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Impact of climate on durum wheat yield (*Triticum durum* Desf.) under different cultivation and irrigation methods

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Abstract
This study was aimed to determine the effects of different cultivation and irrigation methods on wheat in 2017-2018 and 2019-2020. The experiment design was the split-plots in randomized blocks with 3 replications. The main plots were conventional flat cultivation (CFC) and raised-bed cultivation (RBC), and sub-plots were rain-fed conditions, surface irrigation and drip irrigation. The CFC and RBC resulted in the grain yield of 5.13 and 4.33 t ha^{-1}, respectively. The grain yield of 5.21 and 5.55 t ha^{-1} were obtained by surface irrigation and drip irrigation, respectively. The yield in CFC (16%) and drip irrigation (6%) were relatively higher than RBC and surface irrigation. Irrigation water productivity (1.72 kg m^{-3}) in RBC was higher compared to 1.23 kg m^{-3} in CFC. The irrigation water applied was 468 and 258 mm in CFC and basin irrigation and in RBC and drip irrigation, respectively. Crop evapotranspiration was 813 and 725 mm in CFC and the basin irrigation, and in RBC under the drip irrigation, respectively. The CFC under basin irrigation was more appropriate compared to RBC and drip irrigation. Insufficient and improper distribution of rainfall and temperatures more than 30 °C caused lower yield.

Keywords
Cultivation systems, Durum wheat, Irrigation methods, Grain yield, Climate

Introduction
Wheat production is restricted in arid and semi-arid regions due to insufficient rainfall or poor distribution of rainfall. Efficient use of rainfall and irrigation water is extremely important for wheat (IWMI, 2007; Cetin and Akinci 2014; FAO, 2016). The lower yields of crops such as wheat grown under the rain-fed conditions may pose a risk for increasing population and food demand. Therefore, it is inevitable to apply new production or irrigation techniques. Effective use of rainfall or supplemental irrigation have shown to overcome unstable yield levels (Tavakoli et al., 2012). In order to obtain higher grain yield, supplemental irrigation is, thus, essential. Farmers in this study area generally irrigate three or four times each season considering critical development stages of winter wheat (Cetin and Akinci, 2014). However, competition in the use of water resources between sectors is rapidly increasing. There are also considerations on the more efficient use of irrigation water in agriculture due to the higher global water use (approximately 70%) in the agricultural sector (OECD, 2020). Thus, effective use of irrigation water should be sought and implemented.

Developing planting systems that use effectively rainfall and/or irrigation water and providing moisture conservation in the soil are some of the important ways to increase water productivity (Wang et al., 2011; Zaman et al., 2017). One of these methods is the “raised-bed” cultivation system for field crops. It has been reported that it could provide moisture conservation in the soil, ease of irrigation, more water productivity and more wheat production (Sayre and Hobbs, 2004; Gursoy et al., 2010; Shao et al., 2011).

Furrow irrigated raised-bed planting consumed less water than the flat planting pattern by reducing the irrigation amount and improved control of evaporation from the top soil (Zang et al., 2007). Zaman et al. (2017) reported that the raised-bed wheat cultivation saved 14.3% water and increased grain yield 15.7% relative to the flat bed. The highest water productivity (1.81 kg m^{-3}) was observed in raised-bed and full irrigation condition. In another study, the ridge-furrow irrigation treatment increased significantly soil water and soil respiration in topsoil, whereas there was reduction (44.2%) in crop evapotranspiration rate and soil temperature. Therefore, the grain yield (14.6%) and water use efficiency (64.8%) significantly increased owing to the morphology of winter wheat and rooting system improvement compared to border irrigation. Ridge irrigation system combined with 75 mm deficit irrigation can be an efficient water saving strategy in semi-arid regions due to increased soil moisture across the rooting zones, a resulting in higher water productivity and wheat production (Ali et al., 2019).

The raised-bed cultivation with bed configuration of 90 cm, 4 rows and irrigation schedules (40 mm) at 0.8 times of class A pan evaporation resulted in significantly higher grain yield, straw yield, harvest index, net return, N, and K uptake (Sagar et al., 2017).

Considering different irrigation methods for wheat, drip irrigation provided 20% water saving compared to surface irrigation on wheat in Morocco. In addition, both grain yield and irrigation water productivity were higher in drip irrigation (Kharrou et al., 2011). In another study conducted in Azerbaijan, the raised-bed cultivation system saved 13% water compared to the traditional flat cultivation system.

Although there were studies on the advantages of raised-bed cultivation systems, some results showed that there was no significant differences on grain yield between raised-bed cultivation and conventional flat cultivation systems. Loper et al. (2020) reported that the planting on the flat produced 5.5 t ha^{-1} (wheat); 5.6 t ha^{-1} (barley) which were better than the planting on beds 4.9 t ha^{-1} (wheat); 5.1 t ha^{-1} (barley). In another study, irrigation amounts and nitrogen use efficiency did not show any differences in the two planting systems. Wheat yield was similar under different treatments during all the years but wheat planted on raised-beds recorded about 22.7% higher water use efficiency than under flat layout (Ram et al., 2012). Thus, some agricultural techniques needs to be developed and applied in order to use efficient irrigation water and rainfall.

This study was carried out to determine the effects of different cultivation and irrigation systems on wheat grain yield. In addition, the effects of main climatic factors such as rainfall, maximum and minimum temperatures on grain yield were also studied.

Material and methods

Experimental Site

This study was carried out in Southeastern Anatolia Region of Turkey, Diyarbakır (longitude: 40 ° 14’ E, Latitude: 38° 01’ N and elevation: 675 m). The experiments were established at Research and Experimental Station, Faculty of Agriculture, Dicle University, Diyarbakır, Turkey during the growing periods of 2017-2018 and 2019-2020. The study area has a continental climate where most of the precipitation falls in winter and there is almost no or insignificant rainfall in summer. Average yearly precipitation is 495.7 mm for long-term (1921-2021) (DMI 2020). The soils of the experimental site were clay texture (clay content of 65%) and the content of $CaCO_3$ was about 7.8%. Some chemical and physical properties of the experimental soil are given in Table 1).

Experimental design and treatments

The experiments were carried out for 2 years in the wheat growing periods of 2017-2018 and 2019-2020. The experiment could not be conducted due to some extreme climatic conditions during the sowing period in 2018-2019, thus, the experiment in the second year was carried out in the growing season of 2019-2020.

The experiment was performed in the spit plots with three replications using randomized blocks. The main plots were conventional flat cultivation (CFC)(C_1) and raised-bed planting (RBC) (C_2) and sub-plots were rain-fed conditions (RF) (Io), surface irrigation (basin irrigation for CFC, furrow irrigation for RBC) (I_1) and drip irrigation (I_3). Experimental treatments are given in Table 2. The plot size in conventional flat cultivation (treatment C_1) and raised-bed cultivation (treatment C_2) was 22.4 m^2 (2.8 m x 8 m).

In RBC, each furrow or ridge spacing in the plots were70 cm and 2 rows of wheat plants at 20 cm spacing on each raised-bed. Row interval was 20 cm in CFC. The beds were 40 cm wide at the top and 15 cm in height and separated by furrows 30-cm wide in RBC. Two rows of wheat were seeded on each bed at 20-cm row to row spacing (Fig. 1).

Irrigation

Irrigation systems for surface irrigation were designed according to the characteristics of the cultivation methods. For this, basin and furrow irrigation methods were used for CFC and RBC, respectively. Irrigation was performed carried out 3 times for surface irrigations, during the stem elongation, heading and milking stages (Cetin and Akinci, 2014). The current soil moisture at the each critical stage was fullfilled to the field capacity based on soil depth of 90 cm. In the drip irrigation, irrigation started at the period of stem elongation and it was ended at the milking stage based on every 7 days and soil depth of 60 cm. In the calculation of irrigation water applied for drip irrigation, the whole area of the plots in CFC under drip irrigation was considered. However, 60% of total area of the plots in RBC under drip irrigation was considered because of space between furrows (Keller and Bleisner, 1990; Allen et al., 1998). Thus the surface of furrows which had no plants was not considered for drip irrigation.

Crop evapotranspiration was calculated using water balance equation (Allen et al., 1998).

Agricultural applications

The experimental area was plowed deeply, the cultivator and rototiller were pulled out and the field surface was leveled and made ready for planting. In CFC plantings, wheat seeds were sown in rows of 20 cm using 200 kg ha^{-1} (500 grains m^{-2}) in rain-fed conditions and 160 kg ha^{-1} (400 grains m^{-2}) in the irrigated plots. In RBC, sowing was implemented using a ridge planter. Accordingly, 120 kg ha^{-1} (300 grains m^{-2}) in the RBC and 100 kg ha^{-1} (250 grains m^{-2}) in the irrigated plots (Kilic and Gursoy, 2010; Keskin, 2014). Sowing were implemented on 15.11.2017 and 26.11.2019 for two growing seasons. In the experiment, durum wheat variety of Sena (*Triticum durum* Desf.) developed and registered by the Faculty of Agriculture, Dicle University was used.

In the irrigated plots, 80 P_2O_5 kg ha^{-1} for phosphorus and 150 N kg ha^{-1} for nitrogen, and in the rain-fed plots, 60 P_2O_5 kg ha^{-1} and 80 N kg ha^{-1} were applied (Cetin and Akinci, 2014). Under rain-fed conditions and other irrigated plots, all of the phosphorus and half of the nitrogen were given during the sowing and the other half of the nitrogen was applied at the tillering stage of the plants. As a fertilizer source, the fertilizer of 20.20.0 (N-P-K) and urea (46% N) were used during sowing and tillering stages, respectively.

When the weeds had wide leaves reached the 2-3 leaves in the plots, some herbicides were used. Some narrow leaf weeds were collected by hand and there was no need any precaution for insects.

The harvest was implemented by a harvester machine for cereals. For evaluation, 1.0 m from the head of the plots, 1 ridge from the right-left of the plots to the ridge, and 2 rows in conventional flat cultivation were left out of the plots. The harvest was made on June 21 in 2018 and June 18 in 2020.

Statistical analysis and evaluation

The data were analyzed using ANOVA with SPSS. The data obtained from each sampling event were analyzed separately. Duncan's multiple range test was used to determine statistically difference between the treatments at P(0.05 and 0.01) (Yurtsever, 2011). Daily climatic data for rainfall, maximum and minimum temperatures were shown in graphs and evaluated connecting yields.

Table 1. Some chemical and physical properties of soil in the experimental site

Soil depth (cm)	pH	Org. mat. (%)	$CaCO_3$ (%)	EC (dS m^{-1})	Soil texture	FC (%)	WP (%)	BD (g cm^{-3})	IR (mm h^{-1})
0-30	7.7	1.67	7.8	0.48	C	35.5	25.5	1.19	8
30-60	7.9	1.60	7.8	0.37	C	35.2	25.3	1.25	
60-90	7.8	--	8.7	0.20	C	36.4	27.0	1.27	

EC: Electrical conductivity, FC: Field capacity (weight (w) w^{-1}, %), WP: Wilting point (w w^{-1}, %), BD: Bulk density, IR: Infiltration rate

Table 2. Experimental treatments

Main plots (Cultivation methods)	Sub-plots (Irrigation methods)
C_1: Conventional flat cultivation (CFC)	Io: Rain-fed conditions
C_2: Raised-bed cultivation (RBC)	I_1: Surface irrigation (border and/or furrow irrigation)
	I_2: Drip irrigation

Results

Grain Yields

The experiments were planned for the growth season of 2017-2018 and 2018-2019. However, the second year of the experiment (2018-2019) could not carried out because of some extreme climatic conditions. Thus, the experiments in the second year were carried out in the growth season of 2019-2020.

The grain yields obtained depending on the experimental treatments and years are given in Table 3. According to the results of variance analysis, there was no statistically significant effect of cultivation systems on grain yield. However, the effect of different irrigation systems and rain-fed conditions on grain yield were found to be significant ($P<0.01$) and there was also significant ($P<0.05$) effects of the interaction of "irrigation systems x planting systems" on grain yield. Although the effect of cultivation systems on yield were not statistically significant on grain yield, the yield obtained from CFC was relatively higher than the yield obtained from RBC in 2018. Although the effect of irrigation systems on yield was not significant except for the rain-fed conditions, drip irrigation provided more yield compared to surface irrigation systems (border and/or furrow irrigation) (Table 4, Fig. 2). The main reason of significantly differences on the treatments in sub-plots was because of the rain-fed conditions. Accordingly, the most important factor limiting the yield was water, thus the wheat grain yield increased by means of increasing irrigation water. In addition, the effect of different irrigation systems on grain yield was not significantly different (Table 4, Fig. 2).

The results of the experiment in season of 2019-2020 were quite different compared to those in season of 2017-2018. The lowest and highest grain yield were 5.29 t ha^{-1} and 7.98 t ha^{-1} in this season (Table 3). As the previous experimental results in the study, the lowest yield occurred under the rain-fed conditions and the highest yield was under the CFC and drip irrigation conditions. Accordingly, the grain yields obtained in 2019-2020 were quite higher compared with the results of the previous experimental year for all the treatments (Table 3, Fig. 2).

The effects of different cultivation and irrigation systems including rain-fed conditions on grain yield were found to be statistically significant (P<0.01). As the results in the season of 2017-2018, the yields in the CFC were higher than in the RBC (Fig: 2). However there was no significant difference between drip irrigation and surface irrigation applications. That is, the main difference occurred because it was rain-fed treatment. The grain yield was relatively higher in the drip irrigation compared to the surface irrigation. As the results in the season of 2017-2018, the grain yields in the season of 2019-2020 were relatively higher in the drip irrigation method compared to surface irrigation even if there was no significant difference (Table 4, Fig. 2).

According to the results of this study, there was no statistically significant differences in terms of grain yield between the RBC and CFC in 2017-2018, however the difference between yields at the cultivation methods was statistically significant in 2019-2020.

Climatic factors, rainfall and temperature

Considering amount of rainfall during the growing season, a total of 399.7 mm of rainfall occurred during the growing period of 2017-2018 (Fig. 3a). In addition, the rainfall distribution for the months covering the crop growth period was also given in Fig. 3b. Accordingly, the rainfall during the first two months of the planting date of crop was very insignificant and very low. This was not enough to germinate and to grow for the plants. The plants have run across the winter period without appropriate development of the plants and root system in this period.

The amount and distribution of rainfall during the growing period of 2019-2020 was significantly different compared to those in the first experimental year. Accordingly, a total of 675.8 mm of rainfall occurred this year (Fig. 3a). A very high amount of rainfall occurred approximately one month after planting date, which was quite sufficient to have germination and growth of plants according to the rainfall distribution in the season of 2019-2020. For this reason, the plants has run into the winter period with a sufficient development and growth. This situation resulted in a positive effects on the development plants, thus the plants developed faster and sufficient growth in the spring period. The effect of much more amount of rainfall and irrigation resulted in the yields that is incomparably higher than those in the season of 2017-2018 (Fig. 2 and 3b). These results showed that winter wheat significantly depends on the amount and distribution of rainfall during the growing period of the plant.

According to the maximum temperatures in the growing period of the plant (Fig. 4), the maximum daily temperatures in the season of 2017-2018 were relatively higher than those in 2019-2020. This event was especially evident in the planting, emergence and development periods of the plant, and similarly, the daily maximum temperature between the 120th and 140th days after sowing were found to be quite high (Fig. 4). This condition has also explained why the yield was very low in this experimental year considering the amount and distribution of rainfall.

Considering the minimum temperatures during the growing season, the minimum temperatures between the 40th and 65th days of planting in 2017-2018 are considerably higher than those in 2019-2020. The climatic conditions might not be sufficient for the need of vernelisation in the plants, or it might has a negative effect on yield compared to the growing season of 2019-2020 (Fig. 5).

Irrigation water and crop evapotranspiration

As given the previous part of the paper, the deficit soil moisture considering the field capacity at the date of irrigation water was applied as amount of irrigation water for all the treatments. In CFC plots in 2017-2018, irrigation water of 461.3 mm and 594.5 mm were applied in basin and drip irrigation, respectively (Table 3). In the RBC plots, irrigation water of 501.8 mm and 326.8 mm were applied in furrow irrigation and drip irrigation, respectively.

The main reason of irrigation water difference between drip irrigation in CFC and raised-bed irrigation was used the application of coefficient of 0.60 (60%) as a percentage of wetted area in RBC. It was, because, planned to irrigate the furrow ridges where the plants were located. However, there was no restriction of wetted area in the CFC plots since the plants were dense and homogenous. Thus, the wetted area was 100%. This resulted in significantly difference in irrigation water (Keller and Bliesner,1990).

In the second experimental year, in 2019-2020, irrigation water of 475.0 mm and 368.1 mm was in basin and drip irrigation in CFC, respectively. In the RBC, irrigation water of 491.8 mm and 189.1 mm were applied in furrow irrigation and drip irrigation, respectively (Table 3). The amount of rainfall and distribution during the growing period affected the amount of irrigation water applied. The amount of irrigation water applied in 2017-2018 were more than those in 2019-2020. The reason of this was occurred a rainfall of 399.7 mm and 675.8 mm in 2017-2018 and 2019-2020, respectively (Fig. 3a). That is why more irrigation water was to be applied to all the treatments in 2017-2018 and the lower yields were obtained compared to the yields in 2019-2020.

Considering the average results, the amount of irrigation water was 468.2 mm and 481.3 mm in basin and drip irrigation in CPC, respectively. The irrigation water was 496.8 and 258.0 mm in surface irrigation (furrow) and drip irrigation in the RBC, respectively.

The reason for the fact that the irrigation water applied in drip irrigation was much lower in RBC was to irrigate (wet) the ridges area where only the plants were located depending on the planting. For this reason, the wetting rate corresponded to 60% of total area and thus the amount of irrigation water was approximately 40% lower.

The values of crop evapotranspiration (ETc) for all the treatments are given in Table 3. The amounts of ETc was mainly controlled by the irrigation water applied and rainfall. The ETc in the CFC was 394.7 mm and

551.1 mm in 2017-2018 and 2019-2020, respectively. Similarly, ETc was calculated to be 392.9 mm and 527.8 mm in RBC in 2017-2018 and 2019-2020, respectively. The ETc for rain-fed conditions was almost the same with the amount of rainfall during the growing period since there was no irrigation and moisture (water) coming from the soil profile. ETc in the CFC under the basin irrigation was measured to be 729.6 and 897.0 mm in 2017-2018 and 2019-2020, respectively. In the same treatment under the drip irrigation, CFC, it has been determined as 885.2 mm and 915.3 mm in 2017-2018 and 2019-2020, respectively.

Table 4. The separate effects of the treatments on wheat grain yeild

SP	Yield ($t\ ha^{-1}$)			WP ($kg\ m^{-3}$)	IWP ($kg\ m^{-3}$)	MP	Yield ($t\ ha^{-1}$)			WP ($kg\ m^{-3}$)	IWP ($kg\ m^{-3}$)
	2018	2020	Av.				2018	2020	Av.		
Io	0.86 b	6.02 b	3.44	0.74		C_1	2.87	7.39 a	5.13	0.72	1.23
I_1	3.29 a	7.12 a	5.21	0.64	1.08	C_2	2.55	6.11 b	4.33	0.67	1.72
I_2	3.98 a	7.12 a	5.55	0.70	1.89						

SP: Sub-plots, Av. Average, WP: Water productivity, IWP: Irrigation water productivity, MP: Main plots
C_1: Conventional flat cultivation, C_2: Raised-bed cultivation; Io: Rain-fed, I_1: Surface irrigation, I_2: Drip irrigation.
The same letter is not significant according to the Duncan's multiple range test

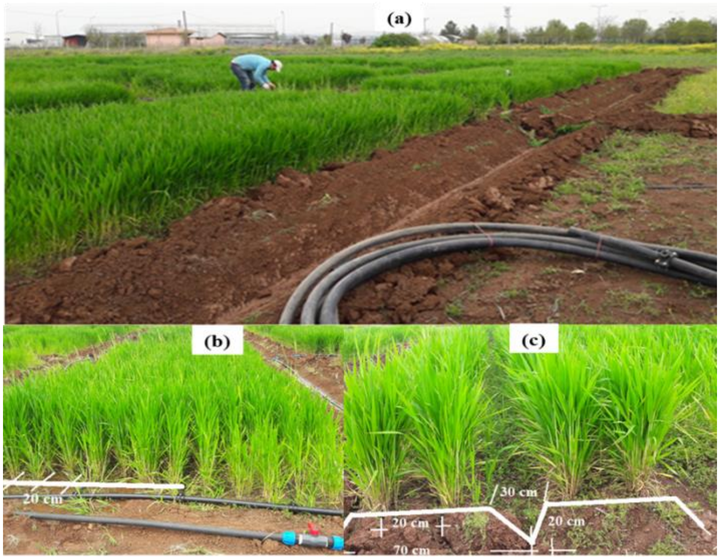

Figure 1. The general view of the experimental plots (a), conventional flat (b) and raised-bed cultivation (c)

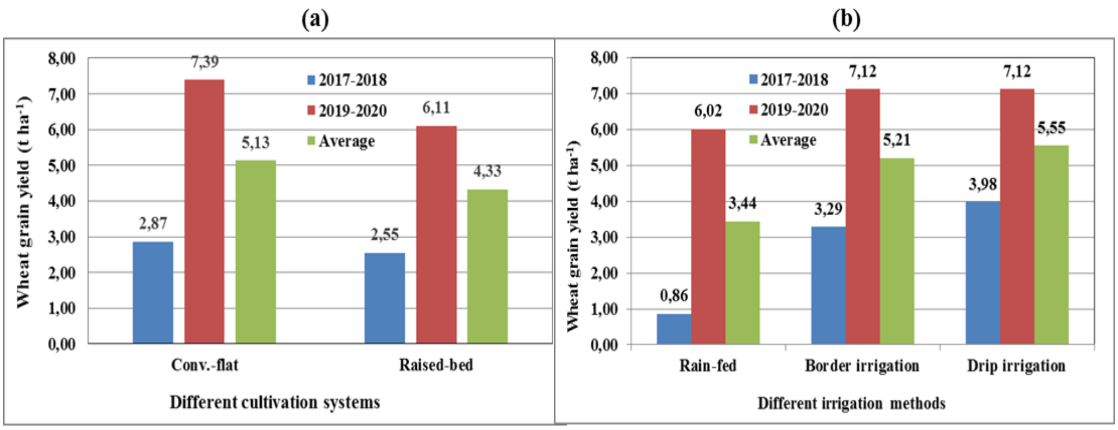

Figure 2. Effects of different cultivation (a) and different irrigation systems (b) on wheat grain yield in the experimental years.

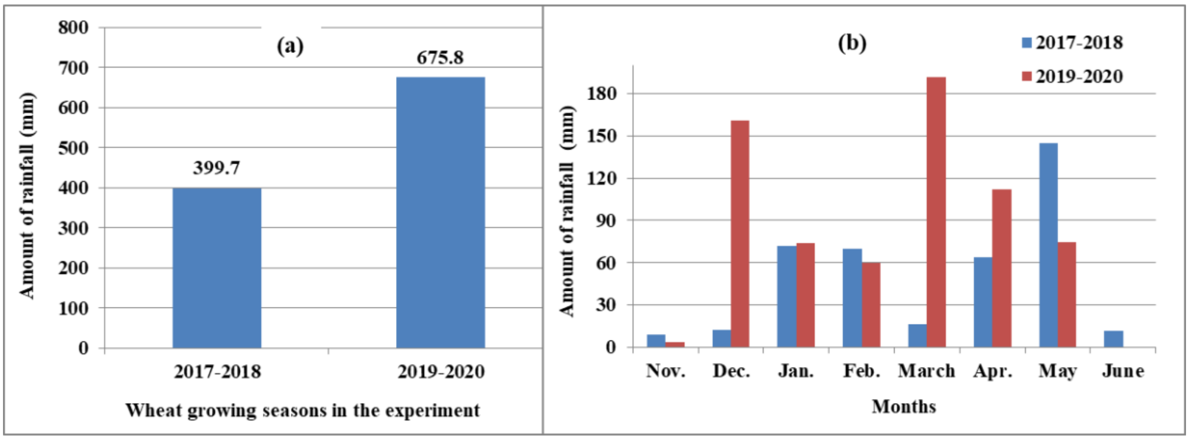

Figure 3. Total amount of rainfall during wheat growing season (a) and rainfall distribution according to the months in the experimental years

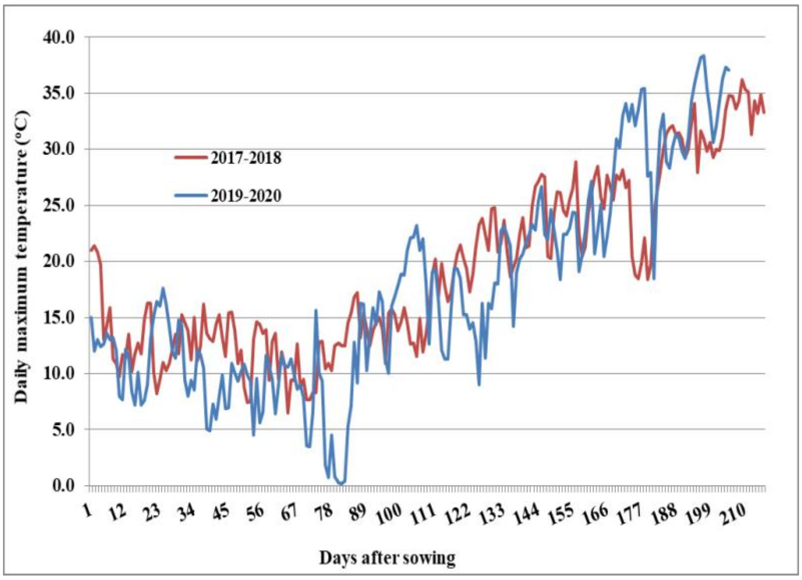

Figure 4. The variation of daily maximum temperature during the growing season in the experimental years

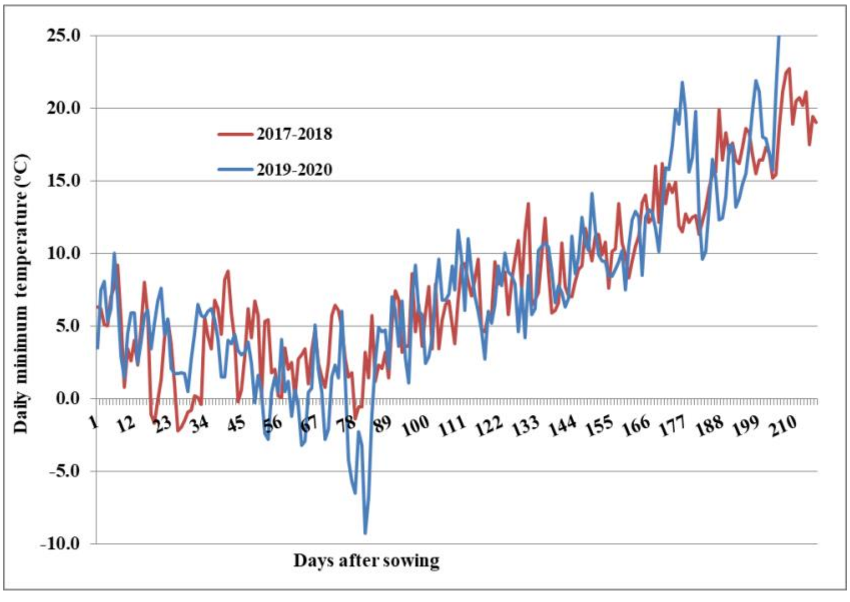

Figure 5. The variation of daily minimum temperature during the growing season in the experimental years

Discussion

Yields under conventional flat and raised-bed cultivation

Irrigation and/or rainfall increased wheat grain yield in all the experimental years. The most important factor limiting plant growth in arid and semi-arid climates was, because, insufficient of available water in the crop root zone (Lal, 1991; Falkenmark and Rockstrom, 1993; Cetin and Akinci, 2014). Although the irrigation implementation increased dramatically the yield, it was not sufficient to get maximum yield without rainfall and other climatic conditions in the study region (Cetin and Akinci, 2014). It is clarified that how important is the amount and distribution of rainfall during the growing period of the plant (Figure 3a and 3b). The other climatic factors such as maximum and minimum temperature and relative humidity also have a very important effect on yield.

In this study, there were no any statistically difference between CFC and RBC on grain yield even if the grain yield was relatively higher in CFC compared to RBC. One of the important reason for higher yield in CFC was used more amount of seed in CFC and this resulted in more tillering and more plant and spike number compared to those in RBC (Table 3). In addition, wide plant row spacing per unit area in ridge planting, not sowing the whole area, might cause less effective use of irrigation water due to more evaporation from the furrow surface. Thus, yields were low in the RBC. However, irrigation water productivity (1.72 kg m^{-3}) was higher compared to 1.23 kg m^{-3} in CFC (Table 4). Although irrigation water productivity is important for water saving and efficient use of water, increasing yield is more important to get higher net return for farmers.

On the contrary to the results of this study, some successful results and advantages of the RBC have been given by the previous studies in the different regions. These advantages, were use of approximately 100 kg ha^{-1} of seeds, regular use of field traffic in this system, ease and an appropriate irrigation water management, control of plant diseases in heavy soils by means of furrow irrigation (Sayre and Hobbs, 2004; Gursoy et al., 2010). Sayre (2001) reported that the RBC could provide at least 10% increase in water productivity and it could reduce production costs by 20-30% and reduce irrigation water use up to 35% under Mexican farming conditions.

In another study, permanent raised-beds demonstrated 13%, 36% and 50% higher grain yield, water saving and water productivity for the wheat crop, respectively, (Hassan et al., 2005). For equal yields beds saved 750 m^3 ha^{-1} of water compared to flats in China for spring wheat. Requirement of the raised-bed planting system appears to be a promising way to resolve the key issues and maintain food production in Northwestern China (Zhongming et al., 2005). Wheat on raised-beds had 19.2% lower water use than on flat layout. Similarly, water use efficiency recorded in wheat on the raised-beds was 22.6% more than on the flat layout. Less water use in bed planted treatments than in flat layout was possible due to the lower amount of irrigation water (Ram et al., 2012). The permanent raised-bed plots increased wheat yields by 4.8 to 6.2% ($P < 0.05$) compared with traditional tillage (Li et al., 2014).

In another some studies, the RBC increased 12% of wheat grain yield compared to flat cultivation under farmer conditions in Pakistan. In addition, The RBC and furrow irrigation have also provided 30-35% savings in irrigation water and more benefit of 100 $ ha^{-1} (Hussain et al., 2018). Jha et al. (2017) used three irrigation methods (sprinkler, drip irrigation and flood irrigation) using different rates of field capacity (70, 60 and 50%) in wheat. According to the research results, irrigation water applied and crop evapotranspiration ranged 105-270 mm and 261-330 mm, respectively.

On the other hand, basin irrigation in the wheat had 30% more net economic return compared to furrow, sprinkler and drip irrigation because the cost of the irrigation system was lower than those irrigation systems. In addition, the economic productivity of irrigation water was higher in basin irrigation and basin irrigation for wheat irrigation was, thus, recommended (Fang et al. 2018). In a study conducted with drip irrigation in summer wheat, it was found that the highest daily water consumption was 5.18 and 7.52 mm d^{-1} during the stem elongation and flowering periods, respectively. Drip irrigation increased the number of grain per spike and grain weight (Want et al., 2013).

In Pakistan, average wheat grain yield was 12% higher with ridge-furrow planting as compared to conventional planting. Wheat grain yield with ridge-furrow planting was higher than 0.1 t/ha in all districts (Hussain et al., 2018). The moisture content under the ridge irrigation was considerably improved by 29% than that of border irrigation at the flowering stage. The ridge irrigation system, moisture content significantly improved by 31% compared to border irrigation at the soil layers of 0–200 cm at three different growth stages. The ridge irrigation system increased moisture content at key growth stages, as a result significantly increased crops production (Ali et al., 2019).

CFC and RBC methods in durum wheat were tested in rain-fed and irrigated conditions under the conditions of Harran Plain of Turkey, the same region where this study was conducted. The more yield was obtained from CFC under rain-fed conditions compared to RBC and no difference was found between treatments as similar in our study. There was no also difference in yield between all cultivation methods in the irrigated conditions (Kabakci, 1999). In other studies conducted in the same region, there was no significant difference in grain yield between RBC and CFC (Gursoy et al., 2007; Kilic and Gursoy, 2010). However, the average grain yield of wheat was found to be 5615 kg ha^{-1} for the farmers who planted on the RBC while it was found to be 4923 kg ha^{-1} ha for the farmers who planted CFC in Mexico (Aquino, 1998). In addition, Jin et al. (2008) stated that permanent raised-bed cropping system could make a significant contribution to productivity, and they emphasized on requirements of the studies such as irrigation management, determination of suitable varieties and seed density etc.

On the other hand, the highest yield of wheat was obtained in the reduced tillage method while the lowest yield was in the CFC (Aykanat, 2009; Karaagaç et al., 2016).

One of the main reasons on less yield of wheat grain yield in the RBC compared to CFC was to be used less seed and planting area depending on experimental design of RBC, thus this resulted in less spikes and yield per unit area (Table 2). In addition, different results obtained from this research and other previous studies might lead to the conclusion that such agronomic studies might vary depending on the region, soil and climatic conditions, therefore the results of regional research should be valid for that region.

Crop evapotranspiration

In this study, irrigation water in drip irrigation, especially in CFC, was applied slightly more than the amount of irrigation water in surface irrigations. The main reason for this was that there were only three different periods in surface irrigation, whereas irrigation was implemented at each every 7 days in drip irrigation. Due to the application of irrigation water according to the deficit moisture in the soil and frequent irrigations in drip irrigation, the irrigation water cumulated in the soil encouraged the plant's water consumption. This increased the amount of irrigation water applied.

In some previous studies, requirement of irrigation water for wheat reported as 434 mm in Ankara-Kesikköprü (Ustun, 1990), and 430-480 mm in the Southeastern Anatolia Region where this study was carried in Turkey (Karaata, 1987; Cetin and Akinci, 2014). As a result of this study, the irrigation water requirement in the same region was almost the same and/or closer to the amounts in the previous findings.

The main reason of a high difference in ETc during the experimental years was that the amount of rainfall during the growing period was quite different. As the amount of rainfall increased, the ETc increased because deficit moisture in the soil was met almost by rainfall (Allen et al., 1998; Reynolds et al., 2000; Nagler et al., 2007), however deep infiltration increased in both irrigation water application and higher amount of rainfall in this study. The main reason of which the ETc was higher in drip irrigation was due to the higher amount of applied irrigation water, thus the plants have used water in the soil under availability conditions (Allen et al., 1998; Fries et al., 2020). The ETc of the plants was encouraged since the moisture level in the soil was higher in the drip irrigation than other surface irrigations and this resulted in higher ETc.

The difference in yield among management zones increased as crop suffered from more severe water deficit. Similar to the variation pattern of irrigation applied, the lowest seasonal ETc was obtained in the rain-fed treatment in both seasons (Li et al., 2019).

Effects of climatic factors on grain yield

Lower rainfall caused relatively lower grain yield also under the rain-fed and all irrigation systems (drip irrigation and surface irrigations). For this reason, the yield was very low during the period of 2017-2018 under the rain-fed conditions although there was a slight increase in rainfall in the following periods (Fig. 3b), the poorly developed weak plants caused insufficient grain formation. Climatic factors such as rainfall and temperature directly affect, thus, grain yield. Climatic factors control both plant health and yield over time (Paudel et al., 2014; Ray et al., 2018).

Considering the annual amount of rainfall (495.7 mm) in the study region for the long-term (1921-2021), the season of 2019-2020 could be taken into account as an extreme year in terms of rainfall (675.8 mm) in growing season. Considering all these, wheat yield may vary from year to year according to weather conditions and agronomic practices (Yu et al., 2014). In a study, a decreasing rainfall of 28% resulted in a decrease grain yield of 27% (Hochman et al., 2017). Wheat yield and crop evapotranspiration were limited by lower rainfall during the growing season of wheat. The rainfall was more important than temperature, especially during the rapid growth period of the plant, growing up and flowering. Because, these periods were covered in which generative organs develop and grain maturity and these are sensitive to drought. Lower rainfall could produce infertility flowers and are not grown enough, thus it could resulted in lower yields (Erdelyi, 2008). Water deficit resulting from drought reduces crop yield because of its negative impacts on plant growth (Karl et al., 2009) and there is, thus, a strong relationship between rainfall and yield of wheat (Cetin and Akinci, 2014; Giunta et al., 2003; Dehgahi et al., 2014). In addition, precipitation patterns with fewer rainfall events could lead to reductions in biomass and grain yield (Oweis et al., 1998; Gooding et al., 2003) and the lowest yield was obtained in the rain-fed treatments (Li et al., 2019).

Studies have shown that water deficits applied in stem elongation and heading stages significantly decrease wheat yields (Tari, 2016), and that the drought following anthesis can negatively affect photosynthetic characteristics as well as significantly advance senescence in flag leaves (Wu et al., 2014).

The maximum temperatures occurred more than 30 ºC after flowering stage (Fig. 3) in this study. The extreme maximum temperatures affect negatively the plant physiology on pollination and grain formation. Sabello et al. (2020) showed that the plant life cycle was clearly shorter under the higher temperature conditions due to the physiological strategy of the plant to escape the high summer temperatures through early ripening of the kernels. Royo et al. (2014) reported also, the climatic zone accounted for 32.8, 28.3 and 14.5 % of variance for days to anthesis, plant height, and grain filling rate, respectively. The number of days to heading and anthesis steadily increased when moving from the warmest and driest zone of origin to the coldest and wettest one. Thus, accordingly, the increase in temperature causes a decrease in yield in hot and dry regions (Parry et al., 2004; Gregory et al., 2005; Sivakumar et al., 2005). All these findings have been verified the results in this study. High temperatures also negatively affect the assimilation and grain quality (Hatfield et al., 2011). Heat stress during the reproductive phase is, thus, more harmful than a vegetative stage due to its direct effect on grain number and dry weight (Wolenweber et al., 2003). This stage cover grain filling and heat stress at grain filling stage is one of the key factors (Luo, 2011). It is stated that average maximum temperatures greater than 30°C cause physiological stress and thus reduce the grain set or grain fill (Ferris et al., 1998; Russel et al., 2014). Thus, the increasing maximum temperature affected negatively the yield (Cetin and Akinci, 2014; Lobell et al., 2005; Luo, 2011) and high temperature decreases also mean photosynthetic rates and mean total biomass

(Monson et al., 1992). Considering the climatic conditions in this study region, higher maximum temperatures and insufficient rainfall are the main limited factors on grain yield.

The minimum temperatures between the 40th and 65th days from the sowing date in 2017-2018 were considerably higher than those in 2019-2020 (Fig.5). This temperature level might not be sufficient for the requirement of vernelisation for the plant, thus it has a negative effect on yield compared to the growing season of 2019-2020. It has been stated that the yield of wheat was directly affected by climatic parameters such as precipitation, temperature and relative humidity (Basciftci et al., 2012; Yu et al., 2014). Similarly, some researchers showed that every 1 °C temperature increase might cause a decrease of 3-66% in yield of wheat (Ozturk et al., 2017; Zhao et al., 2017). The main reason for this is the acceleration or shortening of wheat development periods with the increase in temperature (Valizadeh et al., 2014). Because, winter wheat requires a period of low temperatures (vernalization) at the beginning of crop development stage for a proper flowering time in case the wheat experiences successful grain reproduction. This requirement could make winter wheat more vulnerable to a higher temperature via insufficient vernalization (Li et al., 2013).

Conclusions

Considering the experimental years, the amount and distribution of rainfall affected significantly on wheat grain yield under the both rain-fed and irrigated conditions. For this, while rain-fed in the dry season (399.7 mm) caused the grain yield to be as low as 1.0 t ha^{-1} in 2017-2018, wet season (675.8 mm) resulted in high grain yield of up to 6.75 t ha^{-1}. Accordingly, rainfall during the growing period is extremely important even if all kinds of agricultural techniques are applied.

The CFC and RBC resulted in the grain yield of 5.13 and 4.33 t ha^{-1} for the average data of a two year, respectively. However, irrigation water productivity (1.72 kg m^{-3}) was higher compared to 1.23 kg m^{-3} in CFC. Similarly, the grain yield of 5.21 and 5.55 t ha^{-1} were obtained surface irrigation and drip irrigation, respectively. Drip irrigation resulted in higher irrigation water productivity (1.89 kg m^{-3}) compared to surface irrigation (1.08 kg m^{-3}).

Although there were small differences between the CFC and RBC on grain yield, this was not statistically significant apart from the rain-fed conditions. Accordingly, the yield in CFC and basin irrigation was relatively higher than other treatments (RBC and drip irrigation). The irrigation water requirement was 468 and 258 mm in CFC under basin irrigation and in RBC and drip irrigation, respectively. Crop evapotranspiration was 813 and 725 mm in CFC under the basin irrigation, and in RBC under the drip irrigation, respectively. In RBC under the drip irrigation, irrigation water was applied at a lower level because the whole area was not wetted, only the ridge of the plot was wetted. In addition, one of the main reasons for the lower yield in RBC was to be used less seeds therefore there were lower plants number and spikes number per unit area.

As a result, some advantages of RBC could not be obtained in terms of water use and grain yield in this study. CFC under basin irrigation more appropriate compared to RBC and drip irrigation. Because higher grain yield is more important for farmers' returns. However, land leveling, appropriate land dimensions for basin irrigation, use of simple devices and equipments in irrigation, reducing water conveying losses will be important in order to increase water use efficiency in this cultivation.

Compliance with Ethical Standards

Conflict of interest

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Author contribution

The author read and approved the final manuscript. The author verifies that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

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