INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print) 2222-5234 (Online)
http://www.innspub.net
Vol. 4, No. 6, p. 190-200, 2014

RESEARCH PAPER OPEN ACCESS

Nitrogen agronomic efficiency of wheat in different crop rotations, and the application rates of nitrogen

Reza Nasri[1*], Ali Kashani[1], Mehrshad Barary[2], Farzad Paknejad[1], Saeed Vazan[1]

[1]*Department of Agronomy and Plant Breeding, Karaj branch, Islamic Azad University, Karaj, Iran*

[2]*Department of Agronomy and Plant Breeding, Faculty of Agriculture, Ilam University, Ilam, Iran*

Key words: Nitrogen agronomic efficiency, nitrogen recovery efficiency, nitrogen uptake efficiency, rotation, wheat.

http://dx.doi.org/10.12692/ijb/4.6.190-200 Article published on March 25, 2014

Abstract

This research was carried out under the temperate climate condition of Ilam province, Iran, during 2011-2013 growing seasons to determine the suitable crop rotation for enhancing the nitrogen use efficiency of wheat. The experiment was performed in a split plot arrangement based on randomized complete block design with 4 replications. The main plots consisted of 6 pre-sowing plant treatments (control, PerkoPVH, Buko, Clover, Oilseed radish and combination of three plants; Ramtil, Phasilia, and clover), and sub-plots were allocated to four levels of nitrogen fertilizer (Zero, fertilizer recommendation based on soil test, 50% lower and 50% higher than the recommended fertilizer).The results showed that there were significant differences among the pre-sowing treatments for the grain yield. The highest and lowest grain yield, were obtained for Buko: wheat rotation and fallow: wheat rotation with 8345, and 4491 kg/ha, respectively. The highest and the lowest nitrogen uptake were obtained for Buko: wheat and clover: wheat rotation, respectively. The difference between the various rotations was significant for nitrogen agronomic efficiency. The rotation of oilseed radish: wheat increased nitrogen economic performance up to 20.36 kg/ha.The physiological nitrogen efficiency in fallow: wheat rotation was the highest with 39 kg kg^{-1} of nitrogen. The maximum nitrogen recovery efficiency were obtained for oilseed radish: wheat and PerkoPVH: wheat rotation with 45% and 36%, respectively.The highest nitrogen harvest index was observed in Buko: wheat rotation: (86.5%), and Perko: wheat (85%) and the lowest one in fallow: wheat (79.28%).

* **Corresponding Author:** Reza Nasri ✉ nasri2003_r@yahoo.com

Introduction

There are about 160 species in *Brassica* genus, which are mostly annuals and biennial. The plants in this genus have a good potential for fodder uses. The progress in plant breeding science has produced new crop varieties for oil and forage usage. Perko varieties are derived from crosses tetraploid plants of winter rapeseed (*Brassica napus* L.Var. napus) and Chinese cabbage (*Brassica campestris* L. var. sensulato) and new plants is superior to their parents from various directions. Buko varieties are a new amphiploid plant obtained by crossing tetraploid winter rapeseed, Chinese cabbage and turnips (*Brassica campestris* L. var. Rapa). Oilseed radish with scientific name (*Raphanus sativus* L.)is a genus of the Brassica and consumption, oil, green manure, feed and fodder (Kashani *et al.*1986:Lupashku, 1980).This plant in many countries, including Canada, is cultivated in gardens as cover crop. Oilseed radish is growing quickly in the cool seasons. Ramtil (*Guizotia abyssinica*) belongs to the family *Compositae*, Phasilia (*Phaceli atanacetifolia*L.) belongs to *Boraginaceae* family (Marianne, 1994) and clover belongs to *Fabaceae* family that are grown for feeding purposes.

An increase of 33 to 60 percent in crop yield due to fertilizer application has been confirmed by FAO in different countries and so FAO called fertilizers as the key to food security. Nitrogen is one of the macro nutrients which is effective in improving plant growth and productivity (Garnett *et al.* 2009).A large amount of nitrogen (N) fertilizer is applied to crops worldwide each year. In 2007/08, approximately 128 million tonnes of N fertilizer was applied globally(FAO, 2008) of which approximately 65% is utilized for cereal production(FAO, 2006). Nitrogen(N) is often the most limiting nutrient for crop yield in many regions of the world (Giller, 2004), N fertilizer is one of the main inputs for cereals production systems. The increase of agricultural food production worldwide over the past four decades has been associated with a 7-fold increase in the use of N fertilizers. Therefore, the challenge for the next decades will be to accommodate the needs of the expanding world population by developing a highly productive agriculture, whilst at the same time preserving the quality of the environment (Hirel *et al.* 2007).Nitrogen fertilizer application to cereals has achieved large increases in yields; however its use is generally inefficient with anaverage only 33% of the total N applied (Raun & Johnson 1999). Almost all results in estimated NUE for cereal production vary from 30 to 35% (Moll *et al.* 1982). Nitrogen use efficiency may be affected by crop species, soil type, temperature, application rate of N fertilizer, soil moisture condition and crop rotation (Halvorson *et al.* 2004). The remaining N is lost as either surface runoff; leached nitrate ($NO3^-$) in ground water; volatilization to the atmosphere; or by microbial denitrification, all of which pose environmental concerns (Vitousek *et al.*1997).

Stacy *et al.* (1992) estimated stored nitrogen in the Earth is about 1.69×10^{17} ton. Because plants use only certain forms (nitrate and ammonium) of this element, thereby limiting nitrogen as one of the main elements of plant growth is important. The deficiency of this element in most ecological farming systems can be compensated through the use of various types of fertilizers. Therefore, proper management of soil fertility and plant nutrition reduce nitrate pollution and maintaining biodiversity by avoiding the use of un necessary and excessive nutrients minimize costs and increase efficiency of inputs.

Moll *et al.*(1982) defined NUE as the grain yield per unit of available N in the soil (including the residual N present in the soil and the fertilizer). This NUE can be divided into two components: uptake efficiency (NupE; the ability of the plant to remove N from the soil as nitrate and ammonium ions) and the utilization efficiency (NutE; the ability to use N to produce grain yield).

Dobermann (2006) reported Nitrogen Recovery Efficiency, for rice 44%, wheat, 54% and maize,63%. Rahimi-Zadeh *et al.* (2010) statedthe frequency of maximum recovery of nitrogen in corn-wheat was 56% and sugar beet-wheat was 48%.Nitrogen use efficiency for wheat following legumes is greater than that for wheat following fallow or continuous wheat(Badaruddin and Meyer, 1994).

Many N recovery experiments have reported losses of N fertilizer in cereal production from 20 to 50%.These losses have been attributed to the combined effects of denitrification, volatilization, and/or leaching (Karlen *et al.* 1996: Wienhold *et al.* 1995).

Lopez-Bellido & Lopez-Bellido. (2001) showed that nitrogen efficiency indices significantly affected by crop rotation and N fertilizer rate. Yamoah *et al.* (1998), by studying of particular N efficiency indices, concluded that efficiency is greater in crop rotation systems than in monoculture systems.

Some of the general purposes of crop rotation are: to maintain soil structure, increase soil organic matter, increase water use efficiency, reduce soil erosion, reduce the pest infestation, reduce reliance on agricultural chemicals and improve crop nutrient use efficiency (Halvorson *et al.* 2001).

According to Delogu *et al.* (1998) nitrogen use efficiency indices reduced with increasing the amounts of nitrogen fertilizer, that show the usefulness of nitrogen is low in these conditions. Zhao *et al.* (2006) also reported the use of nitrogen fertilizer in moderation and optimization of the periodic system in wheat:corn nitrogen use efficiency than the conventional system with excessive nitrogen fertilization rate of about 3.5 fold.

Rahimizadeh *et al*,(2010) reported that that nitrogen use efficiency, were significantly affected by crop rotation and N fertilizer rates. Maximum utilization of nitrogen was observed 56% in corn-wheat rotation and for sugar beet- wheat was as much as 48%.

Average recovery N efficiency (REN), agronomy N efficiency (AEN) and N partial factor productivity (PFPN) in Optimum N treatment was 44%, 11 kg kg^{-1} and 56 kg kg^{-1}, respectively, which were an increase of 139%, 214%, and 179% over Con.???N treatment(REN 18%, AEN 3 kg kg-1, PFPN 20 kg kg-1), respectively. Sites with high NUE (REN > 60%, AEN > 15 kg/kg, PFP > 50 kg/kg) in Optimum N treatment was 21%, 10% and 46% of all sites, respectively, while no such sites was observed in Con. N treatment(Cue *et al.* 2008).

Winter wheat based rotations are main cropping system in Iran, but no information exists on better rotation for wheat under temperate climate in Iran. Conventional crop rotations are not much diverse. An improved understanding of NUE of wheat is needed to increment sustainability of winter wheat based rotations. According to Miller *et al.* (2002) the types of plants that can be grown in the years before the creation of the different conditions in the soil (nitrogen availability, organic matter, and available water volume) should be further improved plant performance. The objectives of this research were to evaluate the effects of rotation, N fertilizer rate on N use efficiency indices of wheat.

Materials and methods

Experimental site and design

The field experiment was conducted from 2011 to 2013 at the Karezan region of Ilam, Iran (42°33′N, 33°46′ E) on a Silty- Clay with low organic carbon (1.26%and slightly alkaline soil (pH=7.9). Other soil test parameters are presented in Table 1. This site characterized by temperate climates with 370 mm annual precipitation.

The experiment was arranged in a split plot based on randomized complete block design with four replications. The main plots consisted of 6 pre-sowing plant treatments (control, Perko PVH, Buko, Clover, Oilseed radish and combination of three plants Ramtil, Phasilia, clover), and Sub plots were four N fertilizer rates including no fertilizer N(Control), 50% lower than recommended N rate, recommended N rate and 50% more than recommended N rate.

Winter wheat (Cv. Pishtaz) was planted on mid-November with arrow spacing of 15 cm and a seeding rate 200 kg ha^{-1}. Weeds were controlled by 2,4-D and Clodinafop-propargyl herbicides. Soil samples were taken after harvest of each crop from the 0 to 30 cm and 30 to 60 cm soil depths using a soil Auger. Wheat grain yield (according to 14% moisture) obtained by harvesting the center 3m by 10m with a plot combine, but yield components were determined from two randomly selected areas ($2m^2$) within each plot. Plant samples collected at harvest were separated into grain and straw and oven-dried at 60°C for 72^{hr}. Biomass and grain sub samples analyzed for total N content using a micro-Kjeldahl digestion with sulfuric acid. The terminology of N efficiency parameters is according to Delogu *et al.*, (1998) and Lopez-Bellido & Lopez-Bellido (2001), Rahimizadeh *et al.* (2010), Limon-Ortega *et al.* (2000), Moll *et al.* (1982), Heffer (2008).Timsina *et al.* (2001), Abbasi *et al.* (2005), Sowers *et al.* (1994), Fan *et al.*(2004).

Nitrogen agronomic Efficiency (NAE)

$$(NAE) = \frac{YNx - YN0}{FN}$$

Y Nx = Total yield of crop rotation per unit area of kilogram of fertilizer treatments.

Y N0 = Total yield in kilograms per unit area of crop rotation control that did not receive fertilizer

FN = N fertilizer consumption in kgper unit area.

Nitrogen physiological efficiency(NPE)

$$(NPE) = \frac{\text{YNx} - \text{YN0}}{(\text{D} - \text{E})}$$

D= Total nitrogen uptake by crops in rotation, in kilogram per unit area in the fertilizer treatments for each plant is (nitrogen concentration × grain yield per unit area) + (dry weight of residue per unit area × N concentration).

E= Total nitrogen uptake by crops in kilogram per unit area in control (no fertilizer) which is equal for each plant (dry weight per unit area × nitrogen concentration) + (dry weight of residue per unit area × nitrogen concentration).

Nitrogen Recovery Efficiency(NRE)

$$(NRE) = \frac{(D - \text{E})}{FN} \times 100$$

N Harvest Index (NHI)

$$(NHI) = \frac{Ng}{D} \times 100$$

Where Ng is total grain N uptake. Ng was determined by multiplying dry weight of grain by N concentration.

Nitrogen Use Efficiency(NUE)

(NUE, kg kg^{-1}) = Gy / N supply

Where Gy is grain yield and N supply is Sum of soil N content at sowing, mineralized N and N fertilizer. According to Limon-Ortega *et al.* (2000), N supply was defined as the sum of (i) N applied as fertilizer and (ii) total N uptake in control (0 N applied).

Results and discussion

Total economic yield(TEY)

Results showed that the effect of rotation were significant($P \leq 0.05$) on the economic performance of the entire rotation (Table 2). The highest (15273 kg/ha) and the lowest (4491 kg/ha) TEY of wheat were observed for the perko- wheat and fallow-wheat rotations, respectively(Table 3). The effect of nitrogen fertilizer were significant ($P \leq 0.05$) on the economic performance of alternative treatments (Table 2).The highest (13309 kg/ha) and the lowest (9908 kg/ha) TEY of wheat were observed for the N recommended rate and control (no fertilizer), respectively (Table 3).The highest and the lowest grain yield, with 8345, and 4491 kg/ha were obtained for Buko- wheat rotation and fallow- wheat rotation, respectively (Fig 1).

Table 1. Results of soil tests implementation of experimental site.

Soil depth (cm)	Soil Texture	P (ppm)	K(ppm)	N%	OC%	pH	EC(ds/m)
0-30	Silty- Clay	10.5	760	0.11	1.26	7.9	0.58
31-60	Silty- Clay	4.4	420	0.07	0.76	7.8	0.58

Nitrogen use efficiency(NUE)

The results showed that NUE of wheat was affected by preceding crop and nitrogen fertilizer rate in preceding crop and interaction between N rate and crop rotation was significant(Table 2).The highest and lowest NUE of wheat observed in oilseed radish-wheat (25.56 kg kg-1) and Fallow- wheat (15.09 kg kg-1) rotations, respectively (Table 3). The NUE of wheat grown after oilseed radish was 69% more than wheat NUE in Fallow- wheat system (Table 3).In addition, the lowest NUE of wheat were always associated with the control treatment (no N) regardless of preceding crops. Reducing wheat NUE in Fallow- wheat system was due to lower grain yield and a greater supply of residual N in the soil profile and highly wheat NUE in the oilseed radish- wheat rotation may be ascribed to the higher wheat yield. Whereas, according to Moll *et al.*(1982), NUE multiplying N uptake efficiency by the N utilization efficiency, these finding support the conclusion that low NUE of continuous wheat is related to its low grain yield and NUpE compared with the other rotations.

Table 2. The mean of squares of Nitrogen agronomic Efficiency(NAE),Nitrogen physiological efficiency(NPE), Nitrogen Recovery Efficiency(NRE),Total nitrogen uptake(TNU), N use efficiency (NUE), N harvest index (NHI), Total economic yield(TEY)of wheat at different rotation and N rates.

S.O.V	df	Mean-square(MS)						
		TEY	NAE	*NPE*	*NRE*	TNU	NUE	NHI
Replication	3	7737456	148.47	781.19	533.5	2830/6	11.75	9.63
Rotation(A)	5	31364561*	587.62*	430.03ns	7667.8**	15089/3*	388.14**	93.15**
Fertilizer N rate(B)	3	62707253**	2197.15**	13355.8**	8915.9**	47724/9**	20.88**	15.29 ns
AB	15	2929758ns	201.39*	1728.6 ns	1714.1**	3091.9*	*7.22	8.48 ns
%CV	-	20.96	23.5	12.4	23.7	21.8	11.8	3.46

*Significant at 0.05 probability level. ** Significant at 0.01 probability level.ns non-significant.

Based on the comparison of means, with the increase N fertilizer is reduced efficiency, so that the highest and lowest NUE of wheat observed in no application control (no N) (22.85 kg kg-1) and 50% more than the recommended (20.44 kg kg^{-1}), respectively(Table 3). Similar results Lopez-Bellido & Lopez-Bellido. (2001) Raun & Johnson,(1999) and Montemuro *et al.* (2006) based on crop rotation and nitrogen fertilizer effects on NUE was reported. Power *et al. (*2000), Hossaini *et al.* (2013), Rahimi- Zadeh *et al.* (2010), Sowers *et al.* (1994), Limon-Ortega *et al.* (2000) and Zhao *et al.* (2006) reported similar results and indicated that NUE decreased with increases N rate, Moll *et al.* (1982) reported That the highest NUE usually attracts is obtained by first fertilizer unit and its efficiency decreases with increasing fertilizer(Fig 2).

Nitrogen agronomic Efficiency(NAE)

The results showed that the nitrogen agronomic efficiency in the six studied rotations were significantly different (*P ≤ 0.05*) (Table 2).Oilseed radish-wheat rotation was the highest NAE so that the consumption of nitrogen per kg of the rotation increased the economic performance of 20.36 kg ha^{-1}.While the Buko- wheat rotation showed the lowest NAE. For every kg nitrogen consumption the economic performance increased up to 6.67 kg ha^{-1} (Table 3).With the increasing of nitrogen application except fallow-wheat rotation nitrogen agronomic efficiency decreased in other crop rotations.The highest (22.06 kg) and the lowest (13.70kg) NAE of wheat observed for the N recommended rate, respectively (Table 3).The interaction of nitrogen fertilization and crop rotation was significant for different indices.The highest NAE(35.17 kg) of wheat was observed for the N recommended rate and oilseed radish –wheat rotation, and the lowest (2.5 kg) NAE was achieved forthe 50% lower than recommended rate N and oilseed Buko– wheat rotation, respectively(Fig 3).

The results showed that the cultivation of oilseed radish- wheat reduced nitrogen consumption can lead to decreased yield, while the rest of the rotation system due to the positive effects ofrotation, the sensitivityof yield is less to nitrogen fertilizer use. Lopez-Bellido & Lopez-Bellido (2001), Rahimizadeh *et al.* (2010), Abbasi *et al.* (2005), Thuy *et al.* (2008), Cui *et al.* (2005) also reported that the interaction of crop rotation and nitrogen fertilization on the NAE was significant and decreased NAE with increasing nitrogen.

Table 3. Mean comparisons of nitrogen agronomic Efficiency(NAE),Nitrogen physiological efficiency(NPE), Nitrogen Recovery Efficiency(NRE),Total nitrogen uptake(TNU), N use efficiency (NUE), N harvest index (NHI), Total economic yield(TEY)of wheat at different crop rotationsand N application rates.

	TEY (kg)	NPE (kg kg^{-1})	NAE (kg kg^{-1})	NUE (kg kg^{-1})	NRE (kg kg^{-1})	NHI (%)	TNU (kg)
Preceding crop							
Fallow	44719	39.86	7.47	10.92	5.63	79.38	90.31
perko	15273	26.87	18.47	23.25	36.98	85	162.99
Buko	14003	34.78	6.67	18.75	3.58	86.5	172.2
Clover	11212	26.14	17.07	22.18	40.84	83.4	133.73
Ramtil,Phacilia,Clover	12065	30.09	9.46	19.90	29.04	83.6	142.85
Oilseed radish	14102	30.15	20.36	24.63	45.37	84.48	145.82
LSD (*P* <0.05)	2875	16.1	12.87	4.235	36.09	4.15	78.15
N rate							
Control (no fertilizer)	9872	-	-	20.201	-	83.74	100.59
50% lower than recommended rate	11212	36.44	17.86	20.353	29.01	84.57	120.04
Recommended rate	13273	57.05	22.06	20.644	53.77	83.93	170.42
50% more than recommended rate	13071	31.76	13.07	18.564	40.91	82.65	174.19
LSD (*P* <0.05)	852.3	25.34	6.89	1.365	17.08	1.27	17.24

Nitrogen physiological efficiency(NPE)

The results showed that the NPE in the studied rotations was not significantly different, however the NPE response to N fertilizer rate was significantly different (*P* ≤ *0.01*) (Table 2). In fallow- wheat rotation the NPE was more than the other rotation so that the nitrogen adsorbed per kg increased total yield was about 39 kg. While clover- wheat rotation had the lowest NPE and only N uptake per kg increased total yield up to about 26 kg (Table 3).

In the rotation investigated, NPE decreased with increasing nitrogen fertilizer except fallow- wheat rotation, whereas the maximum NPE in fallow- wheat rotation under optimum use of nitrogen fertilizer and then decreasing trend (Table 3).This result confirmed that the response to nitrogen in the system is higher due to reduced soil fertility and productivity factors limiting in this rotation.Lopez-Bellido & Lopez-Bellido (2001), Rahimizadeh *et al.* (2010), Cui *et al.* (2005)also reported that, depending on the NPE in rotation system and nitrogen consumption, NPE decreases with increasing nitrogen use.

The maximum NPE is achieved under optimum use of nitrogen fertilizer, so that the nitrogen adsorbed per kg increased total yield to about 55 kg. According to Zhao *et al.* (2006) in moderate amounts of nitrogen fertilizer and optimum maize- wheat in the rotations system NPE can be more than conventional systems with excessive nitrogen fertilization rate with an increase of about 3.5 times.

The interactions were found to be most efficient for NPE in conditions which exists optimum use of nitrogen fertilizer in the Boko- wheat rotation, so that the total yield per kg N uptake increased to about 114 kg. The high NPE with optimum use of nitrogen fertilizer has been confirmed by Rahimizadeh *et al.* (2010).

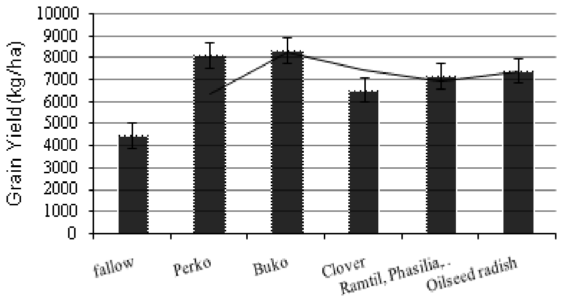

Fig. 1. Wheat grain yield affected by different crop rotations.

Nitrogen Recovery Efficiency(NRE)

The results showed that NRE of wheat affected by preceding crop and nitrogen fertilizer rate in preceding crop and interaction between N rate and crop rotation was significant($P \leq 0.01$) (Table 2).The highest and the lowest NRE of wheat were observed in Oilseed radish- wheat (46%) and Fallow- wheat (5.6%) rotations, respectively (Table 3).The high NRE in oilseed radish- wheat rotation indicated that the loss of nitrogen in the soil is less than other rotations.None the less about half of the use nitrogen fertilizer in the soil remained as organic or lost. Rahimizadeh *et al.* (2010) has also reported a positive impact of this system on the efficiency N use based on NRE.

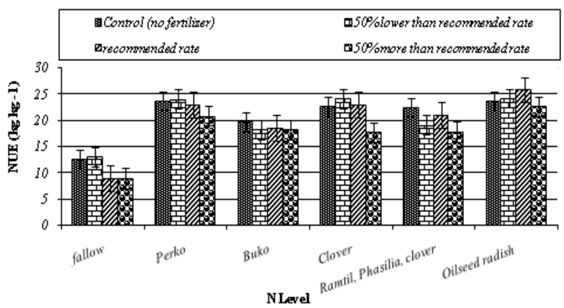

Fig. 2. Nitrogen use efficiencyaffected by different crop rotations.

Until the optimum use fertilizer nitrogen conditions NRE of the process will increased and then decrease with increasing nitrogen use. Rahimizadeh *et al.* (2010), Sieling *et al.* (1998) and Zhao *et al.* (2006) have reported NRE decreases with increased of nitrogen consumption.

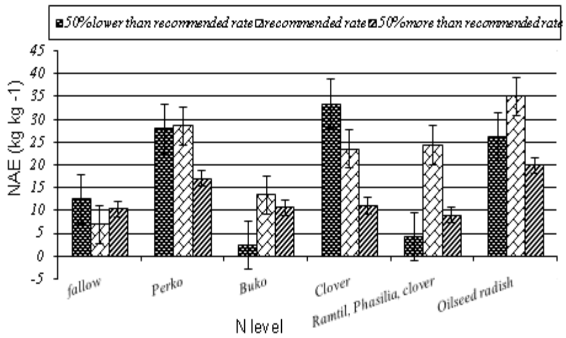

Fig. 3. Nitrogen Agronomic Efficiency(NAE)affected by different crop rotation.

Total nitrogen uptake(TNU)

The results showed that there was a significant difference ($P \leq 0.05$) for the effect of main factor level on the total nitrogen uptake, (Table 2). Nitrogen uptake differed by the crop rotations and in response to different levels of nitrogen fertilizer (Table 3). The highest and the lowest TNU of wheat were observed in Buko- wheat (172.2 kg) and fallow-wheat (90.31 kg) rotations, respectively (Table 3). Nitrogen uptake from the soil increased with increasing of N fertilizer and in different of crop rotations. The highest response to the highest level fertilizer N was observed in Buko- wheat(68%) rotation compared to the control treatment. Guillard *et al.* (1995) also were reported an increase in dry matter yield and N uptake in non-legumes rotation by increasing nitrogen use. However, in this rotation nitrogen use efficiency and nitrogen recovery efficiency decreased.

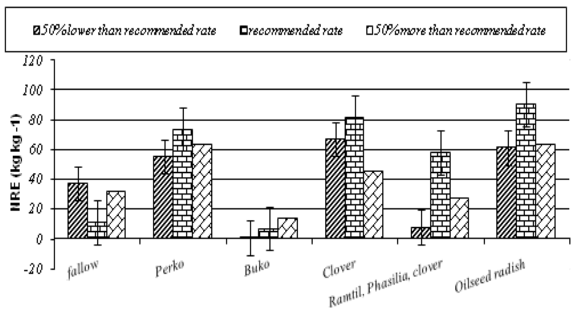

Fig. 4. Nitrogen Recovery Efficiency (NRE)affected by different crop rotations.

Nitrogen harvest index (NHI)

The N harvest index, defined as N in grain to total N uptake, is an important consideration in cereals. NHI reflects the grain protein content and thus the grain nutritional quality (Hirel *et al.*, 2007). Results indicated that NHI of wheat varied significantly with preceding crops (Table 2). The lowest and the highest value for NHI observed in continuous wheat (79.28%) and Boku- wheat rotation (86.5%), respectively. In fallow-wheat rotation NHI of wheat was significantly lower than other rotations, while there were no significant differences in wheat NHI between perko-wheat, clover-wheat, Oilseed radish-wheat, and Ramtil, Phacilia, Clover- wheat rotations. These results agreeing with the finding of Delogu *et al.* (1998) who reported that NHI in continuous wheat was significantly different with crop rotations.

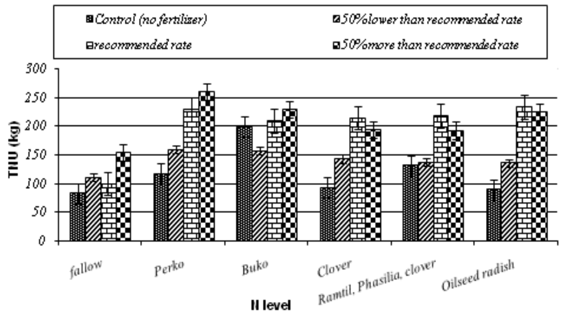

Fig. 5. Total nitrogen uptake(TNU) affected by different crop rotations.

NHI was unaffected by N rate and none of the rotation ×N rate interactions were significant. Montemurro *et al.* (2006) suggested that grain N uptake was positively correlated with yield, protein content and total N uptake and a significant positive correlation found in NHI, yield and total N uptake. Lopez-Bellido and Lopez-Bellido. (2005) showed that the increase in crop N uptake with rising N fertilizer rates was greater than the increase in grain yield, so there is less transfer of N to grain when N rates was increased.

Conclusion

Significant differences between crop rotations were observed for NUE, NHI, NAE, NRE, TNU and TEY of wheat. The highest NUE, NRE, NAE and TEY were obtained for oilseed radish-wheat, while fallow-wheat recorded the lowest NUE, NRE and TEY indices.

Nitrogen fertilizer rates had a significant effect on NUE, NAE, NRE, NPE, TNU and TEY in each rotation, but NHI were not significantly affected by N fertilizer rate. This study showed that NUE decreased with increasing N rate.

In fallow- wheat rotation NPE was more than other rotation, and the rotation due to higher NPE can be improved nitrogen utilization. Oilseed radish- wheat rotation showed the highest NAE so that consumption of nitrogen per kilogram of the rotation increased the economic performance of 20.36 kg per hectare. The lowest and the highest value for NHI observed in continuous wheat (79.28%) and Boku- wheat rotation (86.5%), respectively. Appropriate amount of nitrogen (fertilizer recommendations), although increase the whole system yield rotation but result in reduced NAE and apply more N is a pressure on the environment.

References

Abbasi MK, Kazemi M, Hussain F. 2005. Nitrogen use efficiency and herbage production of an established grass sward in relation to moisture and nitrogen fertilization. Journal of Plant Nutrition **28**, 1693-1708.

Alva AK, Paramasivam S, Fares A, Delgado JA, Mattos Jr D, Sajwan K. 2005. Nitrogen and irrigation management practicesto improve nitrogen uptake efficiency and minimize leaching losses. Journal of Crop Improvement **15**, 369–420. http://dx.doi.org/10.1300/J411v15n02_11

Atkinson D, Black KE, Dawson LA, Dunsiger Z, Watson CA, Wilson SA. 2005. Prospects, advantages and limitations of future crop production systems dependent upon the management of soil processes. Annals of Applied Biology **146**, 203–215. http://dx.doi.org/10.1111/j.1744-7348.2005.040061.x

Brussaard LDe, Ruiter PC, Brown GG. 2007. Soil biodiversity for agricultural sustainability. Agriculture, Ecosystems and Environment **121,** 233 – 244.
http://dx.doi.org/10.1016/j.agee.2006.12.013

Christen O, Sieling K, Hanus H. 1992. The effect of different preceding crops on the development, growth of winter wheat. European Journal of Agronomy **1,** 21-28.

Cui Z, Zhang F, Chen X, Miao Y, Li J, Shi L, Xu J, Ye Y, Liu C, Yang Z, zhang Q, Huang S, Bao D. 2008. On-farm evaluation of an in-season nitrogen management strategy based on soil Nmin test. Field Crops Research, **105,** 48–55. http://dx.doi.org/10.1016/j.fcr.2007.07.008

Delogu G, Cattivelli L, Pecchioni N, Defalcis D, Maggiore T, Stanca AM. 1998. Uptake and agronomic efficiency of nitrogen in winter barley and winter wheat. European Journal of Agronomy **9**, 11-20.

Dobermann A. 2006. Nitrogen use efficiency in cereal systems.
http// www. regional. org .au/asa/2006/plenary/soil/dobermann

Fan X, Lin F, Kumar D. 2004. Fertilization with a new type of coated urea. Evaluation for nitrogen efficiency and yield in winter wheat. Journal of Plant Nutrition **25,** 853-865.

Fauci M, Dick R. 1994. Soil microbial dynamics, short and long-term effects of inorganic and organicnitrogen. Soil Science Society of America **58,** 801-806.
http://dx.doi.org/10.2136/sssaj1994.03615995005800030023x

Halvorson AD, Nielsen DC, Reule CA. 2004. Nitrogen fertilization and rotation effects on no-till dryland wheat production. Agronomy Journal **96,** 1196-1201.
http://dx.doi.org/10.2134/agronj2004.1196

Hiremath AJ, Ewel JJ. 2001. Ecosystem nutrient use efficiency, productivity and nutrient accrual in modeltropical communities. Ecosystems **4,** 669-682.

Hirel B, Gouis JLE, Ney B, Gallais A. 2007. The challenge of improving nitrogen use efficiency in crop plants: toward a more central role for genetic variability and quantitative genetics within integrated approaches. Journal of Experimental Botany **58(9),** 2369-2387.
http://dx.doi.org/10.1093/jxb/erm097

Garnett T, Conn V, Kalser BN. 2009. Root based approaches to improving nitrogen use efficiency in plantspce, Plant, Cell and Environment **32,** 1272–1283.
http://dx.doi.org/10.1111/j.1365-3040.2009.02011.x

Guillard K, Griffin G, Pietrzyk S. 1995. Nitrogen utilization of selected cropping systems in U.S. Northeast. Agronomy Journal **87,** 193-199.
http://dx.doi.org/10.2134/agronj1995.00021962008700020010x

Karlen DL, Hunt PG, Matheny TA. 1996. Fertilizer 15 nitrogen recovery by corn, wheat, and cotton grown with and without pre-plant tillage on Norfolk loamy sand. Crop Science **36,** 975–981.

Kashani A, Bohrani J, Alami- Saeeid K, Mesgarbashi M.1986. Science report introduces three varieties of forage plants of the genus Brassica and report preliminary results in Khuzestan. Journal of Agricultural Science **11,** 74-78.

Limon-Ortega A, Govarets B, Sayre KD. 2008. Straw management, crop rotation, and nitrogen source effect on wheat grain yield and nitrogen use efficiency. European Journal of Agronomy **29,** 21-28.
http://dx.doi.org/10.1016/j.eja.2008.01.008

Lopez-Bellido RJ, Lopez-Bellido L. 2001. Efficiency ofnitrogen in wheat under Mediterranean condition: effect of tillage, crop rotation and N fertilization. Field Crops Research **71(1),** 31-64. http://dx.doi.org/10.1016/S0378-4290(01)00146-0

Lopez-Bellido L, Lopez-Bellido RJ, Redondo R. 2005. Nitrogen efficiency in wheat under rainfed Mediterranean conditions as affected by split nitrogen application. Field Crops Research **92**(94), 86-97. http://dx.doi.org/10.1016/j.fcr.2004.11.004

Lopez-Bellido L, Lopez-Bellido RJ, Lopez-Bellido FJ. 2006. Fertilizer Nitrogen Efficiency in Durum Wheat under Rainfed Mediterranean Conditions: Effect of Split Application, Agronomy Journal – Abstract **98(1),** 55-62. http://dx.doi.org/10.2134/agronj2005.0017

Lupashku MF. 1980. Perko RVH - a new fodder crop. VestnikSel'skokhozyaistvennoiNauki. Moscow, USSR **4(6),** 94-98. http://eurekamag.com/research/000/947/perko-rvh-feed-crop.php

Marianne S. 1994. Rodale Institute; Managing Cover Crops Profitably, Sustainable Agriculture Research and Education Program, USDA .http://www.advancedagsolutions.com /resources/ covercropsprofit2.pdf

Miller P, McConkey B, Clayton G, Brandt S, Baltensperger D, Neil K. 2002. Pulse crop adaptation in the Northern Great Plains. Agronomy Journal **94,** 261-272. http://dx.doi.org/10.2134/agronj2002.2610

Moll RH, Kamprath EJ, Jackson WA. 1982. Analysis and interpretation of factors, which contribute to efficiency of nitrogen utilization. Agronomy Journal **74,** 562-264. http://dx.doi.org/10.2134/agronj1982.00021962007400030037x

Montemuro F, Maiorana M, Ferri D. Convertini G. 2006. Nitrogen indicators, uptake and utilization efficiency in a maize and barley rotation cropped at different levels and source of N fertilization. Field Crops Research **99,** 114-124. http://dx.doi.org/10.1016/j.fcr.2006.04.001

Rahimizadeh M, Kashani A, Zare-Feizabadi A, Koocheki AR, Nassiri-Mahallati M. 2010. Nitrogen use efficiency of wheat as affected by preceding crop, application rate of nitrogen and crop residues. Australian Journal of Crop Science **4(5),** 363-368.

Raun WR, Johnson GV. 1999. Improving nitrogen use efficiency for cereal production. Agronomy Journal **91,** 357-363. http://dx.doi.org/10.2134/agronj1999.00021962009100030001x

Sieling K, Schroder H, Finck M, Hanus M. 1998. Yield, N uptake, and apparent N use efficiency of winter wheat and winter barley grown in different cropping systems. Journal of Agricultural Science **131,** 375-387.

Sinclair TR, Purcell LC, Sneller CH. 2004. Crop transformation and the challenge to increase yield potential. Trends in Plant Science **9,** 70–75. http://dx.doi.org/10.1016/j.tplants.2003.12.008

Soon YK, Clayton GW, Rice WA. 2001. Tillage and previous effects on dynamics of nitrogen in a wheat-soil system. Agronomy Journal **93,** 842-849. http://dx.doi.org/10.2134/agronj2001.934842x

Sowers KE, Miller BC, Pan WL. 1994. Optimizing grain yield in soft white winter wheat with split nitrogen applications. Agronomy Journal **86,** 1020-1025. http://dx.doi.org/10.2134/agronj1994.00021962008600060017x

Stacey G, Burris RH, Evans HJ. 1992. Biological Nitrogen Fixation. Chapman and Hall, New York.

Timsina T, Singh U, Badaruddin M, Meisner C, Amin MR. 2001. Cultivar, nitrogen, and water effects on productivity, and nitrogen-use efficiencyand balance for rice–wheat sequences of Bangladesh. Field Crop Research **72,** 143-161.

Thuy NH, Shan Y, Singh B, Wang K, Cai Z, Singh Y, Buresh RJ. 2008. Nitrogen supply in rice based cropping systems as affected by crop residue management. Soil Science Society of America Journal **72,** 514-523. http://dx.doi.org/10.2136/sssaj2006.0403

Velasco JL, Rozas HS, Echeverría HE, Barbieri PA. 2012. Optimizing fertilizer nitrogen use efficiency by intensively managed spring wheat in humid regions: Effect of split application, Canadian Journal of Plant Science **92(5),** 847-856.

Vitousek PM, Mooney HA, Lubchenco J, Melillo JM. 1997. Human domination of Earth's ecosystems. Science **277**, 494–499.

Wienhold BJ, Trooien TP, Reichman GA. 1995. Yield and nitrogen use efficiency of irrigated corn in the northern great plains. Agronomy Journal **87,** 842–846. http://dx.doi.org/10.2134/agronj1995.000219620087000050010x

Zhao RF, Chen XP, Zhang FS, Zhang H, Schroder J, Romheld V. 2006. Fertilization and nitrogen balance in awheat-maize rotation system in North China. Agronomy Journal **98,** 938-945. http://dx.doi.org/10.2134/agronj2005.0157

Zhu Z. 2000. Loss of fertilizer N from the plant–soil system and the strategies and techniques for its reduction in China. Soil Environmental Science **9,** 1–6.