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Araştırma Makalesi/Research Article

Comparisons Nitrogen Use Efficiency in Chickpea under Different Tillage Systems and Soil Residual Nitrogen

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Abstract

The main objective of this study was to investigate the effects of different tillage methods and soil residual nitrogen on chickpea nitrogen use efficiency and yield. This research was conducted with two years (2012/2013-2014/2015) period at research field of Faculty of Agriculture, Eskisehir Osmangazi University, Eskisehir, Turkey. The experiment was designed in randomized complete block design as split split plot with three replicates. Main plots were composed to conventional (CT) and reduced tillage (RT). Wheat-wheat (WW); wheat-fallow (WF); wheat-chickpea (WC) crop rotations were placed in sub plots, and four nitrogen doses (0, 50, 100, 150 kg ha^{-1}) were evaluated as sub-sub plots. Plant protein ratio, plant N ratio and nitrogen utilization efficiency (NU_tE) were higher RT than CT, however nitrogen use efficiency (NUE) and nitrogen uptake efficiency (NU_pE) were higher CT than RT. Increasing nitrogen doses were not affected the plant protein ratio and plant N ratio as expected. NUE and NUpE decreased by increasing nitrogen doses but NU_tE increased. All of the traits except for seed yield were significantly affected by years.
Key words: Nitrogen doses, nitrogen use efficiency, tillage, yield

Nohutta Farklı Toprak İşleme Sistemleri ve Bakiye Azota Bağlı Azot Kullanım Etkinliğinin Karşılaştırılması

Öz

Farklı toprak işleme yöntemleri ve bakiye azotun nohutun verim ve azot kullanım etkinliğine etkisini araştırmak bu çalışmanın temel amacıdır. Araştırma iki yıl süre ile (2012/2013-2014/2015) Eskişehir Osmangazi Üniversitesi Ziraat Fakültesi deneme alanlarında yürütülmüştür. Denemeler bölünen bölünmüş deneme desenine göre üç tekerrürlü olarak kurulmuştur. Ana parsellerde geleneksel ve azaltılmış toprak işleme metodları bulunmaktadır. Buğday-buğday, buğday-nadas ve buğday-nohut ekim nöbeti sistemleri alt parsellere yerleştirilmiş ve dört azot dozu (0, 50, 100, 150 kg ha^{-1}) alt-alt parseller olarak değerlendirilmiştir. Bitkide protein oranı, bitkide azot oranı ve NU_tE azaltılmış işlenen topraklarda daha yüksek iken, NUE ve NU_pE geleneksel işlenen topraklarda daha yüksek olmuştur. Artan azot dozları bitkide protein oranı ve bitkide azot oranını beklendiği şekilde etkilememiştir. Artan azot dozları NUE ve NU_pE azaltırken, NU_tE artırmıştır. Tane verimi hariç incelenen tüm özelliklerde yıllar arasındaki farklılıklar önemli çıkmıştır.
Anahtar Kelimeler: Azot dozları, azot kullanım etkinliği, toprak işleme, verim

Introduction

Annual rainfall in Central Anatolia is varies between 250-400 mm and a large amount of falls in winter (35%) and in spring (34%) seasons. Hot and dry weather becomes dominant during summer season. It has been determined that the water intake in the region is slow and difficult and the loss by evaporation is rapid and easy. (Oner et al., 2016). For this reason, the fallow - cereal rotation system has been necessary in region. The region has semi-arid climate (Kapluhan, 2013) and cereal-fallow crop rotation is important in region for agricultural production due to amount and distribution of irregular precipitation (Baskan and Unver, 2000). The purpose of fallow is that accumulate moisture in soil and eliminate weeds. Furthermore fallow is produce rich soil in terms of nutrients. However, when legumes sown instead of fallow in crop rotation, legumes will leave less moisture than fallow in soil but they will leave inorganic nitrogen close to fallow (Kun et al., 1990). As known, mono culture (fallow - wheat), the same nutrients are being continuously consumed and as a result the balance plant nutrients is being disturbed. Furthermore, nitrate formation and nitrogen mineralization are

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considerably reduced due to soil compacting in this agricultural system (Aksakal, 2004). When the legumes are taken into crop rotation, these drawbacks may be eliminated.

Mouldboard ploughing is excessive used in conventional tillage and it is causing soil compaction and erosion. Conventional tillage method is widely used in our country and all of the stubble is bury in soil. Therefore, erosion increases especially in dry farming areas and the available moisture in soil is lost due to evaporation (Genctan, 2006). Reduced tillage requires less energy than conventional tillage. In other words, reduced tillage contains less intensive and count tillage than conventional tillage (Ozturk, 2014).

The nutrient efficiency is defined as nutrient use and uptake capacity of plants for produce seed yield and biomass. (Gourley et al., 1993). Nutrient efficiency is complex and it involves two basic mechanisms. These; nutrient uptake efficiency (nutrient uptake mechanism is controlled by root secretions and root morphology) and nutrient use efficiency (produced dry matter quantity responsed to unit nutrient) (El Bassam, 1998). The nitrogen efficiency is defined as the economic yield manufactured per unit of soil nitrogen (Moll et al., 1982). Nitrogen efficiency is include nitrogen use efficiency (NUE), nitrogen uptake efficiency (NU_pE) and nitrogen utilization efficiency (NU_tE) (Ortiz-Monasterio et al., 1997).

Different tillage methods and soil residual nitrogen on chickpea nitrogen use efficiency and yield were investigated in this study by using two tillage methods, three crop rotations, and four nitrogen doses in Central Anatolia Region.

Material and Methods

The research was conducted during to two years (2012-2013 and 2014-2015) at the experimental area of Faculty of Agriculture, Eskisehir Osmangazi University, Eskisehir, Turkey (39°48' N; 30°31' E, 798 m above sea level). Climatic conditions for Eskisehir were given Figure 1. Long term annual total precipitation was 329.7 mm and it was 338.5 and 546.1 mm in the experimental years, respectively. Annual average temperature was 12.65°C in 2012-2013 and 11.13°C in 2014-2015. The soil analysis results of experimental area were presented in Table 1 (Anonymous, 2015).

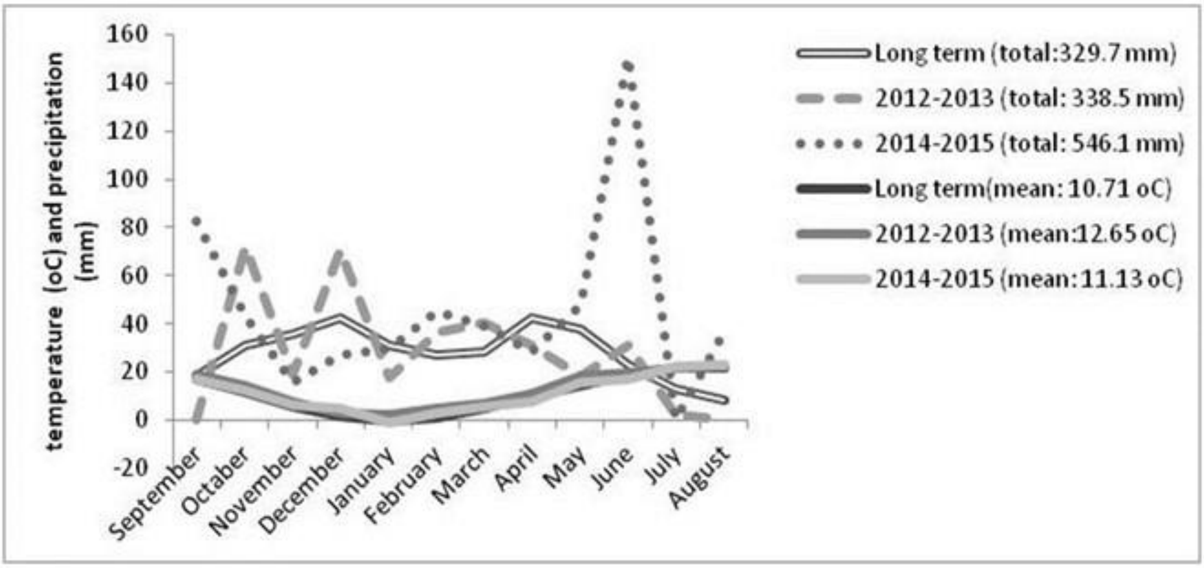

Figure 1. Climatic conditions for experimental area

The field experiment was conducted four years duration (2012-2015). The experiment was designed in randomized complete block design as split split plot with three replicates. Tillage methods (CT: conventional tillage and RT: reduced tillage) were in main plots, crop rotations (WW: wheat-wheat; WF: wheat-fallow; and WC: wheat-chickpea) were subplots and N levels (0, 50, 100, 150 kg ha^{-1}) were sub-sub plots. First and third years, all of the plots was sown with wheat. Wheat, chickpea and fallow were sown considered on the research plots in second and fourth years. The effect of crop

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rotation was investigated only for wheat plant traits. Only chickpea data were given in this article, since effect of crop rotation could not be evaluated on chickpea. Therefore, the results were evaluated according to split plot with three replicates.

Table 1. Soil characteristic of the experimental site.

Year	Texture	pH	Total salt (%)	Lime (%)	Organic matter (%)	P_2O_5 (kg ha^{1})	K_2O (kg ha^{-1})	N (%)
2012-2013	loamy	7.99	0.064	3.65	1.18	34.9	2258.6	0.05
2014-2015	loamy	7.46	0.020	5.40	1.63	65.3	3630.0	0.07

Tillage

The CT included mouldboard ploughing. Sweep and/or rototiller cultivation followed mouldboard ploughing. The RT included sweep plowing and/or rototiller. CT was tillage 25-30 cm depth but this depth was 8-10 cm for RT. Tillage practices were performed in September in all years. Empty plots were tilled by rototiller for weeds control when chickpea sown in spring.

Crop rotation

Three crop rotations were applied. First and third years, all of the plots was sown with wheat. Wheat, chickpea and fallow were sown planned plots in second and fourth years

Fertilization

Ammonium nitrate as nitrogen fertilizer was applied for wheat. Nitrogen fertilization was divided two parts and applications performed at the sowing time and at beginning of the wheat stem elongation (pre-shooting stage). Nitrogen fertilizer levels were applied to only wheat. 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 at the sowing time.

Seeding

Each sub-subplot was 12 m^2 (4 m x 3 m) and cv. Gökçe was used as research material. Chickpea was sown 30 cm row spacing and seeding rate was 60 seeds m^{-2}. The sowing time was 01 April 2013 and 14 April 2015, respectively. Weeds were removed by hand and herbicide was not applied. Chickpea was harvested on 29 July 2013 and 25 August 2015, respectively.

All of the sub-subplots were harvested separately and the yields of each sub-subplots was found. After crop seeds matured, a 0.5 m^2 part was harvested from the each sub-subplot and N content of straw and seed were determined. Straws and seeds were dried 72 h at 65°C and then they were analysed for total N by a microKjeldahl method (Bremner and Mulvaney, 1982). NUE is calculated according to the applied nitrogen doses. In addition, the NU_pE and NU_tE were also determined using various parameters (Moll et al., 1982; Sowers et al., 1994)

$$NUE = ((\text{yield at Nx} - \text{yield at N0}) \div \text{applied N})$$

$$NUpE = \left((\text{total aboveground plant N at Nx} - \text{total aboveground N at N0}) \div \text{applied N}\right)$$

$$NUtE = ((\text{yield at Nx} - \text{yield at N0} \div (\text{total avoveground plant N at Nx} - \text{total aboveground plant N at N0}))$$

The variance analysis were subjected according to General Linear Model with the Statview package (SAS Institute). Least Significant Differences (LSD) test was used to compare the means.

Results and Discussion

Plant protein ratio, plant N ratio, NUE, NU_PE and NU_tE were significantly affected to different tillage methods. Effect of soil residual N applied wheat on plant protein ratio, plant N ratio,

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NUE, NU_pE and NU_tE were significant. Differences between the years were significant in all of the investigated characters except plant protein ratio and seed yield. Year × tillage interactions were significant for plant protein ratio, plant N ratio, NU_pE and NU_tE. Plant N ratio, NUE, NU_pE, NU_tE and seed yield were significantly affected year × N doses interactions. The effects of tillage × N doses interactions on NU_pE and NU_tE were significant. Differences between the year × tillage × N doses interactions were significant for all of the investigated characters except for plant N ratio (Table 2). While seed protein ratio, plant protein ratio and seed N ratio had higher values all of the plots in 2014-2015 growing season, these traits showed the lower values in 2012-2013 growing season (Figure 2A, B; 3A).

Table 2. Variance analysis and means of the some characters of chickpea for different tillage methods and soil residual nitrogen

Treatments	**Seed protein ratio (%)**	**Plant protein ratio (%)**	**Seed N ratio (%)**	**Plant N ratio (%)**	**NUE (kg ha^{-1})**	**NU_pE (kg ha^{-1})**	**NU_tE (kg ha^{-1})**	**Seed yield (kg ha^{-1})**
CT	20.03	4.22 B	3,51	0,78 B	55.41A	17.48 A	25.58 B	1331.9
RT	20.04	4.56 A	3,51	0,85 A	41.44 B	15.53 B	42.24 A	1233.4
Mean	20.03	4.39	3,51	0,81	48.42	16.50	33.91	1282.7
0 kg ha^{-1} N	20.29	5.00 A	3,56	1,06 A				1211.2
50 kg ha^{-1} N	20.06	3.98 D	3,51	0,69 B	72.00 A	30.65 A	18.62 C	1260.8
100 kg ha^{-1} N	19.72	4.40 B	3,46	0,77 B	43.95 B	11.30 B	24.66 B	1351.9
150 kg ha^{-1} N	20.08	4.18 C	3,52	0,73 B	29.32 C	7.57 C	58.46 A	1306.6
Mean	20.03	4.39	3,51	0.81	48.42	16.50	33.91	1282.7
2012-2013	18.56 B	3.96 b	3,25 B	0,79	21.62 B	11.93 B	22.23 B	1178.5
2014-2015	21.51 A	4.82 a	3,77 A	0,84	75.22 A	21.08 A	45.59 A	1386.9
Mean	20.03	4.39	3,51	0,81	48.42	16.50	33.91	1282.7
Year	**	*	**	ns	**	**	**	ns
Tillage	ns	**	ns	**	**	**	**	ns
N doses	ns	**	ns	**	**	**	**	ns
Year x tillage	ns	**	ns	**	ns	**	**	ns
Year x N doses	ns	ns	ns	**	**	**	**	**
Tillage x N doses	ns	ns	ns	ns	ns	**	**	ns
Year x tillage x N doses	**	*	**	ns	**	**	**	**

ns: non significant, *: p≤0.05, **: p≤0.01.

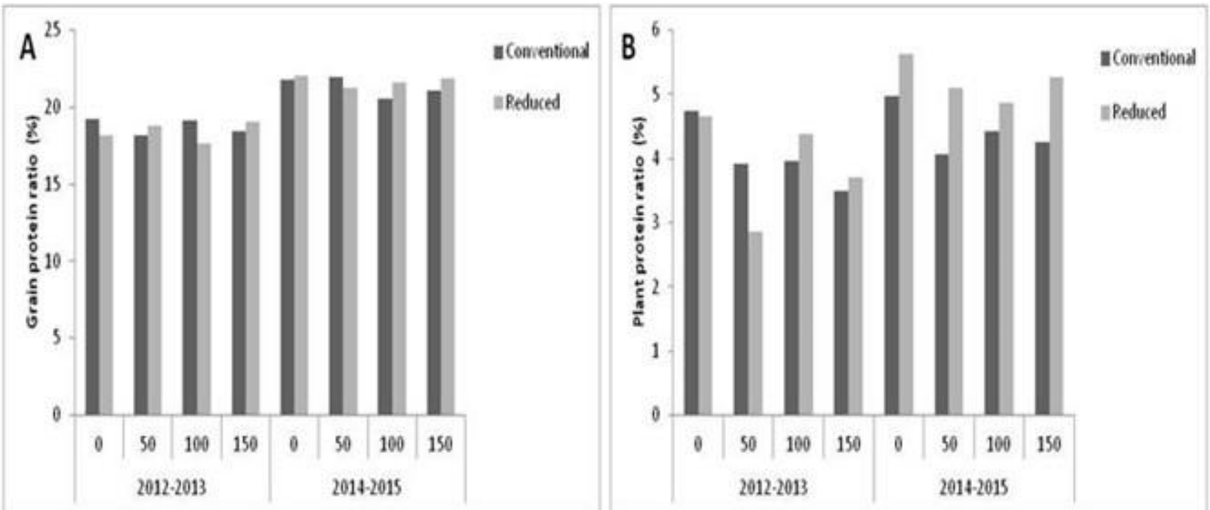

Figure 2. The interaction between tillage methods, years and soil residual nitrogen on seed protein ratio (A) and plant protein ratio (B) of chickpea [LSD1%: 1.325 (A); LSD5%: 0.686 (B)].

2020: 8 (1): 243-250
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The NUE and NU_pE showed highest value on 50 kg N ha^{-1} and 2014-2015 growing season however 50 kg N ha^{-1} showed lower value in 2012-2013 growing season (Figure 4B, 5A). The 100 kg ha^{-1} N levels showed superior performance for NU_tE in 2014-2015 growing season however the same N dose showed lowest values in 2012-2013 growing season (Figure 5B). While 100 kg ha^{-1} N levels showed superior performance under CT for seed yield in 2014-2015 growing season, the same N dose showed lower value in the other plots (Figure 6). Plant N ratio had higher values reduced tillage in 2014-2015 growing season however these traits showed lower values in conventional tillage same year (Figure 3B). While 0 kg ha^{-1} N levels showed superior performance under 2012-2013 growing season, another N doses showed lower value in the same year (Figure 4A). For this reason interactions were significant.

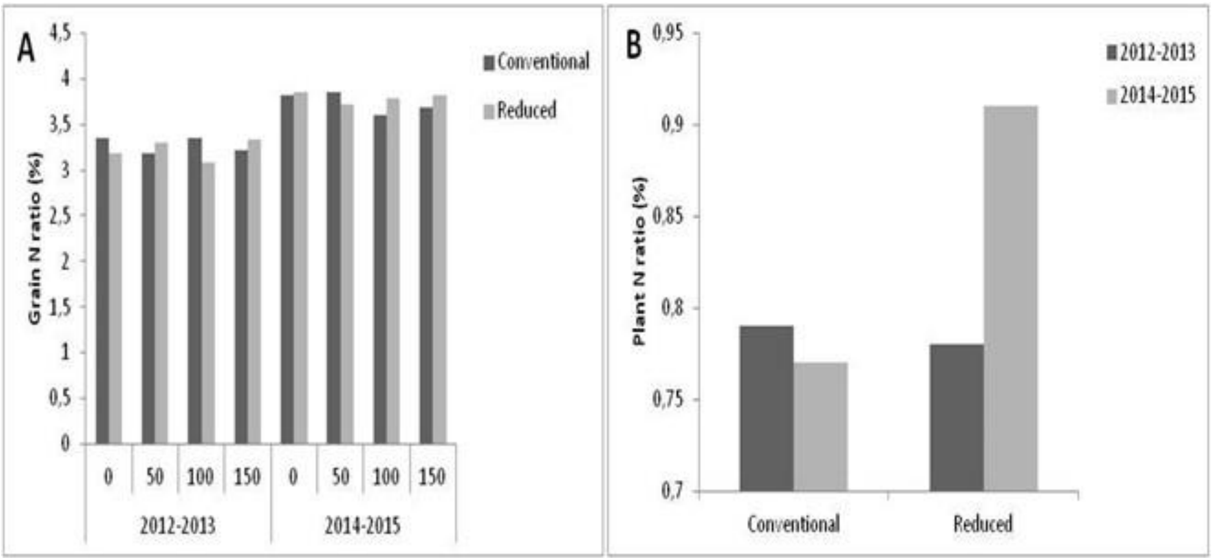

Figure 3. The interaction between tillage methods, years and soil residual nitrogen on seed N ratio (A) and tillage methods and years on plant N ratio (B) of chickpea [LSD1%: 0.228 (A); LSD1%: 0.059 (B)].

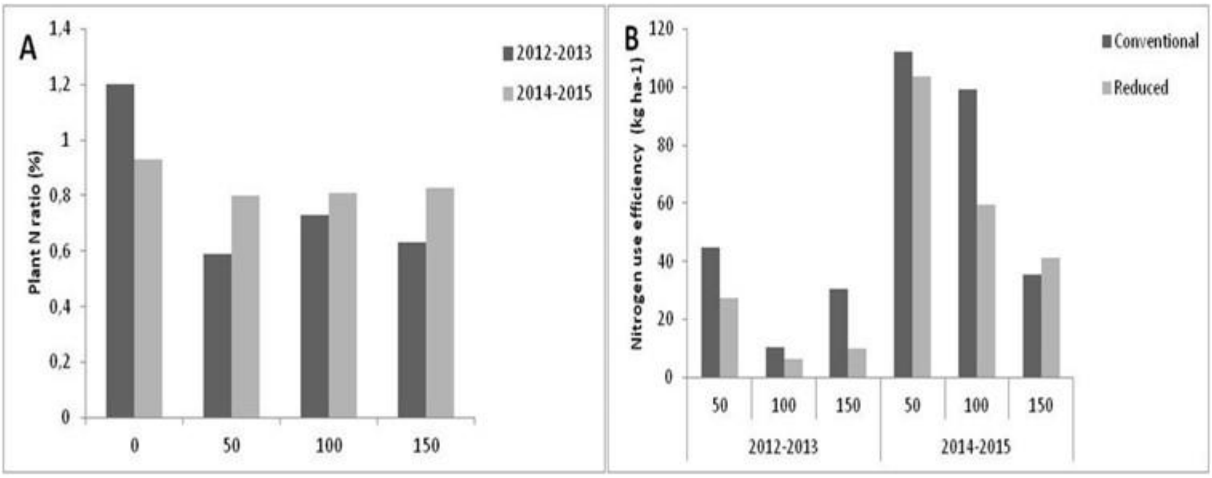

Figure 4. The interaction between years and soil residual nitrogen on plant N ratio (A) and tillage methods, years and soil residual nitrogen on NUE (B) of chickpea[LSD1%: 0.125 (A); LSD1%: 1.211 (B)].

The seed protein ratio, plant protein ratio, seed N ratio, plant N ratio, NUE, NU_pE and NU_tE were higher in 2014-2015 growing season than 2012-2013 growing season (Table 2). Uzun et al. (2012) indicated that seed protein ratio of chickpea can be varied between 16.4% and 31.12% and seed protein ratio is affected both of the genotypic and environmental conditions. Gul et al. (2007) indicated that seed protein ratio was highly influenced by climatic conditions in growing season.

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Nitrogen intake is higher in high temperature and rainfall (Muchow, 1994). Differences between years for seed protein ratio and plant protein ratio might be occurred ecological conditions, cultural practices and soil factors. NUE and NU_tE might be high due to high seed yield in 2014-2015 growing season (NUE: Seed yield / applied N; NU_tE: Seed yield/total aboveground plant N). NUE and NU_pE were higher in 2014-2015 growing season than 2012-2013 growing season. While the 2012-2013 total precipitation was 338.5 mm, the total precipitation was 546.1 mm in 2014-2015 growing season (Figure 1). Muchow (1994) found that N uptake and use of plants were limited by temperature and humidity and these traits were higher when temperatures and humidity were high.

Plant protein ratio, plant N ratio and NU_tE were higher RT than CT but NUE and NU_pE were higher CT than RT. The higher NUE in CT might be due to the higher seed yield compared to the RT. NUE and NUpE were higher in CT than RT (Lopez-Bellido and Lopez-Bellido, 2001; Brennan et.al., 2014). Lopez-Bellido et. al. (2004) indicated that NU_tE was higher in zero tillage than CT but Brennan et. al. (2014) reported that the NU_tE was higher in CT than RT.

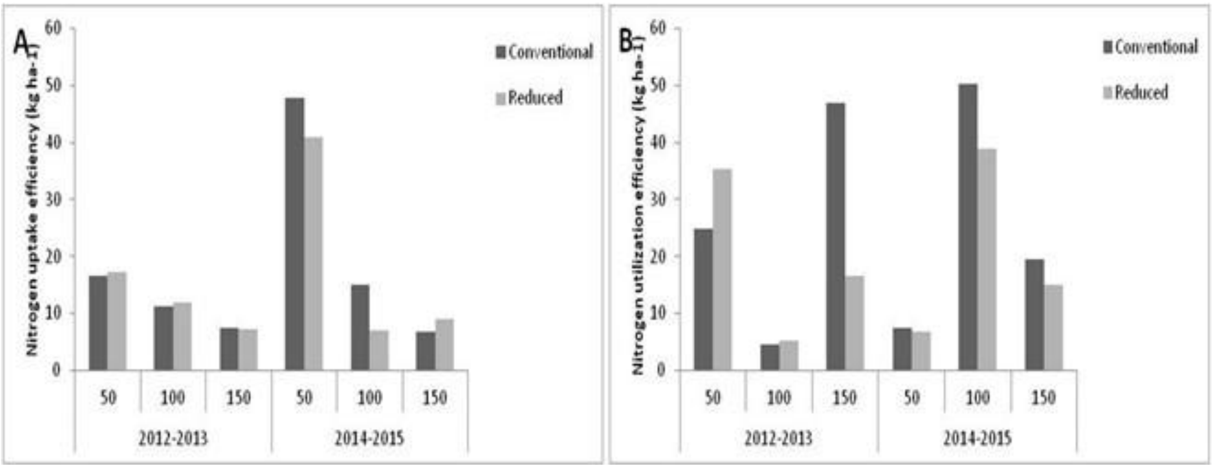

Figure 5. The interaction between tillage methods, years and soil residual nitrogen on NU_pE (A) and NU_tE (B) of chickpea [LSD1%: 0.086 (A); LSD1%: 0.554(B)].

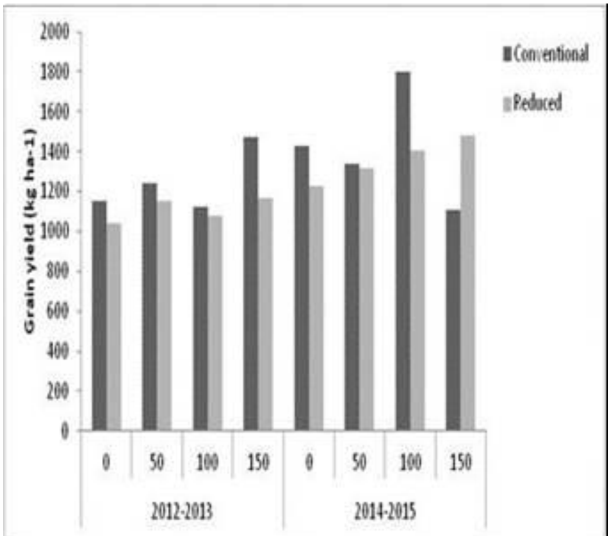

Figure 6. The interaction between tillage methods, years and soil residual nitrogen on seed yield of chickpea [LSD1%: 391.73].

Increasing N doses affected the plant protein ratio and plant N ratio. While the highest plant protein ratio and plant N ratio were obtained from the 0 kg N ha $^{-1}$ plot, the lowest plant protein ratio and plant N ratio were determined in the 50 kg N ha $^{-1}$ plot. The seed protein ratio and plant protein ratio increased depending on the increasing nitrogen doses (Abad et al., 2000; Ottman et al., 2000; Lopez-Bellido et al., 2004; Sumer et al., 2010). Our results were different than expected. Total precipitation in both 2012-2013 and 2014-2015 is higher than the long term. The N doses were applied to the pre-plant instead of chickpea. The N might be washed away in this long period from the harvest of wheat to the cultivation of chickpea. Therefore increasing N doses may not have been affected seed protein ratio, seed N ratio, plant protein ratio and plant N ratio in our research. NUE decreased at higher N doses however it increased at lower nitrogen doses (Table 2). NUE is that seed yield is proportional to applied N doses (Moll et al., 1982). Therefore, the NUE is lower at higher N doses (Muchow, 1998). In addition, when the N is applied excess, the N taken from the N fertilizer decrease. When the N is applied more than necessary, N losses increase due to washing and NU_tE decreases (William and Randall, 1997). Kara (2006) and Maral (2009) reported that there was a negative relationship between N dose and N efficiency, also NUE was decreased depending on increasing N doses. Increasing N doses were decreased the NU_pE (Table 2). NU_pE is that beneficial N in soil is proportional to amount taken by plant (Karasahin, 2014). Kamara et al. (2003) and Kara (2006) reported that the NU_pE was decreased depending on increasing N doses. NU_tE was increased due to increasing N doses (Table 2). Kara (2006) and Maral (2009) reported that NU_tE was decreased in low N doses.

Conclusion

The plant protein ratio, plant N ratio and NU_tE were higher in the RT than in CT, while the NUE and NU_pE were higher in CT than RT. Increasing N doses were not affected the plant protein ratio and plant N ratio. Because, the N doses were not applied to chickpea and the N might be leaching in the long period from the harvest of wheat to the cultivation of chickpea. NUE and NU_pE were decreased at higher N doses however NU_tE was increased due to increasing N doses. Ecological conditions, cultural practices and soil factors affected differences of years in all traits except seed yield.

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