THE EFFECT OF THE FIRST TILLAGE TIMES AND ROTATION SYSTEMS ON PRODUCTİVİTY OF WHEAT (*T. AESTIVUM L.*)

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This study was carried out in the Ilıca location of Erzurum, Turkey during the three year period, from 1999-2002. The objective of this study was to determine the effect of rotation systems (wheat-fallow and vetch-fallow-wheat rotation systems) and soil tillage times (early spring, early summer and fall tillage times) on grain yield, spike number per m², soil moisture, soil organic matter and soil aggregate stability in wheat. The results showed that significant increase of yield and spike number per m^2 and, well improvement of soil conditions for soil moisture content, aggregate stability and soil organic matter occurred when the soil was tilled in Early Spring and Vetch-Fallow-Wheat rotation system was applied compared to Fall tillage and Fallow-Wheat rotation system. As a result of this study, it has been shown that using Early Spring Tillage and Vetch-Fallow-Wheat rotation system wheat production could be increased, and soil conditions in terms of soil moisture, soil organic matter and soil aggregate stability could be improved under rain fed conditions.

***Keywords**: Wheat, rotation, soil tillage times, yield, spike number per m², soil moisture, soil organic matter and soil aggregate stability.*

The fallow-wheat cropping system is found on 1.5 million hectares in Eastern Anatolia of Turkey and is one of the most important cropping patterns for food self security in the region. About 70 percent of the annual rainfall in the winter-dominant rainfall areas like our region falls during the growing season. The average annual rainfall totals can be over 500 mm rainfall in some areas, but the majority of the wheat crop is produced in areas that receive less than about 500 mm annually. Depending upon elevation and distance from the sea, the mean minimum temperature of the coldest month varies from about -15° to over -40°C. Mean maximums during the grain maturation period can be as high as 30°C. Rainfall, both low and high temperatures have an almost equal influence to limitations of water supply in shaping the cropping system, the appropriate management practices and the choice of genotypes. Amount and duration of rains are variable but can often be a guide to the length of the growing season (Kassam, 1988; Unger et al., 1989; Aase and Pikul, 2000).

In most dry lands where annual precipitation is <450 mm farmers use wheat-fallow system (Greb, 1979). In one study, wheat yield in wheat-fallow system averaged about 2.2 times higher than wheat yield in wheat-wheat system (Hay, 1982). Tosun et al. (1987) revealed that sainfoin-fallow-wheat-fallow-wheat or vetch-fallow-wheat rotation systems increased wheat yield and improved soil properties. Applying cultural practices including tillage and rotation systems increase wheat yield and contributes increasing of economic level of farmers (Hobbs, 2001). Meagher and Rooney, (1966) revealed including legumes in fallow-wheat rotation increased wheat yield and soil moisture content. They also stated that Wheat yield following wheat-fallow was increased after two years natural pasture plus fallow but almost doubled after two years barrel medic plus fallow.. Tillage management is very important in wheat-fallow system where appropriate management systems applied on crop residues enhances water storage ability of soil (Lindwall and Anderson, 1981; Lyon et al., 1998; Cutforth et al., 2002; Lyon et al., 2003). Untilled wheat residues on the soil trap and keep snows and allows much more water stores in the soil.

Soils in Eastern part of Turkey are low in soil moisture and organic matter and therefore have weak structure (Demiralay, 1993). Managing tillage times and rotation systems is a vital practice for improving soil structural stability and for maintaining soil productivity Biederbeck et al., 1980). Soil water is more effectively stored if soil is tilled in the spring (Smika and Whitfield, 1966; Gökkuş et al., 1996; Gan et al., 2003). Our experimental objective was to determine the effects of optimal soil tillage time and rotation system on wheat yield, spike number per m^2, soil organic matter, soil aggregate stability and soil moisture content in dry land farming of Eastern Turkey.

MATERIALS AND METHODS

Experimental Site

This study was carried out in the Ilıca location of Erzurum, Turkey from 1999-2002. Precipitations in the study area is given in Table 1. Precipitations in 1999-2000, 2000-2001 and 2001-2002 were 286.9 mm, 384.0 mm and 318.3 mm, respectively. The soil at the beginning of experiment had loamy texture (33.5% sand, 39.3% silt, and 27.2% clay); 0.45 % $CaCO_3$, 321.7 mmol kg^{-1} P_2O_5, 442.7 mmol kg^{-1} K_2O, 7.11 pH (H_2O), 1.03% organic matter and 2.44 dS m^{-1} electrical conductivity.

Tillage and Rotation Practices

Rotation systems (**RS**); fallow-wheat (**FW**) and vetch-fallow-wheat (**VFW**) were applied. The first tillage time of stubbles in the fallow period was evaluated as soil tillage time (**STT**). The first tillage times were therefore: early spring tillage (stubbles were over wintered, first tillage was made in early spring, **SpT**), early summer tillage (stubbles were over wintered, first tillage was made in early summer, **SmT**) and fall tillage (stubbles were tilled in fall after harvesting of wheat and fallow remained as a bare soil, **FT**).

Table 1

Precipitations of Study Area in 1999-2000, 2000-2001 and 2001-2002

Years	Septem.	Octob.	Novem.	Decem.	Janu.	Febru.	March	April	May	June	July	August	Mean
1999-2000	49.6	17.3	11.0	11.0	18.8	21.7	61.3	35.0	42.0	9.7	4.8	4.7	286.9
2000-2001	40.7	42.3	1.6	23.8	4.9	11.9	46.7	95.5	63.2	14.6	36.9	1.9	384.0
2001-2002	11.0	5.1	33.9	29.6	3.2	8.0	57.7	44.9	35.3	49.3	34.2	6.1	318.3

Field Operations

Wheat genotype, Palandöken-97 (*Triticum aestivum* L), was: winter-habit wheat genotype, released for irrigated conditions, white and 42 g 1000 seed weight, tall (98 cm), resistant to lodging, cold and stripe rust resistant. Plot size was 30 m x 6 m (180 m²). Plots were separated by 10 m wide alleys. Wheat was sown in the first two weeks of September (Ozcan and Acar, 1990) at seed rate of 475 seed/m² (Akkaya, 1994). 60 kg N ha^{-1} (½ at sowing stage and ½ at tillering stage; Akkaya, 1993) and 26,2 kg ha^{-1} P (at sowing; Akkaya, 1993) were applied. No K fertilization was made. Wheat-sown plots received (2000 cc/ha) applications of 2,4-D ester [(2,4-dichlorophenoxy)acetic acid] in early spring to control winter annual broadleaf weeds. Hungarian vetch (*Vicia pannonica* Crantz) was sown in the first two weeks of September at seed rate of 120 kg/ha (Tosun et al., 1987). First tillage was made by plough, and once the first tillage was made in fallow plots, second tillage was made by crowbar when regrowth of weeds created problem.

Statistical Analysis

Statistical analysis software MSTAT-C (Freed and Eisensmith, 1989) and TARIST (Olgun et al., 2000) were used to analyze the data. The ANOVA procedure was used to evaluate the significance of each treatment on yield, spike number per m^2 and soil properties in a randomized complete block design with three replications (Little and Hills, 1978; Mead et al., 1994). Treatment means were separated by the least significance difference (LSD) test.

Measurements

Grain Yield

After harvesting time, wheat grain yield was measured as gr/plot and transferred to t/ha (Akkaya, 1994; Ceylan, 1994).

Seed Number per m^2

Before harvesting time, spike number per m^2 in plot was determined (Akkaya, 1994; Ceylan, 1994).

Soil Moisture

Soil moisture contents in all plots were determined by gravimetric method (Demiralay, 1993). Soil samples were taken in September, April, May, June and July and then average soil moisture content of months were analyzed.

Soil Aggregate Stability

The size distribution of the water stable aggregates of the soils was estimated by wet sieving (Yoder, 1936; Haynes, 1993). Soil samples were taken in September, April, May, June and July and then average soil aggregate stability of them were analyzed.

Soil Organic Matter

The organic matter content of the soil was determined by Walkley and Black method (Nelson and Sommers, 1982).

RESULTS AND DISCUSSION

In this study, the first tillage times of soil and rotation systems were compared for yield, spike number per m², soil moisture, soil organic matter and soil aggregate stability.

The first tillage times and rotation systems effects on yield

Wheat grain yield and its response to the first tillage times and rotation systems significantly varied ($P<0.01$) in the amount and distribution of precipitation throughout years (Table 2).

Table 2

Yield, Spike Number per M², Organic Matter, Aggregate Stability and Soil Moisture Related to Soil Tillage Times and Rotation Systems

	Degree of Freedom	Yield (t/ha)	Spike Number per m²	Organic Matter (%)	Aggregate Stability (%)	Soil Moisture (%)
Replication (R)	2	1.06ns	0.74ns	0.13ns	1.03ns	0.34ns
Years (Y)	2	50.17**	18.71**	21.61**	13.68**	10.72**
Soil Tillage Times (STT)	2	41.12**	12.79**	34.14**	13.14**	27.05**
Y x STT	4	1.11ns	0.17ns	1.99ns	1.22ns	2.56ns
Rotation Systems (RS)	1	66.73**	6.06*	19.40**	21.43**	59.83**
Y x RS	2	2.11ns	1.07ns	0.35ns	0.28ns	0.71ns
STT x RS	2	2.09ns	0.96ns	0.73ns	1.62ns	0.98ns
Y xSTT x RS	4	3.52*	2.80*	0.54ns	1.02ns	1.31ns
Error	34					
Mean	53					
C.V. (%)		16.12	17.35	8.12	11.84	13.23

The amount and distribution of rainfall and temperatures were more favorable for grain yield in 2000-2001. Table 3 showed that the highest grain yield was obtained with 2000-2001 (2.25 t ha^{-1}) and lowest one belonged to 1999-2000 (1.70 t ha^{-1}). Olgun et al. (2000) stated that wheat yield and soil moisture greatly depend on annual rainfall. As a average of years, **STT** and **RS** had significant effects on yield. Grain yield decreased with delaying soil tillage time. The highest grain yield was obtained from **SpT** (2.22 t ha^{-1}) and **FT** gave the lowest grain yield (1.72 ha^{-1}). Decreases in grain yield in **SmT** and **FT** were by 13.5 and 22.5%, respectively. Placing vetch into **FW** significantly increased grain yield and **VFW** gave more grain yield (2.14 t ha^{-1}, 17.2% more yield). The results obtained are an agreement with those of O' Leary and Connor, (1997), Demiralay (1993), Pachev et al. (1998), and they reported that in spring tillage of fallow stubble increased yield over the fall tillage in wheat-fallow system. Studies found that including alfalfa in rotation system increased wheat yield improved soil conditions and reduced yield variability, and spring tillage time gave highest yield. (Brandt and Zentner; 1995; Saffari and Koocheki, 2002). Table 4 shows that positive and significant correlations were determined between grain yield and spike number per m^2, yield and organic matter, yield and aggregate stability, and yield and soil moisture content. It appears that making the first tillage in early spring and placing legumes such as vetch assure optimum soil conditions such as soil moisture capacity, organic matter content and soil aggregate stability and therefore give optimum wheat yield.

Table 3

Yield, Spike Number per M², Organic Matter, Aggregate Stability and Soil Moisture Related to Soil Tillage Times and Rotation Systems

Years(Y)		**Yield (t/ha)**				**Spike Number per M²**				**Organic Matter (%)**			
		1999-2000	**2000-2001**	**2001-2002**	**Mean**	**1999-2000**	**2000-2001**	**2001-2002**	**Mean**	**1999-2000**	**2000-2001**	**2001-2002**	**Mean**
Soil Tillage Times (STT)	**Early Spring Tillage (SpT)**	1.95 a	2.58 a	2.13 a	**2.22 a**	540.5	722.3	647.8	**636.8 a**	1.14	1.24	1.30	**1.23 a**
	Early Summer Tillage (SmT)	1.71 a	2.13 b	1.93 ab	**1.92 b**	478.3	638.6	617.0	**578.0 a**	1.08	1.12	1.17	**1.13 b**
	Fall Tillage (FT)	1.43 b	2.05 b	1.67 c	**1.72 c**	384.3	575.5	503.3	**487.7 b**	1.07	1.05	1.15	**1.09 b**
Rotation Systems (RS)	**Fallow-What (FW)**	1.56 b	2.11 b	1.64 b	**1.77 b**	430.5	598.4	584.0	**537.6 b**	1.07	1.11	1.17	**1.12 b**
	Vetch-Fallow-Wheat (VFW)	1.83 a	2.40 a	2.19 a	**2.14 a**	504.8	692.5	594.7	**597.4 a**	1.13	1.16	1.25	**1.18 a**
Mean		**1.70 c**	**2.25 a**	**1.91 b**	**1.95**	**467.7 b**	**645.5 a**	**589.3 a**	**567.5**	**1.10 b**	**1.14 b**	**1.21 a**	**1.15**
L.S.D. (%)		Y: 0.15, STT: 0.15, RS: 0.12, Y x STT x RS: 0.27				Y: 81.1, SPT: 81.2, RS: 49.2, Y x STT x RS: 147.8				Y: 0.05, SPT: 0.04 , RS: 0.03			

Years(Y)		**Aggregate Stability (%)**				**Soil Moisture (%)**			
		1999-2000	**2000-2001**	**2001-2002**	**Mean**	**1999-2000**	**2000-2001**	**2001-2002**	**Mean**
Soil Tillage Times (STT)	**Early Spring Tillage (SpT)**	51.3	57.0	52.5	**53.6 a**	15.4	16.3	14.5	**15.4 a**
	Early Summer Tillage (SmT)	44.8	51.3	50.5	**48.9 b**	13.1	14.4	13.3	**13.6 b**
	Fall Tillage (FT)	42.3	49.5	50.0	**47.3 b**	11.7	14.0	13.5	**13.1 b**
Rotation Systems (RS)	**Fallow-What (FW)**	43.2	50.6	48.7	**47.5 b**	12.2	12.8	12.6	**13.0 b**
	Vetch-Fallow-Wheat (VFW)	49.1	54.6	53.4	**52.3 a**	14.6	14.4	14.9	**15.1 a**
Mean		**46.1 b**	**52.6 a**	**51.0 a**	**49.9**	**13.4 b**	**14.9 a**	**13.8 b**	**14.1**
L.S.D. (%)		Y: 3.5, SPT: 3.6, RS: 2.9				Y: 0.8, SPT: 0.9, RS: 0.7			

Table 4

Path Analysis Showing The Effect of Soil Tillage Times and Rotation Systems in Yield, Spike Number per M², Organic Matter, Aggregate Stability and Soil Moisture Content

	Grain Yield	Spike Number per m^2	Organic Matter	Aggregate Stability
Spike Number per m^2	0.638**			
Organic Matter	0.726**	0.542**		
Aggregate Stability	0.629**	0.435**	0.614**	
Soil Moisture Content	0.685**	0.482**	0.646**	0.739**

Spike Number per m^2				
Correlation Coefficient			0.638**	
Direct Effect	Path Coefficient		%	
	0.28		44.58	
Indirect Effect	Path Coefficient		%	
via Organic Matter	0.19		29.50	
via Aggregate Stability	0.05		7.87	
Via Soil Moisture Content	0.11		18.04	
Organic Matter				
Correlation Coefficient			0.726**	
Direct Effect	Path Coefficient		%	
	0.35		47.83	
Indirect Effect	Path Coefficient		%	
via Spike Number per m^2	0.15		21.20	
via Aggregate Stability	0.07		9.74	
Via Soil Moisture Content	0.15		21.22	
Aggregate Stability				
Correlation Coefficient			0.629**	
Direct Effect	Path Coefficient		%	
	0.11		18.33	
Indirect Effect	Path Coefficient		%	
via Spike Number per m^2	0.12		19.69	
via Organic Matter	0.21		33.92	
Via Soil Moisture Content	0.18		28.05	
Soil Moisture Content				
Correlation Coefficient			0.685**	
Direct Effect	Path Coefficient		%	
	0.24		34.82	
Indirect Effect	Path Coefficient		%	
via Spike Number per m^2	0.14		20.00	
via Organic Matter	0.22		32.74	
Via Aggregate Stability	0.08		12.43	
R^2: 72.1%, Residual Effect: 27.9%				

Spike number per m^2

Spike number per m^2, affecting grain yield, is one of the most considerable yield components in wheat (Ceylan, 1994). Three-year average effects by years, first tillage times ($P<0.01$) and rotation systems ($P<0.05$) on spike number per m^2

were so significant. Spike number per m^2 was significantly lower (467.7) in 1999-2000 than the other years (645.5 in 2000-2001 and 589.3 in 2001-2002). **FT** (487.7) had the lowest spike number per m^2 and the highest was obtained with **SpT** (636.8). Delaying tillage time reduced spike number per m^2 and decreases were 9.2% in SmT and 23.4%i in **FT**. Spike number per m^2 in **VFW** (597.4 and 10.0%) was significantly higher than that of **FT** (537.6). The results obtained for spike number per m^2 in this study agree with those reported by Bauer and Black (1990) and Saffari and Koocheki (2002).

Organic Matter

During three years of study, the effects of years, soil tillage times and rotation systems were determined significant at 1% (Table 1). Soil organic matter increased with running time; 1.10% organic matter in 1999-2000 reached to 1.21% in 2001-2002. Increasing effects of **STT** and **RS** during the three years most likely caused this increase. **STT** and **RS** significantly affected soil organic matter. The lowest organic matter was recorded under **FT** (1.09%) and **FW** (1.12%), whereas **SpT** (1.23%) and **VFW** (1.18%) gave the highest organic matter. **SpT** and placing vetch in VFW allowed more suitable soil conditions more suitable soil conditions such as more moisture and aggregate stability; and these conditions caused more soil organic matter. When compared to **FT**, increases on soil organic matter in **SmT** and **SpT** were 3.6% and 12.8%, respectively. Moreover, this increase was 5.3% when vetch was placed in **FW** rotation system. This was confirmed by different studies (Rasmussen and Collins, 1991; Pavinato, 1993; Mrabet et al., 2000, 2001a and 2001b), showing that organic matter is critically important for improvement of soil and therefore increase of yield. Authors reported that tillaging soil first in early spring and placing legumes in fallow-wheat significantly improve soil conditions.

Aggregate Stability

Crop rotation and tillage is a major factor dictating indicators of soil aggregate stability (Katsvairo et al., 2002). Soil aggregate stability depends on the quality as well as the quantity. Soils that have a higher content of organic matter have greater aggregate stability. Addition of organic matter increase aggregate stability, primarily after decomposition begins and microorganisms have produced chemical breakdown products or mycelia have formed. Soil microorganisms produce many different kinds of organic compounds, some of which help to hold the aggregates together (Tisdall and Oades, 1982). Differences between years, soil tillage times and rotation systems were determined as significant of organic inputs as at 1%. Aggregate stability ranged from 46.1% to 51.0% with lowest value for 1999-2000 and highest value for 2000-2001 (Table 3). Soil aggregate stability from **SpT** plots (53.6%) was higher than from **FT** plots (47.3%). **VFW** had higher soil aggregate stability (52.3%) than **FW** (47.5%). Regarding of **FW** and **FT**, increases in aggregate stability were 10.1% and 13.1% in **VFW** and **SpT**, respectively. Similar to our results, studies revealed that depending on time early tillage in spring and placing legumes in fallow-wheat system improved soil aggregate stability (Raimbault and Vyn, 1991; Hovelmann and Franken, 1993; Kitur et al., 1993; Castro Filho et al., 1998). Mrabet et al. (2001a) found that aggregate stability were highest for medic, vetch and lentil, and lowest for continuous wheat and fallow.

Soil Moisture

The one of the most important obstacles to the development of durable agriculture is limited and insufficient supply of soil moisture (Bradford and Peterson, 2002). Over 3 years, differences between years, soil tillage times and rotation systems were determined as significant at 1% (Table 2). The amount of rainfall during the year mostly affect soil moisture content (Bouzza, 1990; Pala et al., 2000). The highest and the lowest amount of rainfall were taken from the second year and the first year; besides the highest and the lowest soil moisture contents belonged to the second year and the first year. This explains that the soil moisture content mainly depends on the amount of rainfall. **SpT** gave the highest soil moisture content (15.4%), whereas **FT** had the lowest one (15.1%). If **FT** considered, increases in soil moisture contents in SmT and SpT were 3.8% and 17.5%, respectively (Table 3). **VFW** had more soil moisture content (15.1%) than **FW** (13.0%). Soil moisture content is very important factor affecting plant growth and yield (Austin, et al., 1977; Gerling, et al., 1983; Deibert, et al., 1986; Kitur et al., 1993; Debaeke and Aboudrare, 2004). Increase in soil moisture content commonly depends on soil conditions which greatly affected by tillaging times and rotation systems improving soil conditions (Tosun et al., 1987; Raimbault and Vyn, 1991; Campbell and Janzen; 1995; Bradford and Peterson, 2002). Especially early tillage and placing legumes such as vetch in fallow-wheat rotation system increase soil organic matter and aggregate stability (Bauer and Black 1990; Jordahl and Karlen, 1993; Biederbeck et al., 1994; Carefoot and Janzen, 1997; Hulugalle et al., 1998; Mrabet, 2000; Mrabet et al., 2001b).

Explaining the Effect of Charactes in Yield via Path Analysis

Table 4 shows correlation and the effect of the characters in yield via path analysis. Effect of characters on yield is well explained by path analysis (Ehdarie et al., 1989; Agrama, 1996; Guo et al., 2005). As seen in Table 4 and Figure 1, positive and significant correlations were determined between all characters. Correlation between yield and spike number per m^2 was positive and significant (0.638**). Direct effect of spike number per m^2 in yield was 44.58% and the highest indirect effects of this were via organic matter (29.50%) and soil moisture content (18.04%). Significant and positive correlation ($p<0.01$) was determined between yield and organic matter (0.726**). 44.83% direct effect of organic matter occurred in yield, and the highest indirect effects of this were via spike number per m^2 (21.20%) and soil moisture content (21.22%). Correlation between yield and aggregate stability (0.629**) was found as significant and positive ($p<0.01$). 18.33% direct effect of aggregate stability was determined in yield, and the highest indirect effects of aggregate stability were via organic matter (33.92%) and soil moisture content (28.05%). Correlation between yield and soil moisture content (0.685**) was significant and positive ($p<0.01$). Direct effect of soil moisture content in yield was 34.82% and the highest indirect effects of soil moisture content were via spike number per 20.00% and organic matter (32.74%). Path analysis results revealed that soil moisture content, aggregate stability and soil organic matter have important role in determination of yield. Besides, highest values in indirect effects of soil moisture content and aggregate stability assign that soil organic matter content is predominant in changes of soil moisture content and aggregate stability. Therefore, applications such as **SpT** and **VFW** improve soil conditions, cause tremendous increase in soil moisture content, aggregate stability and soil organic matter. Studies assigned soil organic matter content closely related with soil moisture content and aggregate stability. Early tillage of soil and legumes-fallow-wheat rotation well improve soil conditions, and make significant increase on organic matter, aggregate stability and moisture content in soil (Gerling, et al., 1983; Payne, 1988; Bauer and Black, 1990; Raimbault and Vyn, 1991; Hovelmann and Franken, 1993, Biederbeck, et al., 1994; Bissett and O'Leary, 1996; Mrabet et al., 2001a; Husnjak et al., 2002; Debaeke and Aboudrare, 2004; Schillinger and Young, 2004).

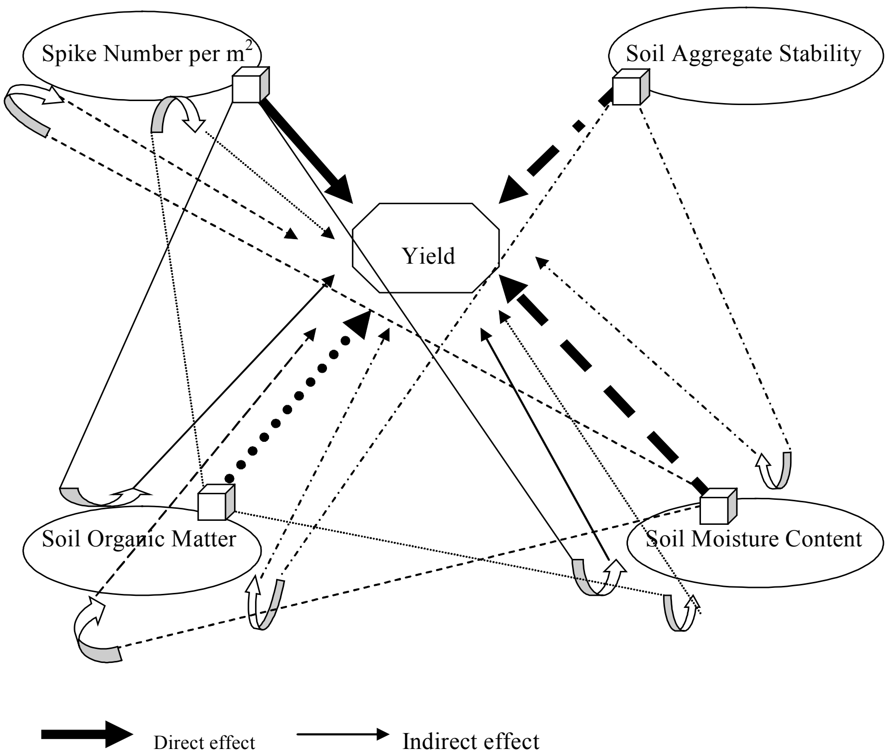

Figure 1. **Direct and indirect effect effect of soil tillage times and rotation systems in yield, spike number per m², organic matter, aggregate stability and soil moisture content**

CONCLUSION

The study results showed an increase of yield and spike number per m^2 and improvement of soil conditions for soil moisture content, aggregate stability and soil organic matter under **SpT** and **VFW** compared to **FT** and **FW**. In other words, Early Spring Tillage and Vetch-Fallow-Wheat rotation system caused prominent increase in yield spike number per m^2, soil moisture content, aggregate stability and soil organic matter. Using Early Spring Tillage and Vetch-Fallow-Wheat rotation system wheat production could be increased and soil conditions in terms of soil moisture, soil organic matter and soil aggregate stability could be improved under rain fed conditions.

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