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THE INFLUENCE OF DIFFERENT TILLAGE, CROP ROTATIONS AND NITROGEN LEVELS ON PLANT HEIGHT, BIOLOGICAL AND GRAIN YIELD IN WHEAT

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Abstract

The purpose of this study was to identify the optimal tillage methods and N levels in a wheat-chickpea (Cicer arietinum L.), wheat-fallow and wheat monoculture in dry farming areas. In this study, two tillage methods (conventional and reduced tillage), three crop rotations (wheat-wheat; wheat-fallow; wheat-chickpea) and four N levels (0, 50, 100, 150 kg ha^{-1}) were evaluated in Central Anatolia Region for 4 year. The experimental design was split-split-plot with three replicates. Tillage methods were in main plots, crop rotations in subplots and N levels in sub-sub plots. Conventional tillage methods resulted in higher grain yield compared to reduced tillage. Four years is certainly not long enough to reveal the full effects of the crop rotation, but wheat-chickpea rotation provided an alternative to wheat-fallow cropping system in the region. Increasing nitrogen doses increased plant height, head length, biological yield and grain yield. Results also indicated that; using conventional tillage with wheat-chickpea rotation and 100 to 150 N kg ha^{-1} for wheat would be recommended for wheat production in the region.

Key words: *crop rotation, N levels, tillage methods, wheat yield.*

INTRODUCTION

Soil water is the major limiting factor in crop production under dryland condition in Central Anatolia region. Mean annual precipitation of the Central Anatolia region is about 400 mm and majority of precipitation falls between September and May. Crop rotation system consisting of wheat-fallow is widely applied in the region as is elsewhere in dry areas. In region, fallow starts in July after the harvest of the preeceding crop and finishes the fallowing year in October, at sowing, about 15-16 months latter. Objectives of fallowing are to maximize soil water storage through improved waterintake and decreased evaporation; maximize plant nutrient availability; minimizesoil erosion hazard (Greb, 1979). Konn et al. (1966) indicated that fallowing in the year before cropping is of little importance with respect to moisture conservation. Papastylianou and Jones (1988) stated that fallowing improves water availability to a crop only when a relatively dry year follows a relatively wet year.

Inclusion of grain legumes inrotation can protect degradation of soil fertility (Derksen et al., 2001), improve soil structure, water holding capacity (Goh et al., 2001), and result in greater productivity and higher income,while minimizing production risk and ensuring long-termsustainability, as well as ensure a greener environment (Goh et al., 2001). Experimental data from temperate Europe show that cereals yield on average 17 and 21% higher after grain legumes than after cereals under usual and moderate fertilisation levels, respectively (Dachler and Köchl, 2003; Jensen et al., 2004). The main goal of tillage is to prepare the land or the seedbed where the plants can easily grow. Different types of tillage systems have different tillage depths and capacity to change soil physical and chemical properties that affect the crop yield and quality (Strudley et al., 2008). Ploughing may damage the pore continuity and agregate stability resulting in sediment mobilization, erosion and surface hardening. Ploughing is also high energy consuming. Shallow tillage has the positive effects on soil health such as aggregate stability

(Vakali et al., 2011) as well as infiltration capacity, hydraulic conductivity and aeration. Also, the importance of reduced or shallow tillage for soil conservation and low cost have been well documented (Sijtsma et al., 1998; Tebrugge and During, 1999; Arvidsson et al., 2004).

Nitrogen is an essential element required for successful plant growth. Although inorganic nitrogen compounds (*i.e.*, NH_4^+, NO_2^-, and NO_3^-) account for less than 5% of the total nitrogen in soil (Brady and Weil, 2008), they are the main form of the element absorbed by most plants. Inorganic and organic fertilizer are applied to maintain the nutritional condition of different cropping systems.

Winter wheat is a major crop in Central Anatolia that is generally grown in rotation with legumes such as vetch, chickpea and lentil. The aim of this study was to determine suitable tillage method and crop design under dry land conditions of Central Anatolia, Turkey. For this goal two tillage systems (conventional tillage and reduced tillage), three crop rotations (wheat-wheat; wheat-fallow; wheat-chickpea) and four N levels (0, 50, 100, 150 kg ha^{-1}) were evaluated in Eskişehir Region for 4 years.

MATERIALS AND METHODS

Study site and soil

Field study was conducted under dryland conditions at the experimental area of the Department of Field Crops, Faculty of Agriculture, Eskisehir Osmangazi University, Eskisehir, Turkey (39^{o}48' N; 30^{o}31' E, 798 m above sea level) for 4 years between 2011-2014. The climate of the region is characterized as semiarid with cold moisty winters and hot dry summers. The long-term (35 years) annual total precipitation and annual average temperature and relative humidity of the study area are 329.7 mm, 9.7^{0}C and 64.3%, respectively. Monthly and annual precipitation and temperature during the study period is presented Figure 1. Physical and chemical proporties of the soil before the starting of the experiment is presented Table 1.

Experimental design and treatments

In this study, two tillage methods [conventional tillage (CT) and reduced tillage (RT)], three crop rotations [wheat-wheat (WW); wheat-fallow (WF); wheat-chickpea (WC)] and four N levels (0, 50, 100, 150 kg ha^{-1}) were evaluated in Central Anatolia Region for 4 years.The experimental design was split-split -plot with three replicates. Tillage method was in main plots, crop rotation in subplots and N fertilizer in sub-sub plots.

Soil tillage: The conventional tillage included mouldboard ploughing followed by one passes of a sweep and/or rototiller cultivation to provide a proper seedbed. The reduced tillage included only sweep plowing and/or rototiller cultivation. Tillage depths for CT and RT were 25-30 and 8-10 cm, respectively. Tillage treatments were made in September in all years but when chickpea sown (in spring), no planting plots were tilled by rototiller for weeds.

Crop rotation: Three crop rotations were considered in the experiment. Wheat were sown in all of the plots in the first and third years. In the second and fourth years, wheat, chickpea and fallow were sown on the research plot.

Table 1. Physical and chemical properties of the soil before starting of the experiment

Depth (cm)	Texture	pH	EC (mmhos cm$^{-1)}$	Total salt (%)	Lime (%)	Organic matter (%)	P_2O_5 kg ha^{-1}	K_2O kg ha^{-1}	N (%)
0-30	loamy	8.04	0.89	0.057	3.7	0.98	60.6	3411.1	0.04

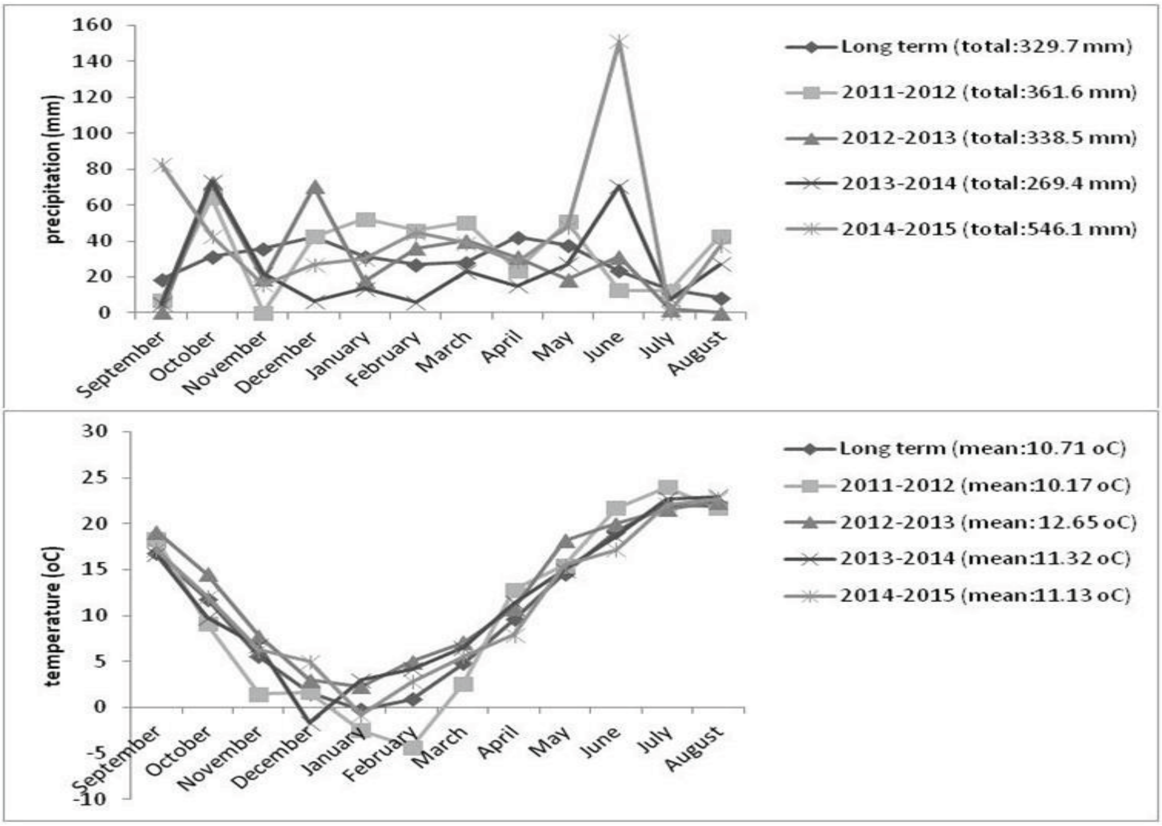


Figure 1. Total rainfall and monthly mean temperature for four seasons at Eskişehir, Turkey

Fertilization: Nitrogen fertiliser was applied to wheat plots as ammonium nitrate. Half was applied at the sowing and the remaining N was topdressed at the begining of the wheat stem elongation.Basal fertilizer application of 60 kg P_2O_5 ha^{-1} (for wheat) and 60 kg P_2O_5 ha^{-1}and 20 kg N ha^{-1} (for chickpea) were applied to each sub-subplot at the time of sowing.

Seeding: Each sub-subplot was 12 m^2 (4 m x 3 m). A sowing machine with 18 cm row spacing was used to sown wheat in all plots. Winter wheat (cv. Sönmez) was sown at the rate of 600 seeds m^{-2} on 8 October, on 12 October, on 11 October and on 21 October, in 2011, 2012, 2013 and 2014, respectively. 2-4 -D was used in early spring to control broadleaf weeds. Chickpea cultivar Gökçe was sown 30 cm row spacing at a seeding rate of 60 seeds m-2 on 01 April and 14 April in 2013 and 2015, respectively. No herbicide was applied and weeds were removed by hand. Winter wheat was harvested on 23 July, on 8 July, on 9 July, on 22 July, in 2012, 2013, 2014 and 2015, respectively. Chickpea was harvested on 29 July and 25 August in 2013 and 2015, respectively.

Crop yield measurements

Plant height, head leght, biological yield and grain yield were measured for wheat. Plant height and head lenghtwere determined by 10 randomly selected plants in each sub-subplot. A 1 m^2 portion at the centre of each sub-subplot was sampled at harvest time. The biological yield was measured from this sample.When the moisture content in grain down to 13%, grain yield was obtained with machine at maturity in each sub-subplot.

Statistical analysis

All data were subjected to analysis of variance based on General Linear Model using the Statview package (SAS Institute). Means were compered by Least Significant Differences (LSD) test.

RESULTS AND DISCUSSIONS

Wheat was sown in all plots in 2011-2012 growing season. Because of rotation was not applied, the results were evaluated according to split-plot with three replicates. Tillage methods did not significantly affected investigated parameters but wheat plant height, biological yield and grain yield was significantly affected by N levels (Table 2). In this season, total precipitation (361.6 mm) was higher than long-term (329.7 mm) and mean temperature for growing season was near the long term (Figure 1). The effect of tillage methods on investigated parameters was not significant due to heavy rain [especially October, January, February, March, and May at the vegetation period (Figure 1). Rainfall could prevent the potential benefit of RT. Adak (1999) reported that conventional tillage and minimum tillage did not affect wheat plant height, head length and biological yield in first experimental year but conventional tillage gave higher head lenght in second experimental year. Ozpınar (2006) estimated that wheat plant height and head lenght affected different tillage methods. Hemmat and Eskandari (2004b) reported that plant height did not affected different tillage methods but head length affected different tillage methods. Eser et al. (1999) and Hao et al. (2001) estimated that conventional and minimum tillage did not affect wheat biological yield and grain yield. Increasing N levels increased plant height, biological yield and grain yield in this season. The highest plant height, biological yield and grain yield were obtained with 150 N kg ha^{-1}. Başar et al. (1998) and Çiftçi and Doğan (2013) reported that increasing N levels increased wheat plant height and grain yield.

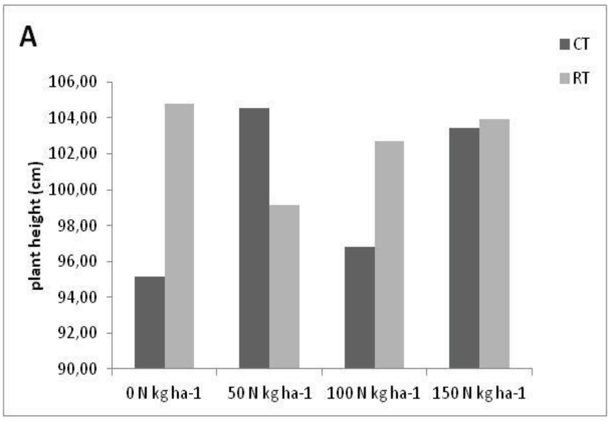
Table 2. Effect of different tillage methods and nitrogen levels on some characters of wheat in 2011-2012 and 2012-2013 growing seasons

	2011-2012 growing season				**2012-2013 growing season**			
Treatments	PH (cm)	HL (cm)	BY (kg ha^{-1})	GY (kg ha-^{1})	PH (cm)	HL (cm)	BY (kg ha-^{1})	GY (kg ha-^{1})
CT	102.1	9.22	17729.2	3876.9	99.99	10.02	18800.0 A	2823.5 b
RT	103.2	8.99	18458.3	3868.1	102.65	10.29	15991.7 B	4071.7 a
Mean	**102.6**	**9.10**	**18093.8**	**3872.5**	**101.32**	**10.15**	**17395.8**	**3447.6**
0(kg ha^{-1})	101.0 b	8.80	15250.0 C	3743.4 b	99.97	9.56 B	13750.0 C	3320.2 bc
50(kg ha^{-1})	100.9 b	9.05	17083.3 BC	3564.9 b	101.85	10.72 A	18016.7 B	3551.0 ab
100 (kg ha^{-1})	103.0 ab	9.20	18091.7 B	3904.4 ab	99.77	9.69 AB	20933.3 A	3218.0 c
150(kg ha^{-1})	105.9 a	9.37	21950.0 A	4277.4 a	103.70	10.66 A	16883.3 B	3701.1 a
Mean	**102.6**	**9.10**	**18093.8**	**3872.5**	**101.32**	**10.15**	**17395.8**	**3447.6**
Tillage met.	Ns	Ns	ns	ns	ns	Ns	**	*
N levels	*	Ns	**	*	ns	**	**	*
Till. x N levels	Ns	Ns	ns	ns	*	Ns	**	*

ns: non-significant, *: p≤0.05, **: p≤0.01. Means in the same column with different letters are significant. PH: plant height, HL: head lenght, BY: biological yield GY: grain yield.

In 2012-2013 growing season, wheat, chickpea and fallow were established on the research area. The results were evaluated according to split-plot with three replicates because of rotation was not applied. The effects of tillage methods on biological yield and grain yield were significant. The differences of N levels were significant for head length, biological yield and grain yield (Table 2). Moreover, the interaction between tillage methods and N levels were significant for plant height, biological yield and grain yield. While 50 kg ha^{-1} N levels had highest plant height under CT, 0 kg ha^{-1} N levels had lowest plant height. Thus, interaction between tillage methods and N levels was significant for plant height (Figure 2a). While 100 kg ha^{-1} N levels had highest biological yield under CT, 0 kg ha^{-1} N levels had lower biological yield. Thus, interaction between tillage methods and N levels was significant for biological yield (Figure 2b). While 50 and 150 kg ha^{-1} N level had high grain yield under RT, 100 kg ha^{-1} N level had lower grain yield. Thus, interaction between tillage methods and N levels was significant for grain yield (Figure 3a). Total precipitation and mean temperature for this season was near the long term. Total precipitation during the growing season and long term were 338.5 and 329.7 mm, respectively. Total precipitation for the April and May growing season (49.4 mm) were below the long-term total precipitation (79.7 mm) in same months but May mean temperatures was above long-term (Figure 1). There were low rainfall and high evaporation in the spring. Wheat grain yield was significantly affected by tillage methods in this season.

Grain yield was significantly higher under RT than CT. The crop residue cover reduces evaporation, and the standing stubble traps snow for extra soil moisture (Avcı, 2011). In our research, RT could better protect the soil moisture and grain yield might have increased. Some researchers reported that wheat grain yield was higher under RT than CT (Hemmat and Eskandari, 2004a; Hemmat and Eskandari 2004b; Özpınar and Çay, 2005; Özpınar 2006). The differences of N levels were significant for head length, biological yield and grain yield in this season. Increasing N levels increased head length, biological yield and grain yield. Ortiz-Monasterio et al. (1997), Eser et al. (1999), Lopez-Bellido and Lopez Bellido (2001) reported that increasing N levels increased wheat grain yield. Başar et al. (1998) reported that increasing N levels increased head length and grain yield.



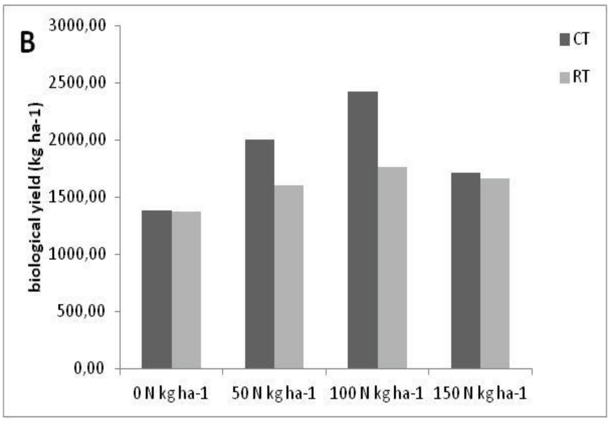


Figure 2. The interaction between tillage methods and N levels on plant height (A) and biological yield (B) of wheat in 2012-2013 [LSD 5%: 6.404 (A);1%:102,33(B)]

Wheat was sown all plots in 2013-2014 growing season. Tillage methods, crop rotation systems and N levels significantly affected grain yield. The effects of crop rotation systems and N levels on biological yield were significant and only crop rotation significantly affected head lenght (Table 3). While WC crop rotation systems had higher biological yield under CT, WW crop rotation systems had lowest biological yield. Thus, interaction between tillage methods and crop rotation systems were significant for biological yield (Figure 3b). The 50 N kg ha^{-1} showed superior performance under CT but 150 N kg ha^{-1} had lowest biological yield same tillage methods. Thus, interaction between tillage methods and N levels were significant for biological yield (Figure 4a). While WC crop rotation systems had highest biological yield on 0 N kg ha^{-1}, same rotation systems showed lower values on 150 N kg ha^{-1} N levels. Thus, interaction between crop rotations and N levels were significant for biological yield (Figure 4b). The 50 N kg ha^{-1} showed superior performance under WF rotation in the RT but same N levels performed better performance under WW rotation in RT. Hence, the interaction between tillage methods, rotation systems and N levels was significant for grain yield (Figure 5a). Total precipitation during this season and mean of long term were 269.4 and 329.7 mm, respectively. Mean temperature for growing season was near the long term but total precipitation was lower than long term (Figure 1). Grain yield, biological yield, plant height and head length were particularly low in the third year than normal. It seems that the water stress clearly tended to reduce these components. Wheat grain yield was significantly affected by tillage methods in this season. Grain yield for CT was higher than RT in third experimental year. Similar results were also reported by Malecka et al. (2012) and Wozniak (2013). He et al. (2017) argued that deep ploughing and conventional tillage may be caused more water store under drought condition. WC crop rotation systems had highest head length and biological yield. Eser et al. (1999) reported that wheat biological yields after lentil were higher than fallow. Wheat grain yields were higher in the WW and WC rotation than in the WF rotation in this season. WW and WC increased wheat yields compared with WF cropping system. Fallow efficiency is general low and variable from year to year. Similar results were also reported by Power and Follett (1987), Peterson and Varvel (1989a,b,c), Mitchell et al. (1991), Lopez and Arrue (1997), Unver et al. (2001), Hao et al. (2001). In our research, narrowing of the difference in yields from the WW and WC rotations may be due to drought (Figure 1). Fisher et al. indicated that wheat grain yield were not significantly different in WW rotation and wheat-legumes rotation. Dalal et al. (1998) reported that the magnitude of wheat yield is likely to be depend on severel factors including seasonal conditions [both fallow period rainfall and crop year rainfall, performance of the previous chickpea crop (plant biomass, grain yield, N accretion and grain N removal), soil fertility levels, tillage practices and disease incidence]. The effects of N levels on grain yield were not clear in this season. No N and 100 N kg ha^{-1} produced higher grain yield (Table 3). The reduction of soil water content due to drought might reduce the N solubility (Figure 1). N solubility and intake might be influenced by drought.

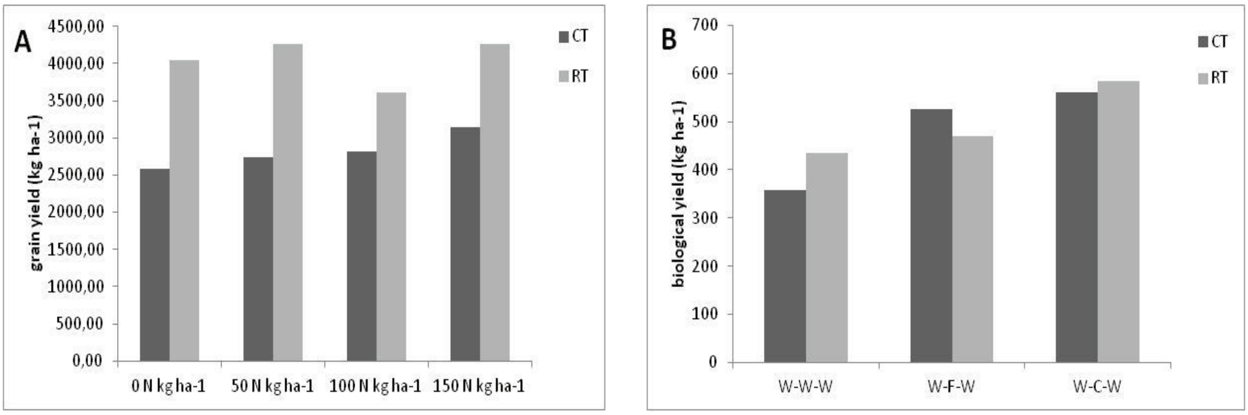


Figure 3. The interaction between tillage methods and N levels on grain yield in 2012-2013 (A) and interaction between tillage methods and crop rotation on biological yield in 2013-2014 (B) of wheat
[LSD 5%: 43,450 (A);1%: 122,896 (B)]

In 2014-2015 growing season, wheat, chickpea and fallow were established in the research area. Tillage methods and N levels significantly affected biological yield and grain yield (Table 4). While 150 N kg ha^{-1} N levels had highest biological yield under CT, 0 N kg ha^{-1} N levels had lowest biological yield on same tillage methods. Thus, interaction between tillage methods and N levels were significant for biological yield (Figure 5b). CT showed superior performance for all of N levels but RT showed better performance for all N levels. Hence, there was significant interaction between tillage methods and N levels for grain yield (Figure 6a). Grain yield was significantly higher under CT than RT. Total precipitation during the growing season and long term were 546.1 and 329.7 mm, respectively. Mean temperature for growing season was near the long term but total precipitation was very higher than long term (Figure 1). Total precipitation for the November and December (42.4 mm) were below the long-term total precipitation (78.0 mm). The low precipitation after sowing caused drought which had negative effect on crop establishment. Therefore, plant height, head length, biological yield and grain yield were particularly low in the fourth year. CT was more productive than RT in this year. Similar results were also reported by Frederict et al. (2001), Lopez-Bellido et al. (2004), Ozpınar and Çay (2005), Malecka et al. (2012), Wozniak (2013). Wet conditions during June in 2014-2015 growing season may be caused decreasing in soil aeration due to excessive water in reduced tillage. Carter and Johnston (1989) indicated that same conclusion for spring cereals. The differences of N levels were significant for grain yield in this season (Table 4). One hundred-fifty N kg ha^{-1} gave higher grain yield with no significant difference with No N treatment. There was an excessive precipitation in the area in fourth growing season (Figure 1) which can leach N fertilizer. Therefore, effect of N fertilization may have been lost.

Table 3. Effect of different tillage methods, crop rotation and nitrogen levels on some characters of wheat in 2013-2014 growing season

	2013-2014 growing season			
Treatments	PH(cm)	HL(cm)	BY(kg ha-[1])	GY (kg ha-[1])
CT	49.76	8.08	4815.3	1283.5 A
RT	48.63	8.02	5007.6	935.6 B
Mean	**49.19**	**8.05**	**4907.2**	**1109.5**
W-W-W	46.76	7.72 b	3888.1 C	1173.0 A
W-F-W	51.61	8.08 ab	4979.2 B	990.1 B
W-C-W	49.22	8.34 a	5727.1 A	1165.6 A
Mean	**49.19**	**8.05**	**4907.2**	**1109.5**
0 (kg ha^{-1})	49.40	7.92	5114.7 ab	1115.6 B
50 (kg ha^{-1})	49.99	8.04	5225.0 a	1034.2 C
100 (kg ha^{-1})	49.57	8.07	4711.8 bc	1192.2 A
150 (kg ha^{-1})	47.82	8.15	4558.8 c	1096.2 BC
Mean	**49.19**	**8.05**	**4907.2**	**1109.5**
Tillage methods	ns	ns	ns	**
Crop rotation	ns	*	**	**
N levels	ns	ns	*	**
Tillage x rotation	ns	ns	**	**
Tillage x N levels	ns	ns	**	**
Rotation x N levels	ns	ns	**	**
Tillage x rotation x N levels	ns	ns	ns	**

ns: non-significant, *: p≤0.05, **: p≤0.01. Means in the same column with different letters are significant.
PH: plant height, HL: head lenght, BY: biological yield GY: grain yield.

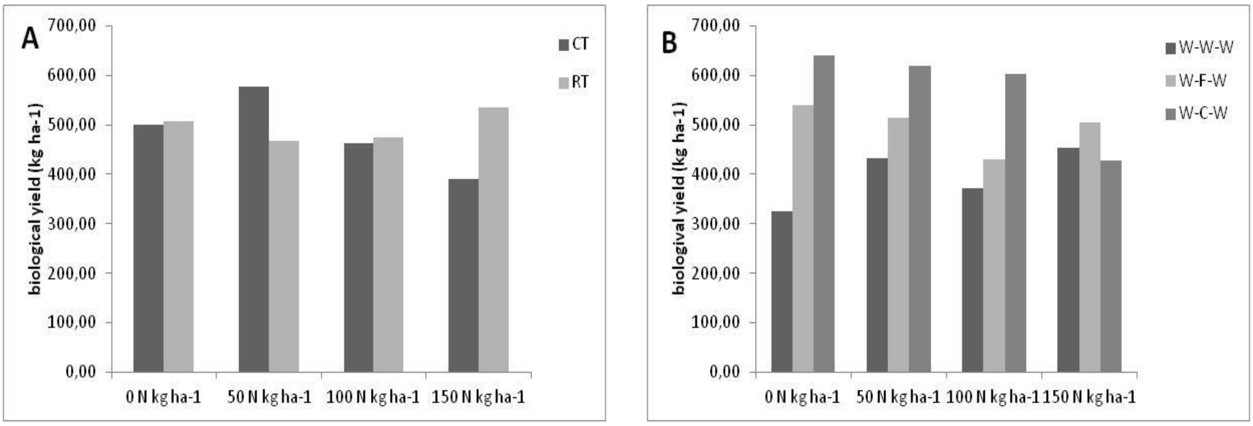


Figure 4. The interaction between tillage methods and N levels on biological yield (A) and interaction between crop rotation and N levels on biological yield (B) of wheat in 2013-2014 [LSD 1%: 81.931 (A);40,965(B)]

Table 4. Effect of different tillage methods and nitrogen levels on some characters of wheat in 2014-2015 growing season

	2014-2015 growing season			
Treatments	PH (cm)	HL (cm)	BY (kg ha-1)	GY (kg ha^{-1})
CT	86.79	9.15	9549.2 A	2178.00 A
RT	82.58	8.80	5707.5 B	1438.00 B
Mean	**84.68**	**8.97**	**7628.3**	**1808.00**
0 (kg ha^{-1})	81.72	8.80	4380.0 D	1851.00 ab
50 (kg ha^{-1})	81.07	9.14	6250.0 C	1654.00 b
100 (kg ha^{-1})	83.87	8.76	7316.7 B	1790.00 ab
150 (kg ha^{-1})	92.08	9.18	12566.7 A	1935.00 a
Mean	**84.68**	**8.97**	**7628.3**	**1808.00**
Tillage methods	ns	ns	**	**
N levels	ns	ns	**	*
Tillage x N levels	ns	ns	**	**

ns: non-significant, *: p≤0.05, **: p≤0.01. Means in the same column with different letters are significant. PH: plant height, HL: head lenght, BY: biological yield GY: grain yield.

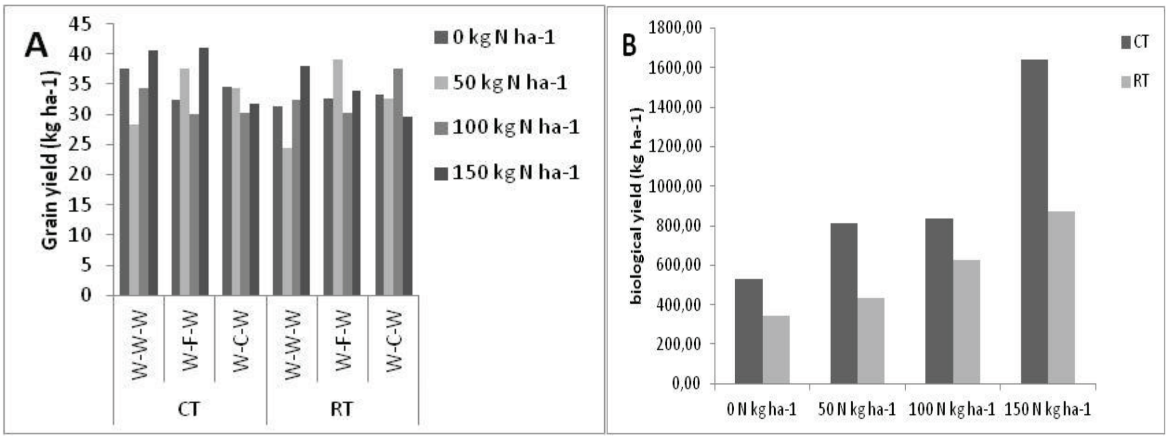


Figure 5. The interaction between tillage methods,crop rotations and N levels on grain yield 2013-2014 (A) and interaction between tillage methods and N levels on biological yield in 2014-2015 (B) of wheat [LSD 1%: 16.574 (A); 265,661 (B)]

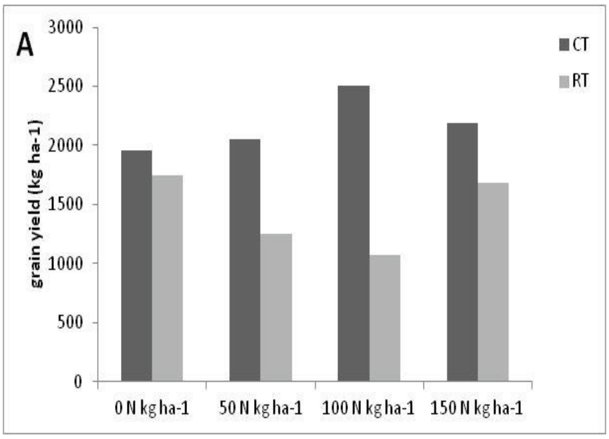


Figure 6. The interaction between tillage methods and N levels on grain yield of wheat in 2014-2015 [LSD 1%:34.983(A)]

CONCLUSIONS

Winter wheat grain yield based on the results of four growing seasons under the dry land conditions of the Central Anatolia region were influenced by tillage systems, crop rotations and nitrogen levels. Conventional tillage method resulted in higher grain yield compared to reduced tillage. Conventional tillage was more productive than reduced tillage due to more water storage, especially in wet years. Four years is certainly not enough to reveal the full effects of the crop rotations, but wheat-chickpea rotation provided an alternative to wheat-fallow cropping system in the region. Increasing nitrogen doses increased plant height, head length, biological yield and grain yield. According to the results, 100 or 150 N kg ha^{-1} is recommended in the region for wheat. Results also indicated that; using conventional tillage with wheat-chickpea rotation and 100 to 150 N kg ha^{-1} for wheat would be recommended for wheat production in the region.

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