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İklim Değişikliğine Bağlı Faktörlerle (Yüksek CO_2, Yüksek Sıcaklık ve Kuraklık) Değişen Yağış ve Sıcaklık İklim Modeli İlişkisinin Türkiye'de Buğday Üretimine Etkisi

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Anahtar Kelimeler:
İklim değişikliği
Buğday
Buğday verimi
Buğday büyüme ve gelişmesi
Triticum spp.
Yüksek CO_2
Yüksek sıcaklık
Kuraklık

ÖZ

Buğday (*Triticum* spp.), dünya nüfusuna bitkisel kaynaklı gıdaların sağladığı toplam kalorinin yaklaşık %20'sini sağlayan, uygun besin değeri, depolama ve işleme tesisleri nedeniyle yaklaşık 50 ülkenin temel gıdası ve Türkiye'nin gıda güvenliğinde önemli bir yere sahip olan bir tarım ürünüdür. Buğdayın verimi, kalitesi ve büyümesi çevre koşullarına bağlıdır. Bu nedenle buğday üretimi, mevsimsel yağış dağılımına, yağış miktarına, sıcaklık ve kuraklık gibi iklim koşullarına bağlıdır. Küresel iklim değişikliğinin yol açtığı aşırı hava olaylarının sıklığının ve yoğunluğunun artmasıyla birlikte buğday üretimine yönelik riskler giderek belirginleşmiştir. En kötü senaryoya göre buğday üretiminin 2100 yılında ortalama %23 oranında azalması beklenmektedir. Bu sorunu çözmek için iklim değişikliğinin buğday üzerindeki etkilerine yönelik araştırmalar yapılmalı ve buğday üretimini arttırmaya yönelik stratejiler geliştirilmelidir. Bunlar, iklim değişikliğine uyum stratejileri, düşük karbon emisyon teknolojileri ve kapasite geliştirme gibi stratejilerdir. Bu çalışmanın amacı iklim değişikliğinin buğday üzerindeki etkileri sonucunda, buğdayda meydana gelen olumsuzlukların giderilebilmesi için iklim değişikliği senaryoları ile durumun tespit edilmesi ve sonrasında, uyum ve azaltım stratejileri etkin bir şekilde uygulanarak iklim değişikliğinin olumsuz etkilerinin en aza indirilmesidir.

Impact of Altered Precipitation and Temperature Climate Pattern Relation with Climate Change-Related Factors (High CO_2, Elevated Temperature and Drought) on Wheat Production in Turkey

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ABSTRACT

Wheat (*Triticum* spp.), that is the staple food of approximately 50 countries, due to its appropriate nutritional value, storage and processing facilities, also providing approximately 20% of the total calories provided by plant-based foods to the world population, and has a relevant importance in the food security of Turkey, is an agricultural crop. Wheat yield, quality, and growth are all affected by environmental factors. Therefore, wheat production is

Climate change
Wheat
Wheat yield
Wheat growth and development
Triticum spp.
High CO_2
Eevated temperature
Drought

affected by climate factors such as seasonal precipitation distribution, precipitation amount, temperature, and drought. With the increasing frequency and intensity of extreme weather events caused by global climate change, the risks to wheat production have become increasingly evident. In a study, it is estimated that, wheat yield in Turkey will decrease by about 8% until 2100, according to the average scenario. To solve this problem, research should be carried out on the effects of climate change on wheat and strategies for increasing wheat production should be developed. These are the strategies such as climate change adaptation strategies, low carbon emission technologies and capacity building can be developed. The aim of this study is to determine the situation with climate change scenarios in order to eliminate the negative impacts on wheat production as a result of the effects of climate change, and then to minimize the negative effects of climate change by applying adaptation and mitigation strategies effectively.

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1. Introduction

Wheat (*Triticum* spp.) ranks as first crop in the world in terms of cultivation and production among the cultivated plants used in human nutrition. This is due to is wide adaptability in terms of different agro-ecological zones. In addition, wheat grain is a staple grain of approximately 2.5 billion people in 89 countries due to its suitable nutritional value, storage and processing facilities (CGIAR, 2022). Wheat demand will increase by 50% by 2050, with a worldwide populace of 9 billion or more and as many as 6.3 billion citizens purchasing convenience food (CGIAR, 2022). Wheat provides about 20% of the total calories provided by plant-based foods to the world population. This rate is 53% in Turkey. It is thought that, the world's population will reach up to 10.2 billion after 30 years, in 2050 (Doğan and Kan, 2019). Therefore, according to FAO's data, global wheat requirement is projected to rise by 60% until 2050 (FAOSTAT, 2017). For this reason, wheat cultivation is done in many parts of the country. Table 1 demonstrates the annual wheat production of the provinces with the most wheat production in Turkey.

Table 1. Average wheat production (Mt) by the provinces from the most wheat production of Turkey between 2016 to 2020, (Ministry of Agriculture and Forestry, 2020).

Cities of Turkey	2016	2017	2018	2019	2020
Konya	2,045,298	2,192,410	2,037,936	1,886,131	1,271,728
Ankara	1,205,676	1,090,500	1,093,264	857,020	981,611
Tekirdağ	825,714	882,674	637,685	738,444	857,020
Diyarbakır	1,151,524	1,129,383	1,038,026	1,030,268	757,671
Sivas	578,709	569,158	624,119	523,687	530,767
Adana	621,872	690,411	680,000	502.562	752,378
Eskişehir	580,788	546,296	531,121	497,094	501,362
Edirne	522,970	505,460	494,001	431,658	497,094
Kırklareli	475,796	552,431	419,000	442,933	467,149
Çorum	607,956	581,078	515,031	557,904	442,933
Şanlıurfa	917,545	1,044,645	860,601	419,371	790,319
Yozgat	766,657	699,052	670,513	553,601	464,295

Table 2. Total average wheat production (Mt) from 2016 to 2020 in Turkey (Ministry of Agriculture and Forestry of Turkey, 2020)

Wheat production in Turkey by year	Wheat production (Mt)
2016	757
2017	762
2018	733
2019	762
2020	766

According to this table, total average wheat production in Turkey increased overall between 2016 and 2020 and decreased in 2018. The temperature increase and natural disasters were limited planting areas and resulted in this decrease in 2018 (ZMO, 2018). Turkey has 92 thousand hectar of land of wheat in 2000. In 2017, 77 000 000 acres of wheat were planted. Wheat imported 49 million tons by Turkey in this process affected product quality and shortenings with increasing temperatures in phenological periods with monitoring and investigating the seasonal timing of life cycle of wheat crop (Dalu et al., 2013). The temperature increase due to climate change continues with all its intensity. As a result, possible yield losses for wheat in developing countries are expected to be around 20-30%. The authors determined that, there would be a decline in wheat crop yield due to the fact that, the growth period, for example, the flowering and ripening times, was pulled forward by an average of 12 days due to the extreme temperatures that, the wheat would encounter. The amount of water required by the wheat plant during the growing season varies according to the development period. Therefore, the amount and distribution of plant growth period affects the precipitation yield, the yield of wheat from year to year depending on rainfall seen major changes in Turkey. For this reason, it often causes serious problems in wheat production in dry agricultural areas. As a result, the most limiting factor in wheat yield is the amount of precipitation and the distribution of precipitation during the year. In summary, wheat production is sensitive to climatic conditions. Wheat production and wheat prices, which have an important place in food security, may vary depending on climatic conditions.

2. Material and Methods

In order to assess climate-change related factors effects on wheat production, the study was designed in three section; (i) literature review for current available specific climate-change related factors' (high CO_2, elevated temperature and drought) studies on wheat production yield and quality parameters in Turkey, (ii) last 50-year precipitation and temperature climatic data collection and analyses from national meteorological station from Turkish State Meteorological Service (MGM, 2020), and (iii) last

5-year wheat production and yield data collection and analyses from national statistical data from Turkish Statistical Institute (TÜİK, 2022).

In Table 3, the studies of climate change-related factors (high CO_2, elevated temperature and drought) by yield and quality parameters on wheat production in Turkey were listed. These specific studies by climate change-related factors may were used as indicators of effects of changed climatic pattern on wheat production.

3. Results

3.1. Wheat Production and Quality Parameters of Climate Change

Assessment of the effects of global climate change on wheat production is essentially based on modeling that, uses limited information on plant responses. Several estimates of the effects have been made. In the previous report of the intergovernmental panel on climate change (IPCC) reveals a significant uncertainty in assessing the effects of 2 times the pre-industrial CO_2 and 4 °C rising temperature. These authors report that, variation in estimated yield effects, methods of analysis and products across countries makes it difficult to generalize results for other regions and for different climate scenarios. However, they experimentally concluded that, the production of wheat would decline significantly. Generally, modeling examinations envisage that, wheat will be grown at higher latitudes (ie substantially more north) and production will decline in areas closer to the equator (Gitz et al., 2016). In a study conducted in Turkey until 2060, it was simulated that, cereals will decrease due to the effect of a CO_2 concentration of 550 mmol $mol^{-1}$of and a 4°C increase in global agricultural production. Studies on the effects of wheat on climate change of some factors related to climate change in Turkey have been investigated (Table 3).

In this section, we first evaluated the responses of the basic functions to the increase in CO_2, temperature and drought, which are the most important aspects of global climate change. These are then; it is associated with changes in biomass production and grain yield observed when wheat is grown at high CO_2 and increased temperature levels (Tansi, 2019).

Table 3. List of studies on climate change impacts of wheat by some of the climate change-related factors in Turkey.

Parameter	Factors related to climate change	Source
Wheat Yield	High CO_2	Bayraç et al. (2016) Tansı (2019) Özdoğan M. (2011) Kapur et al. (2012) Asif et al. (2017) Bozoglu et al. (2019) Doğan et al. (2019)
	High Temperature	Vanli et al. (2019) Temur et al. (2017) Sayılğan (2016) Saadi (2014) Yavaş et al. (2016)
	Drought	Steduto et al. (1986) Asif et al. (2017) Keser et al. (2017)
Wheat Photosynthesis Rate	High CO_2	Tansı (2019) Yano et al. (2007) Koç et al. (2003) Ulukan (2021) Özdoğan (2011) Asif et al. (2017)
	High Temperature	Özdoğan (2011) Coskun et al. (2011) Kobata et al. (2012)
Wheat Stomatal Conductivity	High CO_2	Tanss (2019) Unal (2020) Öztürkci et al. (2019)
	High Temperature	Sharma et al. (2015) Bahar et al. (2019) Barutcular et al. (2017)
Wheat Quality	High CO_2	Özdoğan (2011) Chandio et al. (2021) Asif et al. (2017)
	High Temperature	Tayyar (2010) Barutçular et al. (2016) Erekul et al. (2019)
Wheat Growth	Drought	Yano et al. (2007) Koç et al. (2003) Bagci et al. (2007) Chandio et al. (2021) Keser et al. (2017) Asif et al. (2017)
	High Temperature	Özdoğan (2011) Yavas et al. (2012) Kobata et al. (2012)

3.2. High CO_2 Effects on Wheat Yield and Quality

The most important cause of global warming is CO_2 emissions. In this work the impacts of increasing carbon dioxide effects on the wheat yield and development were researched. Increased CO_2 concentration in the atmosphere, growth of wheat crop (high CO_2 concentration and low temperature, low light intensity, temperate zone plants) have been found to have positive effects. Increasing CO_2 provides the plant to usage the excess water and energy collects in its leaves, causing a serious increase in wheat yield. As a result, wheat grows and develops faster as the CO_2 amount increases (Bayraç and Doğan, 2016). Carbon dioxide is also one of the heat-trapping greenhouse gases that, assist to climate change. Elevated greenhouse gases in the atmosphere are seen biggest cause of climate changes (Eruygur and Özokcu, 2016). Greenhouse gases keep the heat from the sun to the atmosphere, causing the atmospheric temperature to rise. The greenhouse effect in IPCC is attributed to human activities (Doğan et al., 2018). Field greenhouse gas emissions to the atmosphere are increasing due to reasons such as the increase in fossil fuel use, consumption habits, changes in land use, urbanization, reduction of forests and cement production. With the industrial revolution, the rate of CO_2 resulting from greenhouse gases in the atmosphere increased by 30% from 280 ppm to 380 ppm (Temur, 2017). The proportion of methane, another greenhouse gas, in the atmosphere has increased by 151% since the industrial revolution (Temur, 2017). The proportion of nitrogen monoxide from greenhouse gases in the atmosphere has increased by 17% since the industrial revolution. Ozone depletion is also one of the most critical events that, cause climate change. As a result, wheat grows and develops faster as the CO_2 amount increases (Temur, 2017).

3.3. High Temperature Effects on Wheat Production and Quality

The effects of temperature on wheat phenology are quite different from the effects of extreme temperatures. Extreme cold can kill wheat, or late frosts can promote infertility. Temperatures above freezing temperature (lower than 5 °C) and extreme temperatures (more than 30 °C) during flowering may damage pollen formation, which may reduce the yield while ultimately reducing the grain set. There is a wide range of variations in sensitivity to this effect among cultivars. Global climate change will likely lead to lower yields due to extreme temperatures, as global climate change may change the frequency of extreme temperatures, especially during short periods when plant growth is susceptible. The ability to withstand such conditions requires the breeding and selection of varieties that, are better adapted. Higher temperatures shorten all development cycles. As such, there is less time left to receive resources such as light, water and nutrients, and it should come as no surprise that, biomass production decreases with increasing temperature. The magnitude of the impact depends on which growth cycle is affected. Because shortening the highest growth ratio period will make a bigger impact on the ultimate biomass production rather than shortening the initial growth cycles. In a study in England, applying a constant improve of 3.5 °C during the whole growth season, the final biome of winter wheat decreased by 16% and the grain yield by 35%, but the early growth period was greatly stimulated. Generally, in

multi-storey tunnel trials where the ambient temperature changes differently, the effects of rising temperature on the biomass have been found to be more negative (possibly because the changes tend to be greater at the end of the season). However, this varied greatly between seasons and varieties. The negative impact of increasing temperature on grain yields tends to be bigger than its impact on biomass. In other words, the reaping index decreases as the temperature increases. This is due to the special sensitivity of the grain yield to the duration of the grain filling time. The 1 °C improve in temperature pending the wheat filling term shortens the time by around 5% and proportionally decreases the crop index and seed yield. High temperatures during flowering can cause partial infertility, which reduces yields.

The effects of the summer wheat variety on the minaret were carried out in 9 different regions using open-top chambers (OTCs). This statistical analysis reveals that, for every 1 °C increase during the growing season (from emergence to maturity), there is a 6 % reduction in grain. This effect can be well predicted by simulation models the only effect of temperature on phenology (Tansi, 2019). The average annual temperature in Turkey in 1970 increased from 13.5 °C to 14.4 °C in 2020. The average annual rainfall was 500 mm in 2020 from 530 mm in 2000 (Turkish State Meteorological Service, 2020). Studies on claiming elements and agricultural interactions remain popular in Turkey as well as in the world. Studies have been carried out nationwide and regional on this issue (Doğan and Kan, 2019). With these studies, the influence on changes in temperature and precipitation on wheat production were investigated using various modeling methods. Between 1970 and 1999, the impact of temperature and precipitation changes in the Aegean Region on the wheat production was investigated. In the investigation, four diverse climate schemes were planned and evaluated. These climate scenarios cover decreases of 5% and 10% in monthly amount of rainfall and increases of + 1 °C and + 2 °C in average monthly temperatures. Accordingly, in April and May there was a 10% decrease in the amount of precipitation, while the yield decreased by 22.9 kg ha^{-1} (Doğan and Kan, 2019). An investigation was organized to see how climate changes impact crop production in Turkey's southeastern regions. The model of CERES crop was calibrated in this study, which used a total of eight farms, including four farm calibrations and four other farms for evaluation. The model of CERES wheat crop is an exhaustive computer model extensively used for effect of climate change studies. Climate change schemes have been developed for middle 21st century and the late 21st century for the working in areas called Islahiye and also Nurdagi. The model of calibration conclusions indicated a nice fit in the error range of only 1% to 11% between simulated and examined yield. Climate change in the future estimates based as a result of this study showed that, by the middle of the century the highest temperature anticipated to rise among 1.6 °C and 2.3 °C. It also showed that, the lowest temperature anticipates to rise among 1.0 °C and 1.5 °C. Climate change in the future estimates also obtained as a result of this study showed that, by the late of the century the maximum temperature will rise 2.0 °C and the minimum temperature will rise 1.8 °C. These results demonstrated that, a future increase the temperature reduces wheat output by 16.3% by the middle of the century and by

16.8% by the late of the century. In addition, these results are in Islahiye and Nurdagi demonstrated that, a future increase in temperature would reduce wheat outputs by 13.0% by the middle of the century and by 14.4% at the end of the century (Vanli et al., 2019).

In Turkey, using data from 81 provinces between 1995 and 2014, a study was carried out with panel data estimator methods, climatic determinants of wheat yield per hectare. In this study, wheat productivity data obtained from the Turkish Statistical Institute, the province-wide average annual temperature, the maximum temperature in July and August, annual climate data such as total rainfall and average annual humidity from the General Directorate of Meteorology were used for 77 provinces. Econometric estimates were carried out by panel regression method to specify the influence on climate change on wheat yield. According to these estimates, an increment of approximately 13% is expected for the Southeastern Anatolia Region by 2100 at the maximum temperatures of August. An increment of approximately 13% is expected in the maximum temperatures of July by 2100 for the same region. Due to these forecasts, it is estimated that, there will be 7.3% decrease in wheat outputs in the that, region in 2100 (Temur et al., 2017).

In the average scenario, it is estimated that, by 2100, wheat yields in seven regions will decrease by about 8%. On the other hand, in the worst-case scenario, wheat yields in 2100 are predicted to decrease by an average of around 23%. Therefore, the statistically significant upper limit of the decrease is around 23%. However, the statistically significant lower limit can be as much as 1% in the best-case scenario (Temur et al., 2017). The precipitation in Turkey in the last 50 years and the temperature trends in the last 50 years are given in Figure 1 and Figure 2, respectively. As figure 1 shows, the average temperature in Turkey is increasing. As figure 2 shows, the average amount of precipitation in Turkey is irregular.

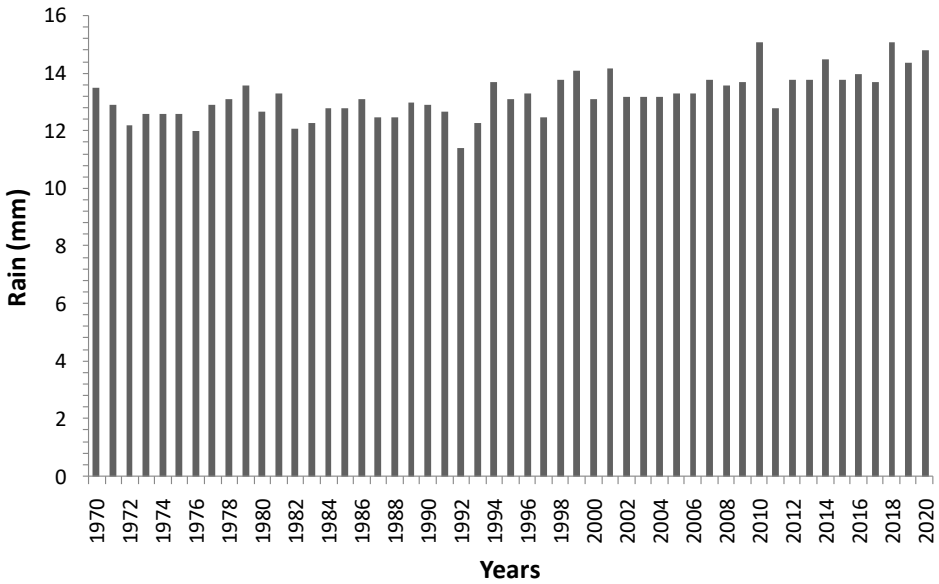

Figure 1. Average annual precipitation (mm) between 1970 and 2020 in Turkey (Turkish State Meteorological Service, 2020)

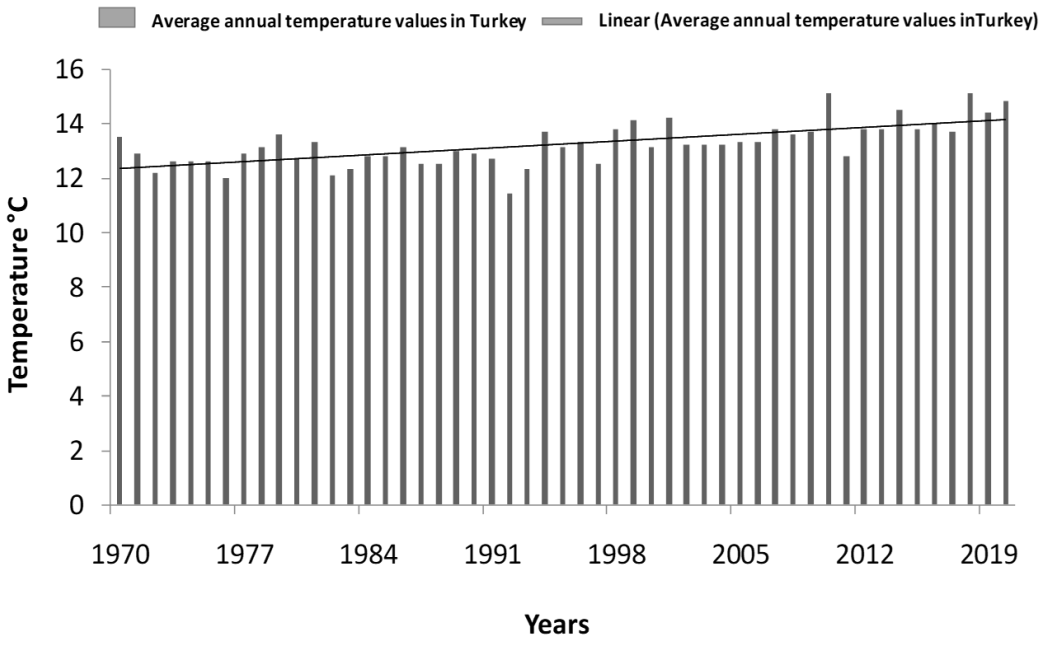

Figure 2. Average annual temperature distribution and trend between 1970 and 2020 in Turkey (Turkish State Meteorological Service, 2020)

Among the effects of climate changes on wheat efficiency, one of the reasons that, most affect wheat yield is high temperature rise. It is estimated that; wheat may be damaged as temperatures rise. Temperature changes the growth and growth rates of plants, including grain filling and late reproduction. Changing climatic conditions cause wheat to be unable to adapt to the environment, and therefore wheat is under stress. Wheat is the most important grain in Turkey, but due to the increasing temperature in Turkey, wheat can come under stress, which leads to a serious decrease in yield. The damage caused by stress factors alters resting on the type, tolerance and adaptability of the plant. Therefore, the determination of suitable wheat varieties and the development of wheat varieties is an important step to solve this threat in production, even to achieve high yields under high-temperature stress (Saadi et al., 2015; Sayılğan, 2016).

3.4. Drought Effects on Wheat Yield and Quality

Drought is the environmental stresses. It is that, important factor negatively affecting crop production in a big part of the world's agricultural field. Wheat production is generally carried out in dry agricultural areas and drought often causes serious problems in wheat production in these areas. A significant part of the annual precipitation in dry farming areas falls between November and April. Although there are dry periods in different growth periods due to the insufficient and irregular distribution of rainfall, the drought stress, which generally begins close to flowering, increases its effect during the grain filling stage. In arid situations, the water potential of the soil first and then the plant declines, and in later phases, a decrease in turgor pressure, stomata closure, a decrease in leaf

growth and a decrease in photosynthesis rate occur (Monti et al., 1986). The impact of drought stress on wheat yield is effective during the development period on wheat crop depending on the severity and duration of the drought. The main reason for the decrease in yield is the negative effect of drought on spike formation and post-flowering leaf area. While the drought stress during the spike forming period causes a reduction in grains number in the spike, the drought after flowering limits the weight increase in the grain. The drought stress occurring 10 days before or close to flowering affects the grain yield of wheat more negatively than the drought stress in other growth periods. Drought in early development periods; It causes earlier flowering, decrease in plant height, leaf area and number of fertile siblings, while drought between stalling and flowering periods; Fertile spike, fertile spikelet in the spike, and the number of fertile flowers in the spikelet, and post-flowering drought stress mainly restrict the leaf area period and the impact of grain drought on the development, efficiency of winter wheat results in a decrease in weight (Fischer et al., 1979). The drought stress throughout the grain filling stage also causes loss of grain set at the top and bottom of the spike by rising intra-spike competition in terms of participating insufficient assimilates (Steduto et al., 1986). Osmotic preservatives and fertilizer (nitrogen, potassium, manganese, zinc, etc.) to be applied to the wheat crop from the outside. Its application promotes the development of wheat and reduces the impact of drought on the crop (Yavaş et al., 2016).

4. Conclusion

Climate change affects wheat production. The atmosphere, hydrosphere and lithosphere that, make up the climate system have started to deteriorate, the natural balance has deteriorated, and the consequences of this have affected the climate. Studies conducted in Turkey, showing some uncertainty of the deterioration in the emerging climate with a warming global dimension and despite taking measures to counter them indicate future will continue this uncertainty and could lead to the emergence of problems. If high-temperature changes and precipitation continue to decrease in Turkey, wheat yields will decrease significantly and agricultural droughts will occur. Due to some effects of climate changes, farm land in Turkey is expected to decrease by 10%, increase in temperature and decrease in precipitation. It is necessary to expand its sustainable use within the balance of protection and use. Future weather forecasts and changes in the necessary weather conditions should be determined, as well as appropriate wheat varieties should be used and grown taking into account climate change factors such as increased CO_2 emissions, high temperature, average rainfall and drought. Therefore, this study is in same line with others to conclude as harmful human activities should be avoided, measures should be taken to reduce the level of CO_2 release (Doğan and Karakaş, 2018). Some measures like replacement of plant mixtures from durable plants to deep-rooted plants, use of residue-leaving planting systems that, reduce soil processing, and changing terrain use from yearly products to perennially products can be taken. In addition, local drought act schemes should be arranged and operated. Water resources should be applied methodically and sustainfully (Bozoglu et

al., 2019). Turkey should pay attention to reducing CO_2 emissions for agricultural and economic growth (Regniere et al., 2012). As a result, the effects of climate change on wheat in order to minimize the use of sustainable agricultural areas should be provided, reducing greenhouse gas emissions, increasing CO_2 emissions, high temperature, drought and climate change factors, such as average rainfall should be taken into consideration also should refrain from harmful human activities (Akalın, 2014).

Ethical Approval

Ethical approval was not required for this study.

Consent to Participate

Consent to participate is not applicable.

Consent to Publish

All authors provide a consent to publish this paper.

Authors Contributions

TK contributed the conceptualization, validation, data analysis, writing, visualization, reviewing and editing. TKA, SG and BT contributed to the conceptualization, methodology, data collection and analysis, drafting and manuscript.

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Competing Interests

The author declares that, there are no conflicts of interest.

Availability of data and materials

Relevant data are available from the corresponding author upon reasonable request.

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