Irrigation in Various Growth Stages effect on Yield and Water Productivity of Drip-Irrigated Sunflower in Semi-Arid Konya Environment, Turkey

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Abstract

This research was conducted to determine water application of different plant growth stages affect on yield and some yield components of drip-irrigated sunflower plant in Research Station of Agricultural Faculty of Selçuk University for 2014. In that regard, a total four-irrigation treatments namely irrigation at all plant growth stages (irrigation in vegetative, flowering and pod filling, VFPF), at only vegetative stage (V), at only flowering stage (F), and at only pods filling stage (PF). Total applied water and evapotranspiration, ETc, varied from 530 mm (VFPF) to 164 mm (V), and from 662 mm (VFPF) to 326 mm (V), respectively. The maximum seed yield as 4911 hg/ha was obtained from the VFPF while the lowest one as 1711 kg/ha from PF irrigation treatments. Water Use Efficiency, WUE, and Irrigation Water Use Efficiency, IWUE, were varied from 0.46 (PF) to 0.85 (F), and from 0.84 (PF) to 1.51 (F), respectively. It is very obvious that water productivity was found maximum in F treatment. In water rich environments, VFPF irrigation treatment is beneficial for maximal yield, and F irrigation treatment is strongly advisable to get reliable yield as well as for irrigation more lands with current water supplies in regions where water scarcity is a big problem such as arid and semi-arid climates. Since, seed yield was found second rank in F irrigation treatment just after the first rank of VFPF irrigation treatment. In result, sunflower plant cannot be exposed to the water stress conditions especially in flowering stage.

Key Words: Sunflower, growth stage, seed yield, crop water use, water productivity.

Introduction

Efficient use of current water supplies particularly groundwater resources in irrigation is very important playing role for sustainable agriculture in water limited environment such Konya plain of Turkey. The main target for water organizers is to obtain maximal yield from the unit irrigation water particularly in those water poor places (Acar *et al.* 2018). In that regard, correct irrigation program is necessary to achieve that target (Yavuz *et al.* 2016). In Konya plain, annual mean precipitation is around 323 mm and about 90 or 100 mm has been observed during crop vegetation period. It is almost impossible for agro-production especially for summer crops without irrigation in Konya plain of Turkey.

Groundwater resources have used with an increase in irrigation, and sprinkler irrigation is very common with an application efficiency of about 73% (Topak *et al.* 2008). Yavuz *et al.*,

(2015) reported that use of fresh water resources in irrigation is about 75% in region and higher than average worldwide. In accordance of present water use status, water saving must be started in irrigation at first.

In Konya basin, cereal, sugar beet, maize plant as silage or grain, alfalfa and dry bean are common field crops. In recently, cultivation area of sunflower has increased notably in Konya and is one of the important production centers in Turkey.

The farm size and seed yield of sunflower are about 27 million ha and 47.50 million ton, respectively in accordance of 2016 record in the world. In last decade, the production area has been widening due to the increment in sunflower oil demand in Turkey. The sunflower, very important source of oil for both world and Turkey, is top rank of both production area and yield for Turkey. The 46% of oil demand has been met from oil sunflower plants in Turkey. Depending on the production years, the production area has reached up to the 6 167 800 ha (Sefaoglu and Kaya, 2018). Like the other agro-plants, correct selection of sunflower cultivar well suited for the region is possibly one of the most important issues resulting high and qualified yield (Ozturk and Kızılgeci, 2018).

There is direct relationship between correct irrigation program and crop yield, and there is no doubt that maximum and qualified yield is obtained from full irrigation treatment. In regions where the water resources are limited, deficit irrigation up to the certain level is practical way to put more area into production with using same amount water. Kazemeini *et al.*, (2009) stressed that deficit irrigation is an alternative strategy to improve water productivity especially in water poor regions. They highly recommended row spacing of 75 cm, and 25% deficit irrigation had no resulting significant reduction in both seed yield and quality of sunflower plant. Considering crop, growth stages are very important for deficit irrigation program. In that regard, they told that deficit irrigation is not applicable for flowering stage of sunflower. Kadayıfcı and Yıldırım (2000) performed a field research to determine irrigations at different crop growth stages affect on applied water, evapotranspiration, ETc, and yield response factor, ky, under Ankara conditions of Turkey for clay or clay-loam soil conditions. They reported applied water in 1994 and 1995 for plot with irrigation at all growth stages as about 903 mm and 643 mm, respectively. They stated ETc values as 929 mm and 755 mm, respectively for those similar conditions. Seed yield of 2332 kg/ha and 2734 kg/ha were obtained from the plot having irrigation all growth stages in 1994 and 1995, respectively. The ky value varied from 0.16 to 0.75, and from 0.12 to 0.71 in 1994 and 1995, respectively.

Although some studies are available in the literatures about the conventional deficit irrigation affect on yield and yield components of oil sunflower, almost none or very little study was performed about the deficit irrigation within plant growth stages affect on yield and water productivity of such plant especially in Konya Basin of Turkey. The aim of present study is, therefore, to analyze deficit irrigation in growth stages affect on yield and water use efficiencies of drip-irrigated sunflower plant for Konya province of Turkey.

Material and Methods

This study was performed at Sarıcalar Research and Experimental Fields of Agricultural Faculty of Selçuk University in 2014. The research site is within Konya City, Turkey and is about 20 km far from the Selçuk University Campus. The geographical position of experimental site is 38°05′ North latitude and 32° 36′ East longitude with 1006 m above the sea level. The chemical such as pH and organic matter content, (OM) and physical characteristics such as soil texture, field capacity (FC), permanent wilting point (PWP) and available water capacity (AWC) of study soils were given at Table 1. As seen Table 1, soil texture and AWC for 0-90 cm soil depth were clay-loam (CL) and 153 mm/0.90 m, respectively. In examine the soil in research site; both chemical and physical compositions were favorable for sunflower farming.

Some climate data during the vegetation periods of sunflower plant were obtained by using the portable meteorological device, Davis Vantage Pro2, mounted within the research site and long-term climate data were taken from the Konya Meteorology Central Directorate (Table 2). In Table 2, the measured climate data recorded in 2014 were parallel with the long term climate data of 1960-2014 periods. The total precipitation recorded at 2014 was about 113 mm. The data of 2014 relevant to the mean temperature, wind speed and relative humidity were found different from long-term climate data.

Table 1. Some physical and chemical components of research site as an average for 0-90 cm.

Parameters	
Texture	Clay-loam
FC (field capacity), $m^3\ m^{-3}$	0.43
PWP (permanent wilting point), $m^3\ m^{-3}$	0.26
Drz (root zone depth), m	0.9 m
Mean bulk density, $g\ cm^{-3}$	1.29
AWC (total available water), mm	153
pH	7.85
Organic Matter, OM, %	1.52

Table 2. Some climate parameters of research site

Months		**Mean temp. (°C)**	**Mean wind speed ($m\ s^{-1}$)**	**Mean Relative humidity (%)**	**Rainfall (mm)**
April	2014[a]	11.1	2.2	57.5	5.6
	54 years*	10.9	2.4	58.3	34.1
May	2014	15.4	2.3	53.1	31.6
	54 years*	15.7	2.2	55.9	43.8
June	2014	19.5	2.6	46.8	55.6
	54 years*	20.1	2.5	48.4	22.9
July	2014[c]	24.7	3.2	35.0	9.6
	54 years*	23.4	2.8	42.1	6.8
August	2014	24.9	3.1	32.2	2.8
	54 years*	22.8	2.6	42.9	5.5
September	2014[b]	20.1	2.4	51.4	8.2
	54 years*	18.4	2.1	48.0	11.0

[a] Calculated by using data between 29 and 30 April (Sowing: 29 April)
[b] Calculated by using data between 1 and 20 September (Harvest: 20 September)
* Calculated by using data between 1960-2014 years (Long-term meteorological data of Region)

Irrigation water was obtained from the deep well within the Sarıcalar Research and Experimental Station. The quality of such irrigation water was C_2S_1 (second class and first class in accordance's of salinity and alkalinity problems, respectively). Drip irrigation system was installed for application of irrigation water to plots. The drip system had followings: lateral tube of 16 mm, emitter discharge rate of 4 L/h under 100 kPa pressure, main line of 63 mm and manifold of 32 mm with fittings. All tubes in drip system were made of polyethylene (PE) material. The emitter spacing in accordance of soil texture and emitter discharge rate was selected as 40 cm. After the performing of field test, percentage of wetted area was calculated as 85%. The *Sirena* oil sunflower variety was used in research. It was first Turkish oil sunflower variety registered by abroad. It is within the medium early maturity group. The yield potential of such variety is highly satisfactory under irrigation conditions. In addition, it is also very suitable cultivar for various soils.

In research, three different crop growths stages namely vegetative growth, flowering and pod filling were considered with every other irrigation with a total of 4 irrigation treatments. The study was planned as randomized block design with 3 replications. The irrigation treatments were namely irrigation at only growth of stages of V, F and PF, and irrigation in all three-growth stages of VFPF. The VFPF treatment was considered as control and phenologic observations were made at this treatment. The irrigation treatments of study were presented at Table 3.

Table 3. Irrigation treatments in research

Treatments	Plant Growth Stages		
	Vegetative Development (V)	Flowering (F)	Pod Filling (PF)
VFPF	+	+	+
V	+	-	-
F	-	+	-
PF	-	-	+

+: Irrigation made
-: None irrigation made

The sunflower seeds were planted at 29 th April 2014 with row spacing of 70 cm, and 24 cm plant spacing on rows. After the uniform seedlings, plants between plots were removed by manually and then drip irrigation system was installed to the research site. The length and width of the each parcel were 10 m and 2.8 m having 4 rows at each parcel. One lateral tube was installed for each plant rows. The spaces between blocks and parcels were 2.5 m and 2.1 m, respectively. The sunflower heads were harvested at 20 th September 2014. In harvest, the plant rows at outer edges were ignored for preventing outer edge effect. In addition, 2 m distances at both head and tail of parcel were ignored in harvest. Therefore, rest 6 x 1.4 m (8.4 m^2) parcel area was considered in evaluation.

The soil moisture content for 0-30 cm and other soil layers were monitored by gravimetric method, and Profil-Probe (Delta-T Pr2) device, respectively. In research, Profil-Probe tubes were placed at 0-100 cm soil depth for all parcels. In that regard, auger holes were made at experimental plots and Profil-Probe tubes as known Access Tube were lowered to holes. After outer edges of access tubes filling by soils and firmly compaction, they were sealed with special closers. Then, Profil-Probe moisture measurement device was calibrated for soil of research site.

Irrigation water to be applied for each parcel in accordance of treatments was calculated by using eqn.1. The deficiency of soil moisture content in 0-90 cm at VFPF treatment were considered for determination of the irrigation time, and soil moisture status was reached up to FC soil moisture level at each irrigation events. Irrigation water for other treatments was organized in accordance of applied water for VFPF treatment. By multiplying irrigation water, dn, (as depth basis calculated by using eqn.1) with parcel size (m^2) and wetted area percentage, volume of water as liter to be applied each parcel was obtained (eqn.2). The amount of irrigation water for each parcel was measured by using flow meters at heads of the parcels.

$$d_n = \frac{(FC_v - CM_v) \times D}{10} \tag{1}$$

Where;

d_n =Soil moisture content (mm),

FC_v = Volumetric soil moisture content at field capacity (%),

CM_v = Volumetric soil moisture content at Current (existing soil moisture content in root zone depth for irrigation of all three growth stages)

D =Root zone depth (90 cm).

$$I = d_n \times A \times P \tag{2}$$

I =Irrigation water (L),

d_n=Irrigation water (mm),

A=Parsel area (m^2),

P=Wetted area percentage (%),

The crop water use or evapotranspiration, ETc, for the treatments was calculated by using water balance eqn.3 as suggested by James (1988):

$$ET = I + R - D_P + C_P - R_f \pm \Delta S \tag{3}$$

where;
ET or ETc = Evapotranspiration (mm),
I = Applied water (mm),
R = Effective rainfall (mm),

D_p = Deep percolation (mm),
C_p = Capillary rises to the root zone (mm),
R_f = Run off (mm),
ΔS = Variation in soil moisture content (mm).

In eqn. 3, I from applied water, R from portable climate station at Research site, Dn from soil moisture measurement before and after irrigation at 90 cm and 120 cm depths were obtained. In experiment, none deep percolation was observed below 90 cm soil depth. The soil of research site was deep and none drainage and salinity problems were exist. Therefore, there was no capillary rises so C_p value was ignored in the calculations. ΔS was obtained from soil moisture measurements at time of seed planting and fruit harvest. Drip irrigation system was well designated and managed so none run off was observed. Thus, R_f value was also counted out in the calculations.

In research, the relationships between evapotranspiration and yield was determined with eqn. 4 as suggested by Doorenbos and Kassam (1979):

$$\left[1-\frac{Ya}{Ym}\right]=ky\cdot\left[1-\frac{ETa}{ETm}\right] \qquad \textbf{(4)}$$

where;
Y_a = Actual yield (kg/da),
Y_m = Maximal yield (kg/da),
k_y = Yield response factor
ET_a = Actual evapotranspiration (mm)
ET_m = Maximal evapotranspiration (mm)

Water Use Efficiency (WUE) and irrigation water use efficiency (IWUE), the key criteria's using evaluation of irrigation program, were calculated as (Tanner and Sinclair, 1983):

$$WUE=\frac{E_y}{ET} \qquad \textbf{(5)}$$

where;

WUE = Water Use Efficiency (kg/m^3)

E_y = Seed yield (kg/da)

ET = Seasonal evapotranspiration (m^3/da)

$$IWUE=\frac{E_y}{I} \qquad \textbf{(6)}$$

where;

IWUE = irrigation water use efficiency (kg/m^3)

I = Seasonal applied water (m^3/da)

The data obtained from the treatments were subjected to variance analysis to determine differences between yield and quality components and results were grouped with LSD test in accordance of 5% significant level. The analysis of variance and LSD tests were made with 22.0-computer program.

Results and Discussion

Seasonal number of irrigation, total applied water, measured rainfall during the sunflower vegetation period, soil moisture variations (ΔS) for 0-90 cm soil depth between seed sowing and harvest, evapotranspiration, ETc, and percentage of irrigation water compensating the evapotranspiration (I_{rc}) were presented in Table 4.

In Table 4, a total of 2 or 6 irrigation events were made for experimental plots depending on the irrigation treatments. In parcels having no irrigation at two plant growth stages, irrigation was performed at only one growth stage. Those parcels were exposed to none irrigation at other two-growth stages. A total 6 irrigation event was made at parcels having irrigation at all those three plant growth stages. In other words, plants were irrigated at whole growth stages in such treatment. The maximum applied water was found as 530 mm at VFPF experiment. PF had the highest applied water as 204 mm among the experiments with irrigation of only one-growth stages. Total about 113 mm rain was recorded during whole plant growth stages of sunflower plant. The 82%, 8% and 10% of that was observed at stages of vegetative, flowering and pod filling, respectively. In calculation of evapotranspiration, all recorded rainfall was assumed as effective rainfall since research site is flat topography and measured rainfall did not result soil moisture content above the field capacity in the root zone depth. The crop water use, ETc, varied from 326 mm to about 662 mm depending on irrigation treatments. The maximum evapotranspiration was calculated from the highest water applied treatment of VFPF. The I_{rc} was found between 50% and 80% depending upon treatments.

The results of variance analysis relevant to seed yield, yield components, WUE and IWUE, and mean values with significant groups of the treatments were listed at Table 5 and Table 6, respectively.

In Table 5, differences in seed yield, plant height and 1000 seed weight between treatments were found statistically significant in 99% reliability level. Although head diameter was found significant, WUE and IWUE were found none significant in 5% significant level.

In Table 6, maximum seed yield was obtained as 4911 kg/ha from irrigation at VFPF treatment and separated from other irrigation treatments in accordance of LSD test results. In examine irrigation at only one growth stage, the highest seed yield of 3060 kg/ha was determined from irrigation at flowering stage. The seed yield obtained from the only irrigation at one plant growth stage was found notable lower than irrigation at VFPF stages. By comparison to VFPF treatment, maximum seed yield reductions was found as about 60% at treatment with irrigation in PF, and minimum was determined as about 38% from irrigation at only F stage. Sezen *et al.,* (2011) reported to seed yield as 5195 kg/ha for drip-irrigated sunflower plant for Tarsus-Mersin condition and two-year average of 2538 kg/ha reported by Kadayıfcı and Yıldırım (2000) for Ankara province of Turkey. Our result is almost inline with Sezen *et al.,* (2011) and remarkably greater than finding of Kadayıfcı and Yıldırım (2000).

Among irrigation treatments, head diameter varied from about 16 cm to 12 cm, and VFPF treatment had maximum head diameter. The differences of head diameter in accordance of LSD test results between treatments were found none significant in 5% significant level. Kazemeini *et al.,* (2009) reported head diameter of 11.33 cm under full irrigation for silty-loam soil at Shiraz, Iran. The result of our study is greater than those finding of Kazemeini *et al.,* (2009). The possible reasons could be differences in characteristics of sunflower cultivars, climate and soil conditions as well as irrigation water management in both experimental regions.

The plant height varied about from 108 cm to 84 cm with maximum at VFPF irrigation treatment. None statistically difference was found between VFPF and V treatments at 95% reliability level. The plant height in a study performed by Kazemeini *et al.,* (2009) was demonstrated as 146 cm under full irrigation and is higher than our finding.

The 1000 seed weight varied about from 81 g to 35 g in treatments and as expected maximum one was obtained from the VFPF treatment. It was reported 50 g in a study of Kazemeini *et al.,* (2009) for full irrigation. The finding obtained from the present study is almost agreement with Kazemeini *et al.,* (2009).

The WUE and IWUE, highly effective parameters for evaluation of irrigation schedule, varied from 0.85 to 0.46, and from 1.51 to 0.84 kg/m^3, respectively. The maximum WUE and IWUE were calculated from the F treatment. The differences of WUE and IWUE obtained from treatments were found none significant at 5% significant level.

In study, yield response factor, ky, was calculated for determination effect of relative evapotranspiration reduction on relative seed yield reduction (Figure 1). In that regard, the relationships between seasonal evapotranspiration and seed yield obtained from the different treatments were examined by using regression analysis. The ky was found about1.1 for whole sunflower growth stages. Doorenbos and Kassam (1979) reported that in case k_y greater than1, plant is sensitive to the water deficit. According to our result, sunflower is sensitive to the water deficiency in Konya condition of Turkey. Our result is greater than the finding of Kadayıfcı and Yıldırım (2000).

Table 4. Seasonal number of irrigation, total applied water, effective rainfall, soil moisture variations (ΔS), between sowing and harvest date, evapotranspiration and irrigation water compensating crop water use (I_{rc})

Treatments	Number of irrigation	Total applied water (mm)*	Effective rainfall (mm)	ΔS (mm)	Seasonal Evapotranspiration (mm)	I_{rc} (%)
VFPF	6	530	113.4	18.2	661.6	80
V	2	164	113.4	48.6	326.0	50
F	2	202	113.4	43.2	358.7	56
PF	2	204	113.4	58.3	375.7	54

ΔS: Soil moisture difference between seed sowing and harvest times (0-90 cm)
*: Application of 20 mm water after the seed sowing was added to the all treatments

Table 5. Mean squares from the variance analyses obtained from yield and yield components

Source	d.f.[a]	Seed yield	Head diameter	Plant height	1000-seed weight	WUE	IWUE
Blocks	2	8026.3[ns]	0.281[ns]	4.353[ns]	23.58[ns]	0.002[ns]	0.011[ns]
Treatments	3	5616250.4**	8.246*	484.92**	1136.66**	0.087[ns]	0.389[ns]
Error	6	393084.4	1.103	35.148	18.911	0.032	0.124

[a] Degrees of freedom.
[ns] Non-significant.
** Significant at the 1% of probability level ($P<0.01$).
* Significant at the 5% of probability level ($P<0.05$).

Table 6. Seed yield, yield components, WUE and IWUE

Treatments	Seed yield (kg ha^{-1})	Relative seed yield (%)	Head diameter (cm)	Plant height (cm)	1000-seed weight (g)	WUE kg m^{-3}	IWUE kg m^{-3}
VFPF	4911a	100.0	15.9a	107.5a	81.3a	0.74	0.93
V	2448bc	49.9	14.7a	107.0a	47.4c	0.75	1.49
F	3060b	62.3	14.3a	86.7b	56.4b	0.85	1.51
PF	1711c	34.8	11.9b	84.0b	35.4d	0.46	0.84
$LSD_{0.05}$	1252	-	2.10	11.85	8.69	-	-
CV (%)	20.7	-	7.4	6.2	7.9	25.5	29.5

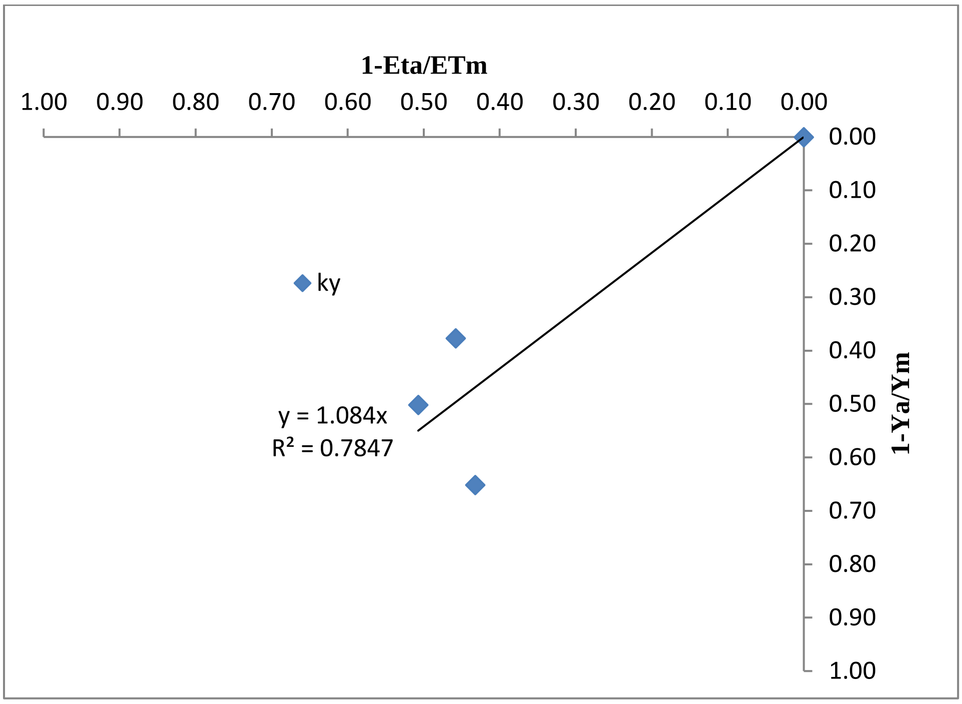

Figure 1. Yield response factor, ky

Conclusion

The present study clearly showed that irrigation period is very important role to play in all field crops particularly for sunflower production. Application of water during whole growth stages have resulted best seed yield and followed by irrigation at flowering stage. The lowest seed yield was obtained from irrigation treatment at only pod filling stage. As result, if the farmers would like to have maximum production, irrigation in all plant growth stages is strongly recommended in regions where water shortage is not a limitation. In accordance of our present research, by comparison to irrigation in all plant growth stages, although 62% less amount of water was applied to irrigation at only flowering stage, yield reduction is about 38%. In water scant regions, arid or semi-arid regions, irrigation at only flowering period is highly suggested to be cultivated more areas with same amount of water supplies. In that regard, flowering is the most critical stage in irrigation program of sunflower plant so it cannot be exposed to water stress conditions in that growth stage.

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