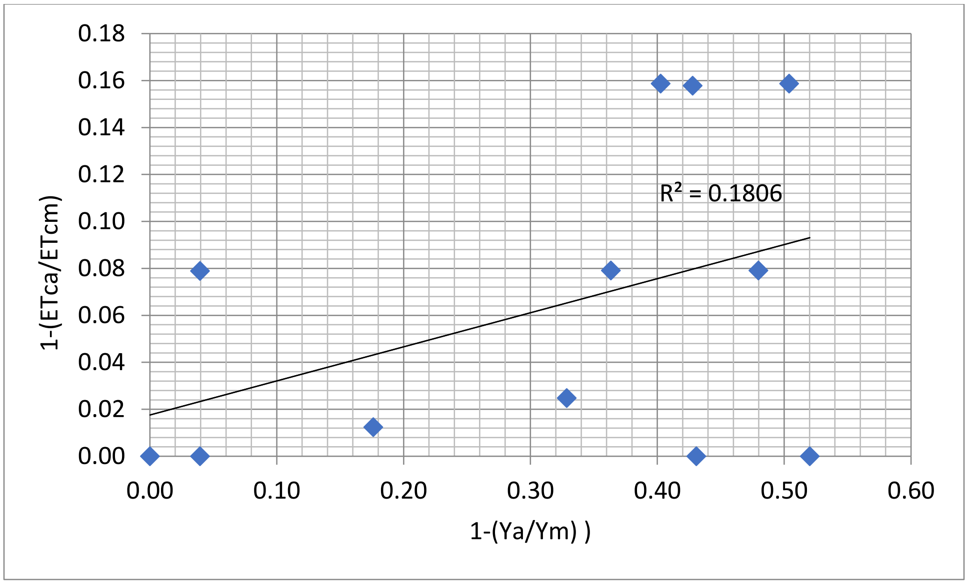

Figure 2. Relationships between relative yield reduction and relative evapotranspiration deficit for hot pepper (ky).

For planning of water supply and water use in terms of crop yield and production, yield response factor (ky) important parameter. Under conditions of limited water distributed equally over the total growing season, the crop with (ky>1) would suffer a greater yield loss than the crop with (ky<1). On this study the slopes of the relationships between relative dry hot pepper yield reduction and relative evapotranspiration deficit (Ky) were found to be 1.24 which corresponded to the result obtained by [15, 16]

Water use efficiency (WUE)

The water use efficiency for fully and deficit irrigation treatments are presented in (table 2) above. There were highly significant differences among treatment means ($p<0.05$). Increasing the irrigation deficit was met by a high increase in the WUE. The highest WUE was recorded for initial crop growth stage and 100%ETc treatments (1.755kg/m^3) while the lowest one was obtained from late-crop stage and 100%ETc treatment (0.842kg/m^3). Increasing the deficit irrigation reduce the yield but increase the water saving.

CONCLUSION

Small scale farmers cultivate Hot pepper under irrigation in warm season and it is a high value crop that increases the livelihood of producers. In dry season and in fully irrigated areas water is the limiting factor for production of any crop. Initial- crop growth stage of hot pepper (Melka

Awaze) is highly sensitive to deficit irrigation. This study revealed that not only identify the crop growth stage determinant in loss of yield due to deficit irrigation technique but also the possibility to produce extra yield from 25%ETc irrigation water saved at initial growth stage, up to 33% additional production as well as the highest water productivity. The late crop growth stage is the most sensitive growth stage so as stressing of water during this stage will cause yield. Deficit irrigation could be a feasible irrigation technique for hot peeper production where the benefit from saving large amount of water in arid and semi-arid agro-ecology as shortage of water is determinant.

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