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Optimal Sowing Times and Irrigation Schedule of the Chickpea (Cicer Arietinum L.) in Semi-Arid Regions

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ABSTRACT

The purpose of this study was to determine the effects of different sowing times and irrigation schedules on seed yield and water use of chickpea in Central Anatolia's semi-arid conditions. For two years, field trials were conducted using a split-block trial design with three replications. The study addressed two sowing times as well as five irrigation treatments. While the effect of sowing time on grain yield varied by year, the effect of irrigation on grain yield was statistically significant for both sowing times. Also, at both sowing times, the three irrigation treatments had the highest grain yield. The efficiency of the water use was higher in late sowing than in early sowing. While plant water consumption increased during the early sowing period, the amount of irrigation water decreased. The seasonal yield response factor in early sowing, on the other hand, was lower than in late sowing.

1. Introduction

Chickpea is the third most-produced legume after cereals in the world in terms of cultivation area and production amount. Chickpeas, which are an important source of vegetable protein, have an important place in human nutrition, especially in countries where animal protein sources are insufficient. World chickpea production is mostly grown in South and West Asia, the Middle East and Southeast regions of Asia, North Africa, North, and Central America, and Europe. Approximately 80-85% of chickpeas produced have been producing by only four countries, India, Turkey, Pakistan, and Iran. In the world, from 14.8 million hectares of land cultivated, 14.24 million tons of products were obtained, and an average yield is 960 kg ha^{-1} (FAO-STAT, 2015).

Chickpea is one of the most grown plants after beans and lentils. Chickpea, which is the most drought and temperature resistant plant after lentils, is one of the most important plants in semi-arid and arid areas. It is the most important alternative plant to be used in the evaluation of light-textured soils in arid regions. For this reason, Chickpea has been included in the planting pattern of the southeastern and central regions of Anatolia.

Chickpea cultivation area in Turkey is 520,000 hectares, while the total production is 620,000 tons, while the yield per hectare is around 1.2 tons (TURKSTAT, 2018). In recent years, chickpea production has decreased in parallel with the chickpea cultivation areas. On the other hand, the spread of anthracnose during rainy periods has a decreasing effect on production. That's why, it was aimed to prevent the spread of anthracnose by delaying the sowing times as well as chemical control.

Many studies have been conducted to determine the effect of irrigation schedule and planting times on chickpea yield. According to Güngör (1980), it should be irrigated at thirty percent of the effective moisture in the effective root zone. According to Günbatılı (1986), two irrigations are sufficient.

Winter sowing in Sicily increased chickpea seed yield by 21% (Calcagno et al., 1987). While early sowing increases chickpea yield by 65%; irrigation increased by 73% the yield (Saxena et al., 1990), late sowing negatively affected plant height and seed size (Poma et al., 1990). Adequate soil moisture is a requirement for an optimum plant number, good growth, and high yield (Singh et al., 2011). Many researchers have observed that optimum humidity conditions during the pod set binding period increase the transfer of assimilates to the reproductive organs, thus reducing flower and increasing yield (Leport et al., 1998, 2006). Water stress causes reproductive development to cease while the plant enters the reproductive stage and consequently the yield decreases. Turner et al., (2006) reported that irrigation during pod development caused an increase in the number

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of pods per plant by delaying the cessation of flowering and pod set development (Leport et al., 1999, 2006).

Many studies have shown that one irrigation (Munirathnam and Sangita, 2009), two irrigations (Abraham et al., 2010), or three irrigation applications (Mansur et al., 2010) significantly increase chickpea grain yield. However, the actual number of irrigations required depends on many factors such as the amount of precipitation received, soil structure, weather conditions, and growing period. Singh et al. (2015) reported that 75 mm of water in vegetative and vegetative + pod formation stages provided a 59% and 73% increase in seed yield, respectively.

Chickpea cultivation in semi-arid climate zones is generally based on rainfall due to the insufficient water resources of these regions. However, considering the growth periods of the plant during the growing season, it has been discussed to what extent one or two irrigations will affect the yield levels in chickpeas. This study mainly deals with the effects of irrigation schedules created for early and late sowing and different growth periods on chickpea yield and water consumption.

2. Material and Method

Field trials were conducted in Central Anatolia on the Konya Plain. The trial site has a height of 1016 m and is located at 37^0 N and 32^o E longitude.

Figure 1
The geographic location of trial site

The soil at the trial site is clayey, sandy, and very calcareous. Its organic matter content is low, and its sand content is high. There was no salinity problem in soils with a slightly alkaline reaction. Considering the soil properties related to irrigation, the field capacity at 60 cm depth was 289 mm and favorable humidity was 158 mm (Table 1).

The area where the trial was conducted has a semi-arid climate with an average annual precipitation of 316 mm, 9% of which falls in the summer. The other seasons receive almost equal amounts of rainfall. It is 36%, 24%, and 31% in spring, autumn, and winter, respectively. The weather is hot and dry in the summer, and cold and snowy in winter.

The weather data for the growing season are presented in Table 2. The average total precipitation from October to harvest varies between and 110-130 mm for the growing season.

In the trial, the Seydişehir chickpea (Cicer arietinum L.) variety was used. Recommended for Central Anatolia, this variety is a mid-late variety, ram-shaped, sensitive to anthracnose, medium-sized, high-yielding, 2.50-3.50 t ha^{-1} in irrigated conditions, and 1.0-2.0 t ha^{-1} in rain-fed agriculture (Kayıtmazbatır, 1978).

The experiments were arranged as A- two sowing times and B–five irrigation schedules, and the field trials were carried out for two years with three replications in the split block trial design.

A-Sowing times

E_1: Early sowing, the second half of March, E_2: late sowing, and the first half of May.

B-Irrigations considering the phenological development periods of chickpeas

I_0: Based on rainfall, I_1: 5% flowering, 1 water, I_2: 1 irrigation for 5% +, I_3: I_1 + I_2, two irrigations, I_4: I_1 + I_2 + pod filling.

After the wheat harvest, the field was ploughed and left for winter. In early spring, after the second ploughing of a disc harrow, it was prepared for sowing by fine levelling.

Plant row spacing is 0.35 m and row top is 0.10-0.15 m, sowing depth is 4-5 cm. Each trial plot has a total area of 7.0 m x 3.15 m = 22.05 m^2 in sowing, and 6.0 m x 1.75 m (10.50 m^2) in the harvest. A sufficient distance is left between the parcels and blocks to prevent horizontal water flow. The experiments were performed using a three-replicated split block trial design. Sowing times are the main treatments and irrigations are a sub-treatment.

The same amount of fertilizer (60 kg ha^{-1} P_2O_5 and 30 kg ha^{-1} N) was applied to all trial plots.

Irrigation water was calculated by determining the current moisture, and the moisture deficit was calculated to match the field capacity. While calculating the irrigation water requirements, the moisture consumed in the 60 cm soil profile was taken into account. Soil moisture was measured gravimetrically before irrigation and at the beginning of each growth period, and the amount of irrigation water to be applied afterward was calculated using the following equation:

$$IW = 1000\,(A)\,(\Delta SW)\,(A_s)\,(D_{rz}) \qquad (1)$$

where IW is the amount of irrigation water, A is the parcel area m^2, ΔSW is the soil water deficit at root depth before irrigation, g g^{-1}; is the difference between field capacity and soil water content; volume weight of soil, g cm^{-3}; and D_{rz} is the soil depth or effective root zone, m. The calculated amounts of irrigation water were applied through the flowmeters.

When the plants were 10 cm tall, the first hoe, light throat filling, and weed removal were performed before blooming.

The seeds were sprayed against fungal diseases such as anthracnose.

Harvesting and threshing were done by hand when the plants reached harvest maturity.

Table 1
Some soil properties of the trial site

Soil depth (cm)	pH	ECe ($dS\ m^{-1}$)	Bulk density ($g\ cm^{-3}$)	Field capacity ($g\ g^{-1}$)	Wilting point (g g-1)	Lime %
0-30	8.1	0.56	1.53	29.43	11.05	22
30-60	8.1	0.60	1.65	31.13	16.17	23
60-90	8.1	0.48	1.56	32.59	17.73	25

Statistical analysis and evaluations were made according to Yurtsever (1984).

Water consumption was calculated using the following water balance equation (James, 1988).

$$ET = IW + P + C_p + D_p \pm R_{off} \pm \Delta S \qquad (2)$$

ET, evapotranspiration (mm); IW, amount of irrigation water; P precipitation amount; Roff, surface flow; Dpis deep percolation; C_p, capillary rise, and ΔS are the changes in moisture content at soil depth (units are mm). In the ET calculations, R_{off}, D_p, and C_p are taken as zero-because there is no surface flow, deep percolation, or capillary rise.

Water use efficiency was determined using the equations given by Howell et al. (1994).

$$IWUE = (Y-Y_0) / I \qquad (3)$$

$$WUE = Y / ET \qquad (4)$$

IWUE and WUE: kg m^{-3}, I, applied irrigation water, mm; Y is marketable chickpea yield, kg da^{-1}, Y_0, yield under non-irrigation conditions, kg da^{-1}, ET, seasonal (total) evapotranspiration, mm

Table 2
Long-term climate data for the trial site

	Months												Total/average
	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	
Precipitation, mm	36	32	34	38	26	26	41	46	21	5	4	7	316
Mean temp., C°	11	4.8	0.5	-1.5	0.5	5	10.6	15	19.2	22.3	21.3	17.3	10.5
Evaporation, mm	90	23	-	-	-	-	110	147	196	254	231	163	1213
Rel. Humidity, %	62	72	78	77	72	65	59	57	51	45	46	50	51
Wind speed, m s^{-1}	1.8	2.1	2.2	2.4	2.7	2.9	3	2.5	2.5	2.8	2.4	1.9	2.4

3. Results and Discussion

Depending on the weather conditions during the growing period, early sowing resulted in a longer growth period and late sowing resulted in a shorter growth period. The development period of late sowings was shorter by 5 days in the first year and 15 days in the second year (Table 3).

Table 3
Chickpea development periods in early sowing

Observations	Early sowing		Late sowing	
	1. yr	2. yr	1.yr	2.yr
Sowing date	28.3	30.3	8.5	7.5
Germination	17.4l	18.4	29.5	17.5
Flowering	1.6	12.6	30.6	25.6
Pod-set	22.6	29.6	18.7	12.7
Pod-filling	4.7	14.7y	30.7	28.7
Harvest	23.7	10.8	28.8	1.9
Growth period days	117	132	112	117

An average yield of 980 kg ha^{-1} was obtained from early sown and non-irrigated (I_0) plots and 890 kg ha^{-1} from late sowing. Before flowering, pod formation, and pod filling, from three irrigated (I_4) and early sown treatments, an average of 2030 kg ha^{-1} and seed yield of 2760 kg ha^{-1} were obtained from those sown late. Grain yields obtained from other treatments were among these values (Table 4).

Ugale et al., (2000) that the lowest average yield was obtained at 1.110 t ha^{-1} when chickpeas are not irrigated, Pramanik et al. (2009), on the other hand, irrigation during the branching and pod period increases the grain yield significantly (2.24 t ha^{-1}), Lende and Patil (2017) reported that seed yield increased significantly (2.692 t ha^{-1}) with six irrigations during the branching and pod-set development phase.

Table 4
Chickpea grain yields (t ha^{-1}) according to treatments

Treat ments	Early sowing (ES)			Late sowing, (LS)		
	1.yr	2.yr	Average	1.yr	2. yr	Average
I_0	0.93	1.03	0.98	0.83	0.95	0.89
I_1	1.49	1.32	1.41	1.26	2.34	1.80
I_2	1.11	1.74	1.43	1.13	2.23	1.68
I_3	1.69	1.75	1.72	2.01	2.98	2.50
I_4	2.10	1.97	2.03	2.03	3.49	2.76

The effect of sowing time on chickpea yield was insignificant in the first year, while the second year was significant at the level of 0.01 (F_{calc} = 399.62**>($F_{0.01}$ = 98.50), and the interaction between sowing times and irrigation in the first year was found to be statistically significant (F_{calc})=12.56*> (F0.05 = 3.84).

This study showed that irrigation significantly increased the chickpea yield in semiarid regions. Irrigation during flowering, pod formation, and pod-set filling yielded similar results for both sowing times. According to the results of variance analysis, the effect of irrigation treatments on chickpea yield in both years was found to be statistically significant (0.01) (F_{calc} = 66.99** 1.yr 80.87** and 2. yr, $F_{0.01}$=7.01).

According to Duncan test results, I_4 treatments irrigated three times in all years constituted the first group for both sowing times. I_4 treatments were followed by I_3, which were watered twice. While I_1 and I_2, once irrigated, did not provide a significant advantage to each other, I_0 treatments alone constituted the last group and early sown I_0 outperformed late-sown I_0 treatments (Table 5).

Irrigation provided a significant yield increase for both planting times, depending on the rainfall. For example, one irrigation applied before flowering or pod formation, in early sown plots increased the seed yield by 30 %–31% on average, while pre-flowering one irrigation increased by 51%–47% in late sowing. Two irrigation yields increased by 43% in early sowing and 64% in late sowing (Table 6). On the other hand, three irrigation yields were increased by 52% in the early sowing period, and 68% in the late sowing period. As can be seen, the effect of irrigation on yield increase in late sowings was greater than that sown early.

Table 5
Duncan ranking of the treatments according to their grain yields

Treatments	Early sowing (ES)		Late sowing (LS)	
	1. yr	2. yr	1. yr	2. yr
I_0	0.93e	1.03ef	0.83f	0.95f
I_1	1.49bc	1.32e	1.26cd	2.34c
I_2	1.11de	1.74d	1.13de	2.23c
I_3	1.69b	1.75d	2.01a	2.98b
I_4	2.10a	1.97a	2.03a	3.49a

(p=0.05)

Many researchers have similarly reported that irrigation for late sowing causes higher increases in seed yield than early sowing. Bray (2002) stated that soil moisture deficit is more important than crop growth periods in planning irrigation.

The researcher pointed out that increasing low temperatures during early flowering appears to be the result of flower fall and watering, so the timing of single irrigation may depend on the region's weather conditions and the weather conditions of the particular season.

Table 6
Increase rates in chickpea grain yields

Treatments	Early sowing (ES)			Late sowing, (LS)		
	1.year	2.year	Average	1.year	2. year	Average
I_1	0.38	0.22	0.30	0.35	0.59	0.51
I_2	0.16	0.41	0.31	0.26	0.57	0.47
I_3	0.45	0.41	0.43	0.59	0.68	0.64
I_4	0.56	0.48	0.52	0.59	0.73	0.68

The increase in the number of irrigation and water consumption in chickpeas significantly increased the grain yield.

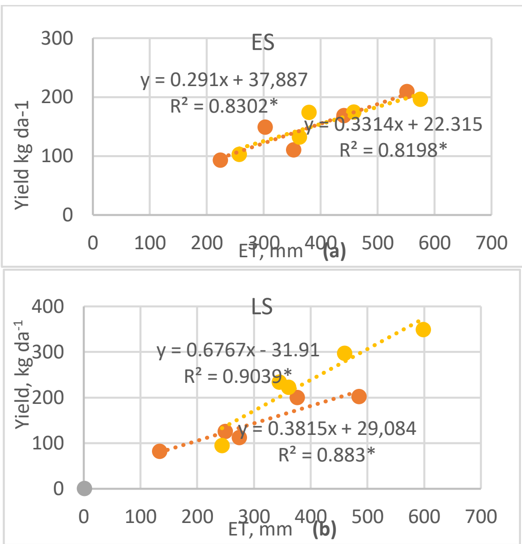

Figure 2
ET and grain yield relationships at different sowing.

High correlation coefficients of both early sowing and late sowing (1_{st}yr, R^2 = 0.82-0.83, and 2^{nd}yr, R^2=0.90-0.88) were found to have linear relationships between ET and seed yield (Figures, 2a, 2b).

An average of 100 mm in early sowing fields (I_1) and early sown fields before flowering, 115 mm in late-sown fields, 333 mm in three irrigated (I_4), and early sown plots; 357 mm of irrigation water was applied to those sown late. The amount of irrigation water supplied to the other treatments varied between these values.

The ET values increased in proportion to the amount of irrigation water applied.

Table 7
Amounts of irrigation water applied to treatments (mm)

Treatments	Early sowing (ES)			Late sowing, (LS)		
	1.yr	2.yr	Average	1.yr	2. yr	Average
I_0	0	0	0	0	0	0
I_1	95	105	100	121	109	115
I_2	137	118	127	143	125	134
I_3	213	202	208	246	224	235
I_4	347	319	333	366	349	357

In both sowing periods, the first-year ET values were found to be lower than the second-year ET values (Table 8, Figure 2a). In contrast, while the Meat values of the early sown treatments were significantly higher (p=0.0004), the differences in ET values were found to be insignificant in the second year (p = 0.565).

Table 8
Sowing times and seasonal ET values, mm

Treatments	Early sowing (ES)			Late sowing, (LS)		
	1.yr	2.yr	Average	1.yr	2. yr	Average
I_0	224	257	241	134	244	189
I_1	303	363	332	250	345	297
I_2	353	380	366	274	361	317
I_3	441	458	449	376	460	418
I_4	552	575	564	485	599	542

(p=0.002)

When the two-year mean values were taken into account, the ET values of the early sowing treatments were found to be significantly higher than those sown late (p=0.002). The long growing period of the early sown chickpea plants caused an increase in ET values (Figure 3a, 3b). Lende and Patil (2017) reported that the highest water saving was observed when irrigation was applied in branching and pod development.

In the first year, irrigation water use efficiency (IWUE) ranged from 0.13 to 0.59 kg m^{-3} for early sown crops and from 0.21 to 0.48 kg m^{-3} for late sown crops. In the second year, however, IWUE ranges between 0.28 and 0.61 kg m^{-3} in early-sown crops and 0.73 and 1.27 kg m^{-3} in late-sown crops. Sowing times had a statistically significant effect on IWUE based on average values. (p=0.014) (Table 9 ve Figure 4a).

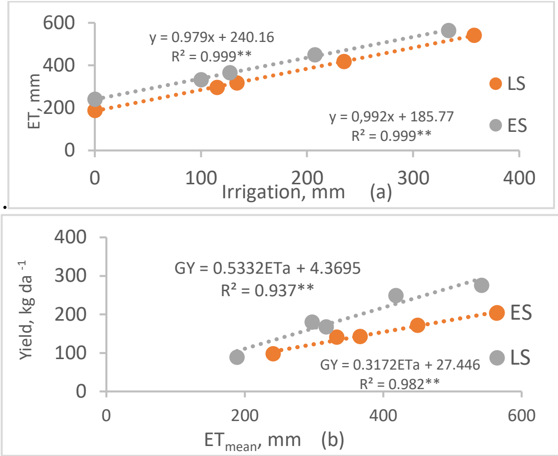

Figure 3
Relationships between mean seasonal ET vs. mean grain yield (GY)

Water use efficiency (WUE) ranged from 0.38 to 0.49 kg m^{-3} for early sown crops and from 0.41 to 0.62 kg m^{-3} for late sown crops in the first year. In the second year, WUE ranges between 0.34 and 0.46 kg m^{-3} in early-sown crops and 0.39 and 0.68 kg m^{-3} in late-sown crops. Based on average values, sowing times had a statistically significant effect on WUE. (p=0.004), (Table 9 and Figure 4b).

Oweis et al. (2004) stated that water use efficiency is significantly affected by planting time, irrigation and their interactions, Pramanik et al. (2009) found the water use efficiency of chickpea to be 1,169 kg m^{-3}

One unit of decrease in proportional water consumption in Konya conditions caused 0.85 units of decrease in yield in early sowing and 0.91 decreases in late sowing (Figure 4).

Table 9
Average irrigation water use efficiency of treatments

Treatments	Early sowing (ES)			Late sowing, (LS)		
	1.yr	2.yr	Average	1.yr	2. yr	Average
I1	0.59	0.28	0.45	0.36	1.27	0.95
I2	0.13	0.61	0.40	0.21	1.02	0.64
I3	0.35	0.36	0.39	0.48	0.91	0.80
I4	0.33	0.29	0.36	0.33	0.73	0.59

(p=0.014)

Zhang et al. (2000) reported that the average WUE values of chickpeas grown in the Mediterranean environment were 0.32 kg m^{-3}. Lende and Patil (2017) reported that the highest water use efficiency was achieved by irrigating all furrows at the pod filling stage (as 1.03kg m^{-3}).

Table 10
Average water use efficiencies of trial treatments (kg m^{-3})

Treatments	Early sowing (ES)			Late sowing, (LS)		
	1.yr	2.yr	Average	1.yr	2. yr	Average
I0	0.42	0.40	0.41	0.62	0.39	0.47
I1	0.49	0.36	0.42	0.51	0.68	0.61
I2	0.31	0.46	0.39	0.41	0.62	0.53
I3	0.38	0.38	0.38	0.53	0.65	0.60
I4	0.38	0.34	0.36	0.42	0.58	0.51

Single irrigation with early sowing (early and mid-February) increased the average yield by 65% and WUE value by 51% (Amiri et al., 2016). As a result, early sowing has been increasing WUE compared with late sowing according to regions and irrigation regimes.

The yield response factor (ky), which expresses the relationship between the proportional yield decrease and the proportional evapotranspiration decrease was determined as 0.85 for early sowing and 0.91 for late sowing, respectively.

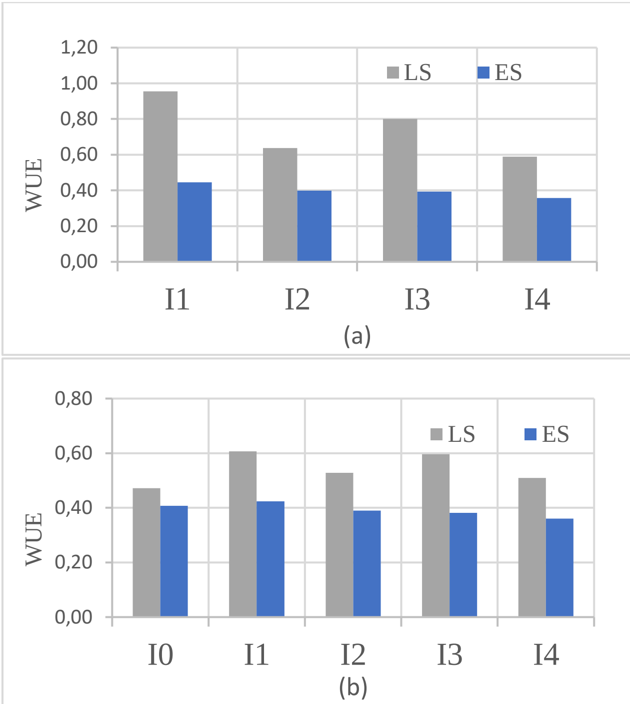

Figure4
Average WUE and IWUE values determined vs different sowing time and irrigation schedules of chickpea

These results show that chickpeas are relatively insensitive to water stress. Seasonal water shortages have been found to affect chickpea yield more in late sowing. It has been reported that the yield response factor for chickpea (ky) under Çukurova conditions is 1.06 (Yılmaz, 2011), and in northwest India between 0.67 and 0.93 (Jalota et al., 2006). It can be said that the data obtained in this study are compatible with similar study results.

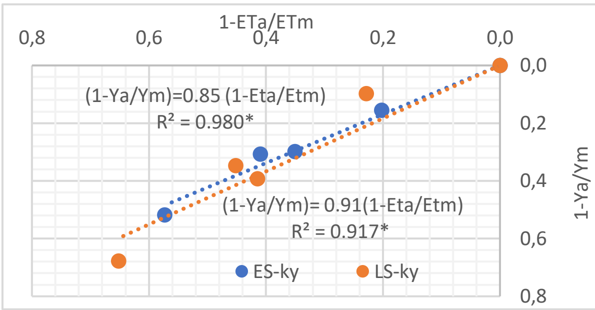

Figure 5
Relations between proportional ET reduction and proportional yield decrease in chickpea plant at different sowing times.

4. Conclusion

Chickpeas, which are sown early in the semi-arid conditions of Central Anatolia, prolonged the growth period by approximately 1-2 weeks. While sowing time did not affect seed yield in irrigated fields, early sowing significantly affected seed yield in non-irrigated fields. The reason for this is that chickpeas sown early have more opportunities to benefit from winter and spring rainfall.

Early sowing caused an increase in water consumption, whereas late sowing caused an increase in irrigation water. Although early sowing increased the risk of anthracnose, it was not observed during the two-year trial. It has been observed that fungal diseases such as anthracnose can be prevented by appropriate agricultural control. If single irrigation is performed in case of water shortage, it should be preferred to irrigate before flowering because the water need is less. However, monitoring soil moisture changes is necessary for optimum water management and yields.

Water resources in Central Anatolia are insufficient to irrigate many crops. As a result, plants whose growth period coincides with the hot and dry summer season suffer significant yield loss due to a lack of water. As a result, in terms of water management, it is critical to implement agricultural practices that maximize the use of winter precipitation while also expanding crop cultivation based on early spring precipitation and moisture accumulated in the soil. However, in order to prevent damage due to anthracnose and fungal diseases, chemical treatments should not be ignored as well as resistant varieties.

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