



Effects of Different Tillage, Rotation Systems and Nitrogen Levels on Wheat Yield and Nitrogen Use Efficiency

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ARTICLE INFO

ABSTRACT

Research Article

Received : 25/07/2019
Accepted : 21/07/2020

Keywords:

Crop Rotation
Grain Yield
Nitrogen Levels
Nitrogen Use Efficiency
Soil Tillage

This research was conducted between 2011 and 2015 at research field of Faculty of Agriculture, Eskisehir Osmangazi University for evaluating two tillage methods (conventional and reduced), three crop rotations (wheat-wheat; wheat-fallow; wheat-chickpea) and four N levels (0, 50, 100, 150 kg ha⁻¹). 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. The N concentration of grain and straw harvested from aboveground plant organs was separately determined using by the Kjeldahl digestion method after the plant samples were ground. Then, grain protein content, nitrogen use efficiency (NUE), nitrogen uptake efficiency (NUPE), nitrogen utilization efficiency (NUTE) were calculated. According to results, effects of tillage methods on NUE were unclear. Conventional tillage methods resulted in higher NUPE than reduced tillage in the last three years of the experiment. The NUTE was higher in reduced tillage than conventional in 2011-2012 and 2014-2015. The effects of tillage methods on grain yield were different due to the climatic conditions. Wheat-chickpea rotation had the better results for examined traits in this research. Increasing nitrogen doses increased grain and plant protein rate, however it decreased NUE and NUPE. The effects of nitrogen doses on NUTE were ambiguous. Nitrogen use efficiency and NUPE is traits that can be differed according to changeable grain yield depend on environmental conditions. Therefore, the experiments should be conducted for more than four years for revealed absolute effects both soil tillage method and nitrogen fertilization.

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Introduction

The cereal-fallow crop rotation is most common method in Central Anatolia region which are greatly contributing to the country for agriculture (Baskan and Unver, 2000). The ways of obtaining crop every year from the fallow fields have been sought since years due to increased demand for the agricultural crops in parallel with the growing population. About 11-23% of the annual rainfall in Central Anatolia is accumulated in the fallow years in suitable climate conditions (Genctan, 2015). Whether or not it would be appropriate to leave the lands empty for one year for accumulating such a low amount of moisture is discussed. It is known that 80-100% of the water held in soil during fallow period is usually lost by evaporation from soil surface. In addition, water accumulation efficiency of less than 90 cm deep soils is less (Genctan, 2015). For this reason, it would be more appropriate for uses the water by plants instead of disappearing by evaporation.

The dry farming areas are poor of organic matters because of fallow-wheat crop rotation. Moreover, in consequence of mono-culture agricultural system, soil compression leads to a deformation of physical construction and reduction of aeration of soils in long-term. These cases as advanced, the accumulation of CO₂ and other matters in the soil is decreased. Also, due to roots exposed to damage, the water absorption by plants, biological nitrogen fixation and microbiological activity decrease. If deep-rooted plants is used to crop rotation, these inconveniences are eliminated (Thériault et al., 2019). Legumes are very important plants for the fallow fields to utilization effectively. Because, the legumes are deep-root plants (up to 1.5–2.0 m) and their roots till the soil deeply and leave an organic matter – rich soil for following sowing season. The annual legumes planted at the fallow area leave less humidity and the same amount

inorganic nitrogen for wheat to be planted next, when compared the fallow (Kun et al., 1990).

The tillage systems are classified in two main groups: traditional tillage and conservation tillage. Soil, water and energy are not conservation in the traditional tillage systems (Ghiyasi et al., 2016). The labour, energy and cost are minimized in the conservation tillage and adequate stubble is left in the field for the protection of water and soil. The conservation tillage mostly applies as minimum tillage or no-tillage sowing and plough is not uses in these tillage methods (Jabran and Aulakh, 2015).

A good genotype uses the nitrogen for grain yield rather than stem by taking high nitrogen in from the soil and fertilizers. Nitrogen use efficiency (NUE) is generally defined as the grain yield produced per unit of N available from the soil and fertilizer (Moll et al., 1982). Nitrogen use efficiency is an indicator for increased yield in low – input sustainable agriculture, minimized fertilizer cost and to reduce harmful effects of excessive fertilization. Moll et al. (1982) reported that both nitrogen uptake efficiency (NUPE) and nitrogen utilization efficiency (NUTE) is supportive for NUE.

In this study, the use of two tillage systems (conventional and reduced), 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 four year and to determine of the effects of tillage, crop rotation and N doses on the grain yield and NUE was aimed.

Material and Methods

The research was conducted during to four years (2011-2015) at the experimental area of Faculty of Agriculture, Eskisehir Osmangazi University, Eskisehir, Turkey (39°48' N; 30°31' E, 798 m above sea level). Monthly and annual precipitation and temperature during the experimental period and long term for Eskisehir are given

Figure 1. According to the results of soil analysis, some of the physical and chemical properties of the experimental area are presented in Table 1.

The study was evaluated effects of on the wheat grain yield and NUE using 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). The experimental design was split split plot with three replicates. Tillage method was in main plots, crop rotation in sub plots and N fertilizer in sub-sub plots.

The conventional tillage included mouldboard ploughing followed by one passes of a sweep plowing 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, however, no-planting plots were tilled by rototiller for weeds when chickpea sown (in spring). Wheat was sown all of the plots in the first and third year. In the second and fourth year, the experimental area was consisted of wheat planted plots to 1/3 part, chickpea planted plots to 1/3 part and fallow to 1/3 part.

Fertilization was applied to 60 kg ha⁻¹ P₂O₅ as TSP (46%) to all plots on wheat. The nitrogen was applied as ammonium nitrate, half of N at the sowing, and the remaining N as top-dressed at the beginning of the wheat stem elongation. 20 kg ha⁻¹ N (ammonium nitrate) and 60 kg ha⁻¹ P₂O₅ [TSP (46%)] applied as basal fertilization to all sub-subplots in the chickpea sowing time.

Each sub-subplot was 12 m² (4 m x 3 m). Wheat (cv. Sönmez) was sown with mechanical seeder to 18 cm row spacing, the rate of 600 seeds m² at on 8 October 2011, on 12 October 2012, on 11 October 2013 and on 21 October 2014. Weed control was made with 2,4-Dichlorophenoxyacetic acid, a chemical herbicide, in early spring.

Table 1. Physical and chemical properties of the soil at the experimental years.

Year	Depth (cm)	Texture	pH	Total salt (%)	Lime (%)	Organic matter (%)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)	N (%)
2011-12	0-30	loamy	8.04	0.057	3.7	0.98	60.6	3411.1	0.04
2012-13	0-30	loamy	7.99	0.064	3.6	1.18	34.9	2258.6	0.05
2013-14	0-30	loamy	7.80	0.079	5.8	1.38	43.1	2151.1	0.06
2014-15	0-30	loamy	7.46	0.020	5.4	1.63	65.3	3630.0	0.07

Table 2. Effect of different tillage methods and nitrogen levels on some charecters of wheat in 2011-2012 growing season.

Treatments	GPR	PPR	NUE	NUPE	NUF	GY
Conventional tillage	12.13	1.95	62.3	13.74	50.92 ^B	3876.9
Reduced tillage	12.00	1.95	66.1	14.08	226.34 ^A	3868.1
Mean	12.06	1.95	64.2	13.91	138.63	3872.5
0 kg ha ⁻¹ N	11.43 ^b	1.86				3743.4 ^b
50 kg ha ⁻¹ N	12.05 ^{ab}	1.84	56.9	15.72 ^a	86.42 ^C	3564.9 ^b
100 kg ha ⁻¹ N	12.28 ^a	2.06	66.6	11.30 ^b	153.43 ^B	3904.4 ^{ab}
150 kg ha ⁻¹ N	12.51 ^a	2.03	69.2	14.72 ^a	176.05 ^A	4277.4 ^a
Mean	12.06	1.95	64.2	13.91	138.63	3872.5
Tillage	ns	ns	ns	ns	**	ns
N doses	*	ns	ns	*	**	*
Tillage × N doses	ns	ns	**	**	**	ns

GBR: Grain protein ratio (%); PPR: Plant protein ratio (%); NUE: Nitrogen use efficiency (kg ha⁻¹); NUPE: Nitrogen uptake efficiency (kg ha⁻¹); NUF: Nitrogen utilization efficiency (kg ha⁻¹); GY: Grain yield (kg ha⁻¹); ns: non significant, *: P<0.05, **: P<0.01.

Table 3. Effect of different tillage methods and nitrogen levels on some characters of wheat in 2012-2013 growing season.

Treatments	GPR	PPR	NUE	NUPE	NUF	GY
Conventional tillage	11.92 ^A	2.99 ^A	48.3 ^B	33.53 ^a	56.94	2823.5 ^b
Reduced tillage	10.30 ^B	2.13 ^B	129.1 ^A	17.68 ^b	59.66	4071.7 ^a
Mean	11.11	2.56	88.7	25.60	58.30	3447.6
0 kg ha ⁻¹ N	10.10 ^B	1.59 ^D	-	-	-	3320.2 ^{bc}
50 kg ha ⁻¹ N	11.39 ^A	2.20 ^C	115.7 ^A	40.62 ^A	20.95 ^C	3551.0 ^{ab}
100 kg ha ⁻¹ N	11.28 ^A	2.69 ^B	72.9 ^B	24.53 ^B	67.45 ^B	3218.0 ^c
150 kg ha ⁻¹ N	11.67 ^A	3.77 ^A	77.5 ^B	11.67 ^C	86.50 ^A	3701.1 ^a
Mean	11.11	2.56	88.7	25.60	58.30	3447.6
Tillage	**	**	**	*	ns	*
N doses	**	**	**	**	**	*
Tillage × N doses	**	**	**	ns	**	*

GBR: Grain protein ratio (%); PPR: Plant protein ratio (%); NUE: Nitrogen use efficiency (kg ha⁻¹); NUPE: Nitrogen uptake efficiency (kg ha⁻¹); NUF: Nitrogen utilization efficiency (kg ha⁻¹); GY: Grain yield (kg ha⁻¹); ns: non significant, *: P≤0.05, **: P≤0.01.

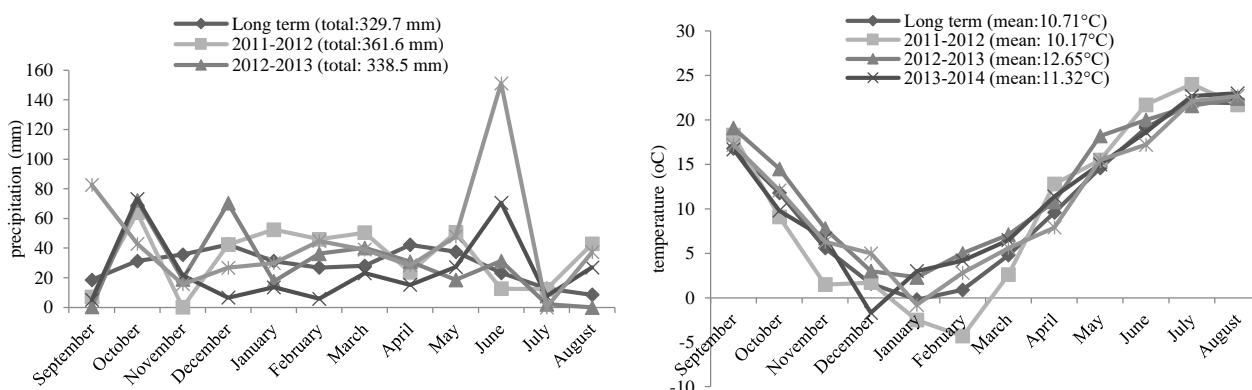


Figure 1. Total rainfall and monthly mean temperature for four seasons at Eskişehir, Turkey

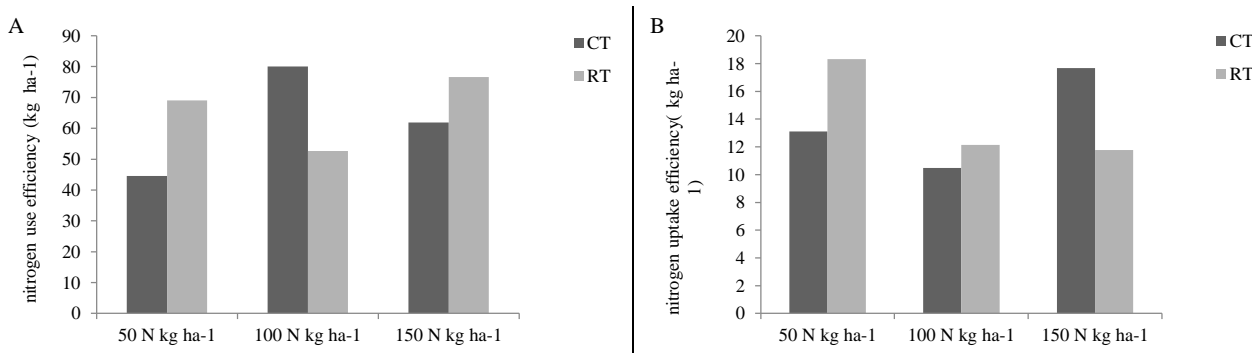


Figure 2. The interaction between tillage methods and N levels on nitrogen use efficiency (A) and nitrogen uptake efficiency (B) of wheat in 2011-2012 [LSD1%: 2.756 (A); LSD1%: 0.559 (B)]

Wheat plants were harvested separately in all sub sub-plots, on 23 July 2012, on 8 July 2013, on 9 July 2014, on 22 July 2015. The yields of each sub-subplot were found by blending and weighing. The N concentration of grain and straw was separately determined using by the micro Kjeldahl digestion method after the plant samples were ground. Then, grain protein ratio and plant protein ratio were obtained by multiplying 6.25 (Jones, 1981).

The NUE, NUPE and NUTE were calculated according to Moll et al. (1982), Sowers et al. (1994) and Delagu et al. (1998) by following formulas.

$$NUE = [\text{yield at } N \times (\text{kg ha}^{-1}) - \text{yield at } N_0 (\text{kg ha}^{-1})] / \text{applied N (kg ha}^{-1})$$

$$NUPE = [\text{total aboveground plant N at } N \times (\text{kg ha}^{-1}) - \text{total aboveground N at } N_0 (\text{kg ha}^{-1})] / \text{applied N (kg ha}^{-1})$$

$$NUTE = [\text{yield at } N \times (\text{kg ha}^{-1}) - \text{yield at } N_0 (\text{kg ha}^{-1})] / [\text{total aboveground plant N at } N \times (\text{kg ha}^{-1}) - \text{total aboveground plant N at } N_0 (\text{kg ha}^{-1})]$$

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

Results and Discussion

Tillage

The grain and plant protein ratio were higher in conventional tillage than reduced tillage during the 2012-2013 growing season while only plant protein ratio were higher in conventional tillage than reduced tillage during the 2013-2014 growing season (Table 3,4). Some researchers (Lopez-Bellido et al., 1998; Ruisi et al., 2016) reported that higher grain protein ratio was obtained at the conventional tillage, the others (Ali et al., 2019; Ruiz et al., 2019) at the zero tillage. Adak and Birsin (2000) noticed that the grain protein ratio at the conventional tillage was

higher in comparison to reduced tillage. The “tillage × nitrogen doses” interaction was statistically significant in the second year (Figure 4A, 4B). The highest values of grain and plant protein ratio obtained from 150 kg ha⁻¹ N levels in the conventional tillage. While 0 kg N ha⁻¹ dose had higher grain protein ratio all of the plots, in the third growing season, it had the lowest value on reduced tillage and wheat-wheat-wheat crop rotation. The highest plant protein ratio was obtained from the conventional tillage, wheat – chickpea crop rotation system and 150 kg ha⁻¹ N levels, while 150 kg N ha⁻¹ caused quite low value at the reduced tillage and wheat - fallow crop rotation systems. For this reason, “tillage x crop rotation x nitrogen doses” interaction was significant (Figure 7A and 7B). Reduced tillage and 50 kg ha⁻¹ N level were caused the highest plant protein ratio all of the plots in the fourth growing season, while the conventional tillage methods showed the highest value in 100 kg ha⁻¹ N level. Therefore, “tillage x nitrogen dose” interaction was significant significantly (Figure 10A).

The NUE was higher in the reduced tillage than conventional tillage in 2012-2013 growing season however in 2013-2014 growing season was vice versa (Table 3, 4).

Nitrogen use efficiency might be high due to high grain yield in these tillage methods (Nitrogen use efficiency: Grain yield / applied N). Devi et al. (2015) reported that the NUE is higher in zero tillage than in conventional tillage. The NUE was decreased in the conventional tillage and 150 kg ha⁻¹ N levels, while NUE was increased in reduced tillage and same N dose in first growing season. This condition was resulted significant “tillage x nitrogen dose” interaction (Figure 2A). In the second growing season, the reason of this significant interaction was higher NUE in reduced tillage and 50 kg ha⁻¹ N level and lower values in the conventional tillage and 50 kg ha⁻¹ N doses (Figure 5A). The highest NUE value in the conventional tillage, wheat – chickpea rotation system and 100 kg ha⁻¹ N levels in third growing season, but the same nitrogen dose had lower values at other plots. Tillage x crop rotation x nitrogen dose interaction was significant (Figure 8A). While 50 kg ha⁻¹ N levels showed superior performance under conventional tillage for NUE in fourth growing season, the same tillage methods showed lower value in the other plots. For this reason, tillage x nitrogen dose interaction was significant (Figure 10B).

Table 4. Effect of different tillage methods, crop rotations and nitrogen levels on some characters of wheat in 2013-2014 growing season.

Treatments	GPR	PPR	NUE	NUPE	NUF	GY
Conventional tillage	13.93	4.13 ^A	30.5 ^A	5.19 ^a	332.19	1283.5 ^A
Reduced tillage	13.89	3.39 ^B	24.1 ^B	4.14 ^b	336.90	935.6 ^B
Mean	13.91	3.76	27.30	4.66	334.54	1109.5
Wheat-Wheat	12.91 ^B	3.52 ^C	25.3 ^B	6.64 ^A	90.87 ^C	1173.0 ^A
Wheat-Fallow	14.20 ^{AB}	3.68 ^B	18.7 ^C	2.68 ^C	601.99 ^A	990.1 ^B
Wheat-Chickpea	14.62 ^A	4.08 ^A	38.1 ^A	4.67 ^B	310.78 ^B	1165.6 ^A
Mean	13.91	3.76	27.30	4.66	334.54	1109.5
0 kg ha ⁻¹ N	13.00 ^C	3.46 ^C				1115.6 ^B
50 kg ha ⁻¹ N	13.82 ^B	3.56 ^C	37.3 ^A	7.32 ^A	267.74 ^B	1034.2 ^C
100 kg ha ⁻¹ N	14.26 ^{AB}	3.90 ^B	31.2 ^B	4.28 ^B	441.86 ^A	1192.2 ^A
150 kg ha ⁻¹ N	14.54 ^A	4.13 ^A	13.5 ^C	2.39 ^C	294.04 ^B	1096.2 ^{BC}
Mean	13.91	3.76	27.30	4.66	334.54	1109.5
Tillage	ns	**	**	*	ns	**
Crop rotation	**	**	**	**	**	**
N doses	**	**	**	**	**	**
Tillage × crop rot.	ns	**	**	**	**	**
Tillage × N doses	ns	**	**	**	**	**
Crop rot. × N doses	**	**	**	**	**	**
Till. × crop rot. × N dose	**	**	**	**	**	**

GBR: Grain protein ratio (%); PPR: Plant protein ratio (%); NUE: Nitrogen use efficiency (kg ha⁻¹); NUPE: Nitrogen uptake efficiency (kg ha⁻¹); NUF: Nitrogen utilization efficiency (kg ha⁻¹); GY: Grain yield (kg ha⁻¹); ns: non significant, *: P≤0.05, **: P≤0.01.

Table 5. Effect of different tillage methods and nitrogen levels on some characters of wheat in 2014-2015 growing season.

Treatments	GPR	PPR	NUE	NUPE	NUF	GY
Conventional tillage	12.92	4.23	174.9	19.90A	60.36B	2178.00A
Reduced tillage	11.98	4.56	71.8	9.87B	77.51A	1438.00B
Mean	12.45	4.39	123.35	14.88	68.93	1808.00
0 kg ha ⁻¹ N	11.93	3.73B				1851.00ab
50 kg ha ⁻¹ N	12.68	5.09A	186.8A	16.43A	126.30A	1654.00b
100 kg ha ⁻¹ N	12.95	4.44AB	108.2B	11.50B	50.80B	1790.00ab
150 kg ha ⁻¹ N	12.25	4.33AB	75.0C	16.72A	29.70C	1935.00a
Mean	12.45	4.39	123.35	14.88	68.93	1808.00
Tillage	ns	ns	ns	**	**	**
N doses	ns	**	**	**	**	*
Tillage × N doses	ns	*	**	**	**	**

GBR: Grain protein ratio (%); PPR: Plant protein ratio (%); NUE: Nitrogen use efficiency (kg ha⁻¹); NUPE: Nitrogen uptake efficiency (kg ha⁻¹); NUF: Nitrogen utilization efficiency (kg ha⁻¹); GY: Grain yield (kg ha⁻¹); ns: non significant, *: P≤0.05, **: P≤0.01.

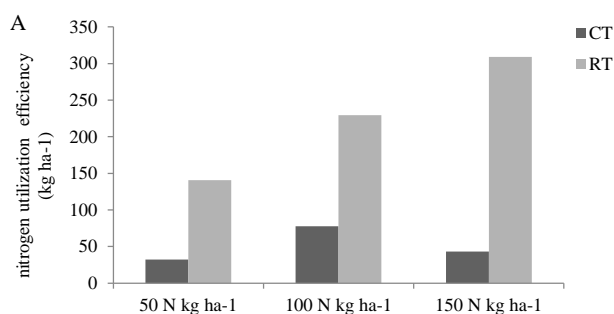


Figure 3. The interaction between tillage methods and N levels on nitrogen utilization efficiency (A) of wheat in 2011-2012 [LSD1%: 1.858 (A)]

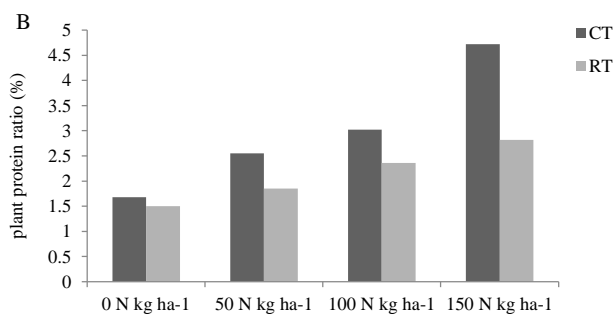
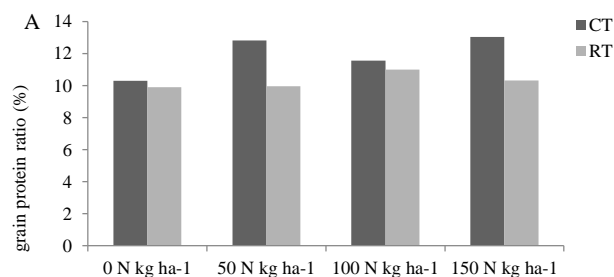


Figure 4. The interaction between tillage methods and N levels on grain protein ratio (A) and plant protein ratio (B) of wheat in 2012-2013 [LSD1%: 1.212 (A); LSD1%: 0.445 (B)]

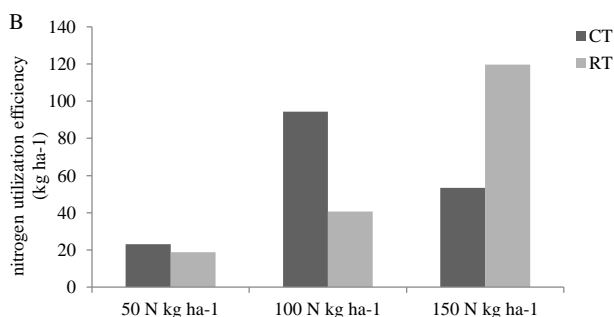
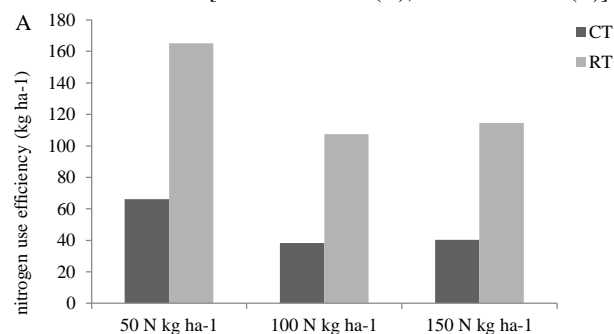


Figure 5. The interaction between tillage methods and N levels on nitrogen use efficiency (A) and nitrogen utilization efficiency (B) of wheat in 2012-2013 [LSD1%: 1.803 (A); LSD1%: 1.644 (B)]

The nitrogen uptake efficiency was higher in conventional tillage than reduced tillage in the 2012 – 2013, 2013 – 2014 and 2014-2015 growing seasons (Table 3,4,5). The NUPE was higher in conventional tillage than zero tillage according to findings of Lopez-Bellido and Lopez-Bellido (2001) and Rani et al. (2017). Brennan et al. (2015) noticed that the NUPE was higher in conventional tillage than reduced tillage. The NUPE showed the highest values in conventional tillage and 150 kg ha⁻¹ N levels in first year, although reduced tillage and 50 kg N ha⁻¹ dose showed the highest values (Figure 2B). While reduced tillage, wheat-wheat crop rotation and 50 kg ha⁻¹ N level had highest NUPE in the third growing season, the same nitrogen doses showed lower values in other plots (Figure 8B). Therefore, the interactions between applications were significant. The NUPE was not increased as parallel at N doses in both tillage methods, so “tillage x nitrogen dose” interactions was found significant (Figure 11A).

The nitrogen utilization efficiency was higher in reduced tillage than the conventional tillage in 2011 – 2012 and 2014-2015 growing seasons (Table 2, 5). Unlike the findings of this study, Rani et al. (2017) indicated that NUTE determined in traditional tillage. “Tillage x nitrogen dose” interactions were significant because NUTE increased in reduced tillage with increasing N doses, while it was irregular in conventional tillage at first and second years in experiment (Figure 3A and 5B). In third year, the variability of NUTE according to crop rotation, tillage methods and N doses was resulted significant “tillage x crop rotation x nitrogen dose” interaction (Figure 9A). For NUTE, 50 kg ha⁻¹ N levels showed superior performance under reduced tillage method in fourth growing season; however the NUTE was found the highest 100 kg ha⁻¹ N dose and conventional tillage. Moreover, the NUTE of both tillage methods in 150 kg ha-1 N dose were close to each other (Figure 11B).

The grain yield was higher in reduced tillage than conventional tillage in 2012-2013 growing season (Table 3). The total precipitation and average temperature showed similar values to the long term in second year but total precipitation in April and May (49.4 mm) is lower than the long term (79.7 mm) and the temperature was higher (Figure 1). The reduced tillage better protect the moisture in the soil (Page et al., 2019). Low precipitation and high temperatures during spring season might be increased evaporation and reduced tillage might be better protecting soil moisture. Therefore the grain yield might be higher in reduced tillage. The grain yield was lower than expected due to drought in 2013-2014 growing season (Table 4). While the long term total precipitation was 329.7 mm, the total precipitation was 269.4 mm in this season (Figure 1). Even though the precipitation was very high during 2014-2015 growing season, the grain yield was lower in comparison to other years. The region was not received adequately precipitation in November and December (42.4 mm) when after sowing and this precipitation was lower than the long term (78.0 mm) (Figure 1). Lower grain yield in this season might be drought after sowing. The grain yield was higher conventional tillage than reduced tillage in 2013-2014 and 2014-2015 growing seasons. The grain yield was highly variable according to tillage method, crop rotations, N doses, and years so significant interactions were found between them.

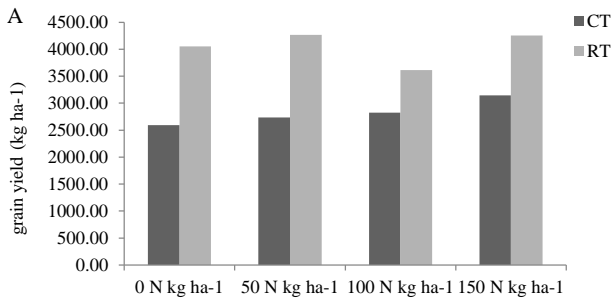


Figure 6. The interaction between tillage methods and N levels on grain yield (A) of wheat in 2012-2013[LSD5%: 43.450 (A)]

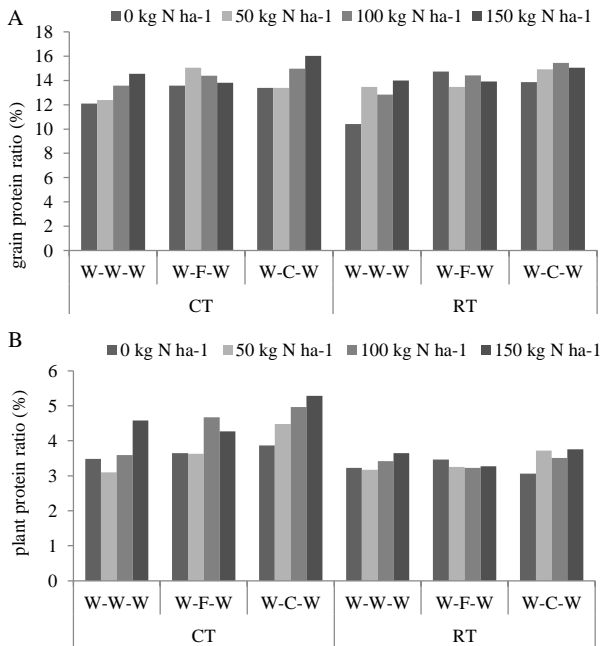


Figure 7. The interaction between tillage methods, crop rotations and N levels on grain protein ratio (A) and plant protein ratio (B) of wheat in 2013-2014[LSD1%: 1.615 (A); LSD1%: 0.279 (B)]

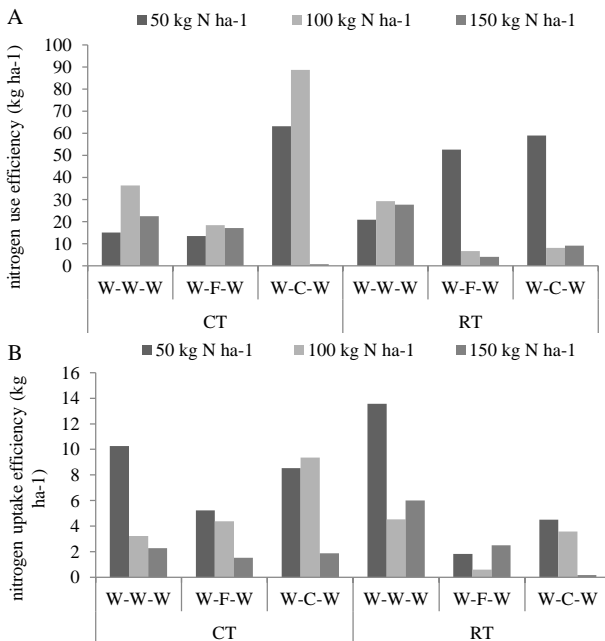


Figure 8. The interaction between tillage methods, crop rotations and N levels on nitrogen use efficiency (A) and nitrogen uptake efficiency (B) of wheat in 2013-2014[LSD1%: 0.618 (A); LSD1%: 0.077 (B)]

Although RT was at the forefront in some years, in general, the CT method, WCW crop rotation and 100 kg N ha⁻¹ seemed suitable for high wheat yield (Figure 6A, 9B and 12A). Malecka et al. (2012), Wozniak (2013) and Ali et al. (2019) indicated that the grain yield was higher in conventional tillage than reduced tillage and zero tillage.

Crop rotation

The effects of different crop rotations were significantly for all of the investigated traits in 2013-2014 growing season (Table 4). The highest grain yield was obtained wheat-wheat crop rotation but it was taken within the same statistical group with the wheat-chickpea crop rotation system. Many researchers have suggested that there was significant increases in the cereals yield when cereals was sown after legumes and this increase was varied according to the type of legume that used as the pre-plant (Unver et al., 2001; Hao et al., 2001; Grant et al., 2016; Kirby et al., 2017). Fischer et al. (2002) found wheat yield close to each other in continuously wheat and wheat-legumes crop rotations.

The highest grain protein ratio, plant protein ratio and nitrogen use efficiency were obtained in wheat-chickpea rotation system. In wheat-legumes crop rotation than wheat-wheat and wheat-fallow crop rotations, higher wheat grain protein ratio was obtained by Lopez-Bellido et al. (1998) and Ali et al. (2019).

While the highest NUPE were obtained wheat-wheat crop rotation, the highest NUTE was obtained wheat-fallow crop rotation. The highest NUE was determined in the wheat-chickpea crop rotation system. The legumes are suggested for higher NUE (Karasahin, 2014). Nitrogen use efficiency might be high due to high grain yield in wheat-chickpea rotation. (Nitrogen use efficiency: Grain yield / applied N). Lopez-Bellido and Lopez-Bellido (2001) reported that the NUE, NUPE and NUTE were higher wheat-legumes rotation system comparison to the continuous wheat and wheat – fallow crop rotation systems.

Fertilization

Grain protein ratio was increased as N doses increased in 2011 – 2012 growing season. This increase was valid for both grain and plant protein ratio in the 2012 - 2013 and 2013 - 2014 growing season. The highest plant protein ratio was obtained at the 50 kg N ha⁻¹ in 2014-2015 growing season (Table 2, 3, 4, 5). The grain and plant protein ratio were higher than expected due to drought in third growing season. If there is low precipitation and high temperature after flowering, the grain yield reduced and the grain protein ratio raised (Panozzo and Eagles, 2000; Ozturk et al. 2006; Bulut, 2009; Sumer et al., 2010). Triboi et al. (2000) argued that grain protein ratio is affected by nitrogen fertilization rather than genotype and environment. Many researchers (Abad et al., 2000; Ottman et al., 2000; Lopez-Bellido et al., 2004; Sumer et al., 2010) determined that increasing nitrogen doses were increased grain and plant protein ratio.

The NUE was decreased depending on the increasing nitrogen doses in 2012-2013, 2013-2014 and 2014- 2015 growing season (Table 3, 4, 5.) There is a linear negative relationships between the N doses and NUE, viz the NUE is lower in high N doses (Ibrikci et al., 2001; Kamara et al.,

2003; Makino et al., 2003; Ev, 2006; Gouis et al., 2000; Semercioglu et al., 2009). Because, NUE is calculated by dividing grain yield to the applied N doses (Moll et al., 1982). The NUE was lower in third growing season comparison to other years however it higher in the fourth year. According to Muchow's findings (1994), the NUE and NUPE are affected air temperature and humidity and increased in higher temperature and humidity. The difference values of NUE between the years might be to climatic conditions, also low NUE in third growing season may be due to the low grain yield occurred because of drought (Figure 1).

Increasing N doses were decreased NUPE in all growing season (Table 2, 3, 4, 5). Nitrogen uptake efficiency is defined that the ratio of beneficial N in the soil to its amount taken by the plant (Karasahin, 2014). Nitrogen uptake efficiency was decreased to increasing N

doses in previous researches (Ibrikci et al., 2001; Presterl et al., 2003; Kamara et al., 2003). When the excessive N application, the plant reaches to maximum saturation and residual N is washed. Therefore, excessive N fertilization is unnecessary to obtain high grain yield (Jokela and Randall, 1997). The NUPE was also determined similar to NUE to be very low in third growing season and very high in fourth growing season. In addition, the high N in soil might be caused higher NUPE.

The highest NUTE was observed at 150 kg N ha⁻¹ in 2011-2012 and 2012-2013, at 100 kg N ha⁻¹ in 2013-2014 and 50 kg N ha⁻¹ in 2014-2015 growing seasons. Kara (2006) and Maral (2009) determined that low NUTE in low N doses, while Kamara et al. (2003) found high NUTE in low N doses. In general, increasing N doses has been increased grain yield (Zaheer et al., 2015; Mansour et al., 2016; Haque et al., 2017; Gad et al., 2018).

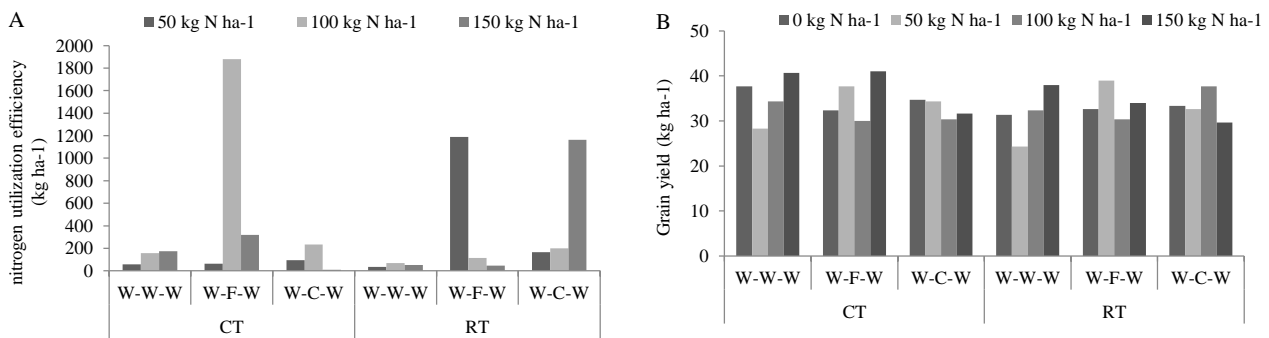


Figure 9. The interaction between tillage methods, crop rotations and N levels on nitrogen utilization efficiency (A) and grain yield (B) of wheat in 2013-2014[LSD1%: 28.420 (A); LSD1%: 16.574 (B)]

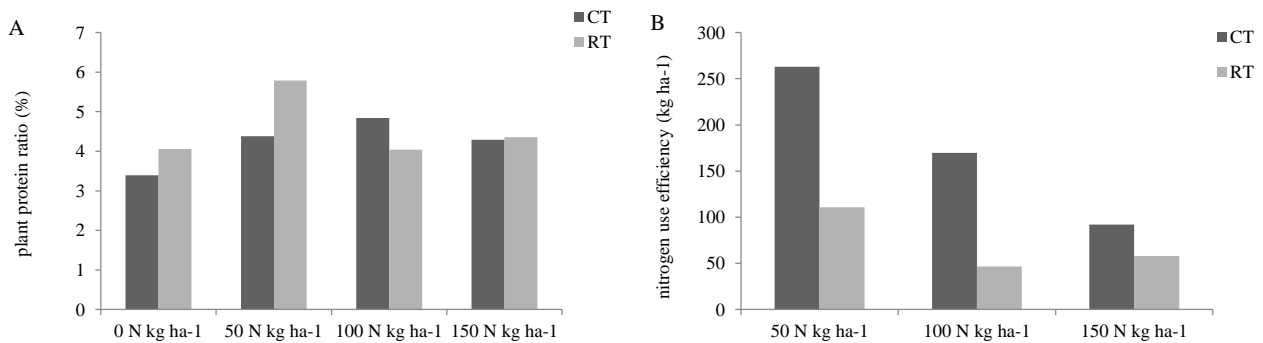


Figure 10. The interaction between tillage methods and N levels on plant protein ratio (A) and nitrogen use efficiency (B) of wheat in 2014-2015[LSD5%: 1.258 (A); LSD1%: 6.397 (B)]

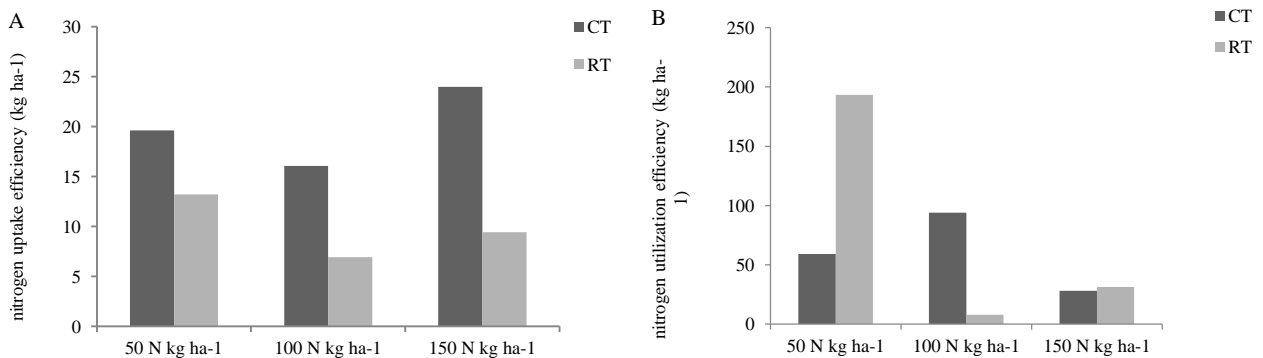


Figure 11. The interaction between tillage methods and N levels on nitrogen uptake efficiency (A) and nitrogen utilization efficiency (B) of wheat in 2014-2015[LSD5%: 0.091 (A); LSD1%: 0.668 (B)]

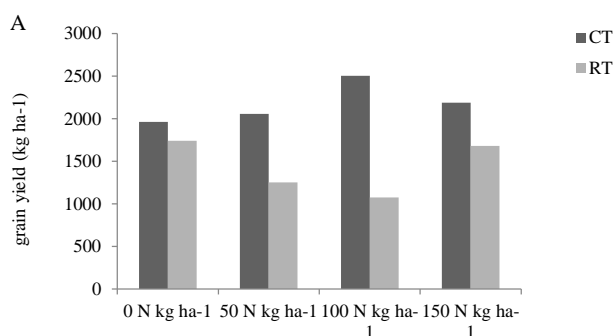


Figure 12. The interaction between tillage methods and N levels on grain yield (A) of wheat in 2014-2015[LSD1%: 34.983 (A)]

Conclusion

This study examined the effects of reduced and conventional tillage methods with applied together three different crop rotation and four N levels on yield, protein ratio, NUE, NUPE, and NUTE. The effect of tillage methods for grain yield and NUE is unclear, however examined traits improved mostly in conventional tillage. Generally, wheat-chickpea rotation system caused higher yield, protein ratio and NUE. Increasing N doses increased grain and plant protein ratio, while decreased NUE and NUPE. Also, N doses caused indeterminate reactions for grain yield and NUTE. These fluctuations might be occurred due to the different climatic conditions. Therefore, there is a need for more long-term studies. As a conclusion in this study, usually, the conventional tillage method, wheat-chickpea crop rotation and 100 kg N ha-1 seemed suitable for high wheat yield, protein ratio and NUEs.

Acknowledgements

This research was supported in part by Eskişehir Osmangazi University Research Foundation as Project no: 201123039.

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