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Effectiveness of Different Weed Management Methods in Silage Maize (*Zea mays* L.) and Effect on Yield

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Abstract: In this study, the determination of the effect of band herbicide, hoeing, brushing and flaming methods that has been used especially row crops on weed management on the parameters of weed management and yield in silage maize has been aimed. Tillage, seed bed preparation, planting and fertilization were applied at the all area of experiment plots with the same method weed management tool and machines have been run at three different ground speeds. After application the number of weeds in the experimental areas were determined using the framework with 0.5 m^2 and compared with the control plots. The best weed control in the weed management areas was determined in the lowest ground speed of Band Herbicide Method with a value of 79% in the 1st year and 81% in the 2nd year. The speed increasing in applied Weed Management Methods caused to increse on weed numbers, the control effectiveness in increasing speeds decreased. As a result, the usage of brushing weeder and flaming which are among alternative Weed Management Methods at lower ground speed in the maize production areas has been effective on weeds at earlier periods. In the research, yield and yield components investigated were negatively affected by weeds and therfore significant differences were determined in management methods according to variance analysis. The highest yield was obtained in the band herbicide application applied by field crop sprayer the lowest yield was obtained in control plots.

Key words: Maize, weed control, band herbicide, brushing, flaming, yield

INTRODUCTION

Maize which can be used in human and animal nutrition and in order to obtain industrial raw material due to expanding industrial areas is rather important among the grains which meet great part of energy and protein requirement of world population. In the world, following wheat and rice maize is in the third place with 159.5 ha cultivation area and in the first place with 817 million tons production. Maize composes 22.5% of total grain cultivation area and 32.8% of the production. Turkey is among 163 countries which produce maize and is in the 32nd place in the sense of maize cultivation area 22nd place in the sense of total production and 24th country in the sense of yield obtained in unit area (FAO, 2010).

Maize is commonly used in human nutrition as flour, starch, cereals, maize oil, glucose syrup, fresh consumption product and it is the plant which is mostly silaged in the world and in the country (Kilic, 1986; Turner and Silage, 2001; Acikgoz, 2002; Filya, 2002). Cultivation area of silage maize for Erzurum 10742 da, production is 51.536 tons, yield is 4.798 kg da^{-1} (Anonymous, 2010). As it is understood from these results, the yield is quite low in the province. This is substantially related with the success of management against diseases and weed which harm crop plants.

Weeds are one of the most important factors which has more damage on crop plants than product loss caused by various factors and which influence product yield, seed quality, research load and expense (Coruh and Boydas, 2007). Product loss among some of the important crop plants such as wheat, maize, rice, cotton, soybean due to disease, pests and weeds is around 67.15, 13.78% of it is caused by diseases, 21.75% is caused by pests and 31.62% is caused by weeds (Oerke *et al*., 1994).

In order to prevent the problem of weed for maize it is the most important point first of all to know how to manage for increasing maize yield. There are various methods of weed management and chemical management is commonly used due to ease of application and being effective in a short time. Paying attention to the living beings within ecosystem and using environment-friendly techniques during agricultural production is a global issue. Therefore, methods which both has the least damage towards environment and can be evaluated in the

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scope of organic agriculture should be developed and appropriate parameters should be determined for these method.

In this study which is carried out in order to enable yield increase by controlling weeds which germinate together with maize especially in the first stages of growth and have negative effects on the growth of maize and on future product yield and Quality Mechanic Management Methods (inter-row hoeing and brushing), flaming which is one the Thermal Weed Management Methods and Chemical Management Method (band herbicide) were applied. Mechanic Weed Management Methods and flaming which are used in the study are evaluated in the scope of organic agriculture and accepted as environment-friendly techniques. Band (strip) herbicide which is to be used in chemical management is important in the sense that herbicide is used not all through the field but in parallel bands. In this way, detrimental effects of herbicide and cost of herbicide will be minimized since the amount of herbicide would decrease.

In this study, it was aimed to keep the maize from the effect of weed in the first stages of growth and to determine Weed Management Methods and suitable parameters that would minimize negative effects such as decreasing product yield and market value of product as a result of weeds competing with the plant in the sense of water, light and nutrients. In this way, it is estimated that a new dimension would be added to the country in the sense of weed management and farmers would be enlightened with useful information about organic agriculture and new horizons would be opened about the subject.

MATERIALS AND METHODS

In this study which was carried out in order to determine the effect of different Weed Management Methods in silage maize on efficiency and yield, DKC 5783 type silage maize seed was used. The first plough was prepared with moldboard plough and the seed bed was prepared with cultivator and toothed harrow + scrubber combination. Cultivation was done with pneumatic sensitive sowing machine in 5 kg da^{-1} cultivation norm, 70 cm inter-row, 20 cm in row and in 5 cm depth (Serin and Tan, 2004) on May 20, 2010 in the 1st year and on May 27, 2011 in the 2nd year. According to the results of soil analysis, 15 kg ammonium sulphate and 5 kg triple super phosphate fertilizer was added per decar together with sowing and given to experiment area with 20 kg da^{-1} fertilizer norm. Plants were irrigated 6 times in the 1st year and 7 times in the 2nd year with the help of irrigation channels during cultivation process.

The experiment area is composed of 3 blocks which have 7 m distance between each other and 15 plots being 20 m long and 3.5 m wide in each block. There are 1 m distances between plots. Field experiments in the study, being hoeing with rotating cultivator (C), brushing weeder (F), flaming (A), band herbicide with field crop sprayer (P) and control (K) were carried out according to randomized complete block design with three replications on 45 plots in 3 different ground speeds of each application. Weed Management Methods were applied two times a year on June 23, 2010 and July 9, 2010 in the 1st year and on June 30, 2011 and July 14, 2011 in the 2nd year. Application time and frequency of Weed Management Methods were determined with observations on the test field by Ataturk University Herbalists. In control group plots, there was no application for weed management apart from fertilization and irrigation which is carried out for every plot.

Rotating cultivator: In this study, in order to hoe weeds rotating cultivator which has 70 cm research width and 5 milling unit was used in 3 rows by removing outermost milling units. Management principle with rotating cultivator can be shown in Fig. 1. Rotating cultivator was used in 6-8-11.5 km h^{-1} ground speeds in weed management (Pullen and Cowel, 1997).

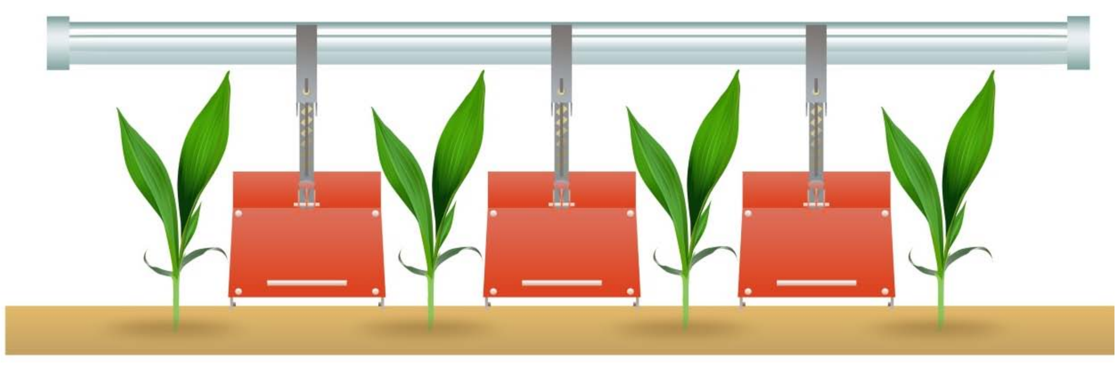

Fig. 1: Application principle of rotating cultivator

Brushing weeder: Brushing weeder which is to be used for the first time in the country in this study was specially produced by Anadolu Fyrca Mak. Plastik Iml. San. Ins. Otom. Ic ve Dis Tic. Ltd. Sti. Brushing device was designed as 3 rows that are adjustable according to the inter-row width of crop plant to be cultivated by placing MH 418 polypropylene brushes that has 1.5 cm width, 80 cm diameter and 26 cm inner diameter on a shaft around horizontal axis together with collets that has 32 cm diameter and 26 cm inner diameter. Brush diameter and shaft speed was determined according to the values accepted by Kouwenhoven (1997). Management principle carried out with brushing weeder is shown in Fig. 2. In the weed management, brushing weeder was used in 6-8-11.5 km h^{-1} ground speed (Pullen and Cowel, 1997) and 240 rpm main shaft speed (Kouwenhoven, 1997).

Flaming machine: Flaming machine was designed by us within literature information and was manufactured in industrial site. Since, the fuel used in flaming machine is LPG, LPG tube was tied on the tractor with three-point linkage system and placed on an iron platform. The fuel coming from LPG tube passes through a hood which has manometer on and is given to flaming unit with guard shield which has 50 cm width. Flaming unit was attached to the edge of platform which carries LPG tube in a way that would be adjusted with a cuff shifting right and left.

In the weed management application, flaming machine was used in 2-4-6 km h^{-1} ground speeds (Raffaelli *et al*., 2000; Rifai *et al*., 2002). Principle of management carried out with flaming machine is shown in Fig. 3.

Field crop sprayer: For the application of chemical weed management, a mounted field crop sprayer with 400 L capacity was used in the tests. In band herbicide, TIM 03-F80 type 3 nozzles with fan beams were used in a way that each nozzle would be on each inter-row between which there are 70 cm distances (Tepe *et al*., 2004). Suspension rods were mounted to the sprayer in 78 cm long and in a way that band width would be adjusted. In the weed management application, field crop sprayer was used in 6-8-10 km h^{-1} ground speeds (Bal, 1989). Band herbicide principle carried out with sprayer is shown in Fig. 4.

As a herbicide, nicosulfuron active agent and weed Sanspor which includes 40 g L^{-1} of this active agent was used with 125 mL da^{-1} (Anonymous, 2002) usage dose and 3 bar spraying pressure, spraying norm was calculated with the Eq. 1:

$$N = \frac{600.Q}{B.V} \tag{1}$$

Where:

N = Pesticide norm (L ha^{-1})
Q = Nozzle flow rate (L min^{-1})

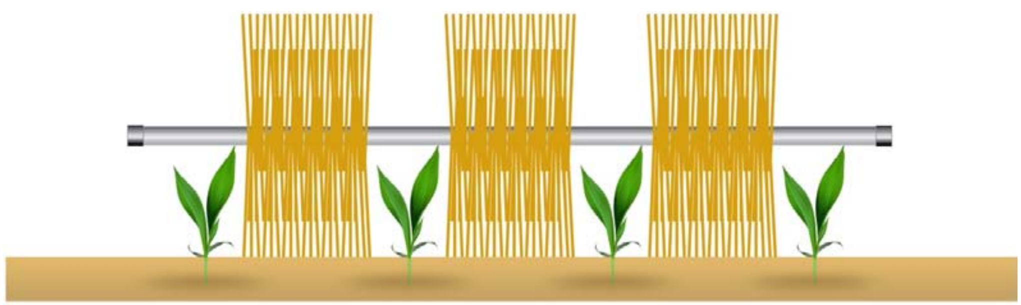

Fig. 2: Application principle of brushing weeder

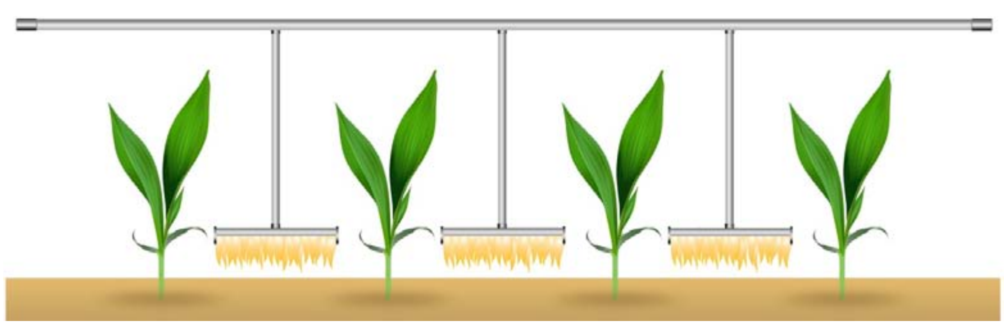

Fig. 3: Principle of flaming

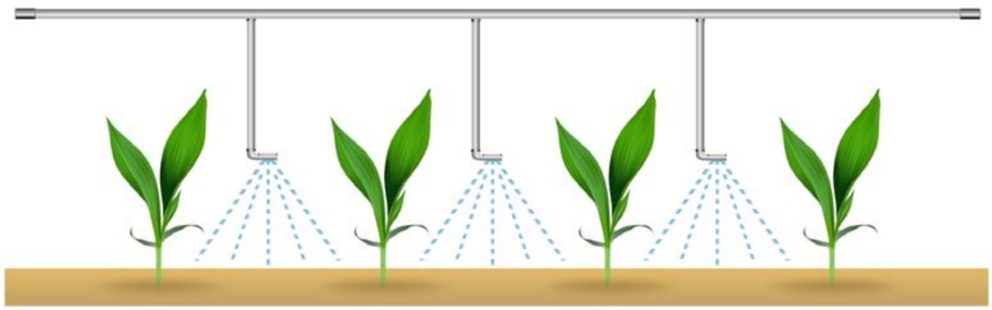

Fig. 4: Principle of band herbicide

B = Band width (m)
V = Ground speed (km h^{-1})

In the Weed Management Methods applied in the tests, Ford 5000 S tractor which has 49.4 kW (2100 days min^{-1}) power and includes speed radar and monitor was used. In order to enable operator drive tractor under control and specific ground speed, DJCMS100 Model multi-purpose monitor and DJRVS II Model speed radar which can do measurement between 0.53-96.6 km h^{-1} speed measurement range and in 0.53-3.2 km $h^{-1} < \pm 5\%$; 3.20-107 km $h^{-1} < \pm 3\%$ sensitivity (Bastaban, 1994).

Number of weeds (number/m^2): In order to determine the effect of methods carried out on test plots 0.5 m^2 frames were randomly placed on each plot and weeds within them were counted data obtained were transformed into 1 m^2 field measurement (Bukun *et al*., 2005).

Weed control effectiveness (%): Value of weed control effectiveness (%) was calculated depending on the number of weed per square meter with Abbort formula after determination of the number of weed in each plot following application of Weed Management Methods (Karman, 1971):

$$Y = \left(\frac{K - I}{K}\right) \times 100 \quad (2)$$

Where:
Y = Control effectiveness of weed (%)
K = Number of weeds on control plot (number/m^2)
I = Number of weeds on plot on which weed management Methods were applied (number/m^2) Yield according to wet weight (kg day^{-1})

Plants chosen randomly on 2 rows of each plot ($1.4 \times 6 = 8.4$ m^2) which are 6 m long were cut 5 cm above the surface and herbage yield per decar was determined (Bayram, 2010).

Statistical analysis: Tests were carried out according to randomized complete blocks design on 45 plots in total being 3 blocks and 15 plots on each block. Average of total data for each plot was calculated in Excel program. Variance analysis of the calculated averages was done with SPSS statistical program (SPSS Inc., in 2004). In order to determine difference level between factors, Duncan multiple comparison tests were used (Yildiz and Bircan, 1994).

RESULTS AND DISCUSSION

Number of weeds: Counting was done before the harvest in order to determine the effects of Weed Management Methods used in the study and ground speeds on the number of weeds, variance analysis, average and Duncan multiple comparison test results related with the data obtained were shown in Table 1.

According to the results of analysis applied on data about number of weeds the effect of Weed Management Methods, ground speed and method x interactions on the number of weeds per meter square was statistically significant in the level of $p<0.01$. When Table 1 is shown, it is seen that the effect of Weed Management Methods on the number of weeds per square meter are quite different from each other. When the methods applied in weed management are compared the least number of weeds was determined in band herbicide with sprayer this was followed by hoeing with rotating cultivator with 56.22 number/m^2, brushing weeder with 68.44 number/m^2, flaming machine with 78.67 number/m^2. The greatest number of weeds was determined on control plot on which no application was done with 142.33 number/m^2.

In the 2nd year of test, similar to the 1st year, the least number of weeds was determined in band herbicide with sprayer, this was followed by hoeing with rotating cultivator with 49.59 number/m^2, brushing weeder with 62.04 number/m^2, flaming machine with 72.33 number/m^2. The greatest number of weeds was again determined on control plot with 145.30 number/m^2.

Table 1: Variance analysis, average and Duncan multiple comparison test results about number of weeds

Comparison of averages												
Block			Methods					Ground speed				
I	II	III	K	P	C	F	A	Low	Medium	High	p (%)	
Number of weeds (number/m^2)												
77.51^{NS}	77.58^{NS}	77.47^{NS}	142.33^{e1}	41.93^{a}	56.22^{b}	68.44^{c}	78.67^{d}	62.89^{a}	78.33^{b}	91.33^{c}	5.00	
73.09^{NS}	72.98^{NS}	73.18^{NS}	145.30^{e}	36.11^{a}	49.59^{b}	62.04^{c}	72.33^{d}	60.33^{a}	73.56^{b}	85.37^{c}		

		ANOVA p-values	
Sources of variation	df	2010	2011
Block	2	0.991^{NS}	0.969^{NS}
Method	4	0.000**	0.000**
Ground speed	2	0.000**	0.000**
Method x ground speed	8	0.000**	0.000**

**p<0.01; *p<0.05; NS: statistically insignificant; [1]Differences between averages which have the same letter in the same column are statistically insignificant

Importance of methods and speed interaction show that difference between the effects on the number of weeds per square meter is not same for each method. As it is observed in interaction values, working in low speed in methods applied for weed management proved to be successful in decreasing the number of weeds compared to control, it was seen that as the speed of application increases so does the number of weeds determined after process (Fig. 5).

In the lowest speed of band herbicide with sprayer, there was a decrease of 79% in the 1st year and 81% in the 2nd year in the number of weeds per square meter compared to control plot. While the change in the number of weeds according to years and the lowest ground speed was 37.33-33.45 number/m^2 for hoeing with rotating cultivator, it was 43.32-40.34 number/m^2 for brushing weeder. The greatest number of weed in the highest ground speed was determined in flaming application with 94.31-95.35 number/m^2.

Hoeing and manual weeding are the best management methods for annual small weeds however these methods control perennial weds for a short time, systemic herbicide application give better results for perennial weeds (Klein *et al*., 1992).

The findings are supported by Jodie and Potter (2002) who explain that herbicide is effective on annual and perennial herbaceous and broad-leaved weeds that grow with maize and has control in the rate of 83-95%, Gokgoz (2010) who explains that herbicide has control on Cockscomb in the rate of 93.3-95, 61.7-63.3% on destroying angel, 51.7-58.3% on field bindweed and 68.3-70% on goosefoot, Kiran (2010) who states that herbicide is in the first place in weed management hoeing is in the second place and flaming is in the third place.

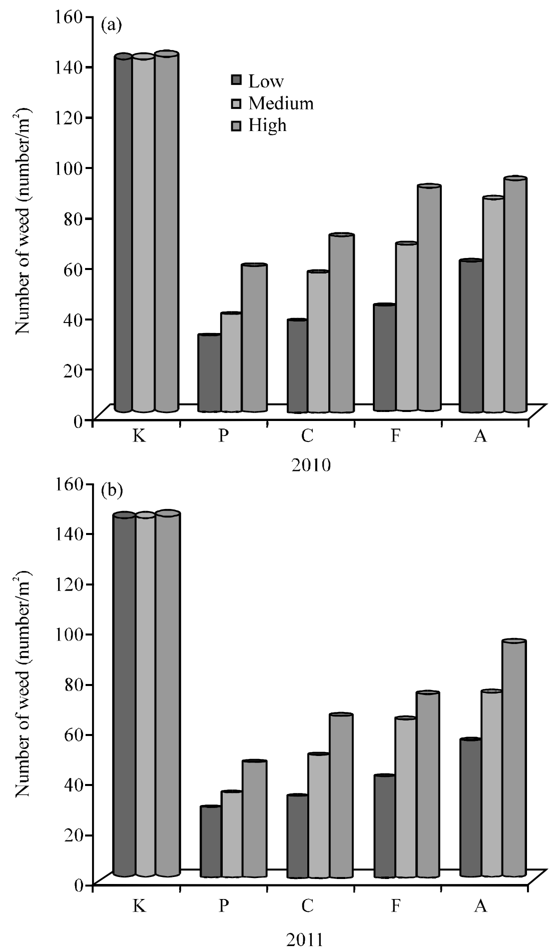

Fig. 5: The change of number of weed per square meter according to Weed Management Methods and ground speeds

Effectiveness of weed control: Values of control effectiveness of Weed Management Methods which were formulated depending on the number of weeds per square meter with Abbort formula was shown in Table 2. As it is shown in Table 2, value of control effectiveness was higher in Weed Management Methods carried out with the lowest ground speed. As the speed increases, control effectiveness decreases depending on the increase of the number of weed per square meter. While the highest control effectiveness was determined in the first speed of band herbicide with sprayer, the lowest control effectiveness was determined in the highest ground speed of flaming application.

Crop yield according to wet weight: Variance analysis, average and Duncan multiple comparison test results about data obtained in order to determine the effect of Weed Management Methods and ground speeds on crop yield according to wet weight were shown in Table 3. According, to the results of variance analysis applied on the data about crop yield which are determined according to wet weight the effect of Weed Management Methods, ground speed and method x interactions on crop yield per decar was quite significant statistically in the level of $p<0.01$.

When Table 3 is shown, it is seen that the effect of Weed Management Methods on the crop yield per decar are quite different from each other. The most crop yield was determined in band herbicide with sprayer. This was followed by hoeing with brushing weeder with 6751.92 kg da^{-1} and rotating cultivator with 6751.79 kg da^{-1}. While the crop yield obtained with flaming application is 6652.90 kg da^{-1}, the least wet crop yield was determined on control plot on which no application was done with 2265.07 kg da^{-1}. There was no significant difference statistically between hoeing application with rotating cultivator and brush weeder on the values of crop yield on the plots where Weed Management Methods are applied and these methods were considered in the same group.

In the 2nd year of test, similar to the 1st year, the most crop yield determined according to wet weight was obtained in band herbicide with sprayer, this was followed by hoeing with rotating cultivator, brushing and flaming machine. The least crop yield was again determined on control plot.

As it is observed from interaction values, working in low speed with methods applied in weed management proved successful in crop yield increase compared to control as the application speed increase there was a decrease in the effectiveness of weed management control in the crop yield (Fig. 6). In the lowest speed of band herbicide with sprayer, there was 202.6% increase in the 1st year and 205.5% increase in the 2nd year in the crop yield per decar compared to control plot. It was determined that wet crop yield per decar according to the lowest ground speed was 6773.2-7080.6 kg da^{-1} in the hoeing application with rotating cultivator and 6770.7-7071.2 kg da^{-1} with brushing weeder. The lowest wet crop yield in the highest ground speed of Weed Management Methods was determined with the flaming application in both years.

Green matter yield which is one of the properties considered in order to compare agronomical performances of plants is a quantitative value that is influenced by all of the elements such as the number of plants in unit area, plant species and type, maturation time, utilization way, harvest time and technology (Soya *et al*., 2001). Findings about crop yield which is determined according to wet weight were supported with the findings of Ozturk and Akkaya (1996), Karayigit (2005), Gencturk (2007) and Bulut *et al*. (2008) about properties of yield.

Table 2: The change of effectiveness of weed control by years depending on Weed Management Methods and ground speeds

		Effectiveness of weed control (%)	
Weed Management Methods	Speed	2010	2011
Band herbicide with field crop sprayer	Low	79	81
	Medium	73	76
	High	60	68
Hoeing with rotating cultivator	Low	74	77
	Medium	60	65
	High	51	55
Brushing weeder	Low	70	72
	Medium	52	56
	High	37	49
Flaming	Low	57	62
	Medium	40	49
	High	34	35

Table 3: Variance analysis, average and Duncan multiple comparison test results about crop yield according to wet weight

Comparison of averages

Block			Methods					Ground speed			
I	II	III	K	P	C	F	A	Low	Medium	High	p (%)
Crop yield according to wet weight (kg da^{-1})											
5844.22^{NS}	5844.32^{NS}	5844.27^{NS}	2265.07^{d1}	6799.67^{a}	6751.79^{b}	6751.92^{b}	6652.90^{c}	5864.39^{a}	5841.06^{b}	5827.36^{c}	5
6108.43^{NS}	6108.41^{NS}	6108.32^{NS}	2333.31^{e}	7115.09^{a}	7066.20^{b}	7054.06^{c}	6973.27^{d}	6119.48^{a}	6109.06^{b}	6096.63^{c}	

		ANOVA p-values	
Sources of variation	df	2010	2011
Block	2	0.921^{NS}	0.767^{NS}
Method	4	0.000**	0.000**
Ground speed	2	0.000**	0.000**
Method x ground speed	8	0.000**	0.000**

**p<0.01; *p<0.05; NS: statistically insignificant; [1]Differences between averages which have the same letter in the same column are statistically insignificant

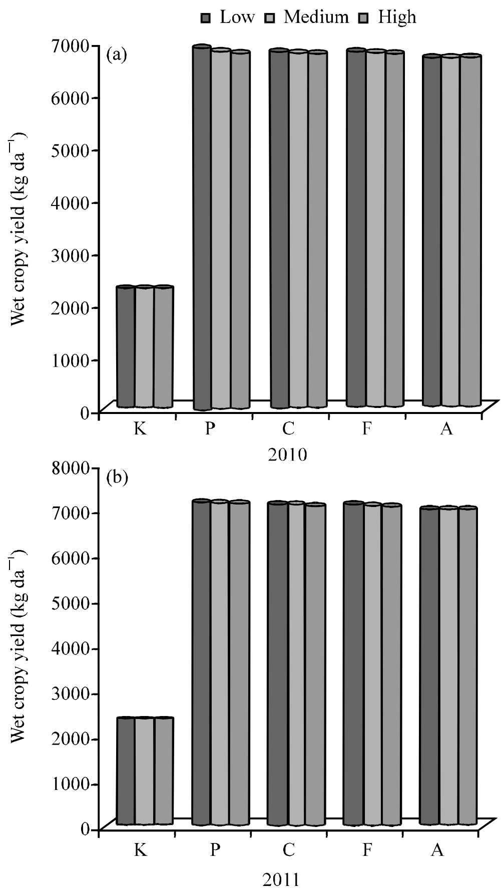

Fig. 6: The change of crop yield according to wet weight by years depending on Weed Management Methods and ground speeds

CONCLUSION

When compared with similar studies carried out in maize fields that have different climate properties, it was understood that *Amaranthus retroflexus*, *Chenopodium album*, *Cirsium arvense* and *Convolvulus arvensis* are important weed species that pose problem in maize production fields.

When the methods applied in weed management are compared the least number of weeds was determined in band herbicide with sprayer this was followed by hoeing with rotating cultivator, brushing weeder and application with flaming machine. The greatest number of weeds was determined on control plot on which no application was done. Working in low speed in methods applied for weed management proved to be successful in decreasing the number of weeds compared to control it was seen that as the speed of application increases so does the number of weeds determined after process. Since, the increase of speed in methods applied for weed management causes increase in the number of weeds, there was a decrease in control effectiveness in higher speeds.

It was determined that crop yield according to wet weight was negatively influenced by weeds. It was determined that yield values obtained in the applications in which control effectiveness is high increase, increases are high when compared to control group on which no weed management was done.

With this study it was concluded that working with brushing weeder and flaming applications which are among the alternative Weed Management Methods in low speed would be rather effective against weeds in early stage compared to chemical management and hoeing with traditional rotating cultivator which are used by the region manufacturer on maize fields. Acceptable weed control was enabled with brushing weeder and flaming applications and it was determined that significant contribution would be provided for country economy, environment and human health since no chemical pesticide is used.

In order to decrease yield losses of maize, doing weed management in the first growth stages when the competition power of maize is weak would minimize the damage caused by weeds and maximize the effect of Weed Management Methods. As a result, weed management is inevitable for meeting the nutrition need of increasing world population and obtaining much more yield from ever-diminishing fields.

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