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Corn production by pre-planting instead of using herbicide: Allelopathic effect of pre-planting

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ABSTRACT

Radish plants are used in organic farming because of their allelopathic effects on weeds. As a result, the effect of radish plants on corn plants was investigated using radish plants as a pre-plant in corn plant production and trialing weed applications on corn plants without using herbicides. Weed removal, which is part of corn plant maintenance, was accomplished using four different applications: hand hoeing, hand + tractor hoeing, tractor hoeing, and control (no hoeing). The experiment was conducted using a split-trial design. Except for the tassel emergence time, it was discovered that the radish as a previous crop had a significant positive effect on the investigated corn characteristics, such as first ear height, plant height, ear length, number of rows per ear, number of grains per ear row, and grain yield. Hand hoeing and hand + tractor hoeing weed removal applications were distinct from other applications and had a positive effect on maize yield components.

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Introduction

Soil uses its resources to produce vital nutrients. There are more living things in the soil than ever before. An increasing number of living things are pounding the ground. Care should be taken during production to safeguard the soil, nurture plants, and maintain productivity for years. Soil preservation is important for the future of agriculture and productivity (Kodas & Er, 2012). New technologies and techniques are being used to maximize the efficiency of a given unit area. Among the few examples are synthetic chemical fertilizers, pesticides, hybrid seeds, and large-scale agricultural implements. Additionally, their excessive use is harmful to human health (Sirat, 2016).

Corn is cultivated intensively worldwide as a result of new technologies and methods being suitable for the task. Because hybrid seeds produce high yields of corn that can be used in a variety of ways, monoculture agriculture is encouraged by the practice of planting the same crops in the same fields, year after year. To avoid the drop in yield caused by growing the same crops in the same field, more than necessary applications of soil cultivation, fertilization, pesticides, herbicides, and irrigation will be made. Weeds that disrupt monoculture cornfields proliferate more widely. The population of pests will increase as a result of this increase. Owing to the reduced ability of corn plants to compete with weeds during their initial development period, the use of pre- and post-emergence herbicides is high. Herbicides are used by farmers under all circumstances because they need them to control weeds to produce the desired yield. Sorghum, a weed that competes with corn plants and spreads through rhizomes, severely harms corn plants and lowers production (Travlos et al., 2018).

Weeds develop resistance to the same herbicide over time, necessitating the use of more herbicides. The best methods to avoid these unfavorable situations are crop rotation and biological control (Bangarwa & Norsworthy, 2014; Jabran et al., 2015; Menguc 2018). Owing to the detrimental effects of drug residues and side effects on both human and environmental health, developed and developing nations are working to develop biological control methods. Legumes and some cruciferous plants reduce weed growth and enhance soil quality by increasing soil organic matter and nitrogen (Kolören & Uygur, 2007; Kitis et al., 2011; Arikan & Elibuyuk, 2015; Goksu & Koloren, 2018; Gundogan and Koloren, 2018). Cover crops that shield the soil from wind or water erosion prevent nutrient-rich soil from being transported by surface waters (Langdale et al., 1991).

The ideal cover crop increases the availability of N for the following crop and decreases the need for N fertilizer

(Delgado & Gantzer, 2015). Potential advantages could come in the form of environmental and financial benefits, given that cover crops remove nitrogen from the soil, reducing the amount of nitrogen applied to corn (Johnson et al., 2021).

Weeds are a major limiting factor in maize production. They can compete with corn for water, nutrients, and light, causing significant losses in yield and quality. Chemical herbicides are widely used to combat weed growth. However, herbicide use can cause soil and water pollution and have adverse effects on human health. Radish (*Raphanus sativus* L.) is a plant with allelopathic properties. Some chemicals released by the roots and leaves of radish plants prevent the growth and development of weeds.

The objective of this study was to investigate the allelopathic potential of radish (Raphanus sativus L.) as a cover crop for weed suppression in corn production systems. Specifically, this research aimed to: (1) evaluate the effect of pre-planted radish on corn growth characteristics and yield components, (2) compare the effectiveness of different weed control methods (hand hoeing, hand + tractor hoeing, tractor hoeing, and control) in radish pre-planted and non-pre-planted plots, and (3) determine whether radish pre-planting can serve as an alternative or complementary approach to herbicide use in sustainable corn production.

Materials and Methods

In the experiment, a hybrid corn variety called P 2088 (Pioneer Hi-Bred International Inc., USA) was used. P 2088 is a single-cross hybrid maize variety characterized by high yield potential, good standability, and adaptation to various environmental conditions. It has a growing period of approximately 110-120 days (FAO maturity group 600-700) and is suitable for grain production in Mediterranean climatic conditions.

Experimentel design: The study was conducted in Kahramanmaras, Türkiye, during the first growing season for crops, where the Eastern Mediterranean climate is predominant in 2017 and 2019. Due to unintentional negativities, the study's 2018 values were canceled. The study looked at the effects of pre-planting and various weed extraction techniques on corn yield. In the experiment, a hybrid corn variety called P 2088 was used. The front plant was used in the experiment, which was set up in the divided plots experimental design, and various weeding extraction techniques were used in the sub-plots. Radish plants were used as the front plants in the main plots, which were otherwise left unplanted.

Techniques applied to the trial design: The sub-plots were weeded using four different techniques: hand hoeing, hand + tractor hoeing, tractor hoeing, and control (no hoeing). In the study, the winter-grown radish (Kadirli radish) was pre-planted in the fall, just before the corn-sowing season. In order to ensure the emergence of the plant, the radish plant, which was planted at the end of August in 2016 and 2018, was irrigated after planting. No maintenance, such as irrigation, fertilization, or pesticide application, has been carried out since the radish plant emerged. In March 2017 and 2019, the radish plant was plowed into the ground without being harvested. In March of both years, the radish was mixed with the soil while taking into account the soil's humidity and the tractor's operational state. *Procedures applied to the trial:* The trial area was prepared for planting by plowing it with inferior tillage equipment before sowing maize. The maize experiment's first year was planted on April 5, 2017, and the second year was hand-sewed at 50 cm between rows and 25 cm above row spacing because of precipitation on April 20, 2019. Fertilizers containing nitrogen and phosphorus in the amount of 6 kg da^{-1} were applied before sowing. Because it rained, irrigation was postponed after planting. When the plant was 50 cm tall, nitrogen fertilizer was applied at a rate of net 19 kg da^{-1}. It was irrigated 9 times in the subsequent year, compared to 8 times in the first year.

Table 1. Some physical and chemical analysis results of the experiment soil.

Examined features	2017				2019			
	PR		NP		PR		NP	
Saturation %	63	Cl	62	cl	77	Clay	79	Clay
pH	7.4	neutral	7.3	neutral	7.2	neutral	7.4	neutral
EC $dS.m^{-1}$	0.7	sf	0.6	sf	85	sf	1126	Sf
Lime %	22.2	vl	23.3	vl	2.4	limy	2.3	Limy
Organic matter %	1.7	poor	1.3	poor	2.0	medium	1.9	Poor
Ph (P_2O_5) kg da^{-1}	9.4	high	6.8	medium	5.6	poor	5.6	Poor
P(K_2O) kg da^{-1}	48.8	high	53.3	high	64.7	high	61.2	High

PR: pre-plan radish, NP: no pre-plan, Ph: phosphorus, P: potassium, cl: clay-loamy, sf: salt free, vl: very limy

Table 2. Some climate data of the experiment area.

	Minimum temperature (ºC)		Maximum temperature (ºC)		Average temperature (ºC)		Relative Humidity (%)		Precipitation (mm)	
	2017	2019	2017	2019	2017	2019	2017	2019	2017	2019
April	12	14.2	25.5	21.5	18.4	8.1	45.3	72.2	71.6	32.2
May	15.7	23.0	28.8	32.1	21.7	14.0	52.6	47.5	28.1	3.6
June	19.9	19.9	32.5	35.9	25.4	27.2	49.1	50.1	39.4	5.2
July	23.2	21.8	35.6	36.6	28.6	28.4	46.2	49.8	0.3	0.2
August	23.3	29.3	36.8	38.0	29.1	29.3	43.8	50.5	0.0	0.0
September	21.0	17.7	34.7	35.2	27.2	26.0	38.4	43.3	0.6	1.0

Physical and chemical soil analyses: The soil at the research area has a clayey texture, is rich in beneficial potassium, is calcareous, neutral, and has a medium level of organic matter. Table 1 lists some of the findings from physical and chemical analyses of soil samples taken from the experimental area.

Climate data of the experiment area: The driest and hottest month of the year was August, and according to the climate conditions of the study area when the experiment was conducted, the total amount of precipitation was 139.4 mm. The total amount of precipitation for the months of April through September of the subsequent 2019 research year was 42.2 mm, with August being the hottest month of the year. Table 2 provides some climatic information related to the experimental period.

Characteristics examined in the study: Tassel emergence time, cob emergence time, first node diameter, first ear height, plant height, ear length, ear diameter, ear row number, number of grains per ear, grain ratio, and grain yield were studied in the studies. (Idikut et al., 2015; Idikut et al., 2020)

Statistical analysis: The experimental design was arranged in totally randomized blocks. Each block was divided into plots using four different techniques: hand hoeing, hand + tractor hoeing, tractor hoeing, and control. Observations were made in the field and measurements of the examined characteristics were taken. Two-year data from the trial was analyzed by variance analysis using the JMP package program. Groupings were made with Duncan's multiple comparison test (JMP, 2021). The result means were compared using least significance difference (LSD) test at $p<0.05$.

Results

The tassel emergence time: The radish plant, which was used as a pre-plant, did not have a statistically significant impact on the emergence of the corn tassels, according to research done to examine the impact of the previous plant and various weed removal applications on the corn plant. The P. 2088 corn cultivar used in the study was found to be significantly affected by different weeding techniques ($p<0.01$), years ($p<0.01$), and the years x different weeding application interaction ($p<0.01$). A shorter tassel emergence time was the result of weed removal in the corn plant using only a hand hoeing and a hand hoe + tractor hoeing as opposed to the control with no application. It was discovered that weed removal with only a tractor hoeing did not differ statistically significantly from the unweeded control. The tassel emergence time has produced a significant difference, according to the data. The first year's tassel emergence time was longer than the second year's. In the first year, the trial was planted 15 days earlier than the following year. The rains the following year caused a 15-day planting delay as a result of the late field preparation. The tassel emergence time was shortened by the rise in temperature brought on by late sowing. Tassel emergence time was observed in hand + tractor hoe application with 78.5 days at the earliest in the first year and was significantly different from only tractor hoeing and control. It was obtained from only hand hoe application with 65.5 days at the earliest in the second year and was noted to be different from others (Table 3).

The differences in the first year's conditions (ecological conditions) and the soil properties are thought to be the cause of the variation in the second year's tassel emergence period. The emergence of the tassels was reduced because the front plant was a radish plant, but there was no statistically significant difference between it and the empty front plant. Additionally, the influence of the climate feature is greater than the influence of the soil feature on the timing of the tassel emergence.

Ear silk emergence time: It was shown that the radish plant, when utilized as a pre-plant, had a statistically ($p<0.01$) significant influence on the timing of the emergence of the ear silk in the research study to examine the impact of fore plant and various weed control techniques for corn plant. According to Table 3, there was a statistically significant difference in the silk emergence times for the P. 2088 corn variety when the radish plant was utilized as a pre-plant in the winter and when it was left empty in the winter. The P. 2088 corn variety's silk emergence period was 83.3 days in the first year of the research and 68.0 days in the second, with a statistically significant ($p<0.01$) difference between them in terms of years. When the radish was used as the fore plant in both experimental years and it was in a statistically different group from each other, it was found that the ear silk emergence period was the earliest (year x front plant interaction, $p<0.05$).

The section that was left vacant during the winter months when the front plant was not in use was where the emergence time of the ear silk was found to occur more later in both years. The ear silk emergence time of various weed removal methods was 74.1 and 74.0 days in hand hoeing and hand + tractor hoeing, respectively. It has been determined that these methods are in the same group, do not statistically differ from one another, occur earlier than other weeding methods, and differ statistically ($p<0.01$) from others. The different weed removal application x years interaction led to statistically significant differences in the timing of ear silk emergence ($p<0.01$). It was noted that the tassel emergence time in the control application in the first year reached the highest value with 87.5 days and varied greatly from other interactions (year x different weeding). It was discovered that the interactions of year x weed removal application in the second year were in the same group, differing significantly from the interactions of year x weed removal application in the first year, and did not differ between them in terms of ear silk emergence time. The previous plant x different weed remove interaction was found to have a significant ($p<0.05$) impact on the timing of ear silk emergence. Before the introduction of the P. 2088 corn cultivar, radish was used as a pre-plant, and the emergence times of the ear silk in four different weeding applications did not statistically differ from one another. However, it was discovered that the front-planted radish's ear silk emerged earlier than the weeding treatments in the winter-vacant areas. This resulted in a statistically significant difference between the previous plant and various weed treatments interaction (Table 4).

First node diameter: The first node diameter of the corn plant's stalk was observed to be unaffected by different pre-crop applications, but different weeding applications were statistically significant ($p<0.01$).

Table 3. The tassel emergence times (days) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		Overall
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	78.0	82.0	80 0 bc	62.3	66.6	65.5 e	70.1	74.3	72.2 c
hand +tractor hoeing	77.3	79.6	78.5 c	67.3	67.0	67.1 d	72.3	73.3	72.8 bc
tractor hoeing	79.3	84.0	81.6 ab	65.0	68.0	66.5 d	72.1	76.0	74.0 ab
Control	79.6	85.6	82.6 a	65.3	68.0	66.6 d	72.5	76.8	74.6 a
Mean	78.5	82.8	80.7 a	65.2 d	65.0	67.4 b	71.7	75.1	
S.E.	0.54	1.29		1.03	0.35		0.55	0.79	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t:hand+tractor.

Table 4. The ear silk emergence times (days) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	78.0	84.3	81.1 c	66.0	68.3	67.1 d	72.0 d	76.3 c	74.1 c
hand +tractor hoeing	77.3	82.6	80.0 c	67.0	69.3	68.1 d	72.1 d	76.0 c	74.0 c
tractor hoeing	81.3	88.0	84.6 b	66.3	70.3	68.3 d	73.8 d	79.1 b	76.5 b
Control	83.0	92.0	87.5 a	64.6	72.3	68.5 d	73.8 d	82.16 a	78.0 a
Mean	79.9 b	86.7 a	83.3 a	66 d	70.0 c	68.0 b	78.4 a	72.9 b	
S. E	1.35	2.08		0.5	0.85		0.5	1.43	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t: hand+ tractor.

Table 5. The first node diameter (mm) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	21.4	16.6	19.0	23.2	16.6	19.9 ab	22.3 a	16.6 cd	19.5 ab
hand +tractor hoeing	20.4	20.7	20.5	20.6	23.5	22.0 a	20.5 ab	22.1 a	21.3 a
tractor hoeing	18.2	15.4	16.8	18.7	18.7	18.7 bcd	18.4 bc	17.1 cd	17.7 bc
Control	19.2	12.4	15.8	19.8	17.5	18.6 bcd	19.5 abc	14.9 d	17.2 c
Mean	19.8	16.3	18.0	20.6	19.1	19.8	20.2	17.7	
S. E	0.69	0.95		0.95	1.53		0.82	1.54	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PRXW: pre plant x weed interaction, h+t: hand+ tractor.

The first node's diameter was 21.3 mm, and the application of hand hoe + tractor hoeing produced the highest value. Although this application did not statistically differ from that of hand hoeing alone, it did differ significantly from that of tractor hoeing alone and the controlapplication. The control application yielded the lowest measurement of 17.2 mm for the diameter of the first node. The initial node's diameter was impacted by the statistically significant ($p<0.01$) interaction between weed removal and pre-plant treatment.

The highest value of first node diameter in the aforementioned bilateral interaction was recorded to be 22.3 mm with just the hand hoe and pre-plant radish application interaction, as well as 22.1 mm from the hand + tractor hoeing application without the front planting, and they were both in the same group. Pre-plant radish and no pre-plant control treatment resulted in the lowest initial node diameter. In terms of years, pre-plant, or vacant, the initial node's diameter did not statistically differ (Table 5).

First ear height: It was discovered that years, previous plant application, year x previous plant, year x different weeding, and year x previous plant x different weeding application interaction had a statistically significant ($p<0.01$) effect on the first ear height in the study that examined the effect of previous plant and different weeding applications on P. 2088 maize plant. The first ear's height was 85.1 cm in the study's first year, but it was 49.7 cm in the second year, and it was noticed that they were noticeably different from one another. Early planting and the characteristics of the soil contributed to the high values in the first year; the plant enters the generative phase as a result of the high temperature in the latter year, which accounts for the low first ear height. When the field was empty and the previous plant was radish, it was observed that the height of the first ear was 78.5 cm instead of 56.4 cm, and there was a statistically significant difference between them.

The applications with radish as the front plant had the greatest initial ear height in the year x front plant application interaction, with 103.2 cm in the first year and 67.0 cm in the second, and there was a significant difference between them and other applications. It was observed that the hand hoeing application produced the greatest value in the first year, 91.7 cm, and the control application produced the lowest value in the first year, x various weeding treatments. In the aforementioned bilateral interaction, it was noted that the hand hoe application in the second year had the lowest value for the initial ear height (45.2 cm), which was statistically distinct from other weeding applications. The control application yielded the greatest first ear height, with 53.0 cm, despite the fact that there was no statistical difference between other applications in the other year (Table 6).

Plant height: It was noted that the plant height of the P2088 maize variety was 170.6 cm in the first year and 128.80 cm in the later year, and there was a statistically significant ($p<0.01$) difference between years. The height of the plant in the first year was caused by the earlier planting of the corn plant, the higher rainfall in the first development period and the significant positive effect of soil properties. Although it was supplemented with irrigation water in the second year, the desired success cannot be achieved in meeting natural conditions. It was determined that the plant height was 170.0 cm in the case of pre-plant radish, while it was 129.4 cm when the fore plant was not used, and there was a statistically significant ($p<0.01$) difference between them. It was seen that different weeding practices had a significant ($p<0.05$) effect on the plant height of maize. In the study carried out, it was noted that the highest plant height was 164.5 and 159.6 cm, respectively, with hand hoeing and hand + tractor hoeing applications, these two applications did not create a statistical difference between themselves, they were in the same group and significantly differed from the control (Table 7).

The ear length: The use of various previous plants ($p<0.01$), various weeding techniques ($p<0.01$), and the interactions of year x pre plant x weeding applications ($p<0.05$) have been found to significantly affect the length of the corn plant's ear. The second year's ear length was 14.7 cm instead of the first year's 16.6 cm, and the difference between the two was found to be statistically significant at the 5% level. There was a statistically significant difference between the ear lengths of radish grown in the winter before the P2088 corn variety and radish grown in the winter with non-pre-plant, which was 14.0 cm. The longest ear lengths were obtained using a hand hoeing + tractor hoeing (18.4 cm) and a hand hoeing alone (17.8 cm), respectively, during various weeding applications. In terms of ear length, it wasn't noted to be statistically significantly different from other tractor hoeing and control applications, but it was noted to be different from them (Table 8).

The ear diameter: Varied pre-plant applications ($p<0.01$), weeding applications ($p<0.01$), and pre-plant x different weeding interaction applications ($p<0.05$) all had a statistically significant impact on the P2088 maize cultivar's ear diameter. When radish was utilized as the pre-plant, it was found that the diameter of the cob was 43.3 mm; when it wasn't, it was found to be 39.0 mm, and they were statistically distinct from one another. In various weeding applications, the hand hoeing and the hand + tractor hoeing were in the same group and substantially different from the other tractor hoeing and control, with ear diameters of 43.8 mm and 43.7 mm, respectively. The control application's 37.4 mm ear diameter was found to be the smallest, and it produced statistically significant differences from the other applications. The ear diameter of the plants in the region where radish was used as the pre-plant was statistically substantially higher than the plants in the areas where non-pre-plant was used in all weeding applications. This resulted from the interaction of pre-plant x various weeding treatments (Table 9).

Table 6. The first ear height (cm) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	103.1a	80.3b	91.7 a	53.3 ef	37.1 h	45.2 e	78.2	58.7	68.4
hand +tractor hoeing	101.5a	71.3c	86.4 b	57.2 e	43.8 gh	50.5 d	79.3	57.6	68.4
tractor hoeing	102.3a	64.3d	83.3 bc	52.1 ef	48.2 fg	50.1 d	77.2	56.2	66.7
Control	106.6 a	52.3ef	79.20 c	52.2 ef	53.7 ef	53.0 d	79.1	53.0	66.1
Mean	103.2 a	53.7c	85.1 a	67.0 b	45.7 d	49.7 b	78.5 a	56.4 b	
S. E	1.12	5.9		1.19	3.59		3.5	1.23	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h: hand+tractor.

Table 7. The plant height (cm) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	202.0	164.3	183.6	167.6	124.3	139.8	184.8	138.1	164.5 a
hand+tractor hoeing	195.4	144.6	170.0	162.0	136.3	149.1	178.7	140.5	159.6 a
tractor hoeing	191.3	140.3	165.8	142.6	119.3	131.0	167.0	129.8	148.4 ab
Control	159.6	128.3	144.0	133.3	114.1	128.8	146.5	126.3	133.8 b
Mean	187.1 a	144.4 b	165.7 a	151.4 b	123.0 c	137.2 b	169.2 a	133.7 b	
S. E	9.41	7.48		8.06	4.74		8.43	3.61	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t:hand+tractor.

Table 8. The ear length (cm) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	20.6 a	17.3 cd	19.1	19.9 ab	13.3 fg	16.6	20.3	15.3	17.8 a
hand +tractor hoeing	20.8 a	17.5 cd	19.1	17.8 bc	17.6 bc	17.7	19.3	17.5	18.4 a
tractor hoeing	15.7 cde	12.9 fgh	14.3	15.2 def	10.1 i	12.6	15.4	11.5	13.4 b
Control	16.3 cd	12.7 gh	14.5	13.4 efg	10.7 hi	12.1	14.9	11.7	13.3 b
Mean	18.3 a	15.1 b	16.7 a	16.6 b	12.9 c	14.7 b	17.5 a	14.0 b	
S. E	1.36	1.32		1.42	1.70		1.36	1.45	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t:hand+tractor.

Table 9. The ear diameter (mm) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	44.1	44.3	44.2	45.9	41.1	43.5	45.0 a	42.7 b	43.8 a
hand +tractor hoeing	46.5	44.0	45.2	44.0	40.4	42.2	45.2 a	42.2 b	43.7 a
tractor hoeing	42.5	37.6	40.0	42.1	36.9	39.5	42.3 b	37.2 c	39.8 b
Control	41.3	32.3	36.8	40.5	35.6	38.1	40.9 b	33.9 d	37.4 c
Mean	43.6 a	39.5 b	41.5	43.1 a	38.5 b	40.8	43.3 a	39.0 b	
S.E.	1.12	2.86		1.16	1.33		1.05	2.1	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t:hand+tractor.

Table 10. The row number on the ear of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	mean	PR	NP	Mean	PR	NP	OM
hand hoeing	14.6	14.9	14.7	16.4	14.9	15.6	15.5	14.9	15.2 a
hand +tractor hoeing	15.6	15.0	15.3	15.8	13.6	14.7	15.7	14.3	15.0 a
tractor hoeing	14.7	13.8	14.2	14.5	11.7	13.1	14.6	12.7	13.6 b
Control	15.0	12.1	13.5	14.9	12.0	13.4	14.9	12.1	13.5 b
Mean	14.9 a	13.9 b	14.4	15.4 a	13.0 c	14.2	15.2 a	13.5 b	
S.E.	0.22	0.67		0.43	0.74		0.25	0.65	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t: hand+tractor

Table 11. The grain number on the ear row of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	38.1 a	37.5 a	37.8	40.5 a	26.5 bc	33.5	39.3	32.0	35.6 a
hand +tractor hoeing	37.1 a	36.4 a	36.7	39.2 a	36.0 a	37.6	38.2	36.2	37.2 a
tractor hoeing	27.6 bc	24.1 cde	25.8	30.0 b	20.8 def	25.4	28.8	22.4	25.6b
Control	27.3 bc	19.2 f	23.2	25.2 cd	19.8 ef	22.5	26.2	26.2	22.9 c
Mean	32.7 ab	29.3 b	30.9	33.7 a	25.7 c	29.7	33.1 a	27.5 b	
S.E.	2.93	4.53		3.67	3.71		3.29	3.05	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t:hand+tractor.

The row number on the ear: It was discovered that the pre-plant ($p<0.01$), various weeding applications ($p<0.01$), and year x pre-plant interactions ($p<0.05$) all significantly affected the row number on the ear of the corn plant. The number of rows on the corn ear was 15.2 for the P2088 corn plant when the radish plant was employed as a fore plant, compared to 13.5 when it wasn't. The difference between them was found to be statistically significant. The row number of the ear in the various weeding applications was found to be 15.2 and 15.0, respectively, in the hand hoeing and hand + tractor hoeing groups, which were in the same group. It was discovered that these values were significantly different from the tractor hoeing and control. The number of rows on the ear had a maximum value from the year x pre-plant interactions of 14.9 units in the first year and 15.4 units in the second year, and they formed the same group in both years. It was noted that there was a statistically significant difference in the number of rows on the corn plant's ear between the areas where the front crop was radish in both years and those where it wasn't used for the corn plant (Table 10).

The grains number on ear row: In the study, there were significant changes in the amount of grain on the ear rows of the corn plant depending on the previous plants ($p<0.01$), weeding methods ($p<0.01$), year x pre-plant ($p<0.05$), and year x pre-plant x weeding application ($p<0.05$) interactions. The grain number of maize on the ear row was 33.1 when the radish plant was utilized as a pre-plant prior to the P2088 corn variety, compared to 27.5 when no pre-plant was used. This difference was statistically significant. The highest grain number on an ear row was obtained in 37.2 and 35.6 hand + tractor hoe and hand hoe applications, respectively, in different weeding applications. It was discovered that they belonged to the same group and were significantly different from the other tractor hoeing and control applications.

The control treatment yielded the lowest grain number on the ear row, which was statistically distinct from other applications. In the year x pre-plant interaction, it was found that the maximum grain number on ear row was 33.7 in 2019 and that this value was obtained from the area where radish was used as a pre-plant. In the first year of the experiment, a high value of 32.7 was also obtained from this area. The grain number on the ear row was higher in the plants where radish was used as a pre-plant in both years and in all weeding applications when year x pre-plant x weeding applications were combined (Table 11).

The grain ratio: According to the various pre-plants and years used, the grain ratio in the corn ear demonstrated statistical differences ($p<0.05$) and differences ($p<0.01$). The P2088 maize cultivar's grain ratio was unaffected by the various weeding techniques. The kernel ratio was noted to have changed from 86.7% in the first year of the study to 84.3% in the second, with statistically significant differences between the two years. When the radish plant was used as the pre-plant, the ear's seed ratio was found to

be 86.3%, compared to 84.8% for the plant in the area where the winter was empty without the use of the pre-plant plant. This difference was found to be statistically significant (Table 12).

The grain yield: The grain yield was 741.6 kg da^{-1} in the first year of the study, while it was 672 kg da^{-1} in the later year, according to research done with corn plants in the first crop growing season under Kahramanmaras conditions in 2017 and 2019. This difference between the research years was statistically significant ($p<0.05$). Plant development was significantly aided in the first year compared to the second by planting 15 days earlier, better soil conditions, and regular rainfall around plant emergence. When radish was used as a pre-plant in the corn-planted area, it was found that 822.8 kg da^{-1} of corn grain product was produced, and 591.1 kg da^{-1} of corn grain product was produced from the area where no pre-plant was used. It was also determined that there was a statistically significant difference between the two. It is acknowledged that the use of radish plants as a pre-plant affects corn grain yield in a statistically significant ($p<0.01$) way. The highest corn grain yield was noted to be 952.0 and 929.7 kg da^{-1}, respectively, obtained from hand hoeing and hand + tractor hoeing applications. These applications did not statistically differ from one another, but they did differ significantly ($p<0.01$) from other applications and control applications.

With an extraction of 890.9 kg da^{-1} in the first year from the area where radish was used as a pre-plant, the P. 2088 maize cultivar had the highest grain yield in the year x previous plant extraction. It was noted that it was obtained from an area with 592.9 and 589.8 kg da^{-1}, respectively, where the front plant was not used in the first year and where the radish was used as the front plant in the following year. There was no difference between the two, and it was statistically ($p<0.05$) different from other applications. The area where the pre-plant was not used in the following year had the lowest grain yield, which was 672.2 kg da^{-1} in the year x pre-plant injection. It was found that the corn grain yield was statistically ($p<0.01$) significantly affected by the year x weeding application interaction.

The yield of corn in the year x seed extraction was 949.2, 912.8, 952.8, and 946.6 kg da^{-1} in the first and second years, respectively. This yield was attained using hand hoeing, hand + tractor hoeing, and both of them were in the same group. Tractor hoeing and control applications diverged significantly from other applications in the first and later years. The control application produced the lowest grain yield in both years. On the corn grain yield, it was discovered that the pre-plant x weeding application had a significant ($p<0.05$) impact. With 1071.6 kg da^{-1} and 1002.3 kg da^{-1}, respectively, the hand + tractor hoeing produced the highest corn grain yield in these two incisions. The regions without pre-planting had the lowest corn kernel yield, which was measured at 258.1 kg da^{-1}. In four separate weeding applications, radish was utilized as a front plant and greatly increased grain output in that region (Table 13).

Discussion

In the study, it was discovered that the climate had an impact on how long it took for tassels to emerge the following year (Ozturk, 2002; Ceballos et al., 2011). The time it takes for the tassel to emerge is shortened as the temperature rises. Tasselling emergence, ear silking emergence, and cob formations all have an impact on corn yield. These yield factors are affected by temperature changes. According to Shao et al. (2021), when weeding was applied in various ways to the control plants, the tassel emergence time was prolonged. Weeds hinder the corn plant's growth by preventing it from absorbing light, water, and nutrients, which lowers its ability to compete (Najwa et al., 2012; Stoimenova et al., 2008).

Table 12. The grain ratio (%) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	88.0	86.0	87.0	84.6	84.0	84.3	86.3	85.0	85.6
hand +tractor hoeing	86.3	87.0	86.6	85.6	84.0	84.8	86.0	85.5	85.7
tractor hoeing	88.0	85.0	86.5	85.0	82.3	83.6	86.5	83.6	85.0
Control	87.6	86.3	87.0	85.3	84.0	84.6	86.5	85.1	85.8
Mean	87.5	86.0	86.7 a	85.1	83.5	84.3 b	86.3 a	84.8 b	
S. E	0.40	0.41		0.21	0.42		0.11	0.41	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t:hand+tractor

Table 13. The grain yield (kg da^{-1}) of P.2088 maize variety under different weed removal and pre-planting applications.

Applications	2017			2019			PPXW		
	PR	NP	Mean	PR	NP	Mean	PR	NP	OM
hand hoeing	1044.5	853.8	949.2 a	960.1	945.6	952.8 a	1002.3 ab	899.7 b	951.0 a
hand+tractor hoeing	1081.7	743.9	912.8 a	1061.4	831.9	946.6 a	1071.6 a	787.9 c	929.7 a
tractor hoeing	889.6	390.4	640.0 b	635.3	446.8	541.0 bc	762.4 c	418.6 d	590.5 b
Control	547.9	381.1	454.5 c	361.8	135.1	248.4 d	454.8 d	258.1 e	356.4 c
Mean	890.9 a	592.3 c	741.6 a	754.6 b	589.8 c	672.2 b	822.8 a	591.1 b	
S. E	121.67	121.35		159.39	185.38		139.4	151.27	

PR: pre-plan radish, NP: no pre-plan, OM: Overal mean, PPXW: pre plant x weed interaction, h+t: hand+tractor.

The emergence of the corn plant's ear silk was accelerated by the fact that the front plant in four different weeding applications was radish. The top tassel emerges first, followed by the emergence of the ear. The top tassel emergence time and the ear emergence time are both characteristics. Tassel emergence is impacted by a sudden temperature increase just before it occurs (Oury et al., 2016). In the study, it was found that the climate had an impact on how quickly corn would emerge the following year. (Ozturk, 2002; Ceballos et al., 2011). The ear silk time is shortened as the temperature rises. The cob formations and emergence of the ear silking are the variables that affect corn yield. These yield parameters are affected by temperature fluctuations (Shao et al., 2021). The control plants that did not use any weeding had a longer ear silk emergence time than the others in the various weeding applications. Weeds slow down corn growth by preventing the plant from absorbing light, water, and nutrients, which makes corn less competitive (Stoimenova *et al.,* 2008; Najwa *et al.,* 2012). The development of ear silks has been hindered by the difficulty of emerging from the ears in high temperatures (Oury et al., 2016). The thickness of the stem diameter in maize provides more root density, the plant to stand upright, and carries more nutrients (Kong et al., 2013). In maize, stem diameter is used as a selection criterion (Wang et al., 2008). It was believed that the field's climate and soil properties were to blame for this scenario. Despite efforts to make field conditions homogenous, difficulties persist in achieving the needed true homogeneity in field circumstances. In the study, it was found that, with the exception of the control application the next year, the initial ear height of corn was higher when the fore plant was radish in both years x previous plant x weeding applications, hand + tractor hoe, tractor hoe, and control applications. The radish plant was seen to have a significant impact on ear height situation. In maize plants, ear height is a selection factor. More plants can be tolerated per square foot with low ears (Wang et al., 2008). The generation of silage becomes more important when the cob height is high. The poultry litter maize plant was said to have boosted the first ear height (Mendes et al., 2021). It is seen from the results obtained that weeds suppress the plant height of the maize and the use of allelopathic compounds or secondary metabolites in weed control contributes to the development of corn (Khan et al*.,* 2016). Plant height is a phenotypic feature in maize and a selection criterion for adaptation to regional conditions (Wang et al*.,* 2008; Cokkizgin et al., 2022). It has been stated that poultry litter maize plant increases plant height (Mendes et al*.,* 2021). It was noted that in the year x pre-plant x weeding interaction application, the first year's values were higher than the second year's values, and in the triple interaction application, the length of the ear in all applications was significantly greater in the area where the radish was used as a fore plant in the first and subsequent years than in the area where non-pre-plant was used. As a front plant, radish made a positive impact. It is believed that growing radish as a pre-plant allelopathic decreases the weed density that competes with maize and improves the living conditions for maize (Dhima *et al.,* 2006; Uremis et al., 2009; Makoi & Ndakidem 2012). Because it increases the percentage of organic materials, it contributes to ear length (Jabran et al., 2015). Poor environmental conditions were to blame for the decrease in ear length (Borras et al., 2018). Poultry litter on maize plants was shown to boost plant height (Mendes et al., 2021). In this study, it is obvious that using radish as a front plant would significantly increase the ear's diameter. It has been discovered that poultry litter maize plants increase ear diameter (Mendes et al., 2021). Yustisia et al. (2021) noted that ear thickness varieties and lines ranged from 48.00 to 50.18 mm. It is recognized that cultivar differences as well as environmental factors affected the number of rows on the ear. According to Idikut et al., (2020), there were between 14.5 and 16.9 rows of ears in 17 distinct hybrid maize cultivars. These results suggest that radish served as an excellent pre-plant for maize. Due to unfavorable environmental conditions, there was less pollen, longer emergence times for the ear silks, and fewer seeds as a result (Aslam et al., 2015; Shin et al., 2015). It is known that the radish plant had a significant impact on the corn ear's grain retention rate. Idikut & Yildiz (2018), discovered statistically insignificant differences and a grain rate of 82–84% when various phosphorus doses were applied to first-crop corn plants. According to Idikut et al., (2020), there was a statistical difference in the grain rate of various second crop maize varieties, which ranged from 84 to 94%. According to previous research, the grain ratio in maize varied significantly depending on the varieties, but the applied phosphorus dose was not significantly different. However, it was discovered in the study that while the pre-plant application had a significant impact on grain rate, the weeding application had no statistically significant impact on it. According to earlier studies, the grain ratio in maize affects the applied phosphorus dose significantly differently depending on the varieties, but not the grain ratio itself. However, it is clear from the study that while the pre-plant application has a significant impact on grain rate, the weeding application is not statistically significant. It was determined that adding radish as a pre-plant will boost grain yield. It was believed that corn's weed population would decrease due to the allopathic effects of radish. The germination and growth of some plants in soil are impacted by the density of radish roots. It was claimed that a 40% increase in radish density produced the greatest effect (Resul & Ali, 2020). According to Johnson et al., (2021), the use of the radish plant as a foreplant increased corn yield by 5% in comparison to the control without a foreplant. It was claimed that red and black radish species had more allelopathic effects than white radish (Resul & Ali, 2021). Under the ecological conditions of Greece, corn plants produced more grain in both red and white clovers (Kanatas et al., 2020). Another strategy for eliminating allelopathic weeds was to rotate with one season of an allelopathic crop (Jabran et al., 2015). As part of the rotation, Brassicaceae species were used as cover crops to fend off johnsongrass (Uremis et al., 2009). According to reports, strong competition between corn and johnsongrass plants during the growing season resulted in an 88% reduction in corn grain yield. The reduction was brought on by light, nutrients, moisture, and soil (Mitskas et al., 2003). Johnsongrass and bermudagrass interference decreased corn grain yield by 30 and 41%, respectively (Vasilakoglou et al*.,* 2019). Previous research has shown that radish is a reliable pre-plant for maize.

It was emphasized in earlier studies by Henry et al. (2010), Idikut and Kara (2011), that the pre-plant increased corn yield.

Conclusions

The effects of various weeding techniques on corn grain crops were examined in the first crop of corn farming using pre-plant without the use of herbicides. The weed eradication operations using hand hoeing, hand + tractor hoeing had a good impact on the yield component of maize. Additionally, the pre-planting of radish plants before maize plants had a good impact on the maize plant. The allopathic quality of the radish was believed to be the reason for its beneficial effect on the maize plant. The benefits of the radish plant to corn can be enumerated as follows: since radish is a cover crop, it lowers the density of weeds like sorghum, which is a problem for corn, and increases the competitiveness of corn against weeds; it contributes to the physical structure of the soil through deep cultivation of the soil with its root body; and it provides nutrients to the soil. Information on ecology, biology, agriculture, and economics is necessary for the control techniques of sustainability. The use of radish as a pre-plant benefits both human health and environmental protection, while also bringing in money for farmers. In order to prevent the widespread invasion of weeds against corn, more research is needed on sustainable long-term management strategies using non-chemical methods.

Declarations

Conflict of Interest

We would like state that there are no conflicts among authors.

Authors' contribution statement

Conceptualization: *Leyla İdikut*; Data curation: *Leyla İdikut, Duygu Uskutoğlu, Gülay Zulkadir, Songül Çiftçi Sakin*; Formal analysis: *Duygu Uskutoğlu*; Funding acquisition: *Leyla İdikut*; Methodology: *Leyla İdikut*; Writing-original draft: *Leyla İdikut, Duygu Uskutoğlu, Gülay Zulkadir, Songül Çiftçi Sakin*; Writing-review & editing: *Leyla İdikut, Duygu Uskutoğlu, Gülay Zulkadir Songül Çiftçi Sakin.*

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