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Influence of Tillage and Crop Rotation Systems on Economy and Weed Density in a Semi-arid Region

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ABSTRACT

A long-term rotation experiment was established in 2001 to compare conservation or reduced tillage systems (shallow rototiller and chisel tillage) with conventional tillage system using mouldboard plough in a semi-arid region with Mediterranean climate. Field experiments were conducted to determine weed density and profitability of cropping systems in a crop rotation of winter wheat (*Triticum aestivum* L.)-winter vetch (*Vicia sativa* L.) from 2001 to 2004 and winter wheat-winter vetch/summer maize (*Zea mays* L.) from 2004 to 2009. Results indicated that, rototiller markedly increased total weed density, as compared with mouldboard plough, by 72% and 58% in maize and vetch, respectively, while total weed density was statistically similar for the three tillage systems in wheat. Maize yield was significantly higher for rototiller and the lowest for chisel compared to mouldboard plough, but, there were no significant differences in wheat yield between the two tillage systems. Chisel and mouldboard plough resulted in a high yield of vetch in the last five years of the vetch growing season, but there were no significant differences in yield between tillage systems in the first three growing seasons of the crop. Based on market returns, gross margin over production costs were significantly higher for rototiller in wheat and maize when compared with mouldboard plough by 20.7% and 15.3%, respectively. Chisel production costs were similar to rototiller and lower than plough; but, chisel had a gross margin similar to mouldboard plough and higher than rototiller, in both vetch growing seasons. Time savings were 43% and 47% for rototiller and chisel, respectively, as compared with plough in wheat. The corresponding values in vetch and maize were, for rototiller, 46% and 50%, and, for chisel, 28% and 32%, respectively.

Keywords: Crop rotation, Mediterranean, Production costs, Tillage systems, Weed density.

INTRODUCTION

Conservation or reduced tillage practices are among emerging agro-eco-environmental issues in arable lands, particularly in subtropical Mediterranean climate. In western parts of Turkey with a Mediterranean climate, annual rainfall ranges from 350 to 750 mm, with high annual variations. The cropping is largely confined to a single crop per year, either winter wheat (*Triticum aestivum* L.) or barley (*Hordeum vulgare* L.), with an occasional legume (*Vicia sativa* L.) within a rotation cycle, followed by a commonly practiced summer-autumn fallow period. More recently, cereal-legume rotation followed by many other summer crops (e.g. sunflower, maize) has been reported in smaller areas (Ozpinar and Ozpinar, 2009) under conventional tillage systems (e.g. mouldboard ploughing). On the other hand, since 2000, conservation tillage systems have been used by farmers in crop

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production instead of the conventional tillage systems, particularly in small grain cereals; but these systems were used in limited dry areas of the region (Ozpinar and Cay, 2005; Ozpinar, 2006). In comparison with conservation tillage systems, conventional tillage systems decrease annual broadleaved and perennial weed population (Froud-Williams *et al*., 1983; Ozpinar, 2006). However, these systems are known to lower soil quality (Ozpinar and Cay, 2005). In contrast, conservation tillage systems can improve soil quality (Weersink *et al*., 1992) that may eventually lead to an increase in crop yields, depending on soil type and local climatic conditions (Derksen *et al*., 1993). In addition, conservation tillage systems result in cost savings for labour, fuel and farm equipment (Raper *et al*., 1994; Hernanz *et al*., 1995; Ozpinar, 2006), and land preparation (Weersink *et al*., 1992; Blevins and Frye, 1993) and save time (Smart and Bradford, 1999; Meyer-Aurich *et al*., 2006; Bueno *et al*., 2007). In the region, a good deal of research about tillage systems and crop rotations has been conducted (Ozpinar, 2006; Ozpinar and Baytekin, 2006; Ozpinar and Ozpinar, 2009), but there is little information in relation to the weed density in conventional or conservation tillage systems in the context of winter cereals-summer crop rotation. To be economically attractive for farmers, conservation tillage should provide a net economic benefit relative to the conventional tillage, in terms of lower production costs or higher crop yields and net returns (Ozpinar, 2006). In contrast, in other semiarid regions, it has been reported that production costs are higher for conservation tillage systems because of higher herbicide costs (Sánchez-Giron *et al*., 2004) where weed control is difficult (Zentner *et al*., 2002).

The objective of this study was to determine weed density and the long-term economic feasibility of conservation or reduced tillage systems (shallow rototiller and chisel tillage) compared with the conventional mouldboard plough for a winter wheat–winter vetch/summer maize rotation in the western parts of Turkey.

MATERIALS AND METHODS

Experimental Site

Field experiments were initiated in October 2001 at the Dardanos Experimental Area (39° 30'N, 26° 80'E) with a relatively flat area (1-3% slope) on a clay loam soil. The soil in the 0-79 cm depths have a pH of 7.7 (1:2.5 soil: water) and organic C of 4.8 g kg^{-1}. The climate of the area is typically Mediterranean with rainy and partially cold winters and very hot dry summers. Annual rainfall ranges from 350 to 750 mm and is mostly distributed between November and April, receiving 25% of the rainfall in May and October. The average annual temperature is 15.0 °C (Table 1).

Table 1. Total annual rainfall and evaporation and average annual temperature for the experimental period.

Year	Total rainfall (mm)	Total evaporation (mm)	Average temperature (ºC)
2001	765	57.3	16.2
2002	600	45.0	15.7
2003	509	43.6	14.7
2004	505	42.1	15.4
2005	729	40.7	15.1
2006	483	44.0	14.8
2007	590	54.1	16.0
2008	344	36.6	15.6
Ave.	566	45.4	15.4
LT [a]	599	50.0	15.0

[a] LT; long-term (1975-2008).

Tillage and Cropping Experiment

The experiment was conducted in two parts according to the crops grown in the particular years. In the first part, crop rotation in the first three growing seasons i.e. 2001-02, 2002-03, and 2003-04, consisted of winter wheat and winter vetch. During the second part that was carried out in the last five growing seasons i.e 2004-05, 2005-06, 2006-07, 2007-08, and 2008-09, crop rotation consisted of winter wheat and winter vetch/summer maize (variety "*Agromar MF 714*"). Each rotation was managed with mouldboard tillage (MT), chisel tillage (CT), and shallow rototiller tillage (ST) in the experimental plots before sowing of wheat, vetch, and maize. The experiment was laid out as split-plot design with three replications. Tillage systems were in the main plots and the crops were in subplots. The main plots were 80m by 30m in size, while the subplots were 80m by 15m, in which winter wheat and winter vetch were grown in fall. Maize was grown in summer after the vetch forage harvest in eight rows within 80m by 6.10m plots (Table 2). The tillage systems were maintained in the same location throughout the experiment (from 2001 to 2009) with the same plot layout. They were repeated in each growing season following exactly the same procedure, and using the same tractor and machinery. Conventional tillage consisted of mouldboard ploughing to a depth of 20 to 25cm in the fall for wheat and vetch and in the spring for maize. Plots cropped using mouldboard plough received one or more tillage operations following ploughing with a tandem disk harrow to a depth of 8-10cm. Chiselling was performed without any subsequent secondary operation and penetrated the soil to a depth of 25 to 30cm, while rototiller plowed the soil to a depth of 8 to 10cm. A grain drill with 15cm row spacing was used to sow wheat and vetch in all tillage plots. Maize was always sown with 76cm row spacing using a row planter drill. Operating speeds and working widths were obtained from the machines commonly used in the region (Table 3). The time required for crop establishment in each tillage system was determined using ASAE DA97.6 JUN2009 field efficiency data (ASAE, 2009) as a reference (Table 4).

Wheat and vetch were sown in all tillage systems at the rates of, respectively, 210 and 120 kg ha^{-1} corresponding to 422 and 200 seeds m^{-2}, respectively. Maize was sown at a rate of 68 000 seeds ha^{-1} after previously grown vetch had been chopped to be used as green manure. Wheat was sown and harvested on October and June, respectively, in all growing seasons. Sowing and harvesting dates of vetch and maize are presented in Table 2. Starter and top-dressed fertilizer were applied in all tillage systems for wheat and vetch at locally recommended rates with 150-50-0 kg N-P-K ha^{-1} and 50-50-0 kg N-P-K ha^{-1}, respectively. Starter fertilizer was only applied in a band at sowing in all maize tillage plots at a rate of 50-50-0 kg N-P-K ha^{-1}, while no fertilizer was applied after maize sowing. In this region, the maize crop needs between 150 to 200 kgN ha^{-1} of fertilizer during the growing period. Previous studies in this region indicated that a preceding vetch as green manure could provide between 110 to 200 kg N ha^{-1} to the subsequent crop regardless

Table 2. Dates of cultural practices used for winter vetch kill and summer maize.

Practices	2005	2006	2007	2008	2009
Cover crop sowing	28.12.04	07.12.05	08.12.06	24.12.07	28.11.08
Cover crop kill [a]	01.05.05(125)	02.05.06(147)	24.04.07(139)	24.04.08(123)	21.04.09(115)
Maize sowing [b]	12.05.05(12)	11.05.06(9)	09.05.07(15)	07.05.08(13)	07.05.09(16)
Maize harvest [c]	20.09.05(132)	13.09.06(126)	12.09.07(129)	08.09.08(125)	01.09.09(118)

[a] Numbers in parentheses are days from vetch sowing to vetch kill.
[b] Numbers in parentheses are days from vetch kill to maize sowing.
[c] Numbers in parentheses are days from maize sowing to maize harvest.

Table 3. Performance rates for the field machines used.

Machine	Field efficiency (%)	Field speed (km h^{-1})	Working width (m)	Effective field capacity (ha h^{-1})
Mouldboard plough	85	7.0	0.95	0.56
Tandem disk harrow	80	8.0	2.50	1.60
Roller-packer	85	8.0	2.30	1.56
Rototiller	85	5.0	2.06	0.88
Chisel	85	8.0	1.70	1.16
Grain drill	70	8.0	1.93	1.08
Fertilizer spreader	70	8.1	10.00	5.67
Boom-type sprayer	65	6.6	8.00	3.43
Row crop planter	65	8.5	3.04	1.68
Flail shredder	85	4.0	2.30	0.78
Combine	65	5.0	4.19	1.36
Corn picker	65	4.0	2.00	0.52
Forage harvester	70	5.0	2.00	0.70
Baler	75	4.0	4.15	1.25

Field efficiency: ratio of effective field capacity to theoretical field capacity, expressed in percent (ASAE, 2009).

Table 4. Time required for the field machines used by tillage system (h ha^{-1}) [a].

Operation	Timing			Input		
Winter wheat	MT	ST	CT	MT	ST	CT
Mouldboard plough	Oct			1.78		
Tandem disk harrow(2 passes)	Nov			1.76		
Roller-packer	Nov			0.64		
Rototiller		Nov			1.14	
Chisel			Oct			0.87
Grain drill	Oct/Nov	Oct/Nov	Oct/Nov	0.93	0.93	0.93
Starter fertilizer (kg ha^{-1})	Nov	Nov	Nov	250	250	250
Top-dressing fertilizer (kg ha^{-1})	Mar	Mar	Mar	220	220	220
Fertilizer spreader	Mar	Mar	Mar	0.18	0.18	0.18
Boom-type sprayer	Apr	Apr	Apr	0.29	0.29	0.29
Combine	Jun	Jun	Jun	0.73	0.73	0.73
Baler	Jun	Jun	Jun	0.8	0.8	0.8
Total				7.11	4.07	3.80
Winter vetch						
Mouldboard plough	Oct			1.78		
Tandem disk harrow(2 passes)	Dec			1.76		
Roller-packer	Dec			0.64		
Rototiller		Dec			1.14	
Chisel			Oct			0.87
Grain drill	Nov/Dec	Nov/Dec	Nov/Dec	0.93	0.93	0.93
Starter fertilizer (kg ha^{-1})	Dec	Dec	Dec	250	250	250
Combine	Jun	Jun	Jun	0.73	0.73	0.73
Baler	Jun	Jun	Jun	0.8	0.80	0.8
Total				6.64	3.60	3.33
Summer maize						
Flail shredder		Apr	Apr	1.28	1.28	1.28
Green manure (Mg ha^{-1})	Apr	Apr	Apr	32	32	32
Starter fertilizer (kg ha^{-1})	May	May	May	250	250	250
Mouldboard plough	May			1.78		
Tandem disk harrow(1 passes)	May			0.63		
Roller-packer	May			0.64		
Rototiller		May			1.14	
Chisel			May			0.87
Row crop planter	May	May	May	0.6	0.6	0.6
Corn picker	Sept	Sep	Sep	1.92	1.92	1.92
Total				6.85	4.94	4.67

[a] ST: rototiller (shallow) tillage, MT: conventional tillage with mouldboard plough, CT: chisel tillage.

of tillage systems (Ozpinar and Baytekin, 2006).

All wheat plots received a post-emergence application of 600 ml ha^{-1} of fenoxaprop-pethyl (75g a.i./l) or propaquizafop (100g a.i./l) for weed control, while vetch did not receive any herbicide application. For maize, 2.4 D-Amine (at 500ml ha^{-1}) was applied through pre-emergence. Hand hoeing was done to control weeds between and above maize rows in the experimental area.

Crops and Weed Measurements

Wheat was hand-harvested for grain yield from a $3m^2$ harvested area in each plot and the grain yields were determined when the grain water content was 102 g kg^{-1}. From 2005, half of the vetch plot crop (7.5m wide x 80m long) was harvested for green manure at the end of April or at the beginning of May when it was at the flowering stage. The rest of the vetch plot (7.5m wide x 80m long) was harvested for grain at the beginning of June from 3 m^2 at the 100 g kg^{-1} grain water content. In the maize plots, grain yield was determined by hand-harvesting the ears in September (Table 2) from each of two rows of 5m length with three replications for each plot. The kernels from the ears were removed, weighed, and the grain water content of 155 g kg^{-1} was determined.

For maize, the weed density per unit area was counted twice at 10-day intervals in August. In wheat and vetch, weeds were counted from early January to late April twice monthly. Each time, the emerged weed seedlings were identified as to the species, counted, and then removed. The number of weeds determined in each sampling time was summed as cumulative, 8 years after initiating the study for wheat and vetch. Weed data for each crop included only the 2009 growing season.

Separate analyses were carried out for wheat, vetch, and maize weed data over the last experimental season for individual weed species. The statistical analysis software MSTAT-C was used to analyse the data for a split-plot design arrangement. The analysis of variance (ANOVA) was used to determine the effects of the tillage treatment on all measurement parameters (yield, weed density, input, and output, etc.) of wheat, vetch and maize cropping. The LSD test was carried out to analyse mean square errors at $P<0.05$ level of significance.

Economic Analysis

For economic analysis of the different tillage systems, data were collected on labour input and costs for the various operations, such as land preparation and crop management, (Ozpinar, 2006) for each of the studied crops. Later, market prices of outputs, such as the main product and the by-product (Table 5), and inputs, icluding seeds and fertilizers, (year 2009), and the costs of the different mechanised operations hired from machinery co-operatives were considered in order to determine production costs. The total labour input was calculated in man/woman-hours as the sum of labour involved in all of the operations for each treatment averaged over the years (Table 5). Labour estimates were directly associated with field operations, and did not include time spent in management activities, equipment repairs, and crop scouting. Labour was valued according to the regulations of the Turkish Ministry of Labour and Social Security.

Gross income was calculated by taking into account the main product and the by-product. On arriving at the gross margin, the total cost and the gross income were evaluated together and were calculated as plot yield (kg ha^{-1}) x price of the crop (Euro per kilogram) minus the total cost of crop production (Table 5). The results of the economic analysis for the three tillage systems were based on the average of eight years for wheat (2001-2009) and five years for maize (2005-2009), while they were based on the average of the first three years (2001-2004) and the last five years (2004-2009) for vetch. Similar inputs in each experimental year were used under the three tillage systems for the crops studied; thus, production costs within each year were

Table 5. Summary of selected inputs cost (€).

Particulars	Unit	Cost
(A) Inputs		
1.Human labour		
(a)Adult man	hour	4.15
(b)Woman	hour	2.31
2.Seed		
(a)Wheat	kg	0.23
(b)Vetch	kg	0.55
(c)Maize	kg	18.01
3.Chemical fertilizers		
(a)Nitrogen	kg	0.65
(b)Phosphate (P_2O_5)	kg	0.42
(c)Potash (K_2O)	kg	0.65
(d)Green manure	kg	0.50
4.Chemicals		
(a)Fenoxaprop-pethyl	kg	115.31
(b)2.4 D-Amine	kg	4.6
(c)Propaquizafop	kg	115.31
5.Land rental	ha	691.88
6.Land preparation charges		
(a)Mouldboard plough	ha	138.38
(b)Chisel	ha	124.54
(c)Rototiller	ha	115.31
(d)Tandem disk harrow	ha	119.93
(e)Roller-packer	ha	9.23
(f) Grain drill/fertilizing	ha	161.44
(g)Row crop planter/fertilizing	ha	175.15
(h)Boom-type sprayer	ha	230.63
(i)Fertilizer spreader	ha	115.21
(j)Combine/Corn picker	ha	64.58
(k) Flail shredder	ha	57.60
(l)Baler	Mg	23.90
(B)Outputs		
1.Main product (grain)		
(a)Wheat	kg	0.23
(b)Vetch	kg	0.55
(c)Maize	kg	0.35
2.By-product (dry mass)		
(a)Straw (wheat)	kg	0.49
(b)Straw (vetch)	kg	1.34
(c)Stover (maize)	kg	0.49

essentially the same. The cost of each type of cultivation was determined using hiring prices in the area. Accordingly, hiring costs for each equipment were included through their last year of use (Table 5). All costs are calculated using current (2009) prices. Inputs and crop prices are taken from the Turkish Statistical Institute (TurkStat, 2009).

RESULTS AND DISCUSSION

Weather Conditions

Generally, soil was quite dry coming into September and October before wheat and vetch sowing period, as would be expected from previous months (April-September) with only small rainfall rate (24%) over the long-term period (1975-2008) (Table 1). In the maize sowing period, the dry weather also prevailed from late April to early June, leading to dry soil at seeding time. Growing season (November-June) rainfall for wheat and vetch over the 8-year study period averaged 483.6 mm, which was lower than the long-term mean of 507.3mm for the region. However, growing season rainfall (November-June) was 49% higher in 2001-02 and 26% higher in 2005-06, compared with the long-term average, while it was 56% less in 2008-09. Considering the maize growing season, 16% of the long-term rainfall falls between May and September, but evaporation highly exceeds rainfall throughout the year. Therefore, maize was irrigated by furrows and the amount of irrigation water varied from year to year depending on the growing season climatic conditions.

Weed Density

Mean weed density and richness for eight seasons of wheat and vetch (2001 to 2009) and five seasons of maize (2005 to 2009), under the three tillage systems, are presented in Table 6. Total of 10, 8 and 6 weed species were identified in wheat, vetch, and maize, respectively, regardless of the tillage used. In all cases, fewer of the weed species were monocotyledons, while most of them were annual dicotyledons. Monocotyledons were only *Phalaris paradoxa* L. and *Avena fatua* L., which was reduced by up to 90% when

Table 6. Mean density (weeds m^{-2}) of weed species for winter wheat and winter vetch (2001 to 2009), and for summer maize (2005 to 2009) growing seasons under three tillage systems [a].

Species	Class	Tillage (mean±S.E.) [b] ST	MT	CT	LSD (*P*<0.05)	F-value [d]
Wheat cropping						
Avena fatua L.	Monocotyledon	5(±0.88)a [c]	2(±0.58)b	4(±0.58)a	NS	
Convolvulus arvensis L.	Dicotyledon	8(±4.67)	7(±2.65)	12(±9.17)	NS	
Galium aparine L.	Dicotyledon	11(±4.33)	2(±1.20)	13(±8.08)	NS	
Lamium amplexicaule L.	Dicotyledon	4(±3.67)	0(±0.00)	4(±2.60)	NS	
Malva spp.	Dicotyledon	1(±0.58)	0(±0.00)	0(±0.00)	NS	
Matricaria perforata L.	Dicotyledon	63(±32.54)	19(±7.97)	31(±1.53)	NS	
Papaver rhoeas L.	Dicotyledon	0(±0.33)	1(±1.00)	0(±0.33)	NS	
Phalaris paradoxa L.	Monocotyledon	1(±0.67)	0(±0.00)	0(±0.00)	NS	
Sinapis arvensis L.	Dicotyledon	2(±0.33)a	0(±0.33)b	1(±0.00)ab	1.2	3.3*(75.0)
Veronica persica Poiret	Dicotyledon	25(±10.48)ab	10(±0.33)b	99(±34.56)a	77.9	6.6*(82.6)
Total		120(±30.30)	39(±2.90)	164(±46.40)	NS	
Number of species		8	6	6		
Vetch cropping						
Avena fatua L.	Monocotyledon	36(±4.51)	15(±2.40)	14(±1.53)	NS	
Convolvulus arvensis L.	Dicotyledon	18(±10.84)a	3(±2.03)b	4(±3.38)b	25.8	1.5* (131.0)
Galium aparine L.	Dicotyledon	0(±0.33)	2(±2.33)	0(±0.00)	NS	
Lamium amplexicaule L.	Dicotyledon	4(±3.67)	1(±1.33)	1(±0.67)	NS	
Matricaria perforata L.	Dicotyledon	74(±28.68)	44(±6.94)	17(±5.81)	NS	
Phalaris paradoxa L.	Monocotyledon	4(±3.51)	0(±0.33)	0(±0.00)	NS	
Sinapis arvensis L.	Dicotyledon	3(±3.33)	0(±0.33)	1(±0.00)	NS	
Veronica persica Poiret	Dicotyledon	32(±22.92)a	7(±5.00)b	0(±0.33)c	55.6	1.4*(185.3)
Total		171(±30.20)a	72(±5.70)b	37(±8.50)b	73.9	13.6*(34.8)
Number of species		7	6	5		
Maize cropping						
Convolvulus arvensis L.	Dicotyledon	11(±2.67)a	0(±0.00)b	2(±0.88)b	6.2	9.7*(77.4)
Phalaris paradoxa L.	Monocotyledon	2(±0.00)a	0(±0.00)b	0(±0.33)b	1.2	3.5*(99.2)
Sinapis arvensis L.	Dicotyledon	1(±0.33)	1(±0.33)	0(±0.00)	NS	
Solanum nigrum L.	Dicotyledon	5(±1.20)	4(±0.33)	2(±1.20)	NS	
Veronica persica Poiret	Dicotyledon	11(±1.53)a	0(±0.00)c	2(±0.58)b	NS	
Xanthium spinosum L.	Dicotyledon	10(±2.89)	6(±1.45)	8(±1.73)	NS	
Total		40(±1.80)a	11(±1.50)b	14(±2.30)b	7.5	71.4*(15.7)
Number of species		5	3	3		

[a] Means in each row followed by the same lower case letter are not significantly different (*P*<0.05).
[b] ST: rototiller (shallow) tillage, MT: conventional tillage with mouldboard plough, CT: chisel tillage.
[c] Values in the parenthesis represent standard error (S.E.).
[d] Values in the parenthesis represent coefficient of variation (CV, %).

mouldboard ploughing was used (Lintell-Smith *et al.*, 1999). Among the dicotytledons, *Matricaria perforata* L. was the non-seasonal weed observed mostly in winter cereals with shallow tillage (Ozpinar, 2006).

Except two weed species that had densities equal to, or below, 1 weed m^{-2}, all of the weeds densities were equal to, or above, 5 weeds m^{-2} in wheat and vetch (Table 6), regardless of the tillage systems used. All of the observed weeds were common weeds of the region, as concluded in a previous study (Ozpinar, 2006). In wheat, *Veronica persica* Poiret was found significantly higher in the chisel and rototiller plots than in the mouldboard plough, while, in the case of vetch, this species was higher only in the rototiller than in plough. The density of this species in chisel and rototiller wheat plots was, respectively, more than ten-fold and three-fold higher than in mouldboard plough treatment. The same species was observed to be approximately five-fold higher in rototiller compared with plough in vetch, while no count was found in chisel. *Sinapsis arvensis* L. in wheat grown under rototiller and chisel in this region was also found significantly higher, similar to the results reported by Ozpinar (2006). Perennial species, *Convolvulus arvensis* L., was observed to be higher in rototillered vetch plots than in the plough treatment, with, respectively, 18 and 3 weeds m^{-2}. Increased soil disturbance using the mouldboard plough often results in a decreased number of weed species, while conservation or reduced tillage systems have been found to have more perennial weed densities, such as *Convolvulus arvensis* L. (Cardina *et al*., 1991; Buhler *et al*., 1994; Håkannson, 1995). In addition, several weed species, especially the winter annuals, were apparently favoured by the omittance of mouldboard ploughing (Håkansson, 1995).

Considering maize cropping, there was a general increase in weed density with conservation tillage for individual weed species. The most dominant weed species in maize were perennial *Convolvulus arvensis* L. species and annual *Veronica persica* Poiret L. and *Xanthium spinosum* L. regardless of the tillage systems. On the other hand, with respect to *C. arvensis* and *P. paradoxa,* there were a significant difference between tillage systems when rototiller increased significantly these species density compared with the plough and the chisel. The intensity of soil disturbance in the mouldboard plough treatment decreased the number of emerging weeds (Håkansson, 1995), while the degree of soil disturbance was less under rototiller and chisel plough treatments. The latter tillage practices generally result in an increase in the occurrence of perennial weeds, such as *C. arvensis* (Froud-Williams *et al*., 1983; Stevenson *et al*., 1998; Buhler *et al*., 1994). Buhler *et al.* (1994) also reported that *C. arvensis* developed more after a long-term period of reduced tillage systems than in a mouldboard plough system with maize. Similarly, Guncan (1980) found a total of 75 weeds m^{-2}, but the dominant weed species was *C. arvensis* with 8.5 weeds m^{-2} having the highest density in the Eastern Turkey region, where winter is slightly colder than the area of the present study. It was determined that *X. spinosum* was the only species with a greater weed number in reduced tillage than in conventional tillage (Mas and Verdu, 2003), because mouldboard ploughing decreases the germination potential of fresh weed seeds by burying them in the subsoil layer (Roger-Estrade *et al*., 2001). In contrast, shallow or direct drilling practices tend to maintain a greater proportion of fresh weed seeds near the soil surface.

Taking into account the total number of weeds, rototiller recorded a significantly higher weed density in vetch, with 171 weeds m^{-2}, compared with mouldboard plough, with 72 weeds m^{-2}, and chisel, with 37 weeds m^{-2}. But, there were no significant differences in weed density among tillage systems in wheat. In maize, rototiller plot had the highest weed density at 40 weeds m^{-2}, while mouldboard plough had the least, with 11 weeds m^{-2}. The lower weed density recorded for mouldboard plough compared with rototiller and chisel might be attributed to the effect of mouldboard plough resulting in good weed control during spring land preparation for maize. In addition, there was a general increase in the winter weed species (annual) under the reduced tillage system, as also reported by other authors (Cardina *et al*., 1991; Buhler *et al*., 1994).

In an earlier study with wheat conducted in this region by Ozpinar (2006), some dominant weed species were reported including *Fumaria officinalis* L., *Polygonum aviculare* L., *Raphanus raphanistrum* L., *Lathyrus sativus* L. These are generally found in any tillage systems; especially where mouldboard plough is used. However, those weeds were not observed in the present study. This was probably due to the effect of repeated tillage with mouldboard plough throughout the eight-year experimental period that significantly reduced the germination of those weeds. Moreover, cereal-legume rotation over the eight-year long-term experiment may also be an effective weed management practice. This rotation may change the disturbance patterns for problematic weed species that are well adapted to practices associated with a single crop. Further, the use of crop rotation during the last five-year experimental period, including cereal-legume/maize rotation, could have reduced weed density since the rotation involved a winter and a summer crop (Unger *et al*., 1999). Håkansson (1995) also concluded that soil disturbance, such as tillage of only the topsoil in the autumn, primarily stimulated germination of winter annual weeds, while the influence on summer annuals was limited. It has also been reported that vetch reduced weed occurrence harvested as green manure (Stevenson *et al*., 1998).

Grain and Straw/Stover Yield

The eight-year average showed that tillage systems did not affect wheat grain yield, but they had a significant effect on wheat straw ($P<0.05$, Table 7). Wheat straw was the highest under rototiller, which was higher by 19% and 25%, as compared with plough and chisel, respectively. Our findings agree with those reported by other researchers who found that overall grain yield of wheat was unaffected by the tillage systems (e.g. Al-Issa and Samarah, 2006). It has also been reported that a conservation tillage system using a chisel gave the lowest wheat grain and straw yield. On the contrary, Ghosh *et al.* (2006) found higher wheat grain yield under deep tillage than under shallow tillage systems in a clay loam soil.

The tillage system significantly influenced vetch grain yield ($P<0.05$, Table 7) through the last five years of the study, although there were no significant differences among tillage systems for vetch straw yields in both study periods. However, there were no differences between tillage systems in terms of the average vetch grain yield during the first three years period. In the last five years, the average vetch grain yield was significantly greater under plough by 5% and 26% than chisel and rototiller, respectively. Rototiller produced the lowest vetch grain yield in the last five years compared with mouldboard plough and chisel. This can be attributed in greater weed density under rototiller, as shown in Table 6, with decreased vetch yields. Small differences were found between chisel and plough throughout the last five growing seasons of vetch, when chisel appeared to give yields at least equal to those with mouldboard plough. On the other hand, rainfall during the two months before flowering was the principal determinant of the annual legume forage and grain yields in a Mediterranean continental environment (Caballero *et al*., 1998).

Five-year averages of the maize grain obtained under the three tillage systems studied demonstrated that rototiller resulted in a grain yield similar to the plough treatment, but higher compared to the chisel (Table 7). While there are slight yield differences between the plough and the chisel, the rototiller yielded 8% and 20% more, respectively. The higher grain yield for rototiller may in part be related to higher soil water content throughout the soil profile (Ozpinar, 2010), which seems to be a more important determinant for maize yields in contrast to cereals (Fischer *et al*., 2002). Another possible reason was the higher penetration resistance registered under plough at 20 to 30cm soil depth, which coulc cause a grain yield decrease (Ozpinar, 2010). Ozpinar and Ozpinar (2009) reported that maize grain yields were increased when it was grown after vetch, probably due to the cover crop N supply as green manure. Fischer *et al.* (2002) also reported that maize grown after vetch had greater yield compared with the other rotations. Dou *et al.* (1994) emphasized that N supplied by green manures left on the soil surface during the

Table 7. Means of yield, gross income, gross margin, labour input, and production costs of wheat, vetch, and maize as affected by tillage systems [a] [a].

Data	Growing	Tillage[b]				
Mean yield (kg ha^{-1})	season	ST	MT	CT	LSD (P<0.05)	F-value [b]
Wheat grain	(2001-2009)[c]	4355	4150	4134	NS	
Maize grain	(2004-2009)[e]	11787a	10861ab	9452b	1894.0	5.9*(7.8)
Vetch grain	(2001-2004)[d]	2344	3593	3764	NS	
	(2004-2009)[e]	1200b	1628a	1543ab	343.7	6.7*(10.4)
Wheat straw	(2001-2009)	18012a	14586b	13456b	1262.0	54.5*(3.6)
Maize stower	(2004-2009)	8467a	8245a	6366b	1716.0	6.9*(9.8)
Vetch straw	(2001-2004)	4347	4632	4605	NS	
	(2004-2009)	3834	4905	4391	NS	
Mean gross income (€ ha^{-1})[f]						
Wheat	(2001-2009)	12876a	11006b	10438b	1440.0	12.1*(5.6)
Maize	(2004-2009)	20061a	18702b	15880c	1894.0	19.5*(4.6)
Vetch	(2001-2004)	9125	10326	10372	NS	
	(2004-2009)	7572c	9744a	8731b	752.4	32.1*(3.8)
Total labour input (€ ha^{-1})[g]						
Wheat	(2001-2009)	291b	387a	235c	36.1	69.7*(5.2)
Maize	(2004-2009)	671b	768a	616c	19.1	252.2*(1.2)
Vetch	(2001-2004)	194b	291a	157c	23.6	133.5*(4.9)
	(2004-2009)	194b	291a	157c	23.6	133.5*(4.9)
Total costs (€ ha^{-1})						
Wheat	(2001-2009)	2061b	2429a	2012b	62.9	202.5*(1.3)
Maize	(2004-2009)	8130b	8596a	8028c	87.7	183.9*(0.5)
Vetch	(2001-2004)	841b	1217a	820b	314.5	10.4*(12.7)
	(2004-2009)	829b	1224a	815b	283.5	8.4*(14.5)
Mean gross margin (€ ha^{-1})[h]						
Wheat	(2001-2009)	10815a	8577b	8426b	783.4	44.9*(3.7)
Maize	(2004-2009)	11931a	10106b	7851c	1113.0	5.1*(15.8)
Vetch	(2001-2004)	8284b	9109ab	9552a	1144.0	4.9*(5.6)
	(2004-2009)	6743b	8514a	7950a	946.8	14.1*(5.4)

[a] Based on prices given in Table 5 for inputs and outputs.
[a] Means within rows followed by the same letter are not significantly different (P<0.05).
[b] ST: rototiller (shallow) tillage, MT: conventional tillage with mouldboard plough, CT: chisel tillage.
[c] Average for the eight growing seasons (from 2001-2002 to 2008-2009).
[d] Average for the first three years of the growing seasons (from 2001-2002 to 2003-2004).
[e] Average for the last five years of the growing seasons (from 2004-2005 to 2008-2009).
[f] Mean gross income calculated as (crop yield, kg ha^{-1}) x (crop price per kilogram, 2009 year).
[g] It includes labour input for all operations from tillage to harvest; tillage, seedbed preparation, fertilizer and herbicide charges, cultivation practices during the growing seasons and harvest operations.
[h] Mean gross margin calculated as (gross income) - (production costs).
[b] Values in the parenthesis represent coefficient of variation (CV) (%).

first year of a field experiment was insufficient for reaching maximum maize growth. These yield responses to tillage systems are in general agreement with those reported elsewhere in other soil and climatic conditions (e.g. Hernanz *et al*., 1995). They observed that, in the long-term, maize grain yield was more in conservation tillage than in mouldboard plough tillage. In contrast, others found that, in the short-term, yield of maize grain by mouldboard plough was higher than that of the conservation tillage (Sarrantonio and Scott, 1988).

Economic Analysis

Time input

Tables 3 and 4 show the effective field efficiency and the operation times of the machinery used for the three crops in each of the studied tillage systems. For wheat tillage, the eight-year average of time savings by chisel and rototiller were 47% and 43% (3.31 and 3.04 h ha^{-1} less), respectively, as compared to the mouldboard plough. In the two rounds of the study i.e.2001-2004 and 2004-2009, the time required for all field operations of vetch, from land preparation to harvest, was found to be similar since the same operations were applied in all tillage systems throughout the study and the time spent for each growing season was assumed to be the same. Here again, operation time was less for chisel and rototiller by 3.31 and 3.04 h ha^{-1} i.e. 50% and 46% reduction, respectively, compared with mouldboard plough. Corresponding values for maize were 2.18 and 1.91 h ha^{-1} less, meaning a 32% and 28% reduction, as compared to plough. Time saving is particularly relevant under the soil conditions of the study area due to more time being available for operations after mouldboard plough is performed. Double disking and roller-packer operations increased the time required to establish the crop with mouldboard plough. Rototiller and chisel tillage systems improved the timeliness of crop establishment, because these practices can be performed quicker and at the optimal time. Field practices performed quicker in conservation tillage systems resulted in reduced operator time requirements because of fewer trips to the corresponding plots compared with the conventional tillage systems (Smart and Bradford, 1999). These findings were in agreement with those reported by other researchers (Hernanz *et al.*, 1995; Bueno *et al.*, 2007) who found that conservation tillage systems involved time savings of 65% for crop production, as compared to conventional tillage systems, while others indicate chisel ploughing requires only half of the working time of mouldboard ploughing (Meyer-Aurich *et al.*, 2006).

Labour input

Labour input is one of the important factors in the feasibility of cropping systems. It may also be an indicator of the sustainability of alternative systems. In this study, labour inputs were variable across tillage systems. The highest labour input for wheat was with mouldboard plough, while chisel required the least (Table 7). Labour input was 291 and 235 € ha^{-1} less for rototiller and chisel, corresponding to, respectively, 25% and 39% reduction in costs compared with mouldboard plough, which cost 387 € ha^{-1}. In the case of vetch, similar to the assumption made for tillage operation time, the labour input was assumed to be the same in both the first three and the last five growing seasons. The labour input for vetch was found to be nearly similar in rototiller and chisel (Table 7), while mouldboard plough needed, respectively, 33% and 46% more. This increased use of labour in mouldboard plough compared with rototiller and chisel is, primarily due to its larger number of field operations, especially in seedbed preparation, while rototiller and chisel required less time for field operations. Similar results were obtained for maize labour input (Table 7), which had a generally higher labour input due to hand hoeing. The labour savings of rototiller and chisel indicate that a producer might be able to farm more hectares than in the case of mouldboard plough. However, this depends on whether the labour savings occur at times when labour is a limiting factor. The findings of this study were similar to those of Raper *et al*. (1994) who found that labour inputs were lower with reduced tillage than with conventional tillage. Weersink *et al*. (1992) also reported that the reductions in labor input associated with the reduced tillage systems indicated that labour costs could be reduced by up to 61% annually compared with a moldboard plough system.

Costs

The total costs averaged over the years showed differences between the tillage systems (P<0.05) for the individual crops grown in the experimental plots, as shown in Table 7. For wheat, mouldboard plough resulted in the highest costs, while no differences were found between chisel and rototiller. Cost savings in chisel and rototiller compared with mouldboard plough were 17.2% and 17.0%, respectively, a lower value than reported by Hernanz *et al.* (1995). Similarly, Bueno *et al.* (2007) reported 13.7% cost savings in conservation tillage compared with the conventional tillage. The reason for higher costs in mouldboard plough can be attributed to the ploughing of the field before seedbed preparation, and then harrowing of the field twice for the preparation of the seedbed at sowing time. This, coupled with the high rates charged for tractor services, resulted in the highest costs, whereas rototiller and chisel had similar cost as a result of the same tractor service. Similar results for wheat costs were obtained for vetch. Compared with mouldboard plough, rototiller cost savings were 30.8% and 32.3% for vetch in the first three- and the last five-years of the study, respectively. The corresponding savings for chisel were 32.6% and 33.4%. For maize, the five-years average of cost savings in rototiller and chisel were, respectively, 5.4% and 6.6% higher than the mouldboard plough (Table 7), compared to which, the use of conservation tillage systems in fall and spring seedbed preparation required lower expenditures for machine operations and labour. The savings in machine-related costs with conservation tillage systems arise from a lower number of field operations for seedbed preparation and result in savings of time and labour. These results are supported by Al-Issa and Samarah (2006), who reported that conservation tillage production costs could be lower and the yield profitability higher than conventional tillage for wheat. It was also reported that chisel tillage reduces production costs by 24% compared with conventional tillage (Hernanz *et al*., 1995). Similarly, Raper *et al*. (1994) and Smart and Bradford (1999) indicated that ploughless tillage systems reduce the number of field operations, which results in cost savings for labour, fuel, and farm equipment. However, these findings were in contrast to those reported for a drier environment (Zentner *et al*., 1992), where the total costs of producing most individual crops using conservation practices were generally higher compared to the use of conventional practice because of higher herbicide costs (Sánchez-Giron *et al*., 2004).

The results also indicated that mouldboard plough resulted in higher costs than rototiller and chisel for all crops grown. This can be explained by the fact that more fuel per unit area is necessary in the case of mouldboard plough, which charges high rates for tillage operations, keeping in mind that all plots receive the same amount of seed, fertilizer, and chemicals for cultivation practices during the growing season, since plots are only different in the number of tillage and operation charges in terms of fuel and time consumption.

Gross Income and Margins for Each Crop

Gross income and gross margin of wheat, maize, and vetch are presented in Table 7 for the first three- and the last five- years of the study. Gross income for maize (averaged over five years), vetch (averaged over five years) and wheat (averaged over eight years) were affected (P<0.05) by the tillage systems. But, there were no significant differences among the tillage systems in the first three growing seasons of vetch. Chisel and rototiller provided a similar gross income for wheat when comparing the tillage systems, while rototiller increased wheat and maize gross income. However, gross income in the last five years of the vetch growing season was significantly increased only in mouldboard plough, which was about 10% and 22% higher than chisel and rototiller, respectively. Fewer differences between plough and chisel in terms of vetch gross income, particularly in the first three years, could be due to similar results in vetch grain and straw yields under chisel and plough (Table 7), although there were no significant differences among tillage systems for vetch grain and straw yields in the first three growing seasons.

When considering the benefits of the three tillage systems in terms of gross margin, rototiller was found to have the highest gross margin and both moldboard plough and chisel had the lowest for wheat averaged over the eight years of the growing seasons (Table 7). Similarly, the highest gross margin, averaged over the five years of the maize growing season, was found in rototiller compared with mouldboard plough and chisel. In vetch, chisel provided the highest gross margin for the first three years of the vetch growing season, whereas the gross margin was significantly increased in both mouldboard plough and chisel systems in the last five years of the vetch growing season. Rototiller had the lowest gross margin both in the first three years and in the last five years of the vetch growing seasons. The reduced gross margin of rototiller could be attributed to the highest weed population, such as *Convolvulus arvensis* and *Veronica persica* Poiret, in this treatment with vetch. Although the vetch gross income for plough compared with chisel was the highest in the last five years of the growing season (Table 7), chisel still resulted in a gross margin almost similar to mouldboard plough in both part of the vetch growing seasons. However, all tillage systems provided a similar gross income in the first three years of the vetch growing season, though chisel provided slightly higher gross margin than plough in the same growing season. This is due to the high rates charged for tractor services and the fact that, in the case of a tractor, the land has to be prepared before the seedbed, resulting in more field traffic in mouldboard plough plots. However, Chase and Duffy (1991) found that the mouldboard plough had a greater gross margin than the chisel, particularly under continuous maize, while the gross margin under mouldboard plough was similar to that under chisel tillage in crop rotation. In contrast, Ghosh *et al.* (2006) concluded that gross income from deep tillage was greater than that for shallow tillage in a clay loam soil. For the farmers in semiarid environment, rototiller looks more promising since it conserves the soil moisture due to rainfall and, therefore, it is more productive than mouldboard plough for wheat and maize (Ozpinar, 2010). Most studies agree that conservation tillage systems reduce input costs such as fuel, labour, and machinery repair and depreciation (Raper *et al*., 1994; Smart and Bradford, 1999). However, in most cases, there is an increase in herbicide costs and a decrease in yield when a conservation tillage system is used (Sánchez-Giron *et al.*, 2004).

CONCLUSION

This study assessed the weed density and the economic feasibility of two conservation tillage systems compared with mouldboard ploughing for winter wheat, winter vetch, and summer maize under semi-arid climatic conditions in western Turkey. The experimental analysis was based on eight years data (2001-2009) of wheat, five years (2004-2009) of maize, and eight years (divided into two parts: 2001-2004 and 2004-2009) for vetch. In the last five years of the experiment, rototiller increased total weed density in vetch and maize, while no differences were found between mouldboard plough and chisel in both crops. Rototiller gave the highest straw yield and gross margin among the studied tillage systems in wheat, while the highest maize grain and stover yield were observed in rototiller treatment. As compared with mouldboard plough, rototiller save time and labour by, respectively, 28% and 13%, 43% and 25%, 46% and 33% for maize, wheat, and vetch, respectively. On the other hand, in the case of vetch, chisel and plough provided higher gross margins compared with rototiller. Rototiller gave the largest average maize gross margin compared with mouldboard plough over the experimental years. Considering the fact that the study was carried out in an area with Mediterranean climate and about 80% of semi-arid land, the rototiller system, or shallow seedbed preparation, can easily be adopted for winter or summer crops to increase economic crop production, regardless of weed occurrence in this system. These findings also show that the use of rototiller in semi-arid areas for cereal production, as is common in this region, may be economically favourable, combined with herbicide application. The reason is that yield and gross margin are higher than that of mouldboard plough, while production inputs requirements are lower. Further information is required from more crop cycles to determine whether there is any tendency for tillage systems to influence weed density and economic feasibility in this region.

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REFERENCES

1. Al-Issa, T. A., Samarah, N. H. 2006. Tillage Practices in Wheat Production under Rainfed Conditions in Jordan: An Economic Comparison. *World J. Agricultural Sci.* **2**: 322-325.
2. ASAE, 2009. Standard D497.6 JUN2009: Agricultural Machinery Management Data. ASABE Standards 2009: Standards Engineering Practices Data. American Society of Agricultural and Biological Engineers, St. Joseph, MI, USA.
3. Blevins, R. L., Frye, W. W. 1993. Conservation Tillage: an Ecological Approach to Soil Management. *Adv. Agron*. **51**: 33-76.
4. Bueno, J., Amiama, C., Hernanz, J. L. 2007. No-tillage Drilling of Italian Ryegrass (*Lolium multiflorum* L.): Crop Residue Effects, Yields and Economic Benefits. *Soil Till Res*. **95**: 61-68.
5. Buhler, D. D., Stoltenberg, D. E., Becker, R. I., Gunsolus, J. L. 1994. Perennial Weed Populations after 14 Years of Variable Tillage and Cropping Practices. *Weed Sci.* **42**: 205-209.
6. Caballero, R., Rebolé, A., Barro, C., Alzueta, C., Ortiz, T. 1998. Aboveground Carbohydrate and Nitrogen Partitioning in Common Vetch During Seed Filling. *Agron. J.* **90**: 97-102.
7. Cardina, J., Regnier, E., Harrison, K. 1991. Long-term Tillage Effects in Seed Banks in Three Ohio Soils. *Weed Sci*. **39**: 186-194.
8. Chase, C. A., Duffy, M.D. 1991. An Economic Analysis of the Nashua Tillage Study. *J. Prod. Agric.* **4**: 91-98.
9. Derksen, D. A., Lafond, G. P., Thomas, A. G., Loeppky, H. A., Swanton, C. J. 1993. Impact of Agronomic Practices on Weed Communities: Tillage Systems. *Weed Sci*. **41**: 409-417.
10. Dou, Z., Fox, R. H., Toth, J. D. 1994. Tillage Effect on Seasonal Nitrogen Availability in Corn Supplied with Legume Green Manures. *Plant Soil.* **162**: 203-210.
11. Fischer, R. A., Santiveri, F., Vidal, I. R. 2002. Crop Rotation, Tillage and Crop Residue Management for Wheat and Maize in the Sub-humid Tropical Highlands. II. Maize and system performance. *Field Crops Res.* **79**: 123-137.
12. Froud-Williams, R. J., Chancellor, R. J., Drennan, D. S. H. 1983. Influence of Cultivation Regime upon Buried Seeds in Arable Cropping Systems. *J. Appl. Ecol*. **20**: 199-208.
13. Ghosh, P. K., Mohanty, M., Bandyopadhyay, K. K, Painuli, D. K., Misra, A. K. 2006. Growth, Competition, Yield Advantage and Economics in Soybean/ Pigeonpea Intercropping System in Semi-arid Tropics of India. I. Effect of subsoiling. Field *Crops Res.* **96**: 80-89.

14. Guncan, A. 1980. Die Unkrautdichte in der Umgebung von Erzurum im Getreideanbau und der Nachrstooffentzug Durch Einige Unkraeuter aus dem Bodem. *The J. of Turkish Phytopathlology*. **9**: 1-19.
15. Håkansson, S. 1995. Weeds in Agricultural Crops. 1. Life-forms and occurrence under Swedish conditions. *Swedish J. Agric. Res*. **25**: 143-154.
16. Hernanz, J. L., Girón, V. S., Cerisola, C. 1995. Long-term Energy Use and Economic Evaluation of Three Tillage Systems for Cereal and Legume Production in Central Spain. *Soil Till Res*. **35**: 183-198.
17. Lintell-Smith, G., Freckletn, R. P., Firbank, L. G., Watkinson, A. R. 1999. The Population Dynamics of *Anisantha steilis* in Winter Wheat: Comparative Demography and the Role of Management. *J. Appl. Ecol*. **36**: 455-471.
18. Mas, M. T., Verdu, A. M. C. 2003. Tillage System Effects on Weed Communities in a 4-year Crop Rotation under Mediterranean Dryland Conditions. *Soil Till Res*. **74**: 15-24.
19. Meyer-Aurich, A., Janovicek, K., Deen, W., Weersink, A. 2006. Impact of Tillage and Rotation on Yield and Economic Performance in Corn-based Cropping Systems. *Agron. J*. **98**: 1204-1212.
20. Ozpinar, S., Cay, A. 2005. Effects of Minimum and Conventional Tillage Systems on Soil Properties and Yield of Winter Wheat (*Triticum aestivum* L.) in Clay-loam in the Canakkale Region. *Turkish J. Agric Forest*. **29**: 9-18.
21. Ozpinar, S. 2006. Effects of Tillage Systems on Weed Population and Economics for Winter Wheat Production under the Mediterranean Dryland Conditions. *Soil Till Res.* **87**: 1-8.
22. Ozpinar, S., Baytekin, H. 2006. Effects of Tillage on Biomass, Roots, N-accumulation of Vetch (*Vicia sativa* L.) on a Clay Loam Soil in Semi-arid Conditions. *Field Crops Res.* **96**: 235-242.
23. Ozpınar, S., Ozpınar, A. 2009. Nutrient Concentration and Distribution in Maize as Affected by Different Tillage Systems in the Canakkale Province, Turkey. ISTRO 18th Triennial Conference Proceedings, June 15-19, 2009 Izmir, Turkey.
24. Ozpinar, S., 2010. Changes in Soil Physical Properties in Response to Maize Tillage Management on a Clay Loam Soil. Philipp Agric Scientist. **93(3)**:337-345.
25. Raper, R. L., Reeves, E. W., Burt, E. C., Torbert, H. A. 1994. Conservation Tillage and Traffic Effects on Soil Conditions. *Trans. ASAE*. **37**: 763-768.
26. Roger-Estrade, J., Colbach, N., Leterme, P., Richard, G., Caneill, J. 2001. Modelling Vertical and Lateral Weed Seed Movements During Mouldboard Ploughing with a Skim-coulter. *Soil Till Res*. **63**: 35-49.
27. Sánchez-Giron, V., Serrano, A, Hernanz, J. L., Navarrete, L. 2004. Economic Assessment of Three Long-term Tillage Systems for Rainfed Cereal and Legume Production in Semiarid Central Spain. *Soil Till Res*. **78**: 35-44.
28. Sarrantonio, M., Scott, T. W. 1988. Tillage Effects on Availability of Nitrogen to Corn Following Winter Green Manure Crop. *Soil Sci. Soc. Am. J.* **52**: 1661-1668.
29. Smart, J. R., Bradford, J. M. 1999. Conservation Tillage Corn Production for a Semiarid, Subtropical Environment. *Agron. J*. **91**: 116-121.
30. Stevenson, F. C., Légère, A., Simard, R. R., Angers, D. A., Pangeau, D., Lafond, J. 1998. Manure, Tillage, and Crop Rotation: Effects on Residual Weed Interference in Spring Barley Cropping Systems. *Agron. J.* **90**: 496-504.
31. TurkStat, 2009. Turkish Statistical Institute. Prime Ministry Republic of Turkey. Ankara, 2009.
32. Weersink, A., Walker, M., Swanton, C., Shaw, J. E. 1992. Costs of Conventional and Conservation Tillage Systems. *J. of Soil and Water Conservation*. **47**: 328-334.
33. Zentner, R. P., Brandt, S. A., Kirkland, K. J., Campbell, C. A., Sonntag, G. J. 1992. Economics of Rotation and Tillage Systems for the Dark Brown Soil Zone of the Semiarid Prairies. *Soil Till Res*. **24**: 271-284.
34. Zentner, R. P., Lafond, G. P., Derksen, D. A., Campbell, C. A. 2002. Tillage Method and Crop Diversification: Effect on Economic Returns and Riskiness of Cropping Systems in a Thin Black Chernozem of the Canadian Prairies. *Soil Till Res*. **67**: 9-11.
35. Unger, P. W., Miller, S. D., Jones, O. R. 1999. Weed Seeds in Long-term Dryland Tillage and Cropping System Plots. *Weed Res*. **39**: 213-233.

تاثیر سامانه های خاک ورزی و تناوب کشت بر تراکم علف هرز و اقتصاد تولید محصول در منطقه ای نیمه خشک

س. اوزپینار و ا. اوزپینار

چکیده

به منظور مقایسه دو روش خاک ورزی حفاظتی (شخم کم عمق با گاو آهن دوار و شخم با گاو آهن قلمی) با روش خاکورزی رایج (با گاو آهن برگردان دار)، در سال ۲۰۰۱ پژوهشی با تناوب زراعی دراز مدت در یک منطقه نیمه خشک با آب و هوای مدیترانه ای شروع شد.در پیوند با این هدف، آزمونهای مزرعه ای برای تعیین تراکم علف های هرز و سود دهی سامانه های کشت و کار در تناوب گندم زمستانه (*Triticum aestivum* L.)- ماش زمستانه (*Vicia sativa* L.) از سال ۲۰۰۴-۲۰۰۱ و تناوب گندم زمستانه- ماش زمستانه- ذرت (*Zea mays* L.)تابستانه از سال ۲۰۰۹-۲۰۰۴ اجرا گردید. نتایج نشان داد که در روش گاو آهن دوار در مقایسه با روش گاو آهن برگردان دار تراکم علف های هرز به مقدار ۷۲٪ (در ذرت) و ۵۸٪ (در ماش) بیشتر بود در حالی که در محصول گندم ، تراکم علف های هرز در روشهای مختف خاک ورزی مشابه بودند. تولید ذرت در روش گاو آهن دوار به گونه ای معنی دار بیشتر از روشهای دیگر بود و کمترین تولید از آن گاو آهن قلمی بود ولی در گندم، عملکرد روشهای مختلف خاک ورزی تفاوتی نشان نداد. در دوره پنج ساله آخر مطالعه، عملکرد ماش در تیمارهای گاو آهن قلمی و گاو آهن برگردان دار بالا بود ولی در دوره سه ساله نخست این تحقیق تفاوت معنی داری در عملکرد این محصول در روشهای مختلف خاک ورزی به دست نیآمد. بر مبنای بازده اقتصادی (بازده بازار) سود نا خالص گاو آهن دوار در گندم و ذرت به گونه ای معنی دار در مقایسه با گاو آهن برگردان دار بیشتر بود و مقدار افزایش به ترتیب برابر ۲۰/۷٪ و ۱۵/۳٪ بود. هزینه های تولید ماش در گاو آهن قلمی مشابه گاو آهن دوار بود و هر دو کمتر از گاو آهن برگردان دار بودند. ولی بازده نا خالص تیمار گاو آهن قلمی مشابه برگردان دار و بیشتر از گاو آهن دوار بود. از نظر صرفه جویی در وقت، در کشت گندم گاو آهن دوار و قلمی به ترتیب ۴۳٪ و ۴۷٪ وقت کمتری از گاو آهن برگردان دار نیاز داشتند. مقدار صرفه جویی در وقت در کشت ماش و ذرت به ترتیب ۴۶٪ و ۵۰٪ برای گاو آهن دوار، و ۲۸٪ و ۳۲٪ برای گاو آهن قلمی به دست آمد.