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CHAPTER 1

POTENTIAL EFFECTS OF SOME CLIMATE PARAMETERS ON THE FRIST-CROP MAIZE YIELD AND QUALITY UNDER SEMI-ARID CLIMATE CONDITIONS

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1. Introduction

Spread of cultivated corn to the world occurred after Christopher Columbus' discovery of America (1492). Christopher Columbus and his team brought cultivated corn to Spain in 1493. In 15th century, it was brought from here to Asia via North Africa. In 16th century, it was taken by the Portuguese to West Africa, then to far eastern countries such as India and China. The name of this plant "mısır" in Turkish indicates that it entered into Turkey from Egypt (Mısır in Turkish) and Syria via North Africa (Kün, 1997). Corn, which plays an important role in human and animal nutrition, ranks third after wheat and paddy in world grain cultivation and second in production after wheat.

In Turkey, corn (maize) cultivation and production initiated in 1982 within the framework of the "Second Crop Research and Extension Project" and continued to increase until today. On the other hand, when the second crop corn production was examined, especially in the Southeastern Anatolia Region, it has been determined that cultivation areas and yields have increased from year to year in general. Corn is an important raw material used in industry for starch, syrup, sugar, beer and alcohol production (Süzer, 2003). In Turkey, maize cultivation is practiced over 690,553 ha, annual production is 6 million 500 thousand tons and the yield is 941 kg/da on average. In Southeastern Anatolia, the cultivation area is 215.725 ha, the production is 1 million 932 thousand 107 tons and the yield is 896 kg/da. As such, Southeastern Anatolia region ranks second in Turkey's corn production with a share of 31.24% (TUIK, 2020).

There are many types of corn such as dent corn, flint corn, flour corn, popcorn and sweet corn. In Southeastern Anatolia region, different dent corn varieties belonging to different maturity groups of FAO (World Food Organization) have been adopted by the farmers as second crop and have become widespread. In climate classification; Siirt has a dry climate according to Aydeniz, semi-humid according to Erinç, semi-humid-semi-arid according to Thornthwait and a semi-arid-semi-humid climate according to Demartonne (FAO, 2020; Şensoy, 2007; Anonymous, 2022). Although Siirt province of Southeastern Anatolia region is classified as a semi-humid climate in climate classification according to Erinç, in reality, it has a typical transitional climate. Summers are hot and dry and winters are warm and rainy with few frost days. In places with this climate, severe summer droughts and high temperatures are dominant. In summer days, it is seen that the temperature values often exceed 40°C. Annual precipitations are between 600-650 mm. Precipitation generally occurs in the form of rain in winter and close to winter months (Anonymous, 2009). In other words, precipitation does not show an equal distribution to all months of the year. In addition, some seasonal changes are experienced with global warming, therefore, some negative changes are observed in the time and amount of precipitation. Since there is no rain in the summer, maize plant can only be grown in irrigated areas. As it was in other plants, biotic factors such as diseases, weeds and harmful insects and abiotic factors such as soil, fertilizer, irrigation, tillage and climate play an important role directly or indirectly in maize cultivation. Precipitation, temperature and relative humidity constitute three most important climate parameters of maize cultivation. It is reported that climate was one of the most important factors limiting crop production in agricultural fields (Kapur et al., 2008, Airplane et al., 2010; Kaymaz and İkiel, 2004). In addition, Jones (2000) reported that atmospheric activities were highly effective in production quantities, productivity and quality of agricultural products. Normally, maize plant starts to germinate at 10-11°C. Germination accelerates when the soil temperature at a depth of 5-10 cm reaches to 15 °C. During germination, there is a linear relationship between root and stem elongation and temperature being between 10-30 °C. When the temperature reaches to 32 °C, there is a sudden decrease in root and stem elongation and germination is terminated and germinated plants die out when the temperature reached to 40 °C. On the other hand, root elongation is also terminated when the temperature drops below 9 °C. The ideal temperature for corn production is between 24-32 °C. Although maize is a hot-climate plant, it does not require extreme heat. When the temperature reaches to 38 °C, roots cannot meet the water lost through transpiration even under irrigated conditions. Plant loses its turgor. If this situation continues for a few days, the cell structure loses its flexibility and cannot return to its former form (Cerit et al., 2001; Öner and Sezer, 2007; Atilla, 2009). This study was conducted in Southeastern Anatolia Region (Siirt province) with a significant place in maize cultivation under semi-arid climate conditions to assess direct and indirect effects of climate events encountered during the vegetation period of maize plant in 11-year period between 2005-2015 on maize cultivation.

2. Material and Method

The research area is a fertile plain with fertile soils, Botan, Zarova and Çatak rivers in the Southeastern Anatolia region. It is located in a typical transitional climate zone with hot and dry summers and mild and rainy winters. The superior advantages provided by ecology enabled the cultivation of many field crops in Southeast Anatolia. One of these plants is maize (*Zea mays L.*). Hybrid maize cultivation, which was first started commercially in the 1980s in Southeast Anatolia, has gradually increased until today and has become an indispensable product of the farmers in the region. Southeastern Anatolia ranks the second after the Mediterranean Region in terms of maize cultivation in Turkey. In maize cultivation, abiotic factors as well as biotic factors play a very important role. Among the abiotic factors, climate events have highly significant direct and indirect effect on maize cultivation (Öztürk, 2007; İmanverdi et al., 2007; Fahad et al., 2017; Evans, 1969). In this study, research data of the Ministry of Agriculture and Forestry, Gap International Agricultural Research and Training Center, literature reviews, field surveys, farmer interviews, agricultural production reports from 2005 to 2015, meteorological data of these periods and various sources were used as the primary materials. Climatic data of the relevant years and yield values were graphically correlated and interpreted according to the correlation coefficients between the parameters.

3. Results and Discussion

3.1. Effects of Temperature and Relative Humidity on Maize Plant

Soil is not a limiting factor since maize plants grow in almost any types of soil. However, the most important factors limiting maize cultivation are high temperature, precipitation and very high and low humidity values. Second crop maize cultivation is not practiced in the research area. Since dry climatic conditions prevail in the region during the summer months, in main crop maize cultivation, sowing is practiced in late April and May. Depending on temperature and humidity in different maturity groups, top-tassel formation starts about 55-60 days after sowing, then in the following 2-3 days, cob tassels emerge. In the first crop maize cultivation of the region, pollination coincides with the second week of July and extreme temperatures and low humidity have highly significant effects on flowering plants. Therefore, the relationship between the climate data on these days of July of 11 years between 2005 - 2015 and the yield was investigated and it was determined that climate values of 2005 and 2009 had a decreasing effect on yields. Yield values for the years 2005 - 2015 are provided in Table 1 and climatic data of the relevant years are provided in Table 2 and 3. Figure 1 shows the yield values for the years 2005 - 2015. In present research site, first crop maize is sown in the first week of May and pollination begins in the second week of July. Therefore, instead of entire month, it will be useful to examine the days of July corresponding to pollination period to determine the negative effects of climate on yield. The high temperature, low relative humidity and resultant drought stress encountered in the second week of July 2009 were the main reasons of decreased maize yields. As can be seen from Table 4a, high temperatures up to 42.3˚C and relative humidity values around 30-40% negatively affected pollination, sufficient pollination was not achieved, kernel set rates decreased and yields decreased significantly. Additionally, decreases were encountered in corn breeding and selfing studies carried out in the same year as compared to previous years since the success of breeding works is limited by extreme temperatures and low relative humidity. Therefore, in semi-arid climate conditions, maize plant breeding studies are usually carried out in the main crop for fear of exposure to climate-induced stress in the second crop.

Table 1. Maize cultivation area and production values of Siirt province (2005-2015)

1st Crop			
Years	Sowing Area (ha)	Production (ton)	Yield (ton/ha)
2005	1750	1126	6.43
2006	910	740	8.13
2007	910	740	8.13
2008	1188	951	8.01
2009	11029	8530	7.73
2010	4851	3937	8.39
2011	4912	3882	7.90
2012	14100	12098	8.58
2013	14049	12714	9.05
2014	14678	13037	8.88
2015	9675	17267	8.78
Average	814.2	7428.2	8.19
CV (%)	85,58	89,31	8,80
SD	6850,76	6091,42	0,7202
Correlation (%)	89,70	90,80	78,77

Table 2. Monthly maximum and minimum temperatures (°C)

Years	Temperature °C	Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	Max	6.3	7.4	10.0	21.9	26.6	34.2	37.4	37.8	33.6	25.6	17.8	9.6
	Min	-2.2	0.3	9.0	13.0	13.9	20.8	24.4	25.8	20.2	13.7	7.7	0.1
2006	Max	7.1	11.3	15.3	21.6	26.1	33.9	36.3	36.4	34.2	24.7	17.4	4.6
	Min	-0.4	3.8	5.1	8.9	14.5	20.8	23.8	22.8	17.9	14.5	7.3	5.1
2007	Max	9.7	13.3	16.9	19.0	27.1	37.0	37.0	37.6	32.2	23.7	14.3	10.5
	Min	3.8	4.5	8.4	10.4	15.5	20.8	25.1	25.3	21.4	14.2	8.4	5.0
2008	Max	7.9	10.7	14.4	22.5	26.4	37.1	37.1	36.7	35.0	24.4	15.7	10.2
	Min	1.2	1.1	4.6	9.1	13.1	19.8	24.1	24.0	19.4	11.7	3.2	1.4
2009	Max	5.3	13.1	15.1	19.8	25.3	36.3	37.5	36.8	31.5	26.3	16.4	7.2
	Min	1.0	-0.7	1.3	10.7	14.9	21.4	24.2	24.6	20.3	14.4	9.2	3.2
2010	Max	7.4	7.8	14.7	22.7	25.1	39.1	37.1	39.3	35.8	24.8	16.3	12.6
	Min	0.4	3.1	5.5	10.4	14.5	19.6	24.1	23.7	18.3	12.0	8.5	-2.0
2011	Max	9.7	7.9	18.6	21.3	25.7	38.7	37.5	38.6	34.5	26.2	24.3	12.6
	Min	1.5	2.5	7.1	10.3	14.8	20.0	24.2	24.3	19.3	13.6	5.8	4.4
2012	Max	6.4	12.9	18.5	22.0	26.7	38.8	37.0	38.6	34.5	24.8	17.8	12.6
	Min	1.0	2.4	5.2	9.1	14.5	20.3	24.6	24.2	21.5	14.2	6.7	1.4
2013	Max	7.3	11.8	17.8	21.7	25.8	38.7	36.3	36.6	35.8	26.2	14.3	10.2
	Min	-1.5	4.5	6.0	11.1	14.3	20.0	24.3	25.1	18.7	13.8	6.0	0.6
2014	Max	9.4	12.9	18.4	22.1	26.8	38.7	37.5	38.6	34.8	24.8	17.4	10.5
	Min	-0.2	-1.4	5.3	9.2	13.9	21.0	24.8	24.5	21.5	12.6	7.4	4.5
2015	Max	9.7	13.0	18.6	22.7	26.7	38.8	37.5	39.3	35.9	24.7	17.8	12.6
	Min	2.7	4.8	9.3	11.3	14.9	21.0	25.4	25.5	21.5	15.6	10.0	4.5

Table 3. Monthly temperature (°C), relative humidity (%) and precipitation (mm) values

Years	Climate Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	Temperature	1.3	4.0	13.7	18.0	19.4	27.4	31.7	32.1	25.8	18.7	11.5	3.3
	Relative Hum.	63.1	63.2	49.4	47.1	45.4	34.9	29.9	32.9	48.4	61.4	71.0	76.8
	Precipitation	97,1	92,2	112,3	46,1	31,5	22,7	0	7,4	2,8	27,2	49,5	84,3
2006	Temperature	2.6	6.7	8.5	13.1	20.3	26.7	30.3	29.5	23.6	20.0	10.8	7.4
	Relative Hum.	69.3	73.9	66.6	61.5	47.4	41.0	40.0	32.5	39.8	38.6	68.9	78.4
	Precipitation	136,1	121,2	79,2	97,1	15,8	0	0,4	0,1	0	160,3	87,8	31,6
2007	Temperature	6.5	7.6	12.2	15.1	20.7	27.6	32.1	32.3	27.8	19.5	13.8	8.8
	Relative Hum.	75.1	72.9	60.4	55.9	46.1	28.5	19.6	18.2	26.2	48.6	39.7	57.5
	Precipitation	36,2	34,9	89,7	237,0	24,3	8,7	0,0	2,2	0,0	8,8	48,2	41,7
2008	Temperature	4.3	4.5	9.5	13.4	18.4	26.3	31.2	30.9	25.6	16.9	6.8	4.7
	Relative Hum.	68.3	67.9	49.8	62.7	57.7	32.2	21.0	20.1	27.0	45.8	59.5	66.5
	Precipitation	57,5	75,8	49,9	32,0	29,8	7,0	0,2	8,3	35,5	57,4	23,2	81,9
2009	Temperature	3.2	2.8	5.2	16.3	20.4	28.0	31.1	31.3	26.7	19.4	12.8	5.9
	Relative Hum.	80.8	68.8	62.6	52.3	46.8	24.6	21.2	18.5	22.3	48.6	66.9	76.0
	Precipitation	32,6	127,0	130,3	103,0	13,7	6,9	0,3	0,5	5,5	44,6	213,3	135,0
2010	Temperature	3.2	6.7	10.1	15.8	19.8	26.7	31.1	30.6	24.9	17.9	12.5	0.8
	Relative Hum.	73.2	70.2	57.1	52.5	50.7	25.5	19.2	18.5	24.5	33.0	64.2	75.5
	Precipitation	115,5	58,8	35,8	73,7	60,3	26,4	0,0	0,1	0,9	49,6	0,0	34,2
2011	Temperature	4.8	7.2	11.5	15.8	20.8	26.6	31.4	31.7	25.3	18.1	9.6	6.7
	Relative Hum.	69.6	44.9	57.5	49.9	42.1	26.3	19.2	17.4	29.9	52.3	62.0	81.0
	Precipitation	75,5	88,4	55,1	238,5	83,2	8,6	3,3	0,0	10,5	38,2	47,2	42,6
2012	Temperature	3.9	6.0	9.1	13.7	20.4	26.8	32.1	31.4	28.2	18.6	10.6	5.1
	Relative Hum.	73.9	70.8	63.1	55.8	43.1	27.8	19.6	22.5	22.9	59.1	64.7	61.5
	Precipitation	74,1	171,0	102,4	62,1	63,0	3,6	6,5	0,0	0,9	68,2	36,2	114,8
2013	Temperature	1.7	8.1	10.1	16.6	19.9	26.5	31.4	32.3	25.8	19.5	10.4	3.3
	Relative Hum.	76.2	68.3	62.3	47.5	48.9	32.7	24.5	20.5	29.8	36.0	49.7	73.1
	Precipitation	166,6	117,8	93,0	50,5	84,9	5,7	0,0	0,0	1,8	19,1	62,8	68,3
2014	Temperature	3.0	2.7	9.6	14.0	19.5	26.9	32.3	32.0	28.4	18.4	11.2	8.0
	Relative Hum.	65.9	64.9	63.9	59.5	51.7	29.5	19.0	19.0	19.1	34.6	64.4	65.2
	Precipitation	75,2	38,4	119,6	90,7	18,6	15,1	0,1	5,2	32,1	51,7	94,8	92,8
2015	Temperature	5.7	8.2	13.7	16.8	19.8	27.4	32.3	32.1	27.9	20.4	16.6	8,1
	Relative Hum.	70.5	67.7	55.9	47.6	59.1	31.7	20.1	21.4	22.5	46.3	42.9	66,3
	Precipitation	61,0	92,0	122,3	53,8	29,6	3,6	0,0	2,4	0,1	189,6	41,0	72,3

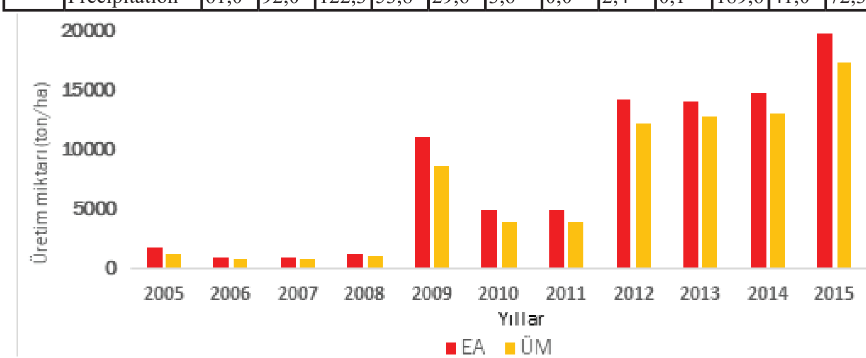

Figure 1. Year-based sowing area and production quantity of Siirt province

When the Table 1 and 4a-4b was compared, it can clearly be seen that especially high temperature and low relative humidity during the pollination period caused significant decreases in yield. In 2009 of the research site, air temperature during the full pollination period, especially during the second week of July (July 13, 14, 15, 16), increased to 42.3˚C and the relative humidity decreased to 32.5%. Consequently, significant yield losses were encountered. Yield decreases were also seen in 2005 and the primary reason of yield reduction was considered as maize dwarf mosaic virus encountered in that year. related to determined that the main reason for this decrease was the dwarfism disease seen in maize that year. Experts of Maize Research Institute indicated that this disease was seen in years with high temperature and relative humidity and the disease was not seen in years without optimum conditions for reproduction of the disease agent. Therefore, decreased maize yields of the year 2005 can be attributed to high temperature and relative humidity of that year. On the other hand, taking into account the maize growing period of the first crop maize (May-September), it was determined that there were polynomial relationships between yield values and monthly temperature and relative humidity values. Considering the first crop maize yield and 5-month average temperature and relative humidity values of the growing period, it was determined that there was no relationship between yield values and temperature and relative humidity values. In addition, there were significant polynomial relationship between 5-month average maximum temperature of the growing season and the yield at 1% level (Figure 3); between the temperature and humidity values of July in which pollination took place and the yield values at 1% level (Figure 4).It can be said that effects of temperature and humidity values on yield of the first crop maize were similar as expected.

It was determined that there were significant polynomial relationships between the average temperature and relative humidity values of the first crop maize growing season and the yield values at 1% level (Figure 4). In addition, it was determined that there were similar relationships between the average maximum temperature and average relative humidity values in the first three months of the growing season, where climate factors were more important, and the yield values. Ultimately, in the first-crop maize cultivation, as compared to temperature values, relative humidity values had greater significant relationships with the yield values (Figure 6). It was probably because high relative humidity values of the months of the first crop maize growing season had a greater effect on maize yield. In addition, polynomial relationships can be attributed to negative effects of both very high temperatures and very low relative humidity values on yield in the years studied.

Maize plant can germinate normally at 10-11 °C and germination accelerates when the soil temperature at 5-10 cm depth reached to 15 °C. During germination, there is a linear relationship between temperatures of 10-30 °C and the root and stem elongation. When the temperature reached 32 °C, there is a sudden decrease in root and stem elongation and germination is totally terminated and germinated plants die out at 40 °C. On the other hand, root elongation is terminated at temperatures below 9 °C (Kırtok, 1998). Although maize is a hot climate plant, it does not require extreme heat. The ideal temperature for maize cultivation is between 24-32 °C. When the temperature reached to 38 °C, roots cannot meet the water lost through transpiration even under irrigated conditions. If this situation continues for a few days, the cell structure loses its flexibility and cannot return to its former form. When the temperature rises above 32 °C during tassel emergence and pollination, differentiation in the reproductive organs develops very rapidly. The cob tassels dry quickly.

Table 4-a. Climate data for pollination days of the second crop maize in July of the years 2005-2010 (Anonymous, 2022).

Years	Meteorological Data	13 July	14 July	15 July	16 July	Years	13 July	14 July	15 July	16 July
2005	Max. Temperature (°C)	36.3	37.1	39.4	42.5	2008	41.2	42.6	40.3	41.7
	Min. Temperature (°C)	25.1	24.1	25.3	25.2		20.4	23.0	20.5	23.1
	Daily Aver. Temp. (°C)	31.2	31.1	31.7	32.3		31.7	32.1	31.8	32.2
	Daily Aver. Rel. Hum. (%)	22.6	22.5	20.7	20.6		29.9	32.9	30.0	33.0
	Precipitation (mm)	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
2006	Max. Temperature (°C)	40.8	42.4	40.9	40.0	2009	39.7	43.5	39.8	40.4
	Min. Temperature (°C)	20.0	22.0	20.1	22.1		20.7	20.2	20.8	20.3
	Daily Aver. Temp. (°C)	33.3	32.6	33.4	32.5		30.3	29.5	30.4	29.6
	Daily Aver. Rel. Hum. (%)	36.2	28.7	36.3	28.8		40.0	32.5	40.1	32.6
	Precipitation (mm)	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
2007	Max. Temperature (°C)	40.7	41.2	40.8	41.3	2010	42.0	41.0	42.1	41.1
	Min. Temperature (°C)	20.8	21.0	20.9	21.1		20.9	23.0	20.1	23.1
	Daily Aver. Temp. (°C)	31.0	30.9	32.0	31.0		32.1	32.3	32.2	32.4
	Daily Aver. Rel. Hum. (%)	34.2	36.1	34.3	36.2		19.6	18.2	19.7	18.3
	Precipitation (mm)	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0

Therefore, it cannot find sufficient moisture in tassel to allow pollen powders to germinate and progress in the tube. As the pollen sacs dry out, they cannot evacuate the pollen or pollen loses its viability and cob kernel set rates decrease (Figure 3). Growers believe that maize plants grow well on warm nights. Contrarily, maize plant does not grow well at hot and humid nights. Respiration increases considerably at hot and humid nights, thus, more energy is consumed in such nights. The nights when air conditioning is needed are the nights that are not suitable for development of maize. Cool nights, sunny days and moderate temperatures are ideal for maize (Kırtok, 1998). Maize, is a hot climate plant, grows and develops at an optimum level when the humidity does not fall below 60-65% with plenty of sunshine and hot days. Although it varies according to FAO maturation groups, varieties and the region, total temperature requirement during the vegetation period is between 2500-4000 °C. It is undesirable for temperatures to rise above 30°C and relative humidity to fall below 60%. Optimum and minimum relative humidity values for maize depend on temperature and amount of available water and it is generally desirable not to fall below 60% (Kırtok, 1998). In an environment where the relative humidity is reduced to 50%, the plant has to close its stomata after maximum transpiration and a decrease in humidity from 75% to 50% doubles its water consumption. Maize plant is adversely affected by low air humidity especially during the pollination period, such a case then hinders kernel set and increases water losses through transpiration. It was stated that moisture stress during the pollination period (50% or below humidity) resulted in 3% yield loss per day when 6% of the plants were in female flower and 7% yield loss per day when 75% of the plants were in female flower. It was reported that moisture stress during kernel-fill period resulted in 4.1% yield loss per day (Kırtok, 1998).

Table 4-b. Climate data for pollination days of the second crop maize in July of the years 2011-2015 (Anonymous, 2022).

Years	Meteorological Data	13 July	14 July	15 July	16 July	Yıl	13 July	14 July	15 July	16 July
2011	Max. Temperature (°C)	42.0	43.2	44.1	43.3	2014	41.1	41.5	41.2	41.6
	Min. Temperature (°C)	19.4	20.6	19.5	20.7		22.1	19.7	20.3	19.8
	Daily Aver. Temp. (°C)	31.2	30.9	31.3	31.0		31.4	31.7	31.5	31.8
	Daily Aver. Rel. Hum. (%)	21.0	20.1	21.0	21.2		19.2	17.4	19.3	17.5
	Precipitation (mm)	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0

2012	Max. Temperature (°C)	42.0	40.5	42.1	42.6	2015	36.4	37.2	39.5	39.0
	Min. Temperature (°C)	17.7	21.3	17.8	21.4		25.0	24.0	25.2	25.2
	Daily Aver. Temp. (°C)	31.1	31.3	31.2	31.4		31.2	31.0	31.9	31.8
	Daily Aver. Rel. Hum. (%)	21.2	18.5	21.3	18.6		22.5	22.4	20.5	21.0
	Precipitation (mm)	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0
2013	Max. Temperature (°C)	39.5	39.5	39.6	39.6					
	Min. Temperature (°C)	22.1	21.6	22.2	21.7					
	Daily Aver. Temp. (°C)	31.0	30.5	31.1	30.6					
	Daily Aver. Rel. Hum. (%)	19.3	18.5	19.3	18.6					
	Precipitation (mm)	0.0	0.0	0.0	0.0					

3.2. Effects of Precipitation on Maize Plants

July and August are the most critical months throughout the growing season of maize plant. While these months do not generate climate-induced stress in the first-crop maize cultivation, some extreme years may show a tendency to have a detrimental effect on maize cultivation during the entire vegetation period. Because maize pollination and kernel-fill take place in these months (Anonymous, 2001). Therefore, drought risk models have been developed in regions where precipitations are irregular and insufficient (WU, 2004). Although precipitation is an important factor that positively affects yield and pollination, almost no precipitation falls in July of the present study area. In semi-arid climate conditions, first-crop maize sowing should be completed before the end of May and delayed sowings may generate a risk as the vegetation period will not be sufficient. Harvest of maize plants largely depend on maturation groups, temperature, humidity and precipitation values of the region where it is grown and dry down rates of the plants and harvests in present research site may continue from August to November. It has been determined that there was generally no rain in summer months of the semi-arid climate zone, even if it does, the precipitation is not sufficient to progress into the effective root depth (approximately 5 mm) and it remains at trace quantities. On the other hand, precipitations in pollination period generate a cool air and prolong pollination period. Precipitation remained from the winter and held in soil profile (residual moisture) also contributes to maize yield and development. In this study, it was determined that there was significant relationships between the total precipitations during the first-crop maize growing season and the yield values at 1% level. Also, the correlation coefficient between precipitation and yield was higher (Figure 7).

Figure 2. Detrimental effects of high temperature and low relative humidity on maize cobs

Precipitation is an important factor in maize cultivation. For a reliable maize cultivation, annual precipitation should be between 600-1200 mm and irrigation should be practiced in areas with less than 600 mm precipitation. Water requirement of maize plant throughout the growing season is higher than the other cereals. Therefore, intermittent precipitations are needed in summer season, the growing season of maize, and majority of these precipitations should coincide with the ripening period (Şahin, 2001). Since the vegetation period of maize coincides with the summer months, water demand is high due to high temperatures and resultant evaporations during the growing season. Kaya and Yanıkoğlu (1990) indicated that maize plants need a total of 500 mm. water throughout the growing season. Distribution of irrigation water to be applied should be 75 mm in May, 100 mm in June, 175 mm in July, 100 mm in August and 50 mm in September. These figures are general values and may vary from region to region. Woodward (1967) determined that plant water consumption values of maize grown in the central plains of California were different during the development periods and daily plant water consumptions varied between 5-5.6 mm during 90-150-day development period (Derviş, 1986). Oylukan and Güngör (1975) indicated in their study conducted in Eskişehir province under field conditions that water consumption of maize was 725 mm and irrigation water requirement was 400 mm. For irrigation scheduling, 1st irrigation was recommended to be practiced when the plant height reached to 40-45 cm, 2nd irrigation at top tassel stage, 3rd irrigation at cob formation stage and 4th irrigation at milk-dough stage and about 100 mm irrigation water was recommended to be applied in each irrigation (Bayrak, 1997). Günbatılı (1979) conducted a study in Tokat-Kazova in 1974, 1975, 1976 and 1977 to determine water consumption of maize and stated that maize should be irrigated 3-4 times during the development period and reported water consumptions as between 569-670 mm and irrigation water requirements as between 358-437 mm. It was also determined that water requirement throughout the growing season was 637 mm, irrigation water requirement was 386 mm and average daily water consumption was 4.2 mm.

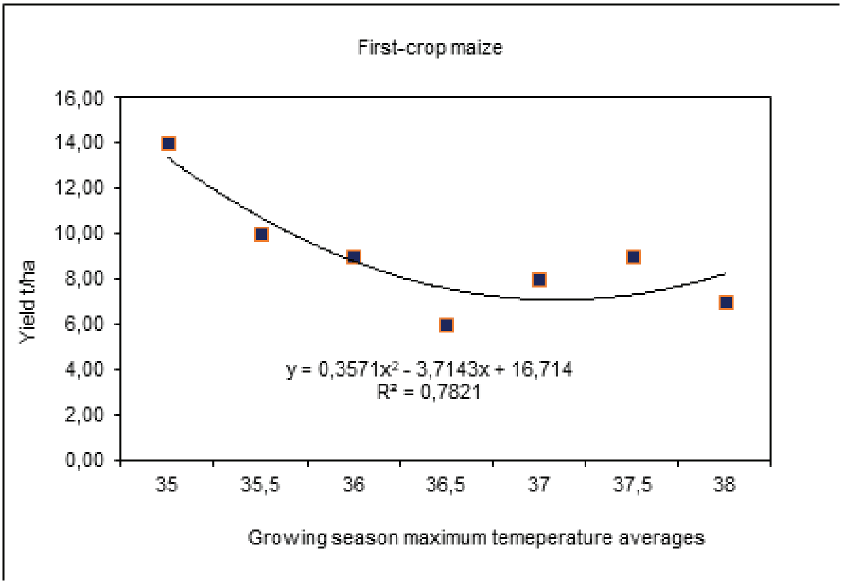

Figure 3. Growing season average maximum temperature – yield relation

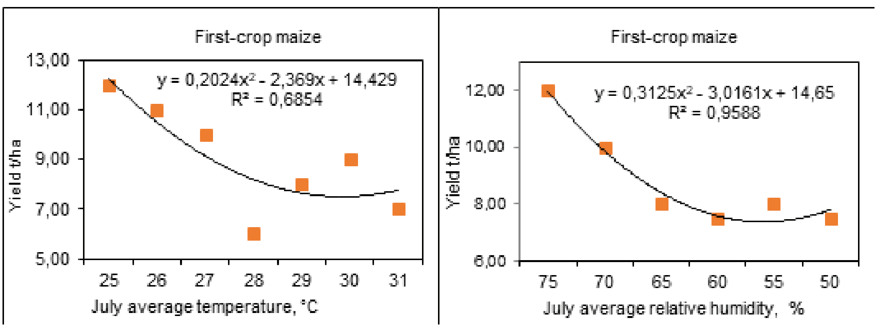

Figure 4. July average temperature and relative humidity – yield relations

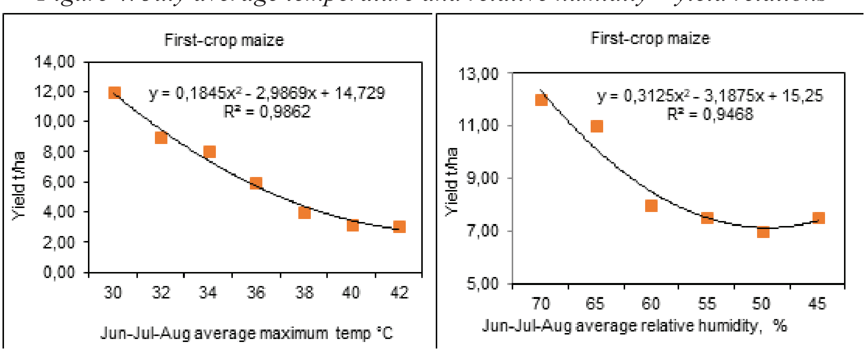

Figure 5. June-July-August average temperature and relative humidity – yield relations

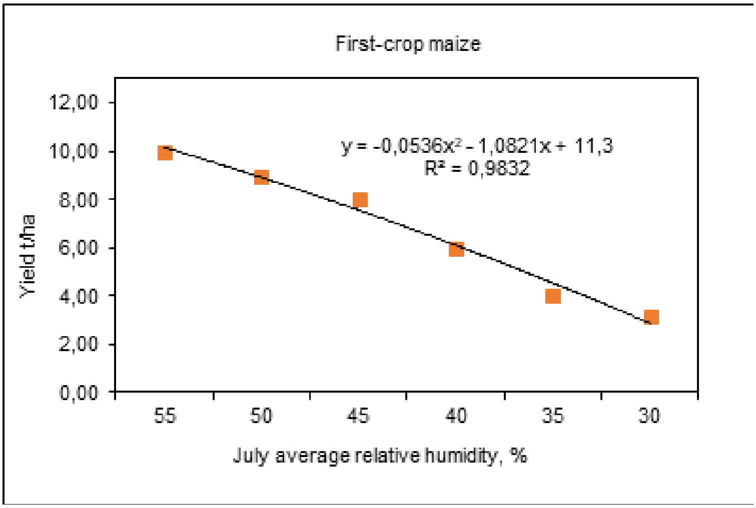

Figure 6. July average relative humidity – yield relations

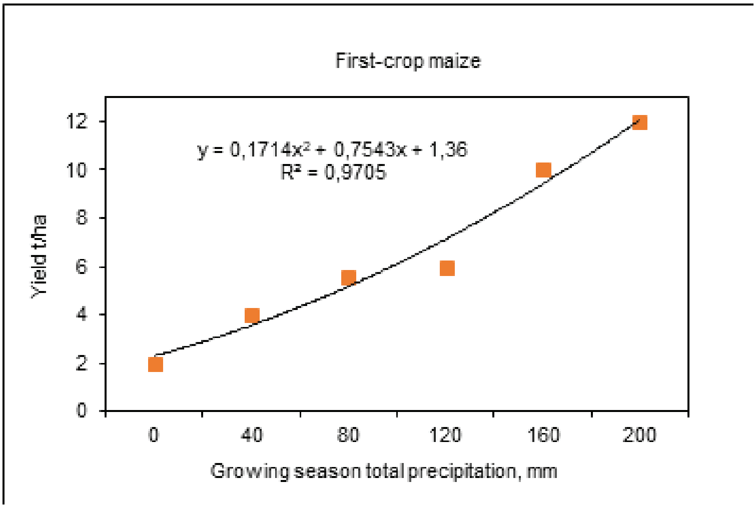

Figure 7. Growing season total precipitation – yield relations

4. Conclusion and Recommendations

In 2008, total maize cultivation area was 1188 ha and total production was 951 tons in the study area. In 2009, sowing area was 11029 ha and production was 8530 tons because of heat damage. Although the yield per unit area was 8.1 tons/ha in the previous year, the yield per unit area decreased to 7.73 tons/ha in 2009. There was a 9.1% yield loss as compared to the previous year. As compared to average of 11 years, 9.4% yield loss was encountered in 2009. In 2009, 10% yield loss occurred due to climate changes. As to conclude, such a decrease in yield could be attributed to climate-related high temperature and undesirable low relative humidity values, high temperature and high relative humidity values. Limit-exceeding values of both parameters had a negative effect on maize yield. Under such conditions, kernels cannot fill or cobs could not grow sufficiently, thus yield losses are encountered. While the cultivation areas and production values exhibited similar trends in relevant periods, productivity values showed a decreasing trends with the effect of climate conditions. Other important climate factors affecting maize farming are temperature, precipitation and humidity. Distribution of low humidity values within a year especially coincided with pollination period and this value decreased to 28.7%. It was determined that average temperature and maximum temperature values exceeded the limit values specified for generative development period of maize only in 2009 and such a case negatively affected the production and productivity in this year as compared to previous years. Therefore, it will be beneficial to develop maize varieties resistant to climate stresses during the pollination period through breeding programs, to make frequent irrigation in pollination period without waiting for 50% depletion of available moisture with the rootzone and to switch to drip irrigation in maize farming. In drip irrigation, soil moisture within the rootzone is usually close to field capacity, thus plants are not exposed to moisture stress, will be able to find sufficient moisture available within the rootzone and such a case ultimately will have positive contributions to both pollination and yield. On the other hand, as the years increased, a positive linear relationship was seen between maize cultivation area, production and yield values.

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CHAPTER 2

INVESTIGATION OF PHYSICAL AND PHYSIOLOGICAL PROPERTIES OF SEEDS OF SOME COMMONLY PRODUCED FORAGE CROPS

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1.Introduction

Due to the gradual decrease of meadow pasture areas, today it has become much more important to cultivate forage crops and evaluate them as wet or dry grass. For this reason, high quality, healthy, durable and high yield plants are preferred by the producers. Thus, research and studies on plants with these characteristics for animal production are diversified.

In this study, seeds of clover of Alexandria (*Trifolium alexandrinum* L.), Italian grass (*Lolium multiforum* L.), tall fescue (*Festuca arundinacea* L.) and alfalfa (*Medicago sativa* L.), which are widely produced by producers, were examined. Some physical (shape size, surface area, average arithmetic diameter, sphericity, thousand seed weight) and physiological properties (germination rate and germination time) of seeds belonging to each plant were determined. These physical properties are especially important in terms of placing the seeds in the seed bed with the least product loss by choosing the appropriate tools, machinery and systems during the planting process of the seeds (Dumanoğlu & Geren, 2020). In addition, these parameters are also used in the harvesting processes and product processing stages at the end of the production phase. Physiological features are; In particular, it provides information to producers and researchers about how long it takes to observe the germination performance of these plant seeds depending on important criteria for cultivation such as climate, soil, irrigation.

Clover of Alexandria (*Trifolium alexandrinum* L.): This plant, which has been produced in Mediterranean countries for years, is a one-year leguminous forage plant with good adaptation to arid conditions (Yücel et al., 2017; Bulut & Kendir, 2019). It can also be grown as a second crop by producers (Soya et al., 2004). In addition to its ability to grow in slightly alkaline soils, it shows good development with irrigation. Seeds are preferred as both main and intermediate products because they can be easily supplied by producers compared to similar products and they develop rapidly (Gençtan, 1983; Soya, 2009; Açıkgöz, 2001; Geçit et al., 2018). In this study, Efsane variety clover of Alexandria was examined.

Italian grass (*Lolium multiforum* L.): This plant, which has a good green grass yield due to its rapid development and irrigation conditions, is produced to increase the amount of organic matter in the soil as well as for animal nutrition (Soya et al., 2004; Çolak & Sancak, 2016; Lale & Kökten, 2020). It is also preferred in raising fodder plants made by the producers in the form of a grass + legume mixture (Geren et al., 2003). In this study, Zeybek variety Italian grass was examined.

Tall Fescue (*Festuca arundinacea* L.): Although it is not resistant to extreme cold, tall fescue, which is determined to be more resistant to heat and pressure than other cool climate grasses (Kılıç & Türk, 2017), is among the grassy forage plants (Öztürk et al., 2018). Having a good root structure increases the rate of adhesion to the soil. It is also a plant resistant to climatic conditions such as drought (Açıkgöz, 2001). Due to the root structure, soil holding is quite good, especially in continuously grazed pastures (Gençtan, 1983). Tall fescue can also be considered as dry grass (Soya et al., 2004). In this study, Nilüfer variety tall fescue was examined.

Alfalfa (*Medicago sativa* L.): Alfalfa is known as the queen of fodder crops due to its wide adaptability, high amount of nitrogen that it has attached to the soil, and being rich in minerals and vitamins (Soya, 1976; Öten & Albayrak, 2018). Alfalfa is the oldest cultured fodder plant, meaning "Media Grass (Herba Medica)" (Gençtan, 1983; Soya et al., 2004). It is preferred by the producers because of its positive aspects such as being perennial, having a fast development period, not having much weeds, and being harvested by mowing (Engin & Mut, 2018). In this study, Özpınar variety alfalfa was examined.

2.Material and Method

In this study, the physical and physiological properties of the seeds of four plants different from the commonly used forage plants were investigated. The study was completed in the laboratories of Bingöl University Faculty of Agriculture, Biosystem Engineering and Field Crops Departments between 2020-2021. As plant material, seeds of Alexandria clover-Efsane (*Trifolium alexandrinum* L.), Italian grass-Zeybek (*Lolium multiforum* Lam.), Tall fescue-Nilüfer (*Festuca arundinacea* Schreber) and Alfalfa-Özpınar (Medicago sativa L.) plants were examined. Seeds were obtained from the Republic of Turkey Ministry of Agriculture and Forestry Aegean Agricultural Research Institute.

The length (mm), width (mm) and surface area (mm2) values of the seeds were measured with the help of Nikon SMZ 745T brand stereo microscope, which has its own software, by randomly selecting 100 seeds from each of the plant materials examined in the study (Dumanoğlu & Geren, 2020; Dumanoğlu & Öztürk, 2021). Using the data obtained from here, the average arithmetic diameter (mm) (D: (L+W)/2) and sphericity (ϕ: D_0/L) values of the seeds were calculated (L: Seed length value (mm) W: Seed width value (mm)) (Mohsenin, 1970; Alayunt, 2000; Kara, 2012). The values that make up the basic dimensions of the seeds were examined by taking into account the classification stated by Yağcıoğlu (2015). In addition, the weight of one thousand grains of each plant material was randomly counted in triplicate and weighed with a precision balance (0.001 g) (Dumanoğlu et al., 2021).

Table 1. Classification of seeds according to their geometric characteristics and shapes (Yağcıoğlu, 2015)

Seeds according to their geometric characteristics	Grain width/Grain length (b/a) (mm)
Long	< 0.6
Medium	0.6 – 0.7
Short	> 0.7
Seeds according to their shapes	**Length (a), Width (b), Thickness (c) (mm)**
Round	a ≈ b ≈ c
Oval	a/3 < b ≈ c
Long	c < b < a/3

The germination rate (%) and germination time (day) of the seeds are among the parameters showing that the seeds are healthy and of good quality (Dumanoğlu et al., 2020). The seeds of four different forage plants were germinated in 8 days in a BINDER brand incubator under controlled conditions (20-25°C, 60% humidity, dark environment) in accordance with ISTA (2007) rules. Data related to each plant material were recorded by daily counting. (Average germination rate (%): (Σ n/N x 100); Average germination time (days): Σ(gxXnx)/(Σnx))(n:Number of germinated/emergent seeds, N:total number of seeds; gx : Day at the start of germination, nx: Number of seeds germinated on the day of counting, Σnx: Total number of germinated seeds) (Duman & Gökçöl, 2017; Akın & Duman, 2018).

3. Results and Discussion

The seeds examined in this study were generally determined as 4.128 mm in length, 1.416 mm in width, 4.300 mm2 in surface area, 2.771 mm in arithmetic diameter, 2.854 in sphericity and 2.495 g in thousand grain weight. However, the highest values among these seeds were Özpınar variety in terms of length (6,022 mm), Efsane variety in terms of width (1,613 mm), Zeybek variety 6,236 mm2 in terms of surface area, Nilüfer variety in terms of arithmetic diameter value (3,678 mm) and sphericity (4,550). As for the cultivar and thousand-grain weights, the Legend variety (3.481 g) stood out with the measured and calculated values (Table 1).

Table 1. Physical properties of some forage crops

Seeds according to their geometric characteristics	**Grain width/Grain length (b/a) (mm)**
Long	< 0.6
Medium	0.6 – 0.7
Short	> 0.7
Seeds according to their shapes	**Length (a), Width (b), Thickness (c) (mm)**
Round	a ≈ b ≈ c
Oval	a/3 < b ≈ c
Long	c < b < a/3

The germination rate (%) and germination time (days) of the seeds of four different fodder plants examined in the study were also investigated. According to the obtained values; While all of Özpınar and Zeybek varieties (100%) germinate; Efsane variety germinated 98% and Nilüfer variety 93% germination. In terms of germination times, the earliest Efsane variety (1,302 days) and the latest Nilüfer variety (1,329 days) germinated (Table 2).

Table 2. Bazı yem bitkisi çeşitlerinin fizyolojik özellikleri

Seed Varietys	Germination rate (%)	Germination time (day)
Efsane	98	1.302
Özpınar	100	1.314
Nilüfer	93	1.329
Zeybek	100	1.315

With this research, some physical and physiological properties of seeds belonging to four different plant groups belonging to forage plant varieties that are widely used by producers were determined. Although they vary depending on climate, environment and regional factors, the values belonging to the seeds examined in this study provide information about the characteristics considered as the characteristic features of the seeds. It is aimed to create awareness on the characteristics of these forage plants by drawing a general framework for the researchers from these data obtained. In addition, by using the values obtained with this study, it is aimed that the producers grow their products with the least loss.

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CHAPTER 3

VACUUM TYPE PRECISION PLANTERS; SETTINGS, CALIBRATION, AND EFFECTIVE PARAMETERS

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1. Introduction

In crop production, various stages are needed in order to grow a culture plant and get a product. These can be listed as tillage, planting, maintenance, fertilization, irrigation, pest control, harvesting, and threshing. It is important to choose the most appropriate time for these stages to be carried out most effectively. One of the plant production stages, where the time factor is most effective, is the planting process. While there is a limited time interval for other stages and the possibility of intervention accordingly, there is no return after the planting process is performed. In other words, it is not possible to make any changes in the planting process after dropping the seed into the furrow and covering it with soil. According to Ahmadi et al. (2008) reported that one of the most important factors affecting product quality in plant production mechanization is the planting process. For this reason, performing the planting process within the framework of a good plan and program and with a fully equipped planter will reduce the negative effects to be encountered.

The main purpose of the planting process is to place the seed in the soil with a distribution in the appropriate horizontal and vertical plane, in a way that will provide the plant requirements in a properly prepared seedbed. The planting method, which provides the most suitable living area for the plant, is the precision (single-seed) planting method in which the seed is placed at certain intra-row spacing and an inter-row spacing. According to Ahmadi et al. (2008) reported that the more sensitive the planting quality, the higher the harvested crop quality.

In precision planting, since the seeds are left one by one at certain intra-row spacing and inter-row spacing, seed consumption and labor costs for maintenance are reduced. Zaidi et al. (1998) reported that in precision planting of sunflower seeds, 70% savings were achieved in planting costs compared to conventional planting methods, and the seed consumption per decare decreased from 7.5 kg to 3.7 kg.

There are seed metering units operating in two different ways, pneumatic and mechanical type, in precision planters. The pneumatic type, on the other hand, is of two types, air suction (vacuum) and air pressure. Vacuum precision planters are widely used by producers in Turkey.

In order to increase the yield in the planting process and to ensure the simultaneous maturation of the plant a seed planting unit and furrow openers are needed, which appropriately takes the number of seeds to be sown per unit area from the seedbox and drop them in the soil with a uniform distribution in the horizontal and vertical planes. This makes seed metering units and furrow openers the most important elements of vacuum precision planters.

The precision planter must be able to sow the seed in a way that provides an optimal emergence and adequate living area for the plant. However, there are many factors that affect the seed distribution uniformity in the soil, the seed metering unit, and the performance of the furrow opener during planting. In this text, the factors affecting the seed distribution uniformity, the performance of the seed metering unit, and about furrow opener in vacuum planters were specified and previous studies on these factors were given.

2. Vacuum Type Precision Planters

The major aim of precision planting is to drop the seeds from seed metering units of the planter to the planned horizontal seed spacings (intra-row and inter-row) and intended planting depth. This operation is one of the most substantial tasks imposed on precision planters (Kuş, 2021a). A uniform intra-row plant spacing, inter-row spacing, and planting depth result in better germination and emergence (Griepentrog, 1998). In addition, as the seed distribution uniformity increases, the plant living area increases after emergence. A decent plant living area reduces intra-specific competition, prevents the development of weeds, and after all increases the yield (Karayel et al., 2006).

Precision planters provide optimum living space for plants. These planters have a separate seed box and disc for each row. Precision planters are of two types according to the seed metering systems. One of them is a vacuum precision seed-metering system and the other is a pressure-plate metering system (Kuş, 2014). Vacuum precision seed metering unit, differently from the pressure-plate metering unit, the pressure differential supply by creating a vacuum on the side of the seed disc opposite the seeds (Srivastava et al., 1993). It consists of a vacuum planter, seed boxes, fertilizer boxes (not maybe), fan, marker, seed metering system, furrow opener, closer, and pressure wheels (Figure 1).

*Figure 1. Vacuum precision planter; seed boxes (1), fertilizer boxes (2), marker (3), seed metering system (4), furrow opener (5), closer (6), pressure wheels (7), row cleaner (8), and depth adjustment lever (9) (*http://www.sakalak.com*)*

In vacuum precision planters, the movement taken from the drive wheel with the chain-gear system is transmitted to the planting units by the spindle. Seed from the seed box enters the seed receptacle, where a vacuum created by a fan holds the seeds in the seed cells on the rotating seed plate. The vacuum is blocked as the cells reach a point above the furrow opener, and the seeds drop into furrow by gravity (Figure 2). Multiple seeds holding to the disc holes are dropped back into the seed cell by a seed singler. In commercially- available vacuum precision planters, appropriate seed plates are available for the metering of dry bean, maize, sunflower, soybean, delinted cottonseed, pea, peanut, sorghum, sugarbeet, oil crops, different vegetable seeds, and many more seeds.

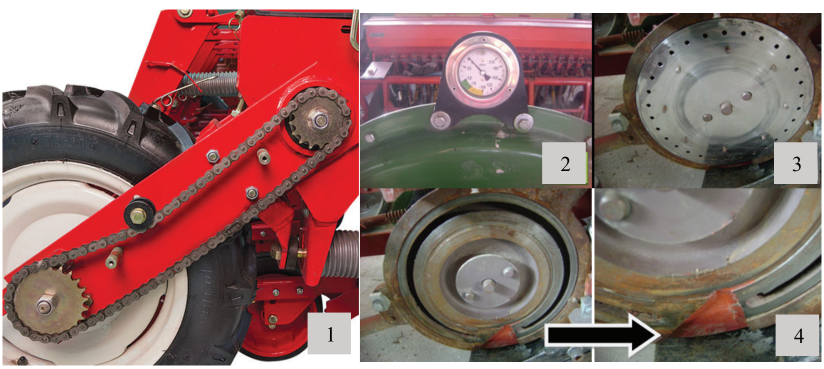

Figure 2. Drive wheel and chain-gear system (1), vacuum meter (2), vertical seed disc (3), and seed drop point (4)

Essentially, the seed metering system consists of a seed box, a seed cell, a vertical rotating disc that has a row of holes around its circumference, a seed cutoff lever and its scale, for seed singulation, and a fan that ensures air suction (Figure 3). Seed discs are generally made of stainless steel sheet. The holes to which the seeds are attached are opened on the disc surface on a diameter. The holes on the disc can be designed in different shapes and numbers of holes depending on the planting method (Figure 4). Önal (2011) reported that the seed is dropped from the seed box into the furrow in single-seed planters in four stages. These stages were expressed as seeds holding to the seed holes on the disc by the effect of vacuum, leaving of the seeds held by blocking the vacuum, free fall between the seed disc and the furrow, and the movement of the seeds in the furrow.

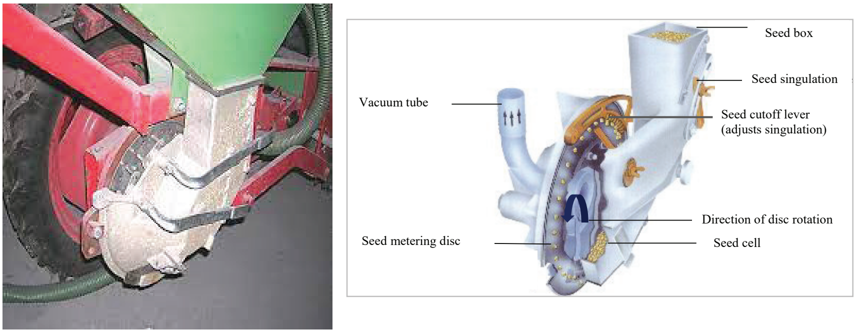

Figure 3. A diagrammatic representation of vacuum disc type precision seed metering unit

Figure 4. Seed metering disc models for vacuum precision planter

2. Planter settings

The uniformity of the plant living area in the field is one of the main objectives in the planting operation. Therefore, planter settings are crucial for seed distribution uniformity. Even in a planter equipped with the latest technology, seed distribution uniformity deteriorates when the planter's settings do not make it properly. Seed rate setting (inter-row spacing and intra-row seed spacing settings), planting depth setting, and seed singulation setting are among the main settings made in vacuum precision planters.

2.1. Inter-row seed spacing setting

Regardless of the type of planter, the spacing between the furrow openers or the distance between the rows is determined according to the same rules (Erol and Göknur Dursun, 1998). During planting with precision planters, the number of rows in one go is as much as the number of furrow openers (Figure 5). Furrow openers are attached to the main beam according to the desired row spacing. By measuring the length of the main beam and the width of the connection clamps, the number of furrow openers to be attached to the beam is determined depending on the desired row spacing. The inter-row spacing setting is carried out by the clamps linking these furrow openers to the beam. This setting is performed by sliding the furrow openers right-left on the beam.

Inter-row spacing in precision planters is calculated by using equation 1.

$$L = (n-1)*m+c \quad (1)$$

L : Beam length (cm),

n : Number of furrow openers (row numbers),

n : Spacing between two rows (cm),

c : Clamp width (cm).

Figure 5. Inter-row spacings in vacuum precision planter

The evenness of the inter-row plant spacing is determined by measuring the amount of deviation from the rows of the plants in each row (Figure 6). This measurement can be carried out in two ways: angle iron and rope method. In the first method, after the germination of the plants is completed, an angle bar is placed on the row of plants in the direction of movement of the planter. The amount of deviation from the row is determined by measuring the horizontal distances of the plants to the angle bar (Karayel, 2005). In the second method, a rope is tied up between two iron bars in the measuring range determined on the row. The amount of deviation from the row is determined by measuring the spacings of the plants to this rope from the right and left (Kuş, 2014).

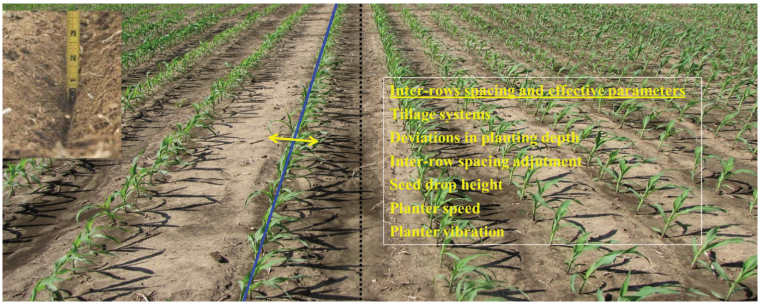

Figure 6. Calibration of inter-row spacing (deviation from row) in vacuum precision planters and crucial effective parameters

An excellent inter-row spacing depends not only on the correct planter adjustment, but also on the furrow opener exactly to making drop on furrow bottom the seeds. When the appropriate furrow opener is not selected or the furrow opener does not perform its duty correctly, the seed will not drop to the bottom of the furrow and the inter-row seed spacing will be disturbed. Kuş and Yıldırım (2020) and Kuş and Yıldırım (2021) investigated the horizontal and vertical seed distribution uniformity in planting carried out at different planter speeds with different size furrow openers in their studies. The researchers reported that the lowest and largest furrow opener sizes significantly increased deviations from the row of the seed and caused deviations in planting depth. In addition, they found that with the increase in planter speed, the deviations from the row of the seeds increased and the seeds were dropped at a shallower planting depth. However, Kuş (2021a) reported that there is a direct relationship between the size of the furrow opener and the vibration of the planter, and that the vibration of the planter disrupts the horizontal and vertical seed distribution uniformity. Kuş (2021b), on the other hand, determined by laboratory test that the seed drop height disrupts the horizontal seed distribution uniformity and that it can disrupt the vertical seed distribution uniformity.

2.2. Intra-row seed spacing setting

Intra-row seed spacing setting is by changing the number of holes on the seed disc or the rotational speed of the disc (the number of turns per unit time); or by replacing both. The purpose of the intra-row seed spacing setting is to ensure that each seed disc drops the same number of seeds into the furrow without miss and multiple. In this way, it is intended that the spacings between consecutive seeds in the intra-row are equal. A procedure is followed to perform this setting (equation 2). The planter, which is connected to the tractor, is taken to a flat surface. A collection container is placed under each seed metering unit. The drive wheel is rotated manually at least 20 times. The seeds that fall into the containers are counted. The distance traveled ($20 _* \pi _*$ D) in 20 revolutions of the drive wheel is calculated and compared with the number of seeds in the containers. If the target seed spacing reached, the setting process is completed, otherwise, the scraper setting is changed and the process continues. However, it is crucial to calibrate the accuracy of the intra-row seed spacing adjustment. For this, a certain distance is performed the planting with the planter adjusted for the calibration process. Then, the soil on the furrow is taken by hand (the location of the seeds in the furrow should not change while this is being carried out) and the distance between the seeds is measured (Figure 7a). If the measured seed spacing and the target seed spacing are compatible, the calibration process is completed. In addition to this, in order to determine the living area of the plants in the researchs, after the emergence of the plants is completed, both the intra-row and inter-row spacings are measured (Figure 7b).

$$a = \frac{\pi * D}{h * i} \quad (2)$$

a : Intra-row spacing, m

D : Diameter of the drive wheel

h : Number of holes on the seed disc

i : Transmission ratio (*i = revolution number of seed disc / revolution number of drive wheel*)

Figure 7. Intra-row seed spacing calibration (a) and determining of plant living area (b)

Some measurement methods are commonly used to evaluate the performance of the single-seed unit of precision planters. Kachman and Smith (1995) characterized intra-row seed distribution using the mean plant spacing and the coefficient of variation in plant spacing. Researchers reported that measurement of spacings between adjacent plants should be carried out after germination of plants is completed. With these measurement values, intra-row mean ($\bar{x}$) plant spacing, the standard deviation (SD) of intra-row plant spacings, and the coefficient of variation (CV) are computed by equations 2, 3, and 4, respectively. The calculation of the coefficient of variation is generally performed according to ISO (1984). According to this, those which were double or more than the theoretical spacing between plants from the measured values are not taken into consideration. Many researchers have carried out the characterization and optimization of the single seed metering unit performance using these methods (Parish et al., 1991; Bracy et al., 1993; Singh et al., 2005; Kuş, 2014, Yazgı and Değirmencioğlu, 2014; Kuş, 2021a; Kuş; 2021b; Kuş, 2021c; Kuş and Yıldırım, 2021). However, Kachman and Smith (1995) reported that the mean and standard deviation were not sufficient to determine the performance of seed metering units in precision planters. Instead, they reported that using multiple index (Mult), miss index (Miss), quality of feed index (QFI) and coefficient of precision or variation (CP or CV) as performance parameters gave more accurate results. According to this, the performance parameters (equations 5, 6, 7, and 8) of the single seed metering unit are as follows (Bracy et al., 1999; Parish and Bracy, 2003; Staggenborg et al., 2004; Singh et al., 2005);

Mean

$$\bar{x} = \sum_{i=1}^{N} \frac{x_i}{N} \quad (2)$$

Standard deviation

$$SD = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}} \quad (3)$$

Coefficient of variation

$$CV = \frac{s}{\bar{x}} \quad (4)$$

where x_i is spacing between plant i and next plant intra-row, and N is the total plant spacings measured.

Miss index

The miss index is the percentage of spacing greater than 1.5 times the intended planting spacing (Z).

$$Miss\ index = \frac{n_1}{N} \quad (5)$$

Where: n_1 is number of spacing >1.5Z; and N is total number of measured spacings.

Multiple index

The multiple index is the percentage of spacing that are less than or equal to half of the target plant spacing.

$$Multiple\ index = \frac{n_2}{N} \quad (6)$$

Where: n_2 is number of spacing $\leq 0.5Z$

Quality of feed index

The quality of feed index (QFI) is the percentage of spacings that are more than half but not more than 1.5 times the target planting spacing. QFI is an alternate way of presenting the performance of miss and multiple indexes.

$$QFI = 100 - (Miss\ index + Multiple\ index) \quad (7)$$

Coefficient of precision (coefficient of variation)

Coefficient of precision (CP) is a measure of the variability or variation in target spacing of seeds or plants after accounting variability due to both miss and multiple indexes.

$$CP = \frac{SD}{Z} \quad (8)$$

Where: SD is standard deviation of spacing more than half but not more than 1.5 times the intra-row intended seed spacing.

In order to carry out a sensitive planting process with single-seed metering systems, it should have the following features (Önal 2011);

a) Single-seed metering systems should not make miss and multiple as much as possible. The recommended values for miss index, multiple index and quality of feed index in the single-seed metering systems are shown in Table 1 (Önal 2011).

b) These metering systems should be able to sow the seeds without calibrating or classifying them.

c) It should not damage the seeds. Because high seed damage will cause seed loss, decrease in percentage emergence and ultimately lower yield.

d) Single-seed metering systems should be able to sow the seeds without damaging the seeds and without allowing high miss and multiple indexes, even at high forward speed.

No current study has been found on whether vacuum single-seed metering systems cause seed damage or not. However, Ivancan et al. (2004) reported that the planter forward speed disrupted the seed distribution evenness. Nielsen (1995), on the other hand, reported that significantly affects the variation in plant spacing and the loss of yield is at least 78 kg per hectare, due to the increase in forward speed.

Table 1. Performance criteria to evaluate planting quality in precision planting

*QFI (%)	MISS (%)	MULT (%)	Performance of planter
>98.6	<0.7	<0.7	Very good
>90.4 –98.6	≥0.7 – <4.8	0.7 – <4.8	Good
82.3 –90.4	≥4.8 – ≤10.0	4.8 – 7.7	Moderate
<82.3	>10	>7.7	Insufficient

*QFI; quality of feed index, MISS; miss index, MULT; multiple index

The uniformity of plant spacing is ensured by the uniformity of seed spacing. Seed spacing is measured by planting stand in the field or a sticky belt (greased band) in the laboratory. Measurements in the field are possible by digging the furrow after planting or measuring the distances between plants after germination (Figure 7). In the laboratory, this may be possible by measuring the distances between consecutive seeds on a sticky belt (Figure 8). In field measurements made by digging the furrow after planting, it is difficult to find especially small seeds without changing their place (Kocher et al., 1998). In addition to this, in plant spacing measurements made in the field, the miss index (skipping rate) of the seed plate holes (unless determined with a sensor) or the ratio of seeds that have not germinated after planting cannot be known. As the data obtained from measuring plant spacings in the field and measuring seed spacing on a greased belt would include the same factors, it is possible to make these measurements on a greased belt (Kuş, 2021b). However, even though laboratory measurements provide convenience in tests, Panning et al (2000) reported that the field and laboratory test results were not alike and laboratory test results could not be used in practice. Therefore, it is crucial for the accuracy of the results should be applied in the field conditions with the same parameters too, the laboratory measurements which are widely used especially in the testing of a new design, in planter adjustments, and in calibration tests.

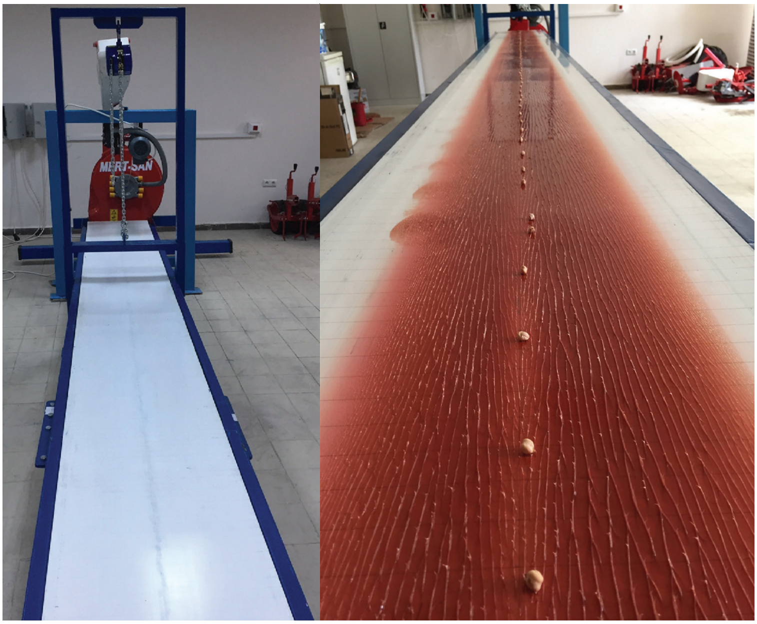

Figure 8. Sticky belt measuring stand

2.3. Seed singulator adjustment

A singulator (scraper) is used to prevent more than one seed from being held in the holes on the seed disc. If more than one seed is held to the seed disc holes, the scraper drops the excess seed into the seed cell. With the scrapers, adjustments can be made for seeds of various sizes.

Scraper adjustment is carried out using a scale graduated between minimum and maximum on the seed metering unit (Figure 9a). The minimum position is the fully closed position (where the scraper apparatus is closest to the holes on the disc). The maximum position is where the scraper apparatus is furthest from the holes. In this case, the seed singulation process does not take place on the disc. For the adjusting process, the seedbox is filled with seeds, and the fan unit is driven by the tractor PTO. The scraper is placed in the maximum setting position. By turning the movement wheel, it is ensured that the seed disc rotates and the seed is filled on the disc. The adjusting process is performed by bringing the scraper (singulator) apparatus closer to the seeds on the disc (Figure 9b). Seed singulation adjustment is carried out together with the intra-row seed spacing adjustment.

Figure 9. Seed singulation adjustment (a) and singulator (b)

2.4. Planting depth adjustment

In the planting process, the placement of the seeds in the soil in accordance with the plant requirements is carried out by the help of furrow openers. Furrow openers are of three types: hoe type, shoe opener type, and disc type (Figure 10a, 10b and 10c, respectively). Its use is not common due to reasons such as the hoe type furrow opener are easily clogged in stubble fields, not suitable for high-speed planting and the planting area must be smooth. Planting depth adjustment in hoe type furrow openers is performed by changing the immersion angle of the hoe type opener. Shoe type furrow openers provide a more even and suppressed furrow base and a good planting depth compared to others. However, these furrow openers cannot work effectively in dry, clod, rooted and overly moist soils. Shoe type openers are generally used for planting of plants maize, sunflower and such. Disc type furrow openers are the most widely used opener type. They work effectively in adverse field conditions at high planter speeds. However, they are not suitable for shallower planting.

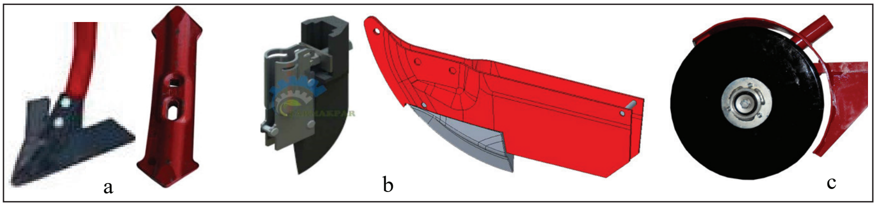

Figure 10. Furrow opener types; hoe type (a), shoe type, and disc type

The planters should provide consistent seed depth in all field conditions. Uniformity of planting depth and firming of soil around the seeds are important considerations for precision planters and are assessed during field tests. Consistency of depth adjustment is crucial to seed placement and even emergence rate. Planting depth adjustment is carried out by pressure wheel height in shoe type furrow openers (Figure 11a) and by springy depth adjusting handle and gauge wheels in disc type planters also (Figure 11b).

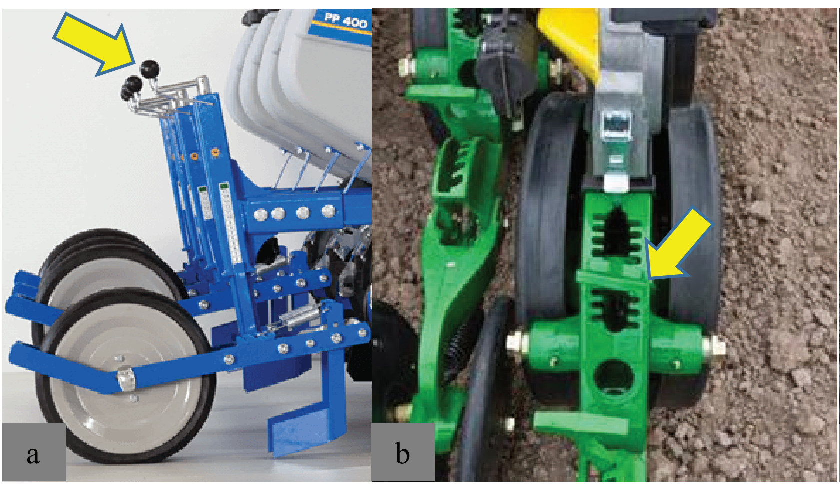

Figure 11. Depth adjusting handles and planting depth adjustment; shoe type (a), disc type (b)

Depth adjustment in planters with shoe type furrow opener is achieved by spinning the pressure wheel height adjustment handle. In these types, the adjusting handle is spun clockwise or counterclockwise (Figure 11a) to adjust the depth. If the pressure wheel and the furrow opener are independent of each other, the planting depth and pressure wheel settings are performed separately. However, the planting depth setting in the planters with the pressure wheel and the furrow opener attached to each other is carried out by taking the pressure wheel mounted behind the seed metering unit up and down from the place where it is connected to the seed metering unit. Superficial (shallow) planting when the pressure wheel goes down; when it is lifted up, deeper planting is performed. In this setting, the pressure decreases as the planting depth increases. Otherwise, the pressure increases (Figure 12a). On the other hand, the planter is raised by removing weight from gauge wheels to perform planting depth adjustment on the planter have disc type furrow opener. Then the depth-adjusting handle is lifted. The adjustment handle is moved forward to decrease the planting depth or rearward to increase it (Figure 12b).

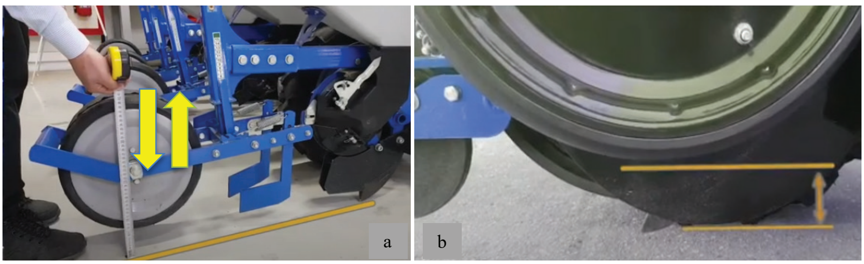

Figure 12. Depth adjustment control; shoe furrow opener (a), disc furrow opener (b)

Planting depth adjustment is carried out by using a unitless scale on the depth adjustment handle. Depth adjustment for both planter types is completed by bringing the adjustment handle to the same initial setting in all units. Then the planter is lowered and is driven a short distance at a normal planting travel speed to check the setting. In order to control the planting depth in each row, the soil is dug down vertically and the location of the seed is determined. The depth from the seed in the furrow to the top of the soil profile is measured (Figure 13c). If the measured planting depth is compatible with the target depth, the adjustment process is terminated, otherwise the process continues.

Figure 13. Calibration for planting depth in field conditions; before emergence (c), after emergence (d)

Two methods are applied to determine the position of the seeds in the soil relative to the soil surface. One of these methods is soil grater (Özmerzi, 1986) and the other is the measurement of the mesocotyl length of the germinated plant (Özmerzi and Keskin, 1983). The soil surface should be smooth and homogeneous in order to make optimum use of the soil grater and to obtain precise results. In the other method, after the seeds have germinated, the plants are dug out from the soil and mesocotyl length (the distance between the seed residue of the plant and the green to white transition border of the germinated plant) is measured (Figure 13d).

As a result, inter-row spacing, intra-row spacing, planting depth, and scraper (singulator) settings must be done with precision in order to reach the targeted plant living area in vacuum precision planters. Because, the more correct the planter settings, the smoother the plant living area will be. However, it is extremely crucial to calibrate the settings.

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CHAPTER 4

CRISPR/CAS GENOME EDITING: RECENT ADVANCES IN ABIOTIC STRESS RESPONSE IN PLANTS

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1. Introduction

Climate change caused by increased CO_2 concentrations in the atmosphere leads to higher temperatures, shifting precipitation patterns, and severe drought periods. On the other hand, the world population is expected to approach 10 billion people by 2050, and global food consumption will rise by 25%–70% over present production levels. For this reason, new varieties of agricultural products should be developed that can withstand harsh weather conditions while also increasing yield and quality. Since traditional plant breeding methods are time-consuming, laborious, and costly, new methods are needed that are more effective and save time (El-Mounadi, Morales-Floriano, & Garcia-Ruiz, 2020; Zhu, Li, & Gao, 2020).

Genome editing is a type of engineering that involves modifying intracellular DNA in a sequence-specific manner. Among the modifications are insertions, deletions, integrations, and sequence substitutions. Targeted genome editing is based on research into the repair mechanisms underlying DNA damage and the consequent structural changes in DNA. Genome editing consists of zinc finger nucleases (ZFNs), transcriptional activator-like effector nucleases (TALENs), and the clustered regularly interspaced short palindromic repeat CRISPR/CRISPR-associated nuclease 9 (Cas9) system, which was recently discovered. ZFNs are DNA cleavage proteins with the ability to break DNA sequences at any site. TALENs cause double-stranded breaks (DSBs) in target sequences, triggering DNA damage response pathways and causing genome alteration. ZFNs and TALENs, which target different parts of the genome, necessitate the re-design or re-engineering of a new set of proteins. Moreover, vector construction for ZFNs and TALENs has some limitations as it is time-consuming and labor-intensive. The most successful genome editing technologies developed in recent years are targeted genome editing technologies utilizing CRISPR/Cas9 in numerous species, including plants. The CRISPR-Cas9 system is a more effective, convenient, and time-saving way to change a gene by comparison to other technologies (Adli, 2018; Gahlawat et al., 2017; Manghwar, Lindsey, Zhang, & Jin, 2019; Moon, Kim, Ko, & Kim, 2019; Osakabe et al., 2016).

Abiotic stressors such as drought, heat, and salt (Figure 1) are increasing as a result of climate change, and they are harming crop health and production all around the world (Ahmad et al., 2021). Therefore, it's vital to discover genes linked to abiotic stress and develop abiotic stress-resistant/ tolerant crop varieties. This study focuses on the recent advances in response to abiotic stress using CRISPR/Cas9 technology in model plants and crops.

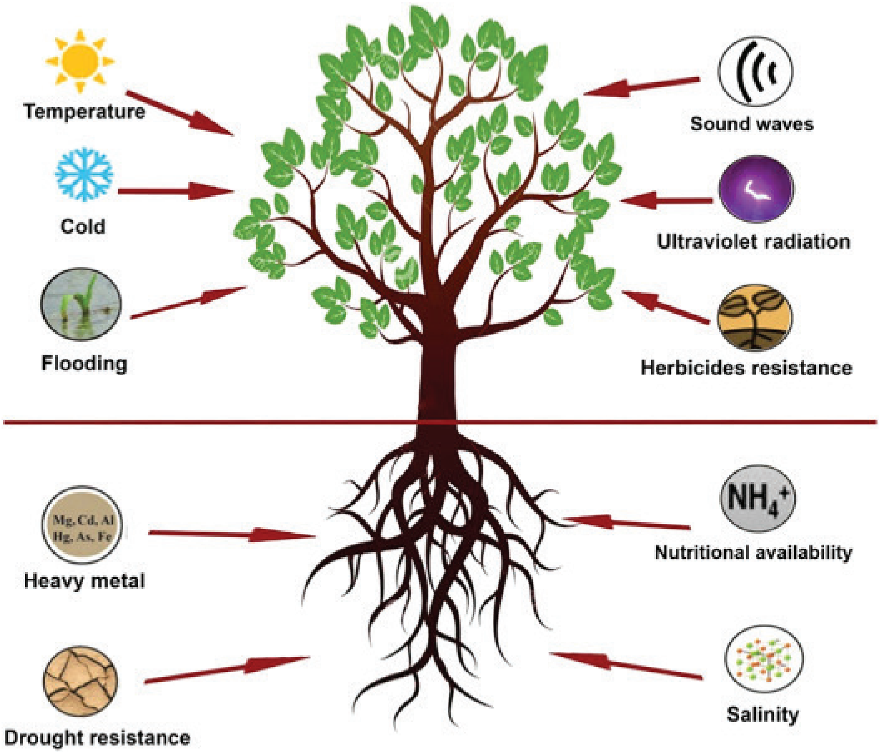

Figure 1. Various types of abiotic stress in plants (Ahmad et al., 2021).

2. CRISPR-Cas9 System: A Powerful Tool For Genome Engineering

CRISPR/Cas9 technology consists of the Cas9 protein, a single guide RNA (sgRNA), and a protospacer adjacent motif (PAM; NGG or NAG). A sgRNA, which identifies the target DNA by typical Watson-Crick base pairing, guides the Cas9 nuclease-mediated cleavage. It's necessary to have a PAM; NGG or NAG site within 3′ of the target site. The sgRNAs have a length of 20–22 nucleotides (nt), making them simple to design and produce as oligonucleotides. Whereas the 20–22 nucleotides sgRNA works as a protospacer, determining the specificity of the CRISPR-Cas9 system and ensuring that the desired section of the DNA is accurately targeted, the latter molecule acts as a pair of "molecular scissors," unwinding and cleaving the target DNA at specified loci (Figure 2) (Eş et al., 2019; Jain, 2015; Ma, Zhu, Chen, & Liu, 2016, p. 9)

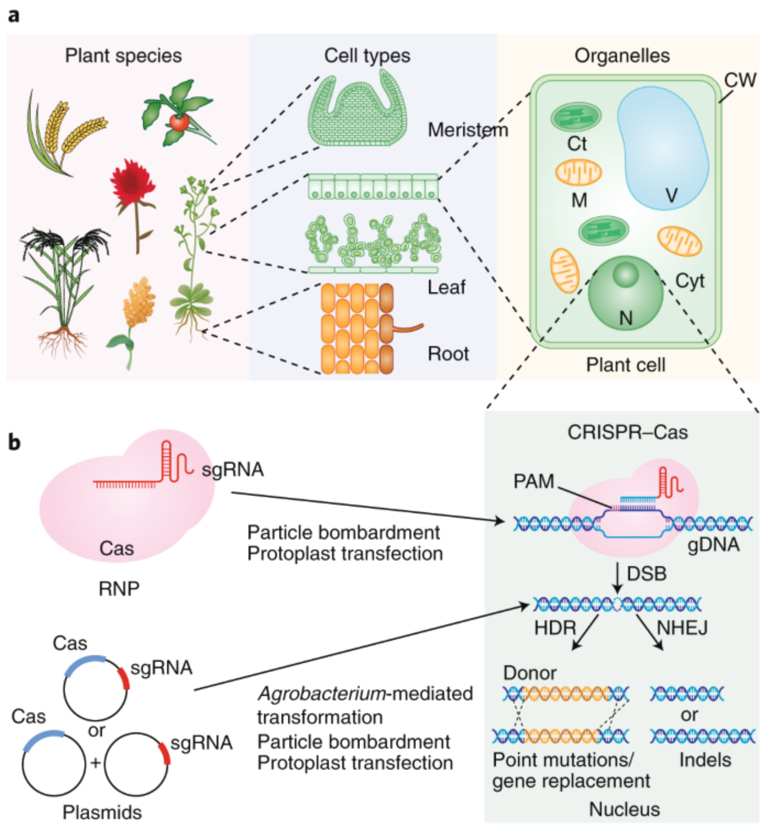

Figure 2. Genome engineering with the CRISPR-Cas9 system in various plant species, cells, and organelles (Demirer et al., 2021).

a) *Plant species, cell types, and organelles that the CRISPR–Cas system can target.*

b)*Bacterial adaptive immunity is the source of the CRISPR–Cas genome-editing system. This system consists of a Cas endonuclease, which cleaves double-stranded DNA site-specifically, and an sgRNA. It is also necessary to have a PAM upstream of the sgRNA binding site in the genome. Cas and sgRNA form an RNP complex in the nucleus, and Cas undergoes conformational changes that allow DNA binding and cleavage. One of two plant DNA repair mechanisms is activated when a double-stranded break (DSB) occurs. Homology-directed repair (HDR) causes point mutations or gene replacements by using a DNA donor template that is homologous to the target sequence. Non-homologous end joining (NHEJ), which is error-prone and creates minor insertions or deletions (indels), is seen much more commonly than HDR. Particle bombardment or protoplast transfection can both be used to deliver ribonucleoprotein (RNPs) into the plant cell. By using Agrobacterium-mediated transformation, particle bombardment, or protoplast transfection, plasmids encoding genes for Cas and sgRNA can be transferred into the cell.*

Ct, chloroplast; Cyt, cytoplasm; CW, cell wall; gDNA, genomic DNA; M, mitochondria; N, nucleus; V, vacuole.

3. Development of Abiotic Stress Tolerant Crop Plants by CRISPR/Cas9

Plants are sessile organisms and are therefore significantly affected by abiotic stress conditions. Abiotic stress, including drought, salinity, heat, and heavy metals, causes significant yield losses worldwide. Abiotic stress is a complicated attribute that is influenced by a number of genes. Therefore, the abiotic stress response and adaptation of plants are influenced by interactions among components of numerous signaling, regulatory, and metabolic networks. In recent years, many studies have been carried out with the CRISPR/Cas gene editing system to develop stress-resistant plant varieties (Ahmad et al., 2021; Biswas, Zhang, & Shi, 2021; Ghosh & Dey, 2022; Jaganathan, Ramasamy, Sellamuthu, Jayabalan, & Venkataraman, 2018; Jain, 2015)such as drought, salinity, temperature, and heavy metals, affect plant health, growth, and development and cause significant yield losses worldwide. In this regard, new breeding technologies, for example, genome editing technologies (GETs.

CRISPR/Cas9 technology has been successfully applied to model plants like *Arabidopsis*, *Oryza*, and *Nicotiana*, as well as agricultural species including wheat, maize, tomato, soybean, sorghum, and others.

Arabidopsis

Arabidopsis is a useful genetic model system for understanding abiotic stress and its molecular activity. In particular, knockout mutant studies in *Arabidopsis* have been successfully implemented with the CRISPR/Cas9 system (Debbarma et al., 2019).

Cold acclimation, the process by which plants enhance their freezing resistance in response to low temperatures, involves the C-repeat binding factors (*CBF*) pathway. This *CBF* pathway is a component of the cold-response system found in many species. For example, in *Arabidopsis*, the three *CBF* genes (*CBF1, CBF2,* and *CBF3*), which encode *AP2/ERF* transcription factors, regulate CRISPR/Cas9-mediated cold adaptation (Zhao & Zhu, 2016). A similar study found that mutant lines using cold-inducible C-repeats/DRE-binding factors like *CBF1, CBF2,* and *CBF3* created by CRISPR/Cas9. Furthermore, the *Arabidopsis* UDP-glycosyltransferases *UGT79B2* and *UGT79B3*, which regulate anthocyanin accumulation, play a role in cold, salt, and drought tolerance (Pan Li et al., 2017).

SAUR41 subfamily genes could be induced by abscisic acid to modulate cell expansion and salt tolerance in *Arabidopsis* thaliana seedlings. Knock out of the *SAUR41* gene by CRISPR/Cas9 results in decreased cell expansion and dysregulation, while overexpression of the *SAUR41* gene has been reported to decrease transcription of iron homeostasis genes in roots and increase transcription of ABA biosynthesis/signaling genes in shoots (Qiu et al., 2020, p. 41).

Improvement of drought stress tolerance through CRISPR/Cas 9 was used by the *EF1* promoter to generate the new allele in the stress response of the *OST2/AHA1* gene in *Arabidopsis*. (Osakabe & Osakabe, 2017).

Rice

Rice (Oryza sativa L.) is one of the world's most significant cereal crops since it provides dietary supplements to more than half of the world's population (˜3.5 billion people) (Y. Li et al., 2018). However, abiotic stress such as drought, salinity, and extreme temperatures, as well as biotic stress, caused significant yield losses in rice production around the world (Romero & Gatica-Arias, 2019)there is a constant requirement for new varieties with improved agronomic characteristics, such as tolerance to different biotic (such as bacterium, fungus, insect and virus.

Major transcription factors are *bZIP, DREB, MYC, MYB, NAC,* and *WRKY,* which are expressed under abiotic stress conditions. In rice, various transcription factors such as *DREB1* and *WRKY* have been found to be induced and applied to minimize salinity stress. There are 1611 genes coding for TFs in the *Oryza sativa* genome. Using the CRISPR/Cas9 technology, functional genes for the protein kinase family (*SnRK2s*) were identified in rice for their role in salt stres (Farhat et al., 2019).

The rice *OsNAC006* mutant regulated by CRISPR–Cas9 acted as a positive regulator of drought stress tolerance, whereas the rice *OsAnn3* annexin gene knockdown regulated by CRISPR/Cas9 was found to decrease cold tolerance (Shen et al., 2017; B. Wang et al., 2020)the rice annexin gene OsAnn3 knockout was performed via the CRISPR/Cas9 (clustered regularly interspaced short palindromic repeats/CRISPR associated proteins.

Herbicide stress is an important type of stress for plants. Therefore, plant breeders and geneticists are working to increase the resistance of plants to herbicides using genome editing technology. One of the important gene families responsible in herbicide sensitivity and tolerance is acetolactate synthase (ALS). *OsALS* mutants, which are mutants that show resistance to herbicides, were generated by using a CRISPR–Cas9-based editing system (F. Wang et al., 2021) .

Heavy metals such as mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead are poisoning and badly polluting agricultural soils (Pb). Heavy metal transportation from the soil to plants is hazardous to human health. For this reason, it is important to develop plant varieties that do not require metal transfer from the soil to the plant. For this purpose, indica rice lines resistant to Cd accumulation in plants were developed while also proving to be nontransgenic lines. The *OsNramp5* gene, a metal transporter gene, was knocked out by the CRISPR–Cas9 system, resulting in lower Cd absorption of the mutant plant compared to the wild type (Ahmad et al., 2021; Tang et al., 2017, p. 5) .

Solanum

As tomato (*Solanum lycopersicum*) is a chilling-sensitive horticultural crop, the fundamental restriction to its development is chilling stres (R. Li et al., 2018). *SlCBF1* mutagenesis using the CRISPR–Cas9 system resulted in decreased tomato-plant cooling tolerance, while downregulation and loss of *ARF 4* function resulted in altered plant growth, stomatal function, and improved tomato tolerance to salinity and osmotic stres (Bouzroud et al., 2020; R. Li et al., 2018).

Table 1. Schematic representation of abiotic stress-related genes identified by CRISPR/Cas9 systems

Gene(s)	**Plant species**	**Stresses**	**References**
WRKY3 and WRKY4	*Arabidopsis thaliana*	Salt	(Peng Li, Li, & Jiang, 2021)
SAUR41	*Arabidopsis thaliana*	Salt	(Qiu et al., 2020, p. 41)
UGT79B2 and UGT79B3	*Arabidopsis thaliana*	Cold	(Pan Li et al., 2017)
ABRE1	*Arabidopsis thaliana*	Drought	(Roca Paixão et al., 2019)
OST2	*Arabidopsis thaliana*	Drought	(Osakabe & Osakabe, 2017)
CBF2	*Arabidopsis thaliana*	Cold	(Sanderson et al., 2020)
CBF1, CBF2, CBF3	*Arabidopsis thaliana*	Cold	(Zhao & Zhu, 2016)
AtCBF	*Arabidopsis thaliana*	Cold	(Zhao & Zhu, 2016) (Park, Gilmour, Grumet, & Thomashow, 2018)
SlCBF 1	*Solanum lycopersicum*	Cold	(R. Li et al., 2018)
OsAnn3	*Oryza sativa L.*	Cold	(Shen et al., 2017)
OsMIR408 and OsMIR528	*Oryza sativa L.*	Salt	(J. Zhou et al., 2017)
GT-1 element in the pro- moter of OsRAV2	*Oryza sativa L.*	Salt	(Duan et al., 2016)
OsPRP1	*Oryza sativa subsp. indica*	Cold	(Nawaz et al., 2019, p. 1)
SlARF4	*Solanum lycopersicum L.*	Salt and osmotic stresses	(Bouzroud et al., 2020)
OsRR9 and OsRR10	*Oryza sativa L.*	Salinity	(W.-C. Wang, Lin, Kieber, & Tsai, 2019, p. 9)
CmRBOHD	*Cucurbita moschata*	Salt	(Huang et al., 2019)
AtC/VIF1	*Arabidopsis thaliana*	Salt	(Yang et al., 2020)
AtEULS3	*Arabidopsis thaliana*	Salt and osmotic stresses	(Dubiel, Beeckman, Smagghe, & Van Damme, 2020)
OsDST	*Oryza sativa subsp. indica*	Drought and salt stresses	(Santosh Kumar et al., 2020, p. 9)
OsALS	*Oryza sativa L.*	Herbicides resistance	(F. Wang et al., 2021)

OsFBDUF54 (LOC_ Os11g37390)	*Oryza sativa L.*	Alkaline	(X. Li et al., 2020)
HvITPK1	*Hordeum vulgare*	Salt	(Vlčko & Ohnoutková, 2020)
OsPQT3	*Oryza sativa L.*	Salt and other abiotic stresses	(Alfatih et al., 2020)
OsPRX2	*Oryza sativa L.*	Potassium deficiency	(Mao et al., 2018, p. 2)
sAUX3	*Oryza sativa L.*	Al stress	(M. Wang et al., 2019)
OsHAK1	*Oryza sativa L.*	Cs+	(Nieves-Cordones et al., 2017)
OsARM1	*Oryza sativa L.*	As	(F.-Z. Wang et al., 2017)
OsNramp5	*Oryza sativa subsp. indica*	Cd	(Tang et al., 2017, p. 9)
OsSAPK2	*Oryza sativa L.*	Drought	(Lou, Wang, Liang, & Yu, 2017)
SlMAPK3	*Solanum lycopersicum*	Drought	Wang et al. (2017b)
OsNAC006	*Oryza sativa L.*	Drought	(B. Wang et al., 2020, p. 006)
PdNF-YB21	*Populus clone NE-19*	Drought	(Y. Zhou et al., 2020)
SlCBF1	*Solanum lycopersicum L.*	Cold	(R. Li et al., 2018)

4.Conclusion

The CRISPR–Cas9 approach has revolutionized the field of plant science due to its simplicity, versatility, precision, and flexible modification. CRISPR-Cas technology allows scientists to change the desired gene sequence in order to gain tolerance for different plant types to abiotic stresses. This technology has also shown the benefits and effectiveness of genome editing tools in the development of crop varieties that can withstand abiotic stress.

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CHAPTER 5

STRAWBERRY IRRIGATION IN THE MEDITERRANEAN ENVIRONMENT

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1. Introduction

Climate change in many parts of the world, emerge as increasing temperatures and decreasing precipitation and increase the severity of drought events with frequent occurrence. The lack of water, which is the main natural source of living things, constitutes the most important limiting factor in agricultural production (Çakmak et al., 2005). In order to increase agricultural products, soil and water resources should be developed in such a way that they can be used conveniently. Irrigation is a versatile application that increases the efficiency of other agricultural inputs that ensures profitability in agricultural production and keeps the economy and social order in balance (Korukçu, 1992). In this context, Turkey must effectively apply irrigated agriculture and plant production component applications, which are the most essential techniques of enhancing yield and quality in agriculture under intensive agricultural settings, in order to provide sustainable national nutrition. While excessive and insufficient irrigation reduce yield and product quality, developing an appropriate irrigation schedule allows for optimal use of methods such as drip irrigation systems.

Strawberry is one of the most valuable fruits in the world. It is popular in the European market and food industry because of its pleasant perfume and flavor, as well as its high vitamin and mineral content (Kumar and Dey, 2011; Morillo et al., 2015). Strawberry production in Turkey began in the 1970s and has steadily increased from 9700 tons in 1970 to 546 thousand tons in 2020. It is becoming increasingly important to determine the appropriate irrigation amounts as well as changes in quality and yield of the strawberry, which ranks fourth in the world in terms of production capacity in Turkey and is becoming increasingly important both in terms of human health and economic reasons such as quick returns on investments (TEPGE, 2021).

Despite the massive variety of planting patterns and irrigation layouts, it is difficult to provide prescriptive standards for strawberry irrigation. Generally, growers in the Mediterranean countries, where strawberry production is high, rely on past experience to determine the amount of irrigation water to use; they analyze the weather and the plant's outward appearance. The Mediterranean region of Turkey has vast water resources; yet, excessive and ineffective irrigation, combined with improper farming practices, disrupts the country's strawberry output. Strawberry farming requires an optimal watering plan because to the shallow root structure, big leaf area, and high water content of the fruit (Grant et al., 2010; Klamkowski and Treder, 2008; Krüger et al., 1999). Due to the higher amount of irrigation used in these conditions, fungal infections and chlorosis due to the iron in the soil cannot be taken up, which have a negative impact on yield, are common, especially in areas with clay and silty soil structures. Furthermore, plants are extremely sensitive to the amount of irrigation water during floral initiation, flowering, and fruit formation (Hegde, 1987), as well as the limited soil moisture condition, which affects photosynthetic activity and reduces potential growth, development, and fruit yield (Farhan and Pritts, 1997; Kırnak et al., 2001, Rannu et al., 2018). In sandy soils, decreases occurred such as Ca, Mg, and P, which have a large impact on yield, are leached away with excessive irrigation water. Another key factor to remember is that lighter-textured soils are easier to irrigate and manage than heavier-textured soils, which have a high clay concentration.

2. Irrigation Systems

Strawberry growing on beds covered in black plastic mulches necessitates enormous amounts of freshwater to meet crop water requirements as well as other agronomic operations such as soil preparation and plantation (Morillo et. al., 2015). Sprinkler, drip, and micro-sprinkler irrigation systems are commonly used to water strawberries. Due to excessive water application strawberry root and root rot induced by water-borne pathogens, furrow irrigation is not suitable irrigation method among the surface irrigation methods. Fruit rot is also an issue when sprinkler irrigation is used during the period of fruit set. On the other hand, it is well known that the micro-sprinkler system uses less water and reduces disease incidence when compared to the sprinkler method. After examining all of the studies, drip irrigation is determined to be the best irrigation system for strawberry irrigation. Drip irrigation is the most suitable system for preventing the development of plant diseases caused by the wetting of the above-ground parts of the plants; a large area can be irrigated with less water, and some cultural operations can be carried out even during irrigation; the desired amount of irrigation water is applied; a continuous and low tension humidity environment is provided in the plant root zone. It has been determined that the plant can take water without exerting much effort, efficiently used fertilizers due to plant nutrients can be supplied with irrigation water, and that losses such as surface flow, deep infiltration, and water transmission can be completely eliminated, reducing weed growth. Furthermore, where applicable, the watering system can also be employed for frost protection. When the temperature falls below 0.50 degrees Celsius, it should be turned on, and left to irrigate until all of the ice sheets on the plants has melted.

To gain high irrigation efficiency, well-designed drip irrigation systems should give equal soil water quantities to all plants in the irrigated field. In the drip irrigation, the drippers that are 25 to 30 cm apart and have a flow rate of 2 l/s. There is no significant problem with strawberry yield if the irrigation water salinity is less than 0.75 dS/m. If the irrigation water salinity is 1.2 dS/m or higher, the yield decreases by 20% immediately and then gradually diminishes as the salinity rises.

3. Irrigation Scheduling

Irrigation, according to precision irrigation principles, should be a precision activity that includes both an accurate assessment of crop water requirements and the precise application of the exact amount of water at the right time, using hydraulic elements with high volumetric efficiencies and that allow spatially uniform applications (Smith et. al., 2010; Morillo et. al. 2015). It's difficult to provide optimum strawberry irrigation scheduling because to the wide variety of planting patterns, climates, soil types, and irrigation system designs. There are, nevertheless, several critical elements to consider in the outline. It is very important to know the soil water content in the strawberry irrigation. In an effective irrigation programming, soil variables such as field capacity (FC), wilting point (WP), available water capacity (AW), and moisture available deficit (MAD) must be considered. As a general rule, plan on roughly 25 mm of irrigation water every week, though this amount may need to be increased to as much as 60 mm during hot, dry summer conditions. A well-managed irrigation program aims to maintain soil water content between field capacity and moisture available deficit. Strawberry's effective root depth varies from 15 to 45 cm, depending on the variety. The water holding capacity of the soil across the effective root zone is related to its texture; for example, sandy soils have a low water holding capacity, but clayey heavy textured soils have a higher water holding capacity (Figure 1). In general, if irrigation schedule information is unavailable, irrigation should be done when the available water capacity is reduced by 50%. (Black and Cardon, 2008).

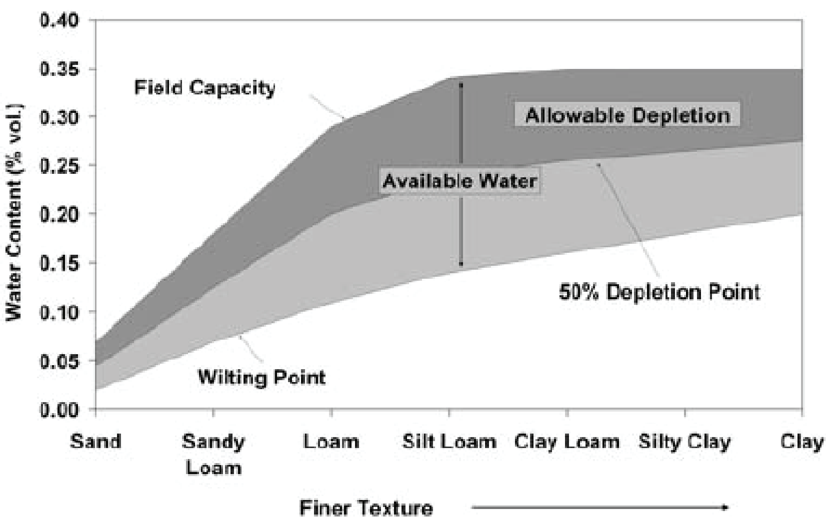

Figure 1. Allowable amount of water loss, representing approximately 50 percent (Black and Cardon, 2008).

Measurements of the soil water content should be taken roughly in the middle of the effective root zone depth. Electrical resistor blocks are a cost-effective and highly accurate method in this context (Photo 1. Watermark sensors). By calibrating with the gravimetric method, the blocks are permanently buried in the soil at the proper depth and can be simply used in irrigation programming. With the method of electrical resistance blocks, the soil water content is measured in centibars, and values close to zero indicate close to field capacity, and high values indicate that the soil water content is close to the wilting point.

Photograph 1. Electrical resistance blocks measuring soil water content.

Depending on the soil type, the connection between soil water content and available water capacity varies. The maximum measuring range, which includes moisture available deficit, can be set to 200 centibar. In sandy soils, these sensors are less effective and measure the soil water content more higher. Sensors estimate 50% allowed soil water loss as 40 centibar in sandy loam soils and 70 centibar in loamy soils in a general approach (Table 1).

Table 1. Recommended irrigation time Watermark sensor values (Black and Cardon, 2008).

Soil Structure	Watermark Sensor values (centibar)
Loamy Sand	40
Sandy Loam	50
Loam	60
Silt loam, Silt	70
Clay loam, Clay	90

The calculation that farmers can easily use in determining the amount of irrigation water according to the soil water content is practically presented below.

$$Ir=(FC-\theta i) \cdot \gamma \cdot D \cdot A \quad (1)$$

Ir (m^3) is the amount of irrigation water, FC is the soil water content (%) at field capacity, θi current soil water content (%), γ is the soil bulk density (g cm^{-3}), D is the soil depth and A is the area of the strawberry field (m^2).

Another inexpensive and effective method in irrigation programming is tensiometers (Photo 2), which indirectly determines the soil water content. The soil water content is monitored by placing the tensiometers in the effective root zone of the strawberry. Letourneau et al. 2015, determined that tensiometers placed at a depth of 15 cm should irrigate when the matric potential value in clay loam soils is between -10 and -15 kPa for the best strawberry yield in the Mediterranean climate regions. This method is supposed to work effectively in the Mediterranean part of Turkey as well.

Photograph 2. Tensiometers that indirectly determine the soil water content

Runoff, infiltration, evaporation from the soil surface, and transpiration from leaves are the current sources of plant water consumption. Evaporation and transpiration, often called as Evapotranpiration or ET, are the most important factors in efficient irrigation programming in recent days. Climate characteristics such as air temperature, relative humidity, radiation, and wind speed can be used to estimate ET using a basic technique. Reference Plant water consumption is calculated using evapotranspiration (ETo). ETo is the maximum quantity of evapotranspiration from the surface of meadow grasses grown in specific climatic conditions, sufficiently irrigated, healthily growth, totally shading the soil, 12 cm height, crown aerodynamic resistance 70 s m^{-1}, albedo value 0.23 (Allen et. al., 1998). For calculating

ETo, a variety of equations have been created, each requiring different data and at different levels of detail. The most appropriate ETo Penman-Monteith (FAO) or Blaney-Criddle (SCS) methods are calculated under Mediterranean climate conditions. ETo values can be calculated with some programs (IAM ETo, CROPWAT) or taken from existing climate stations in agricultural areas. The ETc, or crop water requirement, is calculated by multiplying the computed ETo by a crop coefficient. As a result, each irrigation can be based on net plant water requirement.

$$ETc = ETo \times kc \qquad (2)$$

ETc:crop water requirement (mm)

ETo=Potential evapotranspiration

kc: crop coefficient

Another method for calculating the strawberry crop water requirement is to use a Class A evaporation pan. Class A evaporation pan is cylindrical evaporation pools with a diameter of 120.7 cm and a depth of 25 cm, composed of galvanized sheet or stainless steel (Photo 3). The amount of irrigation water can be calculated using the following formula when these pools are used.

$$I = Ep \times kpc \times CP \qquad (3)$$

I: amount of irrigation water (mm)

Ep: Evaporation amount from Class A pan (mm)

kpc: Crop pan coefficient

CP: Crop cover (%)

Pan coefficient (kpc) consist of pan coefficient (kp) and crop coefficient (kc). If the pan coefficient is set to one, the kc coefficients from FAO56 (FAO56: Crop water consumption calculation guide) can be used as follows: 0.4 (kcin) for the beginning, 0.95 (kcmid) for the mid-term that has reached completion, and 0.75 (kcend) for the end of the effective harvest period.

Photograph 3. Class A evaporation pan

Yuan et. al., (2004), studied to determine the class A pan coefficient and used 0·75, 1·00 and 1·25 times water surface evaporation measured by a standard pan in strawberry irrigation. Plant leaves, flowers and fruits, above-ground biomass, runners, total berry yields, marketable strawberry yields, the size of the strawberry fruits all increased when the amount of irrigation water increased from kpc 0·75, kpc 1·00 to kpc 1·25. However, finally they found the strawberries grown in a plastic greenhouse should be irrigated with a pan factor of 1.1 as a general recommendation for irrigation during the entire growing season.

4. Crop Irrigation Markers

Crop markers are now one of the most extensively used ways for determining irrigation time. The plant's internal water status can better explain the plant's response to variations in climate and soil water content, which is in the soil-plant-water-atmosphere relationships. Therefore, plant markers used for irrigation time determination based on the internal water condition of the plant produce correct results. Due to the advances in technology, leaf water potential, plant water stress index (CWSI), and stomatal conductivity, which define the plant's internal water status and can be easily monitored have become often used in irrigation programming of high-value crops such as strawberries in recent years.

Irrigation programming is done with the help of a leaf water potential meter (LWP), an infrared thermometer, and a photosynthesis meter (Photo 3-a,b,c). In general, research has found that the leaf water potential of strawberries ranges from -5 to -13 bar, depending on the variety, when determining proper irrigation time. It is recommended to irrigate with values between 0.4 and 0.6 molH_2O $m^{-2}s^{-1}$ when stomatal conductivity is measured (Ariza et al., 2021). Also with infrared thermometer determining leaf temperature is a new tool for predicting the crop water stress index. Plant canopy temperature (Tc) behavior under stress and non-stress situations indicates crop water status and yield performance during drought conditions (Sezen et. al., 2014). Idso et al. (1981) proposed an empirical approach to quantifying stress in crops by finding "non-water-stressed baselines". Crop water stress index approach was well defined in Idso et. al. (1981). Approximately the 0.3 to 0.45 is the optimum crop water stress index in strawberry Penuelas et. al., (1992).

Photograph 3. Equipment used in determining the irrigation time; a. leaf water potential meter, b. infrared thermometer, c. stomal conductance and photosynthesis meter.

5. Conclusions

Many investigations(studies) have been conducted under Mediterranean climate conditions in the context of the current subject, and some of these works have been summarized in this chapter. During the 2015-2016 strawberry growing season, Rubygem and Kabarla strawberry varieties were grown in Spanish type high tunnels under four different irrigation regimes, with the amount of irrigation water calculated from class A pan (IR125:417 mm, IR100:345 mm, IR75:274 mm, IR50:203 mm) and bio-activator were used. When four different irrigations were evaluated, it was determined that the IR75 irrigation level applied was the optimum yield in both varieties and the amount of water applied below this level caused a significant decrease in yield. It was determined that the plant's vegetative development was the same for IR125, IR100, and IR75, and that water applications of more than 274 mm during the strawberry growing period were unnecessary given the conditions of that era. The limiting of vegetative development has been determined to be the cause of a decrease in vegetative development under IR50 conditions (Kapur et al., 2018). The less irrigation water application was attributed to late seedling planting and environmental conditions, as opposed to other similar research.

Furthermore, using a bio-activator enhanced the yield of both strawberry varieties significantly. In this context, economic analysis should be used to establish the efficacy of using a plant activator. Plant activator treatments also improved drought tolerance and increased leaf water potential while regulating stomatal conductivity in strawberries. Plant activators are thus expected to be a stress-reduction alternative in water-scarce situations.

During the 2017-2018 growing season under Spanish type high tunnel in the Mediterranean region of Turkey, two different irrigation regimes obtained from a class A pan cumulative evaporation amounts (IR100.:397 mm, IR50:288 mm) with using different colors of mulch (gray, black, transparent, control; no mulch) effects were investigated in strawberry by means of yield and quality conditions (Sarıdas et al., 2021). The soil moisture was kept at the highest level with the IR100 gray mulch treatment (average, 34.3%), followed by black (33.4 %), transparent (27.3 %), and control (23.9 %) applications, according to the study. In the IR50 irrigation regime, it was observed that the control application was extremely close to wilting point, but mulch applications increased the water content of the soil, with the gray (26.3 %) mulch application providing the maximum value. The number of fruits reduced by 27%, the average fruit weight by 20%, and the yield by 49% in under deficit irrigation when compared to fully irrigated strawberry. While the number of fruits and yield values in the gray mulch application were superior to the mulches of other colors, the average fruit weight in the black and transparent mulch applications was found to be higher. On the other hand, unmulched applications were significantly listed behind in all parameters. As a consequence, the interaction of Gray mulch application with IR100 was determined to be the most effective agricultural application.

Four different irrigation levels (IR125, IR100, IR75, and IR50) and Proline application (Proline usage and control; no proline used) were employed in a similar study conducted in the same region (in the 2018-2019 growing season) with Fortuna strawberry cultivars yield and eco-physiological measurements was carried out in the Spanish type high tunnel. The IR125, IR100, IR75, and IR50 applications received a total of 712, 575, 438, and 301 mm of irrigation water from the beginning to the completion of the trial, respectively. There was an increase in production per plant with increasing irrigation water amount in the Fortuna strawberry variety, with the greatest average yield of 1333.2 (g/plant) with IR125 treatments. Soil moisture content varies depending on the application, with an average of 27% soil moisture content in IR100 irrigation, 30% soil moisture content in IR125 irrigation, 23% soil moisture content in irrigation with IR75 and 19% soil moisture content in IR50 deficit irrigation. The yield was roughly 200 g/plant higher with proline applications than in the control (Aksoy, 2021).

Kanber et al., (1986), discovered that the irrigation water and water consumption amounts vary according to the years as a result of a three-year study on the fruit yield and quality of the 'Pocahontas' strawberry cultivar in Çukurova conditions using drip and furrow irrigation methods. Although irrigation methods have been found to have no significant effect on fruit quality. However, drip irrigation has been shown to increase first-quality fruit yield in two different years (Kanber et al., 1986).

Strawberry irrigation water ranged from 564 to 795 mm season^{-1} in the Huelva region of Spain, while fruit yield ranged from 1.027 to 1.084 g plant^{-1} (Lozano et al., 2016). Strawberry irrigation supply ranged from 300 to 700 mm season^{-1} in California's central coast, with yields ranging from 20 to 50 tha^{-1} (McNiesh et al., 1985). In Italy, the proper water treatment on strawberries was 485 mm (Giovanardi and Testolin, 1984), although trials in France and Japan revealed irrigation water use of 415 and 336 mm, respectively (Lemaitre, 1976; Yuan et al., 2004). Thus, these studies highlight the importance of using an appropriate amount of irrigation water that takes into account the local climate, calculating method, and cultivar type.

Consequently, in order to maintain Turkey's national nutrition in the long run, it must be developed good irrigated agriculture methods and schedules, which are the most important method of raising yield and quality under intensive farming conditions. While excessive and limited irrigation causes decreases in yield and fruit quality, the efficient use of methods such as drip irrigation systems is activated by an appropriate irrigation program. Finally, it is crucial for the future of agriculture to better understand the effects of water stress on plant nutrition, and to develop strategies that will minimize the damage caused by drought and the resulting nutrient deficiency.

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CHAPTER 6

THERMAL PROPERTIES OF WOOD-BASED BOARDS PRODUCED FROM DIFFERENT LIGNOCELLULOSIC MATERIALS

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1. Introduction

As the demand for wood panel products has increased in recent years, the effort to find alternative raw material sources continues to be an important issue as the wood raw material obtained directly from the forests is insufficient. Industrial residues, non-wood materials, agricultural residues, fast-growing trees and less common wood species are used to solve the raw material problem and meet the future demand for wood-based products. As a result of forestry activities, a significant amount of waste that can be recycled or reused is generated. In recent decades, there have been different studies on the conversion of these wastes into usable products (Yazıcı, 2020; Dos Santos et al., 2014; Yano et al., 2020, Kurt, 2020). Today, agricultural and other lignocellulosic wastes are usually incinerated, disposed of or used to generate energy. These methods can cause problems such as soil, air pollution and carbon emissions. In addition, an important source of raw materials is lost before it becomes a value-added product. (Nazerian et al. 2016; Sugahara et al. 2019).

With the debarking of wood bark, raw material loss of 15% by volume and 7-10% by weight occurs. Waste barks obtained by debarking wood are generally used in energy production. However, wood and other cellulosic materials have low thermal conductivity due to their high porosity and low density and can be preferred in insulation applications (Dönmez and Dönmez, 2013). In many different studies, it has been stated that the bark of various tree species can be used in the production of insulation boards and that the insulation and mechanical properties of the products obtained from the bark are at a sufficient level (Kain et al., 2012; 2013; 2014; İstek and Özlüsoylu, 2018).

Wood-based board products, which are obtained by shredding wood or different lignocellulosic materials into small sizes called chips, performing fibering process and pressing by molding as desired with binder additive, can also be defined as a composite material containing a certain part or all of its wood structure. Istek and Sıradag, 2013; Istek et al., 2020; Mamza et al., 2014). There is an industrial production of different types of wood-based boards in the world and our country, and the common ones in our country are; It is known by names such as medium density fiberboard (MDF), particleboard (chipboard) (PB), plywood, wood board, solid panel (Istek et al., 2017a; Istek et al., 2017b; Özlüsoylu et al., 2018). The most important factors in the intensive use of wood-based boards in different places of use are that they are relatively cheap compared to solid wood and can be produced with the desired properties. In addition, it is among its important advantages that it is easy to process, can be produced in large quantities to meet the need, and allows to eliminate the defects that can be seen in solid wood (Eroğlu and Usta 2000; Özlüsoylu and İstek, 2015). Investments in wood panel products in Turkey continue to increase and production capacities are increasing every year (Istek et al., 2017a). There are many factors on the physical and mechanical properties of wood-based boards such as raw material type (Istek et al., 2020b), chip size (Istek et al., 2018c), draft humidity (Istek et al., 2019), density change (Istek and Sıradag, 2013), glue type and amount (Özlüsoylu & İstek, 2018b).

PB and MDF stand out among wood-based composites in that they are produced more and used more widely. PB is obtained by pressing the mat obtained from chips or other lignocellulosic material in the form of chips under heat and pressure with the addition of adhesive. PB properties may vary due to random particle deposition during mat formation, with some factors such as adhesive bonding, particle geometry, resin type and density changes (Sanabria et al., 2013; Istek et al.,2010; Istek et al.,2019). MDF is one of the wood-based panels produced in high quantities by combining wood fibers with glue with temperature and pressure (Krzysik, 2001). Since MDF contain at least 80% vegetable fiber, they have high mechanical and technological properties like wood material. However, it also has some features that are not found in wood material (Eroğlu and Usta, 2000). Today, wood-based panels such as MDF and PB are widely used for furniture and structural purposes. MDF production has increased significantly in recent years and has a large market share in the wood composite sector (Istek et al., 2019; Koç and Aksu, 1999; Cabuk et al., 2013; Özlüsoylu and Onat, 2018).

Thermal insulation is defined as the process of taking measures to reduce heat transfer in the exterior walls, glass and joinery, roofs, floors and installations of buildings to reduce the energy consumed for heating in winter and cooling in summer, and to live in a more comfortable environment (Kulaksızoğlu, 2006). Thermal insulation can be done by using different insulation materials. Insulation materials can be evaluated in three different groups synthetic, inorganic and natural renewable materials. Materials of natural origin have significant advantages due to their low risk for human and environmental health, being renewable and having carbon storage feature (Kain et al., 2014; Özlüsoylu and İstek, 2018a; Özlüsoylu and stek, 2019c). Wood and other cellulosic materials have low thermal conductivity due to the absence of free electrons and their high porosity. Renewable resources for insulation from straw, hemp, wool, wood fibers, cellulose balls obtained from recycled paper and tree bark create a great potential in terms of insulation (Kain et al. 2014; Özlüsoylu and İstek, 2019a)

The type and amount of glue have a direct effect on the physical and mechanical properties of the board products. Today, board products are produced with formaldehyde-containing glues up to 90%, since they are economical compared to alternatives and provide sufficient properties (Roffael, 2006; İstek et al., 2018a; Istek et al., 2018b; Istek et al., 2020a).

In addition to formaldehyde-containing glues, polymeric methylene diphenyl di-isocyanate glue (P-MDI) glue with different properties is also used. Although P-MDI glue used in board production is more costly than formaldehyde-containing glues, it is preferred because it hardens faster, has a higher tolerance to moisture and is used in lower doses. Since P-MDI causes harmful chemical effects during production, it does not carry any risk in terms of health after production, although it requires special protection measures (Stark et al. 2010). It is stated that the most suitable adhesive for the production of low-density fiberboard and particleboard is isocyanate glue (Kawai et al., 1988). In studies with different wood-based composites, it has been stated that formaldehyde-containing glues and P-MDI glue can be used as a mixture (Dziurka and Mirski, 2010; Wang et al. 2004; Wang et al. 2007).

In this study, the insulation and thermal properties of board products with different lignocellulosic materials were investigated. For this purpose, board production was carried out using wood chips, wood bark, wood fiber and waste office papers, the thermal conductivity of the obtained boards were determined and mass losses with the effect of temperature were examined.

2. Material and Method

2.1 Material

In this study, wood chips, fibers obtained from wood chips, tree bark and waste office paper were used as raw materials, and urea formaldehyde (UF) and P-MDI glues were used as binding glue. Wood chips, wood fiber, bark and UF glue were procured from a private particle board factory. P-MDI glue was purchased from a private company and used. Table 1 shows the properties of UF and P-MDI glue.

Table 1. Properties of UF and P-MDI glue.

P-MDI		**UF**	
Properties	**Standard**	**Properties**	**Standard**
NCO content (% weight)	30-32	pH	7.5-8.5
Viscosity (25°C) cps	150-250	Solid matter ratio (%)	54-56
Specific gravity (25°C) (g/cm^3)	1.23-1.25	Viscosity (20 °C) (cps)	100-200
Boiling point (°C)	200-208	Specific gravity (20°C) (g/cm$^{3)}$	1.22–1.23
Freezing point (°C)	under -20	Jell time at 100 °C, (s)	15-25
Flash point (°C)	177-218		
Appearance	Brown fluid		

Wood chips and wood fibers were obtained from 50% coniferous and 50% deciduous woods, and tree bark was obtained by debarking the bark of *Pinus nigra* woods. Figure 1 shows the lignocellulosic raw materials used in board production. Boards produced with wood chips, bark and fiber-bark mixture were produced as three layers, while fiberboards and wood chip-paper mixture were produced as a single layer. Each test panel was produced in 3 replications.

Figure 1. **W-CL**: *Wood core layer,* **B-CL**: *Bark core layer,* **F:** *Fiber,* **W-SL**: *Wood surface layer,* **B-SL**: *Bark surface layer,* **WP**: *Waste paper.*

2.2 Three-layer Board Production

Wood chips and wood bark, which are used as raw materials in the production of the three-layer board, were brought to an appropriate size and classified. Wood fibers are supplied directly for production. After the classification process, the raw materials were dried in the drying oven to humidity of 1% to 3% and made ready for gluing. The gluing process was done by spraying method in a rotary drum mixer. The amount of glue was calculated according to the dry chip weight and was applied as a mixture of 7% UF + 3% P-MDI. After the gluing process, the board outline was created by manually forming in the mold. The forming process was carried out in three layers, 20% of the total weight was used in the bottom layer, 20% in the up layer and 60% in the core layer. In fiber-bark mixture boards, the core layer is bark and the bottom and up layers are fiber, in the same proportions. After the forming process, the board production was completed with the hot press application. Table 2 shows the properties and production parameters of the three-layer board.

Table 2. Three-layer board properties and production parameters.

Board type	Type of raw material	Hot Press Conditions	Target board density (kg/m^3)	Target board thickness (mm)
Particleboard	Wood chip	175±5 °C, 160±5 bar, 4-6 minutes	300	20
Bark board	Wood bark		300	20
Fiber-bark board	Wood bark+wood fiber		300	30

2.3 Single-layer Board Production

While single-layer fiberboards were produced from wood fibers, wood chip and paper mixed boards were produced from a mixture of coarse chips and 80g/m2 shredded waste office papers. Waste Office paper and chips ratio is used equally. To produce both types of board, 10% UF glue was used in proportion to the full dry fiber/fiber-paper weight. The raw materials glued in the rotary mixer were formed as a single layer and a mat was produced. Then, the board production was completed with the hot press application. Table 3 shows the properties and production parameters of the single-layer board.

Table 3. Single-layer board properties and production parameters.

Board type	**Type of raw material**	**Hot Press Conditions**	**Target board density (kg/m³)**	**Target board thickness (mm)**
Fiberboard	Fiber	185±5 °C, 165±5 bar, 5 minutes	750	12
Wood chip-paper	Wood chip+ wastepaper		600	12

2.4. Thermal Conductivity Measurement

The ASTM C1113-99 hot-wire method and PD-11 sensor probe were used in the Quick Thermal Conductivity (QTM) - 500 thermal conductivity test device to perform the thermal conductivity (λ) tests. The QTM-500 device used in thermal conductivity experiments is shown in Figure 2.

Figure 2. QTM-500 thermal conductivity measuring device (Sözen, 2019).

Before each measurement, calibration measurements were made with the reference plates given in Figure 3. The temperature in the environment where the tests took place was kept constant between 21-24 °C. Measurements were made from 5 different regions of the panels for each sample. The average of these 5 measurements was recorded in W/mK.

Figure 3. Reference plates are used in calibration (Sözen, 2019).

2.5. Thermogravimetric Analysis (TGA)

The thermal stability of all the boards was investigated using a TGA/DTA and DSC (Perkin Elmer, TA Instruments, USA). In TGA/DTA, the samples were heated from 25 °C to 800 °C with a heating rate of 10 °C/min and a nitrogen flow of 100 mL/min. The samples weighing about 10 mg were used for the tests. Degradation temperatures at 10% weight loss (T_{10}) and 50 % weight loss (T_{50}), maximum degradation temperature in the derivative thermogravimetric peaks (DTGmax), and mass loss of the samples in the TGA curves were measured and compared with the results obtained. The differential scanning calorimeter (DSC) tests were performed on a DSC 2920 (Perkin Elmer, TA Instruments, USA) at a heating rate of 5 °C/min under a nitrogen atmosphere (Myers, 1991; Sözen et al., 2017).

3. Result and Discussion

3.1. Results of thermal conductivity

The average density, thickness and thermal conductivity results of the test boards are shown in Table 4. When Table 4 is examined, it is understood that the average weights and thicknesses deviate a little from the targeted amounts, but this deviation is between the tolerance limit values for density (TS EN-312, 2012).

Table 4. Average density, thickness and thermal conductivity results of the test boards.

Board type	Average board density (kg/m^3)	Average board thickness (mm)	Average thermal conductivity (W/mk)
Bark board	330±29	19,10±0,20	0,06512
Fiberboard	770±72	11,60±0,10	0,12350
Particleboard	325±32	19,21±0,18	0,07556
Fiber/bark-board	320±20	28,27±0,34	0,06811
Wood chip/paper board	610±51	11,80±0,11	0,12230

When the thermal conductivity values were examined, it was determined that thermal conductivity of produced only from the bark and the board groups with low density were lower. It can be said that the board groups containing the bark have a lower thermal conductivity coefficient due to the porous structure of the bark and its low density. Kain et al. (2013) emphasized that the amount of glue did not have a significant effect on the thermal conductivity coefficient, but the density had a significant effect. In another study, it is stated that the thermal conductivity increases by 0,011 W/mK with every 100 kg/m^3 additional density between 200 kg/m^3 and 550 kg/m^3 densities for bark boards (Kain et al., 2012). In another study, it was emphasized that there should be an optimum chip size and panel density where the air gaps and density are as small as possible in order to obtain the lowest thermal conductivity in the boards (Kain et al., 2014). In similar studies on bark insulation boards, the thermal conductivity was found by Pasztory and Ronycz, 2013 to be between 0,0613 W/mK and 0,0765 W/mK. Brombacher et al. (2012) stated that low density insulation boards have a low thermal conductivity due to the high void content in their structure, the effect of the raw material type on the thermal conductivity coefficient is very limited and mthe ain factor is panel density. In a different study, it was emphasized that the thermal conductivity increased as a result of covering the surfaces of the bark insulation boards with veneer, and this was due to the increase in density (Özlüsoylu and Istek, 2019b). It has been emphasized that a lower thermal conductivity can be obtained by using fibers in the surface layers instead of processes such as coating that increase the densities of the bark boards, especially at high densities. (Istek and Ozlusoylu, 2019). Yapıcı et al., (2011) measured the thermal conductivity in their study where they used perlite at different rates on the surface and core in fiberboard production. The highest thermal conductivity was obtained in fiberboards (0.1959) using 20% perlite in the core and surface layers. The lowest thermal conductivity was obtained in fiberboards (0.1695) using 1% perlite only in the surface layer. When the results obtained are examined in terms of insulation properties, it has been determined that the desired limit values (0.065 W/mk-0.090 W/mk) for wood thermal insulation materials (grater chipboards) in the TS 825 (2013) standard are met except for fiberboard and wood chip/paper board.

3.2. Results of Thermogravimetric Analysis (TGA)

TG analyzes and comments of the board variations produced within the scope of the study were examined separately. Figure 4 shows the TG and DTG graphs of the bark board.

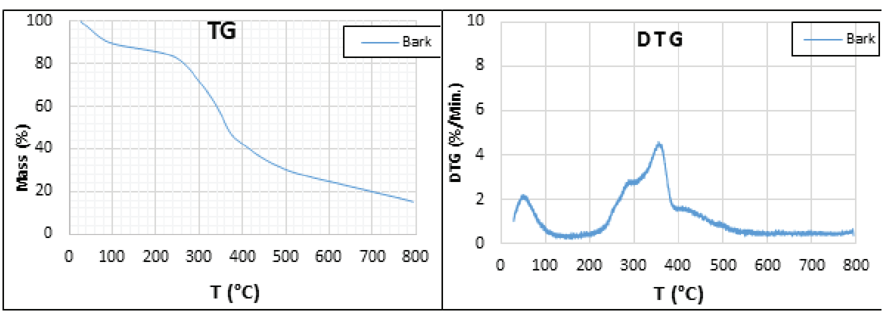

Figure 4. TG and DTG graphs of the bark board.

When the mass losses of the bark boards are examined, it can be said that the first mass losses begin at temperatures between about 60 °C and 90 °C. This decrease is caused by the evaporation of the moisture in the sample due to the humidity in the environment. At 93.4 °C, the total mass loss was determined as 10%. Bark boards, which lost a rapid mass between 220 °C and 365 °C, reached a 50% mass loss at 355 °C. As a result of the TG analysis, the total mass loss was measured as 84.7%. Barta-Rajnai et al., (2017) reported that the extracts and hemicelluloses in the bark lost mass between the temperatures of 200 °C and 300 °C as a result of the TG analyses they conducted in their study examining the thermal properties of the root, wood and bark parts of the spruce tree. In the same study, they determined that cellulose, which constitutes 40% of the bark, decomposes between 300 °C and 400 °C. TG and DTG analyzes of fiberboard produced within the scope of the study are presented in Figure 5.

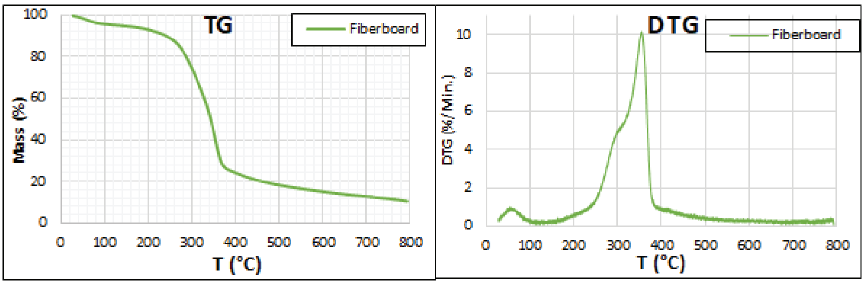

Figure 5. TG and DTG graphs of fiberboard

TG analyzes of fiberboards showed similar properties with bark boards. However, the high amount of cellulose in the fibers that make up the fiberboard was reflected as an increase in mass loss in the regions where cellulose degrades (300 °C-400 °C). Mass losses of 10% and 50% in fiberboards occurred when 241.3 °C and 343.4 °C were reached, respectively. The maximum temperature was measured 2.7% lower (355 °C) compared to the bark boards. Total mass loss in fiberboards was measured as 91.4%. Heikkinen et al., (2004) reported that hemicellulose in DTG diagrams generally lost mass at lower temperatures than the cellulose peak. In the same study, they determined that the degradation of lignin was slower in a wide temperature band, so it could not be seen clearly. The graph of TG and DTG analysis of particle boards, which is another variation, is shown in Figure 6.

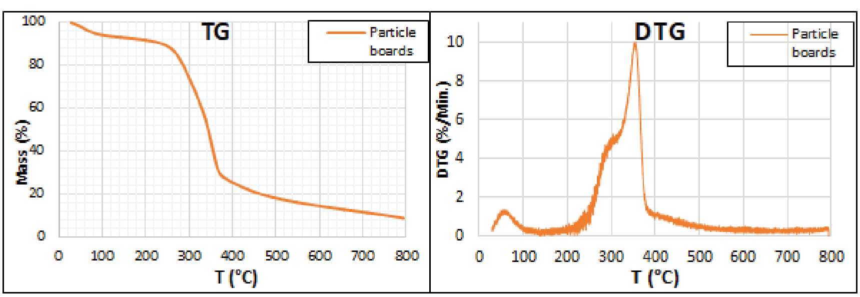

Figure 6. TG and DTG graphs of particleboard.

When the TG and DTG analyzes of the particleboards were examined, it was determined that the thermal behavior of the particleboards showed more similar properties to the fiberboards. The amount of cellulose, which is high in fiberboards, is also found in particleboards more than in bark boards. For this reason, the mass loss amounts, especially between 300 °C and 400 °C, are quite high. 10% mass loss of particle boards reached at 236 °C. This value was determined as 241.3 in fiberboards and 93.4 in bark boards. The maximum temperature reached during the DTG analysis of the particleboards was determined as 354.6 °C. The total mass loss achieved as a result of the analysis was calculated as 91.4%. The visual of TG and DTG analyses of another board type produced within the scope of the study, consisting of fiber and bark mix (fiber/bark), is shown in Figure 7.

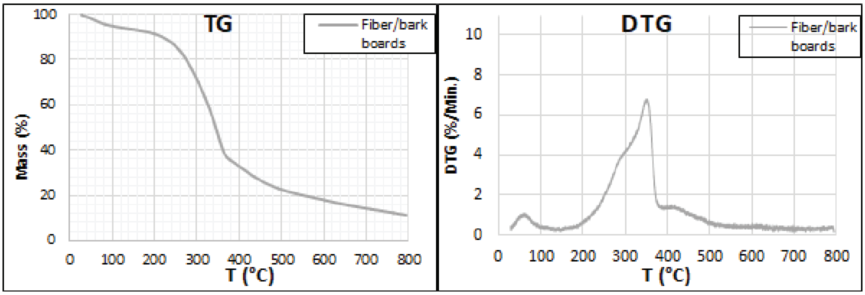

Figure 7. TG and DTG graphs of fiber/bark board.

Initial mass losses due to sample humidity, which are seen between 70 °C and 100 °C in all variations, are also seen on these boards. The bark and fibers used in these boards also affected the cellulose ratios in the board. The cellulose ratio in these boards is less than fiberboards and more than bark boards. This situation emerged in the analysis. Mass losses between 200 °C and 300 °C are more linear than 100% bark boards. Again, while the mass losses between 300 °C and 400 °C, which are the decomposition temperature of cellulose, are less than fiberboards, they are higher than bark boards. Fiber/bark boards are the boards with the highest mass loss in all variations, with a total mass loss of 98.1%. This rate was determined as 84.7% in 100% bark boards and 89.5% in fiberboards. By looking at these values, it can be said that the bark and fibers are in interaction during the analysis. The graph of the TG and DTG analyzes of wood chip/paper, which is the last board variation produced within the scope of the study, is shown in Figure 8.

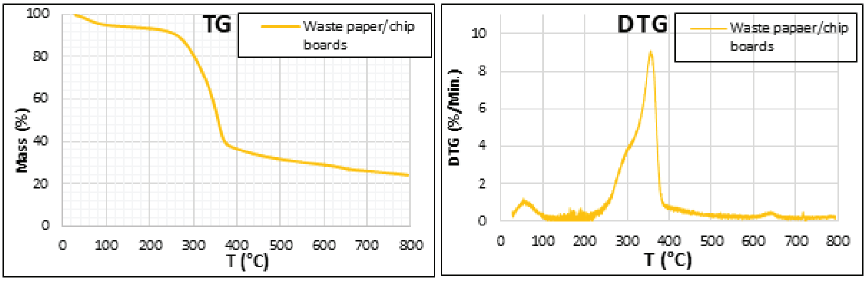

Figure 8. TG and DTG graphs of wood chip/paper board.

The lowest mass loss values (76%) were achieved in these boards, which were obtained by mixing wastepaper (50%) and wood chips (50%) homogeneously. The reason for this is the additives, fillers and bleaching agents found in office papers. Chattopadhyay et al., (2008) examined the TG analysis of the products obtained by mixing polyethylene (PE) and polyvinyl chloride (PVC) plastics with biomass wastes and reported that the mass losses of the samples containing paper after 600 °C were caused by the chemicals used in paper production. The melting temperature of the $CaCO_3$ filler, which is especially used in the production of white office paper, is expressed as 825 °C. When Figure 8 is examined, the fact that mass losses continue up to 800 °C after temperatures (400 °C) at which cellulose degrades confirms this information. On the other hand, wood chip/paper board showed a more stable property in the mass-temperature relation. Mass losses of 10% in these boards were reached at 263.2 °C. Compared to the bark boards, this value has increased by approximately 182%. The maximum temperature reached during the analysis was determined as 355.0 °C. The summary information of the mass loss and DTG analyzes of all variations produced within the scope of the study are shown in Table 5.

Table 5. Mass loss and DTG summary data for all variations produced within the scope of the study

Board type	T_{10}% (°C)	T_{50}% (°C)	DTGmax (°C)	Mass loss (%)
Bark board	93.4	355.1	365.1	84.7
Fiberboard	241.3	343.4	355.0	89.5
Particleboard	236.4	343.9	354.6	91.4
Fiber/bark-board	219.4	344.8	350.6	98.1
Wood chip/paper board	263.2	357.3	355.1	76.0

Conclusion

It has been observed that density is an important factor in the thermal conductivity of the boards obtained from lignocellulosic raw materials of different structures, and the thermal conductivity increases with increasing density. In addition, the lower density of the boards with a hollower structure will contribute to the reduction of thermal conductivity. In terms of insulation, it has been understood that the boards other than fiberboard and wood chip/paper board have insulation material properties when only the thermal conductivity is taken into account.

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