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Full Length Research Paper

Effect of atrazine applications on weed growth and yield at different irrigation levels in corn (*Zea mays* L.) growth

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Corn (*Zea mays* L.), for silage, is very important in animal feeding because winter seasonal conditions last longer in Eastern Turkey. Corn yield components were investigated in plots, in which herbicide had been applied and also not applied at different irrigation levels in this study. The study lasted for two years and soil-water content was kept at five different levels [96% (I-1), 63% (I-2), 32% (I-3), 15% (I-4) and 4% (I-5)]. The species and intensities of the weeds at the irrigation levels were determined in the study. Plant length, green and dry herbage yields, leaf, stem and ear ratios were studied as criteria for corn yield. At the same irrigation levels, higher efficiency values were determined according to non applied plots in the atrazine applied plots. In both years, the lowest green herbage and dry herbage yields were determined at I-4 and I-5 irrigation levels. The weeds that are mostly seen on the plots, in which atrazine had not been applied are *Alopecurus myosuroides* Huds. and *Sinapis arvensis* L, respectively. Similarly, for both years, high densities of weeds were observed in the highly moisturized lands. The atrazine activities increased at the I-1 and I-2 irrigation levels in which water content of the soil is high.

Key words: Corn, weeds, soil moisture, atrazine, corn yield.

INTRODUCTION

Turkey's corn production is estimated at 2.5 million tons annually covering 600,000 ha cultivation area (FAO, 2003). Most of the animal products are produced in Eastern Anatolia in Turkey. Corn, for silage, is very important in animal feeding because winter seasonal conditions last longer in Eastern Turkey. Water is an important factor in obtaining maximum corn yield. The corn is mainly grown in summer seasons and the irrigation is essential for higher yields. In recent years, the yield and the water stress are the main topics of many studies carried out in arid and semi-arid regions. The water scarcity and its uneven distribution have been considered as the main risks for the corn production in these areas.

Soil moisture status is important in maintaining optimal corn yields, and maintaining optimal soil moisture is facilitated by irrigation. The knowledge of corn crop performance under various stages of water deficit in semiarid environment is becoming important to manage water more efficiently. Several studies have been conducted on corn water requirement and the effect of water stress in temperate and semi-arid zones (Musick and Dusek, 1980; Harder et al., 1982; Eck, 1985). Musick and Dusek (1980) cited two reasons for yield reduction at deficit irrigation: high water holding capacity of soil and existence of water stress throughout the growing season. Tassel flowering, ear flowering and milky stage are critical periods for corn yield. Hot and dry climate and also drought during this period result in yield reduction (Dow et al., 1984; Shaw, 1988; Edmeades et al., 1990; Yildirim et al., 1996; Kirtok, 1998).

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Table 1. Climate data for Van Province from 2007 to 2008, long term (LT) averages*.

Month	Temperature (°C)			Rainfall (mm)			Relative humidity (%)		
	2007	2008	LT	2007	2008	LT	2007	2008	LT
May	15.7	12.3	12.9	27.3	39.9	46.3	60.5	51.1	67.0
June	19.9	19.5	17.8	9.1	2.1	18.4	56.6	41.9	50.0
July	22.7	22.7	22.0	28.6	11.1	5.1	54.5	32.8	44.0
August	21.8	23.9	21.5	7.2	6.8	3.9	51.5	37.3	42.0
September	17.8	18.3	17.0	-	44.7	10.5	45.4	39.6	43.0
Total				72.2	104.6	84.2			

*Data collected from Van Meteorological Station.

The weeds that germinated before or at the same period with corn are more competitive than the ones that germinated after the corn, which causes higher yield losses (Swanton et al., 1999; Bükün, 2004). In the semi-arid region, crops and weeds compete for plant growth resources including light, nutrients and especially water (Zimdahl, 1999). Weeds often extract more of each of these resources than necessary for their growth to the detriment of crop growth and production. Therefore, the presence of weeds in a semi-arid environment requires producers to pay special attention in order to achieve the maximum potential yield for corn production. Thus, managers often tend to over-irrigate and over-fertilize in order to feed both the crop and weeds (Ruf, 2007).

Atrazine, a prominent triazine herbicide, is currently one of the most widely used herbicides in world agriculture. It is a selective pre-herbicide for control of many broadleaf weeds and grasses in corn, sorghum, sugarcane, pineapple, turf and orchards.

The aim of the study is to investigate the effect of atrazine used at different irrigation levels, on weeds density and corn yield criteria.

MATERIALS AND METHODS

Site description

This study was conducted during 2007 and 2008 at one site in Van Province in Eastern Turkey (N 38° 41', 31.4''; E 043° 22' 01.7'' 1741 m above sea level). The experimental site was a sandy-clay-loamy texture with pH of 7.5 – 7.9, organic carbon of 0.4 – 0.6%, nitrogen 0.08 - 0.1%, high potassium 182 - 186 kg da^{-1} and medium phosphorus 5.5 - 5.9 mg kg^{-1} in a 0.9 m soil profile. The region has a temperate climate and Table 1 shows the average temperatures, rainfall and humidity for both 2007 and 2008 growing seasons as well as long-term (1929 - 2008) averages for the region.

Experimental details

The experiment was conducted using three replications in a split plot design with irrigation regimes as main plots and herbicide applied as subplots. Main plots had five irrigation regimes (I-1, I-2, I-3, I-4 and I-5) and subplots had herbicide applied plots and plots without herbicide application. Soil moisture was kept at the levels of 96% (I-1), 63% (I-2), 32% (I-3), 15% (I-4) and 4% (I-5), continuously. The flood method was used for irrigation, while the irrigation activities were applied after the homogeneous germination was provided. After output had been ensured, the application of irrigations regimes began. Time Domain Reflectometry (TDR300) was employed in specifying irrigation applications. In this study, single-cross hybrid corn OSSK 644 (FAO maturity group 600) variety was used as the crop material. Each plot consisted of five rows of 5 m in length. The plants were grown, 70 cm apart, between the rows with 20 cm spacing in each row. Intervals between plots and blocks were 2 and 3 m, respectively. Banks were created around the plots for preventing water to pass through. The seeds were sown on 19 May 2006 in the first year and on 24 May 2007 in the second year. The experiment was conducted on the same locations in both years and atrazine (400 cc da^{-1}) was applied in pre-sowing. The phosphorous fertilizer (8 kg/da P_2O_5) in whole and half of the total nitrogen (16 kg/da N) were given at the same time with plantation. The other half of the nitrogen was applied when the plant length had reached 35 - 40 cm. In the trial, two hoeing were made; the first hoeing was applied when the plants grew 4 - 5 leaves and the second hoeing was applied after 15 days from the first one.

Weed density and species composition were measured before the first and second hoeing in both years. A 1 m^2-frame was put on each of the plots, twice. All weeds were counted and identified. Harvest was conducted during milk production period on 21st of September in the first year and 16th of September in the second year. Plant length was determined by employing 20 plants. The rest area was harvested after one row at the edges of each plot, which was extracted for green and dry herbage yields. Dry herbage yield was obtained by drying at 70°C in an oven and 20 plants were obtained from each plot during the harvest. These plants were divided into their stems, leaves and ears. They were weighted separately and their ratios to each other were determined. All data were subjected to ANOVA, and the means were separated using Fisher's protected LSD tests at P = 0.05 level of significance (SAS, 2000). Interaction between years and treatments was significant and thus each year is reported separately.

RESULTS

The effect of the applications on the intensity of weeds

In the period before the first and second hoeing in 2007, the species of black-grass (*Alopecurus myosuroides* Huds.), charlock mustard (*Sinapis arvensis* L.) and binweed (*Convolvulus arvensis* L.) were observed mostly in the presented study. In the period before the first hoeing in 2008, the species of black-grass (*A. myosuroides* Huds.), redroot pigweed (*Amaranthus retroflexus* L.) and charlock mustard (*Sinapis arvensis* L.) were observed, while the weeds of black-grass (*A. myosuroides* Huds.), charlock mustard (*S. arvensis* L.) and binweed (*C. arvensis* L.) grew mostly before the second hoeing in 2008. For both years, in the period before the first and second hoeing, no significant change occurred with the species and intensities of the weeds.

For the parcels without atrazine application, the weeds intensity was generally high at the irrigation levels in which water is not a limited factor. Oppositely, when the water is a limited factor of the irrigation level, a decrease in the weeds intensity was observed. For the plots without herbicide applications, the highest weeds intensity was observed at the I-2 irrigation level, while the lowest value was observed at the I-4 irrigation level before the first hoeing period in 2007. The difference between the two irrigation levels was determined as 65.2%. In the observations before the second hoeing, the highest intensity was determined at I-1 and the lowest intensity was determined at I-3 irrigation levels. Consequently, the difference between them was noted as 69%. In the second year, for both hoeing periods, the highest weeds grew at I-1 irrigation level and the lowest was determined at I-4 irrigation level. The differences between the two irrigation levels were noted as 58.1 and 47.6%, respectively.

In the plots with herbicide application, for both years, the activity of the atrazine increased generally in the soil with high moisture content, and a decrease in the weeds intensity was observed. For the situations in which water is a limited factor, the effect of atrazine on weeds intensity was low. In the previous period of the first hoeing, the lowest weeds density was observed at I-1 irrigation level, while the highest weeds density was observed at I-4 irrigation level. Consequently, the differences between them were detected as 73.7% in 2007. At the second hoeing period, the lowest density was observed at I-3 and the highest was at I-5 irrigation levels with 72.3% difference between them. In the second year, for both hoeing periods, the lowest weeds density was obtained at I-2, while the highest densities were observed at I-5 before the first hoeing and I-4 before the second hoeing periods. The density differences between them were reported as 79% for the first and 81.1% before the second hoeing periods (Tables 2 and 3).

The effects of the applications on the investigated criteria of corn

The effect of different irrigation levels and herbicide application on plant length were considered to be statistically significant in both years. In the first year of the study, at the I-2 irrigation level, the length of the plants were observed and the difference was highest between the herbicide applied plots and the plots without herbicide application. Consequently, this value was noted as 18.7%. In the year 2008, at the I-2 and I-3 irrigation levels, the plant lengths differences between the herbicide applied plots and plots without herbicide application were higher when compared to the other irrigation levels and these differences were reported as 12.7 and 13.1%, respectively (Table 4).

The effect of the different irrigation regimes and herbicide application on green and dry herbage yields were considered to be statistically significant in both years. In both years of this study, the highest green herbage and dry herbage yields were observed at I-1 and I-2 irrigation levels. For the entire irrigation levels, high differences of green herbage and dry herbage yields were observed according to non applied plots in the atrazine applied plots. For these criteria, the highest difference of growth efficiency was observed at I-2 and I-1 irrigation levels in both years. For the green herbage yields, these differences were noted as 47.7 and 34.4% in 2007, and these values were 38.5 and 22.8% in 2008. For the dry herbage yields, these differences were reported as 47.1 and 37.8% in 2007, and these values were 39.4 and 25.2% in 2008 (Tables 4 and 5).

Leaves, stems and ears of selected plants were planted in each plot and weighted separately. The amount of the plant that accounts for leaves, stems or ear was calculated in % by using these weights. The effect of different irrigation regimes on ratios of leaf, stem and ear was considered to be statistically insignificant. However, the effect of herbicide on ratios of stem and ear was considered to be significant. High stem ratio was found in the plots without herbicide, while ear ratio was high in the plots treated with herbicide (Tables 5 and 6).

DISCUSSION

In this study, high yields were obtained when irrigation was continuous during corn growth. However, yields decreased significantly when water was limited. Many researchers highlights that water is a factor restricting growth of plants, and plants grow better in places with sufficient water (Rajcan and Swanton, 2001; Massinga et al., 2003; Naylor, 2002). Summer annual crops, such as corn, expose yield reductions in response to soil water deficits at any growth phase (Denmead and Shaw, 1960; Howe and Rhoades, 1955; Musick and Dusek, 1980).

In this study, as the moisture content of the soil increased, the weeds density increased in the parcels without atrazine application. In the atrazine applied parcels, increasing moisture content increased the atrazine activity, thereby resulting as the decrease in the weeds density. Moisture stress may reduce the effectiveness of herbicides by limiting their absorption and movement (Sundaram, 1965). It significantly reduces herbicide movement in woody plants. Obviously, the reduction in

Table 2. Weed densities on the plots in which herbicide was applied at different irrigation levels (2007) (Unit/ m^2).

Weed	Weed distribution before 1st hoeing										Weed distribution before 2nd hoeing									
	I-1		I-2		I-3		I-4		I-5		I-1		I-2		I-3		I-4		I-5	
	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)
Convolvulus arvensis L.	6	6	9.3	9.3	4.6	6.6	6.6	10	4	5.3	6	4	9.3	9.3	4.6	5.3	6.6	10	4	4
Alopecurus myosuroides Huds.		115.3		112.6	1.3	35.3	8.6	20.6	7.3	26.6		135.3		112.6	1.3	24.6	8.6	20.6	16	6.6
Sinapis arvensis L.		29.3		14.6		9.3		13.3		26		29.3		16.6		6.6		13.3	1.3	24.6
Amaranthus retroflexus L.		2		10.6		2		12.6		1.3		2.6		10.6		4.6		12.6		14.6
Chenopodium album L.		2		12.6		2		0.6		9.3		3.3		14.6		2		0.6		10.6
Xhanthium stromonium L.		3.3		8		2		1.3		1.3		3.3		6.6		2		4		1.3
Agropyron repens L.		2			7.3	11.3						2				10.6				
Total	6	159.9	9.3	167.7	13.2	68.5	15.2	58.4	11.3	69.8	6	179.8	9.3	170.3	5.9	55.7	15.2	61.1	21.3	61.1

Table 3. Weed densities on the plots in which herbicide was applied at different irrigation levels (2008) (Unit/ m^2).

Weed	Weed distribution before 1st hoeing										Weed distribution before 2nd hoeing									
	I-1		I-2		I-3		I-4		I-5		I-1		I-2		I-3		I-4		I-5	
	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)	H(+)	H(-)
Convolvulus arvensis L.	4.6	18.6	2.6		1.3	0.6	3.3	0.6	2.6	0.6	2	16.6	5.3	13.3	1.3	4	4	6.6	1.3	9.3
Alopecurus myosuroides Huds.	0.6	202.3	1.3	140	9.3	86	8.4	84	16	106		252		132	6.6	129.3	6.6	86.6	7.3	78
Sinapis arvensis L.		21.3		27.3		8.6	9.3	17.3		19.3		15.3		28		12.6		15.3	1.3	20.6
Amaranthus retroflexus L.		48.6		9.3		33.3		24		18.6						8.6				4.6
Chenopodium album L.		10		5.3		7.3		0.6		4						1.3		3.3		
Xhanthium stromonium L.		2.6		7.3		1.3		0.6		0.6		0.6		5.3		0.6		1.3		0.6
Agropyron repens L.					2	3.3														
Total	5.2	303.4	3.9	189.2	10.9	140.4	21.0	127.1	18.6	145.5	2.0	284.5	5.3	178.6	7.9	156.4	10.6	113.1	9.9	113.1

movement is affected by a stress herbicide (species interaction). These reductions are most apparent where extensive movement occurs under no stress. Likewise, in the field, moisture stress probably reduces herbicide transport principally under moderate stress and where extensive movement would normally occur (Davis et al. 1968; Merkle and Davis, 1967). Atrazine is mostly effective in wet soils and is therefore usually applied after significant winter rain when soils are at field capacity (Graymore et al, 2001).

In this study, at all the irrigation levels, the corn yield increased significantly in the herbicide applied plots when compared with the plots without herbicide application. Particularly, the green herbage and dry herbage yield increased at a high level with atrazine application. This situation is more evident when the water is not a limited factor in soil (Tables 4, 5 and 6). As the atrazine repressed the weeds under moisturized conditions, it caused significant increases in the corn yield. The weeds having higher competition capacity may produce high population, and the results may yield reduction depending on species density. The yield reduction of the second crop corn is estimated between 38 and 59% (Uremiş et al., 2004).

Finally, it can be said that, water is an important

Table 4. Effect of different irrigation regimes and herbicide applications on plant length and green herbage yield.

Irrigation regime	Plant length (cm)			Green herbage yield (kg ha^{-1})		
	With herbicide	Without herbicide	Mean	With herbicide	Without herbicide	Mean
2007						
I-1	204.83	192.17	198.50 a*	44500.0	29083.3	36791.6 a**
I-2	209.83	170.70	190.26 ab	46790.0	24450.0	35620.0 a
I-3	209.03	207.30	208.16 a	36083.3	32833.3	34458.3 a
I-4	189.83	167.90	178.86 b	34706.7	19535.0	27120.8 b
I-5	205.40	181.03	193.21 ab	32166.7	24000.0	28083.3 b
Mean	203.78 a**	183.82 b		38849.3 a**	25980.1 b	
2008						
I-1	203.50	191.23	197.36 a*	46333.3	35755.0	41044.1 a**
I-2	200.40	174.87	187.63 ab	41750.0	25668.3	33709.1 b
I-3	210.73	183.03	196.88 a	37166.7	30686.3	33926.5 b
I-4	189.87	171.17	180.51 b	32333.3	21405.0	26869.1 c
I-5	189.73	175.87	182.80 b	30833.3	21917.0	26375.1 c
Mean	198.87 a**	179.23 b		37683.3 a**	27086.1 b	

* $P < 0.05$, ** $P < 0.01$.

Table 5. Effect of different irrigation regimes and herbicide applications on dry herbage yield and leaf ratio.

Irrigation regime	Dry herbage yield (kg ha^{-1})			Leaf ratio (%)		
	With herbicide	Without herbicide	Mean	With herbicide	Without herbicide	Mean
2007						
I-1	9581.7	5963.0	7772.3 a**	16.47	15.63	16.05
I-2	10951.7	5787.7	8369.7 a	16.20	16.07	16.13
I-3	8343.7	7455.3	7899.5 a	16.43	15.43	15.93
I-4	7201.7	4839.0	6020.4 b	16.90	16.97	16.93
I-5	6737.3	4683.3	5710.3 b	15.70	16.80	16.25
Mean	8363.2 a**	5545.7 b		16.34	16.18	
2008						
I-1	9239.7	6911.7	8075.7 a**	15.50	15.60	15.55
I-2	10758.3	6516.3	8637.3 a	15.90	14.73	15.31
I-3	7999.0	6475.0	7237.0 b	15.87	14.70	15.28
I-4	7154.0	4872.7	6013.3 c	16.93	14.97	15.95
I-5	6188.0	3925.7	5056.8 c	15.17	14.63	14.90
Mean	8267.8 a**	5540.3 b		15.87	14.92	

* $P < 0.05$; ** $P < 0.01$.

factor for the growth of corn. Under the conditions in which water in soil is not a limited factor for cultivation, the atrazine activity increased. In parallel, a better struggle with the weeds could be achieved under these conditions. Therefore, at all irrigation levels, the corn yield was observed at higher levels in the herbicide applied

Table 6. Effect of different irrigation regimes and herbicide applications on stem and ear ratios.

Irrigation regime	Stem ratio (%)			Ear ratio (%)		
	With herbicide	Without herbicide	Mean	With herbicide	Without herbicide	Mean
2007						
I-1	43.73	49.00	46.36	39.77	35.37	37.56
I-2	43.57	42.53	43.05	40.23	41.40	40.81
I-3	48.57	47.80	48.18	35.03	36.77	35.90
I-4	3.17	45.13	44.15	39.83	36.90	38.41
I-5	45.20	47.47	46.33	39.10	35.73	37.41
Mean	44.84	46.38		38.81	37.23	
2008						
I-1	47.70	45.43	46.56	36.80	38.97	37.88
I-2	43.03	46.83	44.93	41.07	38.43	39.75
I-3	45.83	49.43	47.63	38.30	35.87	37.08
I-4	43.83	47.73	45.78	39.23	37.30	38.26
I-5	40.17	49.40	44.8	44.67	35.97	40.31
Mean	44.11 b**	47.76 a		40.01 a**	37.30 b	

** P<0.01

parcels. In such places, where the winter is heavy and the animal production is so high, the increase in the silage corn farming and yield is very important.

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