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RESEARCH ARTICLE

Pre-plant application and different weed removal applications and their combinations caused positive effects on yield-related parameters

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ABSTRACT

In this study, the effect of corn on grain quality was investigated by applying different weed removal processes in corn plant. These, which was repeated for two years, four weed removal treatments [Hand hoe (H), hand and tractor hoe (HT), tractor hoe (T), and no-operation-control (C)] were tested on corn in a pre-treated [radish (R)] and an untreated [no front crop (NR)] field. According to the means of the applications for the years; thousand grain weight (TGW) and weight of ear grain (WEG) values were high in R, H and HT applications, while the lowest values were obtained in control applications. In protein content (PC), it has been noted that R application reduces the PC value while hoe applications gave parallel results with TGW and WEG. Rod ratio on the cob (RRC) and starch content (SC) values were positively affected by R and C applications. Finally, in the oil content (OC) value, it has been seen that the differences in the combination of the applications where the NR and C applications have insignificant but positive effects are more prominent. As a result, while R, H and HT applications and their combinations caused positive effects on yield-related parameters (TGW and WEG), some inconsistencies were observed in quality parameters (OC, SC and PC). It is thought that these discrepancies are caused by changes in the nutrient content of the soil and its acceptability by the plant, influenced by changes in the amount of precipitation.

Keywords: Agroecology; allelopathy; bio-herbicide; *Raphanus sativus*; *Zea mays* L.

INTRODUCTION

Weeds are in constant competition with cultivated plants. For this reason, weeds are in the pest class that causes significant yield losses in cultivated plants (Zimdahl 2013). In the early stages of agriculture, manual weeding, then mechanical weeding and recently herbicide applications have been the most used methods for weed control (Chauvel et al., 2012). All these applications have solved the problem of the growth of weeds and the decrease in yield in crop plants, but they have caused some problems. Manual sorting requires a lot of labor. Great difficulties are experienced due to the difficulties in finding workers or the increase in labor costs, as well as the recurrence of weeds (Carballido et al., 2013). Therefore, weeds are a worldwide problem and effective weed management is extremely important to obtain high quality yields (Rajcan and Swanton, 2001). It has been determined in studies that weeds have a significant effect on the quality characteristics of the corn plant (Iderawumi and Friday, 2018). The fight against herbicides causes important problems such as the formation of herbicide-resistant weeds, the negative effects of chemical residues on the health of living things and the environment, and its intensive and excessive use (Annett et al., 2014). Therefore, researchers are trying to find innovative approaches in order to be able to develop a weed control application that is closest to the ideal.

Suppressing weeds by taking advantage of the allelopathic phenomenon is among the important innovative weed control methods (Zeng, 2014). Allelopathic plants can have beneficial effects on the agricultural environment due to their physiological effects such as controlling unwanted weeds and/or promoting plant growth (Macias et al., 2019; Sakamoto eta al. 2019). Different plant species have been found to have allelopathic activities (Haramoto and Gallandt, 2004). Among these families, brassicaceae has attracted more attention of researchers (Weston

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and Duke, 2003). It has been found in previous studies that radish from the Brassicaceae family has allelopathic effects on different plant species (Rasul and Ali, 2020a) originating from secondary metabolite compounds such as p-hydroxybenzoic acid and isothiocyanates (isothiocyanate benzyl, isothiocyanateallyl) (Uremis et al., 2009). Some crops and weeds showed varying levels of germination susceptibility to wild radish (*Raphanus raphanistrum* L.) aqueous extract and inhibited root growth of some weeds (Rasul and Ali, 2020b). In a study, it was understood that extracts of different colored radishes at different concentrations prevented the germination and seedling development of wheat and some weed species (Resul and Ali, 2021). It has been determined that black radish has a more allelopathic effect than red and white radish, and the allelopathic effect of increasing doses of all radishes also increases.

Irfan et al. (2022) tested the aqueous extract of wild radish (*Raphanus raphanistrum* L.) on the germination of turnip (*Brassica rapa* subsp. rapa) and concluded that wild radish extract had destructive effects on the emergence and seedling development of turnip. Rahman and Resul, (2023) applied the extracts of radish roots and stems to bread wheat (*Triticum aesitivum* L.), barley (*Hordeum vulgare*), wild barley (*Hordeum spontaneum* L.), and wild oat (*Avena fatua* L.) plants. They determined that the applications inhibited the germination and seedling development of these plants, and the effect of increasing doses increased, and they suggested that the aqueous extract of radish could be used as a bioherbicide.

The use of radish (*Raphanus sativus*) as a cover plant can increase the water intake of the corn plant from the soil (Lawley et al., 2012) and suppress weeds by strengthening the deep rooting system (Chen and Weil, 2011). Due to the fact that it is harvested in winter and leaves little or no residue on the soil surface in spring, the crops planted after it can reach the maximum plant density and, accordingly, the maximum yield potential, especially in conditions of heavily textured soil when soil treatment is not performed (Chen and Weil, 2011). In addition, due to the deep root and stem system of radish, it has a great potential as a good collector product in terms of N in the soil (Clark, 2012). Thus, mixing radish into the soil in the spring allows Nitrogen (N) taken from the soil to mix back into the soil and then be used for plants in the next plantings.

In this study, the usability of radish, which is known to have allelopathic effects for weed control in agricultural systems, as a foreplant, the effects of hand and tractor hoe applications, which are other control methods, together or separately, on weed control in corn production areas and on grain criteria of corn plants were investigated.

MATERIAL AND METHOD

The study was carried out in Kahramanmaras conditions in the first growing season of 2017 and 2019, using the hybrid corn variety P2088. In 2018, the second year of the research, the data were cancelled as a result of the deterioration of homogeneity due to reasons that could not be obtained in the field application.

The experiment was carried out in randomized blocks according to the split plot design with three replications. The trial setup is given in Table 1 below.

Radish was planted in August of 2016 and 2018 in order to make pre- plant application in the research. In order to ensure the emergence of the plant from the soil, only irrigation was done after planting and no treatment was applied afterwards. When the radish plants reached sufficient maturity (March, 2017 and 2019), the land was plowed with disc harrow. Thus, the radish fruits were broken down and mixed with the soil. In this application, both the secondary metabolites in the radish plant were mixed with the soil faster and more intensely, and the nutrient content that the radish removed from the soil was returned to the soil. Then, different hoeing methods, including hand hoe, hand hoe + tractor hoe, tractor hoe and control (no tillage was applied), were applied to the sub-plots as seen in Table 1, and the trial area was prepared for corn planting.

Corn planting was done on April 5 in the first year and on April 20 in the second year due to heavy rains. In both years, the corn harvest was done in September. During the period from sowing to harvest, corn plants were irrigated 8 times in the first year and 9 times in the second year with the flood irrigation method.

Soil samples were observed that the soil properties of the radish and not radish areas differed only in organic matter and usable phosphorus levels, and were the same in terms of other properties. When the soil properties were evaluated in general, clayey-loam (2017) and clayey (2019) structure, neutral pH level, salt-free, slightly calcareous (2017) and calcareous (2019), poor in organic matter (except for tillage radish in 2019), In terms of usable phosphorus content, radish area in 2017 was high and

Table 1: Trial setup scheme

Sub Parcel		Main Parcel	
		Radish (R)	Not Radish (NR)
Hand hoe	(H)	H*R	H*NR
Hand hoe+Tractor hoe	(HT)	HT*R	HT*NR
Tractor hoe	(T)	T*R	T*NR
Control	(C)	C*R	C*NR

not radish area was medium, while 2019 was poor in both areas, while the amount of usable potassium was high in both years and in both soil areas.

After evaluating the results of the analysis, fertilization was carried out so that the plants could receive the nutrients they needed at a sufficient level. Fertilization was done in two stages in both years. First, 6 kg da^{-1} of NPK (20-20-0) fertilizer was used with sowing. The second fertilization was applied in the form of urea at a net weight of 19 kg da^{-1} when the plants reached the period of 40-50 cm.

In the Kahramanmaras region, where the typical Mediterranean climate is dominant, the total amount of precipitation in 2017 was 139.4 mm, and the period with the highest precipitation was April. The highest value in terms of average temperature was observed in August. In the second trial year (2019), the total amount of precipitation was 42.2 mm, while the highest precipitation was again observed in April. Compared to 2017, May and June were drier. The highest average temperature value was observed in August, as in 2017.

In both years, corn plants reached harvest maturity in September and were harvested by hand. After harvest, as stated by Zulkadir and Idikut (2021) in his study, thousand grain weight (TGW), weight of ear grain (WEG), rod ratio on the cob (RRC), oil content (OC), starch content (SC) and protein content (PC) properties were investigated.

In the factorial arrangement of the data regarding the examined features, variance analysis was performed by using the JMP Pro 13 package program in accordance with the randomized blocks trial plan. The mean values were grouped using the Tukey multiple comparison test. Results were also analysed using multivariate methods. Principal component analysis was applied to present the evaluation of multidimensional data into low-dimensional space with minimal loss of information. Thus, it makes it possible to graphically display the diversity in species in terms of all observed traits. The analyses were performed using the statistical software package Past 4 Project.

RESULTS AND DISCUSSION

Thousand grain weight (TGW)

The significant effect of the year and different hoeing applications on TGW was determined, and it was understood that the pre-plant application did not have any allelopathic effects (Table 2). While Y x PPA and PPA x HA interactions were insignificant in the interactions of the factors with each other, Y x HA and Y x PPA x HA interactions were recorded to cause statistically significant ($p<0.01$) differences. Depending on the applications, the average TGW values in corn ranged from 241.28 (Y2-NR-T) to -329.80 (Y1-R-HT) g. In the study, the TGW value in the first year was 301.34 g, which was 4.43% higher than the second year (275.76 g). While the highest value was observed in the H application with 311.55 g in different hoeing applications, the TGW value was the lowest with 260.60 g in the samples without any hoeing process.

We can interpret the high TGW value in the first year of the study by the fact that the corn was planted early in the first year, the climatic conditions accelerated the development of the corn, and the transport of carbohydrates to the grain was earlier. The significant difference between the hand hoeing application and the control in the weeding application explains the effect on the grain quality value clearly. The same situation is seen in year x hoeing applications. It was noted that TGW values were low in the control plots where radish was used as a foreplant and was not used in both years in triple interactions in Y x PPA x HA applications.

Weight of ear grain (WEG)

In the study, the effects of Y, PPA, HA and Y x PPA, Y x HA, PPA x HA, Y x PPA x HA interactions on WEG were statistically significant at $p<0.01$ significance level, while the effect of Y x PPA interaction was significant at $p<0.05$ significance level. (Table 2).

According to years, the WEG value was 148.81 g in the first year and 118.36 g in the second year. The WEG value obtained from the pre-plant applied area was 165.09 g, and it was noted that it was approximately 23% more than the WEG value (102.08 g) obtained from the pre-plant application. While the highest WEG value was obtained in HT (177.23 g) application in hoeing applications, the lowest value was determined in the control group with 90.21 g. When the interaction of all factors was examined, it was seen that WEG values ranged between 26.97 g (Y1-NR-C) and 211.75 g (Y1-R-HT).

ROD ratio on the COB (RRC)

The RRC value varied between 15.63% (second year) and 13.88% (first year) depending on the years, and this difference was statistically significant. In the case of PPA, the RRC value changed between 14.08% -15.42%, causing the radish RRC value to decrease by 3.86%. In hoeing applications, the RRC values varied between 14.25% and 15.50%, but these differences between applications were found to be insignificant. On the other hand, from the interactions depending on the factors; the differences observed in Y x PPA, Y x HA, PPA x HA and Y x PPA x HA interactions were observed to be insignificant (Table 2).

Table 2: TGW, WEGand RRC values of P. 2088 corn variety in different weed removaland pre-plantingapplications

	TGW		WEG		RRC	
	Mean	LSD/Sig.	Mean	LSD/Sig.	Mean	LSD/Sig.
Y						
Y1	301.34±0.41[a]	8.60**	148.81±0.24[a]	1.06**	13.88±4.13[b]	0.90 **
Y2	275.76±2.78[b]		118.36±0.54[b]		15.63±0.07[a]	
PPA						
R	291.49±2.42	8.60[ns]	165.09±0.30[a]	1.06**	14.08±2.71[b]	0.90 *
NR	285.61±0.52		102.08±0.54[b]		15.42±2.34[a]	
Y x PPA						
Y1-R	306.47±22.90[a]	1.18*	179.65±23.08[a]	10.57*	13.33±1.92	0.68[ns]
Y1-NR	296.21±27.31[a]		117.96±27.10[c]		14.42±1.73	
Y2-R	276.51±27.17[b]		150.52±28.38[b]		14.83±1.34	
Y2-NR	275.01±28.76[b]		86.20±27.18[d]		16.42±1.31	
HA						
H	311.55±4.87[a]	16.26**	168.62±0.81[b]	2.00**	14.33±3.63	1.70[ns]
HT	298.83±0.87[b]		177.23±0.72[a]		14.25±3.04	
T	283.23±0.94[c]		98.27±1.18[c]		14.92±2.56	
C	260.60±0.12[d]		90.21±0.17[d]		15.50±10.58	
Y x HA						
Y1-H	319.96±8.13[a]	6.26**	189.90±1.25[a]	105.22**	13.00±1.41	2.78[ns]
Y1-HT	311.40±10.71[a]		189.07±14.90[a]		13.33±1.62	
Y1-T	310.49±2.52[a]		108.21±10.67[d]		13.50±1.87	
Y1-C	263.51±8.03[c]		108.05±28.82[d]		15.67±1.63	
Y2-H	303.13±21.28[ab]		147.33±28.48[c]		15.67±1.50	
Y2-HT	286.26±20.59[b]		165.40±16.59[b]		15.17±1.47	
Y2-T	255.97±17.62[c]		88.32±27.39[e]		16.33±1.63	
Y2-C	257.68±4.28[c]		72.38±18.62[f]		15.33±1.63	
PPA x HA						
R-H	318.07±25.63	1.93[ns]	195.67±5.54[b]	528.60**	13.67±2.07	1.48[ns]
R-HT	294.10±29.11		200.70±12.23[a]		14.00±1.41	
R-T	291.40±12.75		124.74±3.00[f]		13.50±1.87	
R-C	262.38±9.04		139.24±24.65[e]		15.17±1.72	
NR-H	305.02±13.85		141.57±22.17[d]		15.00±1.79	
NR-HT	303.56±2.65		153.77±13.85[c]		14.50±2.17	
NR-T	275.06±27.71		71.79±19.27[g]		16.33±1.63	
NR-C	258.81±3.72		41.19±15.59[h]		14.83±1.47	
Y x PPA x HA						
Y1-R-H	313.43±1.23[ab]	1452**	190.69±1.14[c]	2250.45**	12.00±1.00	0.88[ns]
Y1-R-HT	329.80±1.01[a]		211.75±2.21[a]		13.67±1.53	
Y1-R-T	312.14±1.18[ab]		127.06±1.02[f]		12.00±1.00	
Y1-R-C	270.52±2.32[c-e]		189.12±1.00[c]		15.67±1.53	
Y1-NR-H	326.50±5.98[a]		189.12±0.88[c]		14.00±1.00	
Y1-NR-HT	293.00±7.45[b]c		166.38±1.10[d]		13.00±2.00	
Y1-NR-T	308.83±2.52[ab]		89.36±0.85[i]		15.00±1.00	
Y1-NR-C	256.51±2.96[ef]		26.97±0.24[k]		15.67±2.08	
Y2-R-H	322.71±25.74[a]		200.65±1.05[b]		15.33±1.15	
Y2-R-HT	258.40±0.21[ef]		189.65±1.52[c]		14.33±1.53	
Y2-R-T	270.67±1.70[c-e]		122.42±2.30[g]		15.00±1.00	
Y2-R-C	254.25±0.64[ef]		89.35±1.05[i]		14.67±2.08	
Y2-NR-H	283.54±1.44[cd]		94.01±4.55[h]		16.00±2.00	
Y2-NR-HT	314.12±3.21[ab]		141.15±0.96[e]		16.00±1.00	
Y2-NR-T	241.28±11.21[f]		54.23±1.46[j]		17.67±0.58	
Y2-NR-C	261.11±3.15[d-f]		55.40±1.20[j]		16.00±1.00	

TGW: Thousand grain weight; WEG: Weight of ear grain; RRC: Rod ratio on the cob; Y: Year; PPA: Pre-plantapplication; HA: Hoeapplication; Y1: First year; Y2: Second year; H: Hand hoe; HT: Hand hoe+Tractor hoe; T: Tractor hoe; C: Control; R: Radish; NR: Not radish. Different letters (a–k) indicate significant differencesat the 0.05 level. Significance codes: P<0.001 (***), P<0.01 (**), P<0.05 (*), P>0.05 (ns)

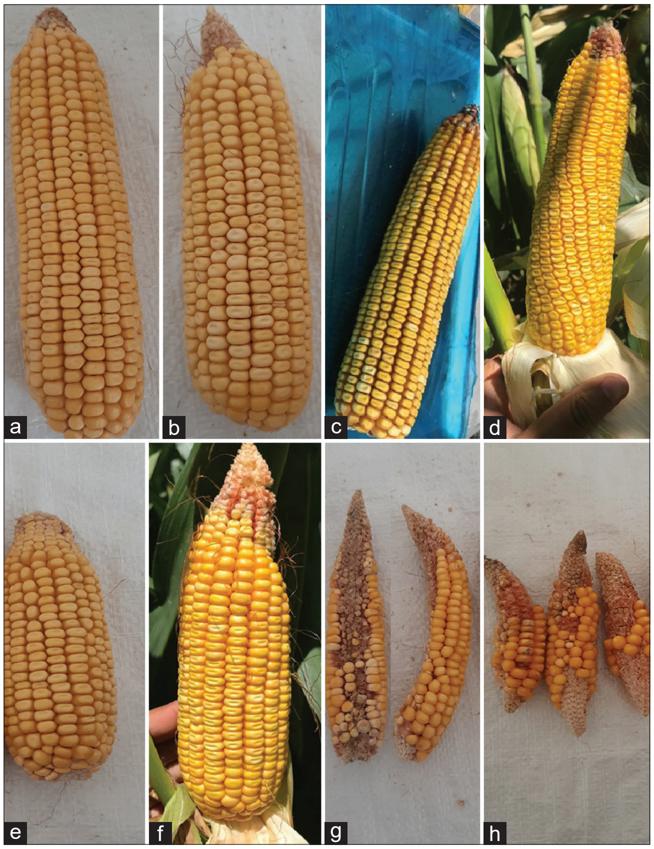

Fig 1. The effects of different weed removal and pre-planting applications on the investigated properties. a) H*R, b) H*NR, c) HT*R, d) HT*NR, e) T*R, f) T*NR, g) C*R, h) C*NR.

Oil content (OC)

When the OC values in the corn kernels were examined, changes were determined at $p<0.01$ importance depending on the Y, Y x HA, PPA x HA and Y x PPA x HA differences. On the other hand, Y x PPA interaction, PPA and HA applications did not cause significant differences in OC values. When evaluated in general, it was understood that the OC values ranged between 2.47% (Y1-R-C) and 4.45% (Y1-NR-C) (Table 3).

The oil content of the P. 2088 hybrid corn cultivar in the following year was higher than the first year. The fact that the kernel weight on the ear was less in the next year compared to the first year was due to the increase in the kernel shell ratio. The fact that the grain oil rate was in the embryo and the shell caused the oil rate in the grain to be high.

While the aleurone layer in the shell part of the grain is rich in oil and protein, the endosperm part is rich in starch and protein (Gulati et al., 1996). In other two- and three-way interactions, we can also note that the high rate of fat is due to the shell ratio. The oil content of corn seed varies between 3.1 - 5.7% (White and Johnson 2003).

Starch content (SC)

In the study, the differences in SC values obtained depending on the applications were very important in the interactions of all factors and factors except PPA, Y x PPA and PPA x HA interaction ($p<0.01$). While the SC values varied between 64.19% (Y1) and 73.03% (Y2) on a yearly basis, it was between 67.94% (H) and 69.06% (C) in hoeing applications. In general, in the interaction of all factors, this value was recorded between 62.42% (Y1-NR-C) and 74.73% (Y2-NR-C) (Table 3).

It is thought that the fact that the starch ratio was low in the first year and high in the following year may be due to climatic conditions. Here, the number of irrigation was higher as a result of earlier planting in the first year compared to the second year. Thus, it was thought that the protein formation network took a shorter time and accordingly starch formation took longer (Shi et al., 2018). The highest starch ratio in weed removal application was obtained from the plots that could not be weeded at all. Cob formation was very low in the control plots, since the carbohydrates formed in the plant were transferred to the few grains formed on the cob, the starch ratio in the grain was high. Ertiro et al. (2022) in their study, they reported that a low level of N in the environment also reduced the formation of protein in the grain, which, accordingly, led to an increase in the formation of starch. This is valid for other double and triple interaction applications. It is also known that processes such as variety, climate, planting and care affect the amount of starch in the corn kernel (Beckles and Thitisaksakul, 2014).

Protein content (PC)

The effect of the year on the PC was found to be significant $p<0.01$, and the effect of different hoeing applications was found to be significant at the $p<0.05$ significance level, and it was understood that there was no allelopathic effect of pre-plant application (Table 3). In the interactions of the factors with each other, only the Y x HA interaction caused significant differences. However, the effect of other interactions was noted to be insignificant. Depending on the factors, mean PC values in corn ranged from 6.21% (Y2-NR-C) to 9.32% (Y1-NR-C) g. In the study, the PC value was 8.45% higher in the first year than in the second year (7.27%) with 7.51%. In different hoeing applications, the highest value was obtained with 8.14% H and 8.06% HT application, the lowest value was obtained from T (7.61%) and C (7.63%) applications. The applications were statistically distributed into two groups.

The protein ratio was significantly higher in the first year compared to the following year. It is thought that the earlier

Table 3: OC, SCand PC values of P. 2088 corn variety in different weed removaland pre-sowingapplications

	OC		SC		PC	
	Mean	LSD/Sig.	Mean	LSD/Sig.	Mean	LSD/Sig.
Y						
Y1	3.41±2.86^{b}	0.15**	64.19±0.29^{b}	0.40**	8.45±1.82^{a}	0.30**
Y2	4.04±0.23^{a}		73.03±0.75^{a}		7.27±2.71^{b}	
PPA						
R	3.66±1.09	0.15^{ns}	68.74±0.81	0.40^{ns}	7.74±3.74	0.30^{ns}
NR	3.79±3.16		68.48±0.22		7.97±2.29	
Y x PPA						
Y1-R	3.23±0.52	4.89^{ns}	64.55±0.78	2.94^{ns}	8.18±0.41	1.76^{ns}
Y1-NR	3.58±0.74		63.84±1.24		8.72±0.52	
Y2-R	4.08±0.23		72.93±1.27		7.31±0.73	
Y2-NR	3.99±0.20		73.13±1.45		7.22±1.02	
HA						
H	3.72±1.70	0.28^{ns}	67.94±0.57^{c}	0.75**	8.14±1.60^{a}	0.57*
HT	3.75±3.78		68.44±1.01^{bc}		8.06±3.39^{a}	
T	3.64±1.85		69.01±0.50^{ab}		7.61±2.43^{b}	
C	3.78±4.53		69.06±0.28^{a}		7.63±1.09^{b}	
Y x HA						
Y1-H	3.36±0.37^{cd}	5.11**	63.93±0.62^{d}	13.26**	8.28±0.47$^{a\text{-}c}$	9.67**
Y1-HT	3.65±0.20^{bc}		64.75±0.99^{c}		8.35±0.28$^{a\text{-}c}$	
Y1-T	3.15±0.57^{d}		64.31±0.82^{cd}		8.42±0.41^{ab}	
Y1-C	3.46±1.13^{c}		63.79±1.61^{d}		8.75±0.83^{a}	
Y2-H	4.07±0.19^{a}		71.95±0.81^{b}		7.99±0.96^{bc}	
Y2-HT	3.85±0.28^{ab}		72.14±1.37^{b}		7.77±0.69^{c}	
Y2-T	4.12±0.20^{a}		73.71±0.71^{a}		6.80±0.26^{d}	
Y2-C	4.10±0.10^{a}		74.32±0.54^{a}		6.50±0.38^{d}	
PPA x HA						
R-H	3.69±0.50^{b}	20.26**	68.17±4.53	2.66^{ns}	7.97±0.66	0.14^{ns}
R-HT	3.71±0.33^{b}		68.18±4.78		7.97±0.76	
R-T	3.93±0.34^{b}		69.07±4.57		7.56±0.67	
R-C	3.30±0.92^{c}		69.54±4.80		7.48±0.87	
NR-H	3.75±0.47^{b}		67.71±4.35		8.31±0.83	
NR-HT	3.79±0.18^{b}		68.71±3.55		8.15±0.40	
NR-T	3.34±0.77^{c}		68.94±5.77		7.66±1.16	
NR-C	4.27±0.34^{a}		68.58±6.77		7.77±1.75	
Y x PPA x HA						
Y1-R-H	3.28±0.34^{g}	16.92**	64.10±0.87$^{f\text{-}h}$	9.94**	8.01±0.54	2.80^{ns}
Y1-R-HT	3.53±0.16$^{e\text{-}g}$		64.01±0.71^{gh}		8.41±0.01	
Y1-R-T	3.65±0.01$^{d\text{-}g}$		64.92±0.73$^{e\text{-}g}$		8.13±0.40	
Y1-R-C	2.47±0.27^{h}		65.17±0.08^{ef}		8.17±0.61	
Y1-NR-H	3.44±0.45^{fg}		63.75±0.35^{h}		8.55±0.23	
Y1-NR-HT	3.78±0.17$^{c\text{-}f}$		65.49±0.56^{e}		8.30±0.43	
Y1-NR-T	2.64±0.20^{h}		63.69±0.09^{h}		8.71±0.11	
Y1-NR-C	4.45±0.43^{a}		62.42±0.91^{i}		9.32±0.61	
Y2-R-H	4.09±0.13$^{a\text{-}c}$		72.23±1.04^{cd}		7.92±0.89	
Y2-R-HT	3.90±0.37$^{b\text{-}e}$		72.34±2.13^{cd}		7.53±0.93	
Y2-R-T	4.22±0.22^{ab}		73.22±0.38^{bc}		6.98±0.03	
Y2-R-C	4.12±0.13$^{a\text{-}c}$		73.92±0.47^{ab}		6.80±0.32	
Y2-NR-H	4.05±0.27$^{a\text{-}d}$		71.66±0.56^{d}		8.07±1.22	
Y2-NR-HT	3.80±0.24$^{b\text{-}f}$		71.93±0.10^{d}		8.00±0.38	
Y2-NR-T	4.03±0.14$^{b\text{-}d}$		74.19±0.63^{ab}		6.61±0.24	
Y2-NR-C	4.08±0.07$^{a\text{-}c}$		74.73±0.14^{a}		6.21±0.02	

OC: Oil content; SC: Starch content; PC: Protein content; Y: Year; PPA: Pre-plantapplication; HA: Hoeapplication; Y1: First year; Y2: Second year; H: Hand hoe; HT: Hand hoe+Tractor hoe; T: Tractor hoe; C: Control; R: Radish; NR: Not radish. Different letters (a–i) indicate significant differencesat the 0.05 level. Significance codes: P<0.001 (***), P<0.01 (**), P<0.05 (*), P>0.05 (ns) planting of the corn plant in the first year compared to the next year and the optimum climatic conditions of the corn in the generative period may be due to the longer development of the protein network (Idikut et al., 2020). In other applications, an inverse relationship is observed between starch ratio and protein ratio. The protein ratio varied according to the pre-plant and different weeding practices throughout the year. The nitrogen content of the soil also affects the protein content and therefore the use and amount of fertilizers plays a very important role in the protein content differences between plant material (Agama-Acevedo et al., 2011).

The effects of the applications on the investigated properties were used as a source data for the multivariate PC analysis of the obtained values (Fig. 2). According to this; while the total variance of the three main components revealed 85.83%, the eigenvalues of the first two components were greater than 1 and constituted 73.22% of the total variation (Table 4).

The first component was positively differentiated in terms of TGW, WEG and PC properties, and the second component in terms of TGW, WEG, OC and SC parameters. On the other hand, the positively distinguished features in the third component were TGW, OC, and PC. Principal component analyses are very useful in breeding programs not only to select potential parents for crossbreeding, to develop traits of interest for productivity in terms of quantity and quality, but also to identify phenotypic traits that contribute to higher genetic variation among the genotypes studied (Basnet et al., 2014).

As a result of the two-year study, it was noted that the use of radish as a cover crop and the application of weeding methods had significant effects on the grain criteria of maize, although there were differences. That is, mixing the radish plant with the soil increases the values of TGW, WEG and SC properties; it was observed that the values of RRC, OC and PC properties decreased. In the difference between years, all features showed significant variability, and an increase was observed in all features in the second year, except for TGW, WEG and PC features (Fig. 3).

As it is known, the incorporation of plants with allelopathic effects into the soil by various methods not only suppresses weeds, but also improves the nutrient availability of the soil for crop plants and increases soil microbial activities. (Zeng, 2014).

Table 4: Distinctive values for principal componentanalysis

Trait	PC1	PC2	PC3
TGW	0.8060	0.2639	0.1081
WEG	0.6761	0.6229	-0.1394
RRC	-0.7170	-0.3079	-0.3936
OC	-0.6406	0.0846	0.7317
SC	-0.8491	0.4689	-0.0705
PC	0.7653	-0.5257	0.1746
Eigenvalue	3.34	1.06	0.76
Variation (%)	55.62	17.60	12.61
Cumulative (%)	55.62	73.22	85.83

PC1: Principle contentaxis 1; PC2: Principle contentaxis 2; PC3: Principle contentaxis 3; TGW: Thousand grain weight; WEG: Weight of ear grain; RRC: Rod ratio on the cob; OC: Oil content; SC: Starch content; PC: Protein content

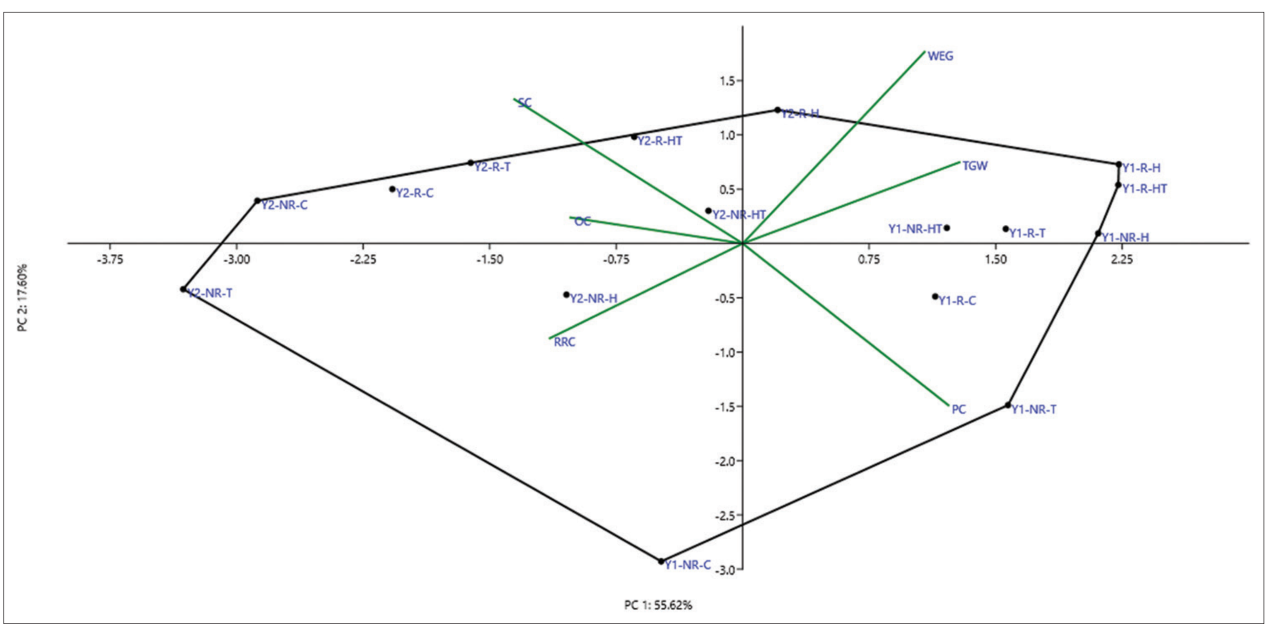

Fig 2. Basic component analysis of combinations of applications based on variables. PC: Principle component; Y1: First year; Y2: Second year; H: Hand hoe; HT: Hand hoe + Tractor hoe; T: Tractor hoe; C: Control; R: Radish; NR: Not radish; TGW: Thousand grain weight; WEG: Weight of ear grain; RRC: Rod ratio on the cob; OC: Oil content; SC: Starch content; PC: Protein content.

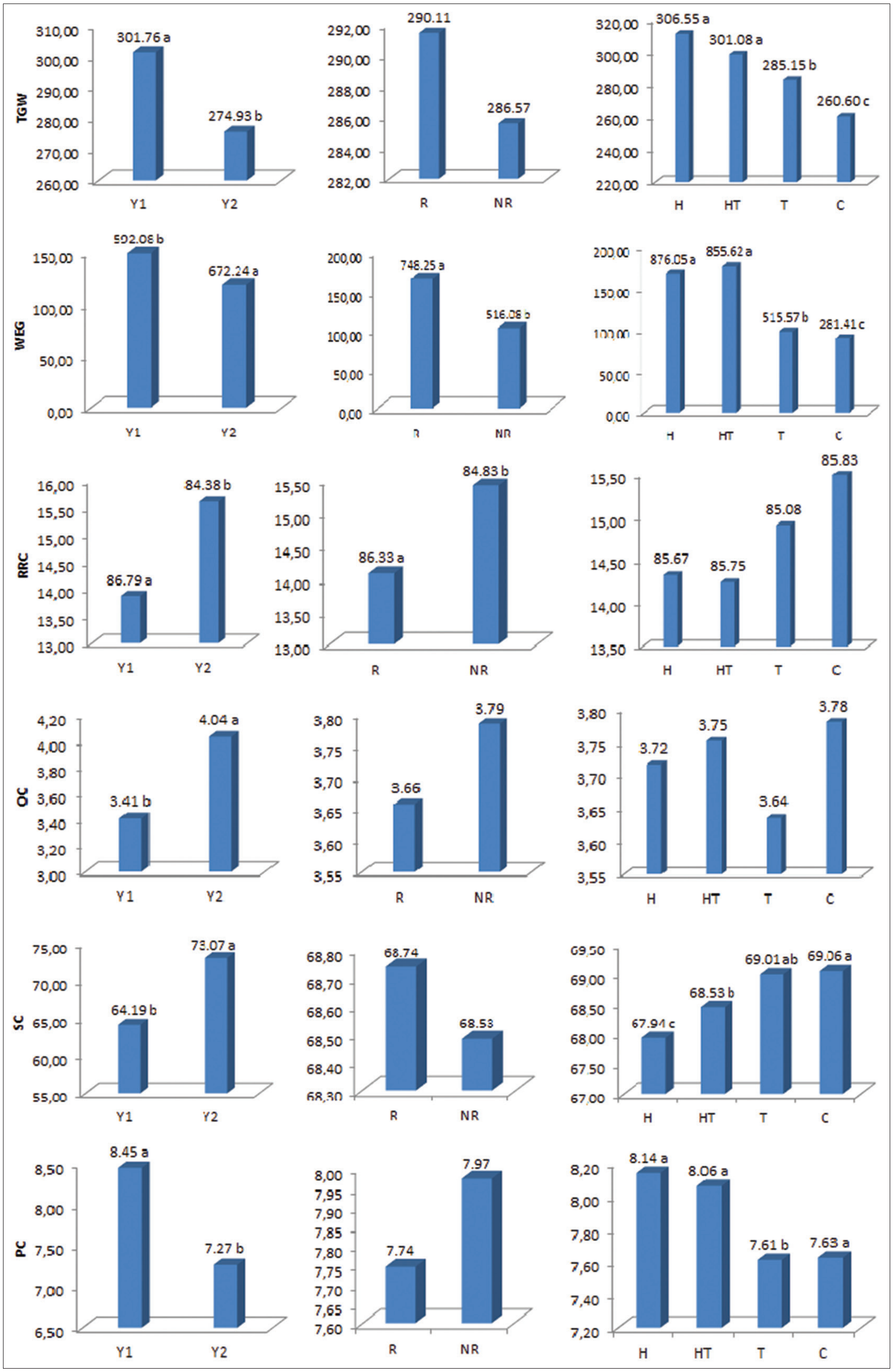

Fig 3. The effects of different weed removal and pre-planting applications on the investigated properties. Y1: First year; Y2: Second year; H: Hand hoe; HT: Hand hoe + Tractor hoe; T: Tractor hoe; C: Control; R: Radish; NR: Not radish; TGW: Thousand grain weight; WEG: Weight of ear grain; RRC: Rod ratio on the cob; OC: Oil content; SC: Starch content; PC: Protein content.

Radish has a great potential as an exploitative crop due to its large and deep root system, which allows the plant planted after it to reach a depth of N in the soil profile (Clark, 2012). De Ruijter et al. (2010) reported that under freeze-thaw conditions, radish shoot biomass lost 4-6% of its total nitrogen as ammonia after 37 days and 7-11% after 119 days. Accordingly, Lawley et al. (2012) found in their study that while radish showed almost complete weed control in early spring, its effect on weeds decreased in summer and was not sufficient to prevent yield reduction in maize due to the termination of weed intervention. On the other hand, in other studies, it was determined that the turnip and radish residues mixed into the soil prevented the germination and development of *Amaranthus retroflexus* and *Portulaca oleracea* for the first 30 days, about 45% for black and hazelnut radish, about 52% for turnip and Pistachio radish, and their effects disappeared after this date (Ozdemir and Uremis, 2019).

CONCLUSIONS

In this study, only the short-term impact of different hoeing practices and soil cover management results was determined. Consequently, in order to accurately assess the impact of conservation agriculture, especially on the soil system, a holistic approach should be preferred, taking into account the effects on both crop production and soil physics, taking into account different soil functions at different scales. Our results show that conservation agriculture, and especially weeding methods, has the potential to increase the environmental and agricultural sustainability of farms.

Authors' contributions

Gulay Zulkadir, Duygu Uskutoglu and Songul Ciftci Sakin executed the field research and laboratory analyses, whereas Leyla Idikut conceived the idea and supervised the work.

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