Optimizing application rate of nitrogen, phosphorus and cattle manure in wheat production: An approach to determine optimum scenario using response-surface methodology

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Abstract

Optimal application rates of inorganic nitrogen (N), phosphorus (P) and cattle manure were estimated using Response Surface Methodology (RSM). A Central Composite Design (CCD) was conducted at field level during 2012-13 and 2013-14 growing seasons. The applied levels of N were 0, 150 and 300 kg N ha⁻¹ in form of urea. The levels used for P fertilizer were 0, 100 and 200 kg ha⁻¹ (P₂O₅) and for cattle manure were 0, 15 and 30 t ha⁻¹. Both seed yield (SY), biological yield (BY) were measured at harvest time. N loss (NL) and Agronomic N Use Efficiency (ANUE) were calculated based on other measurements. Increasing N and P rates up to 200 kg ha⁻¹ increased SY. Optimization of N, P and manure application amount was based on economic, environmental and eco-environmental scenarios. Under economic scenario, using 145.4 kg ha⁻¹ N, 200 kg ha⁻¹ P and 18.4 t ha⁻¹ manure resulted in 6500 kg ha⁻¹ SY with ANUE of 10.49. For environmental scenario, by N application of 21.2 kg ha⁻¹, no application of P and applying 16.3 t ha⁻¹ manure, SY and ANUE of 3160 kg ha⁻¹ and 9.08 were obtained, respectively. Using eco-environmental scenario, by applying 144.7 N and 34.3 kg ha⁻¹ P, plus 30 t ha⁻¹ manure, about 4031 kg ha⁻¹ SY and a considerable high ANUE of 16.5 were recorded. The results of this study showed that the privilege of eco-environmental scenario compared to the other scenarios was mainly due to higher ANUE.

Keywords: ANUE, nitrogen losses, eco-environmental scenario, seed yield, central composite design

1. Introduction

Higher required production of wheat has intensified consumption of agrochemicals that in turn have resulted in negative impacts on environment. Sustainable and sufficient food production is a necessity that simultaneously should consider social, economic and environmental aspects. The first step to achieve this goal is optimization and improvement of resources use efficiencies (Gliessman, 1998). It is reported that up to 50 percent of applied nitrogen would drift from agricultural systems as gaseous compounds and other types of activated nitrogen (Jarvis *et al.*, 2011; Weligama *et al.*, 2010). At the high level application of P (more than 200 kg ha⁻¹), up to 90% of phosphorous fertilizers would be fixed in soil together with metallic elements as insoluble forms which finally lead to further phosphorus pollution (Adesemoye *et al.*, 2009). In many crops, low absorption efficiency of fertilizers, is the main reason of leaching, volatilization and diffusion of soluble chemical fertilizers easily released to soil and air (Akiyama *et al.*, 2000). It has been reported that between 18-41 percent of applied nitrogen retain in soil after crop harvesting (Fageria, 2014). Nitrogen losses occur in various ways as ammonium volatilization in lime soils (10-70%), denitrification (9-22%) and leaching (14-40%) (Doberman & Cassman, 2004).

Wheat crop shows a strong positive correlation between productivity and NPK fertilizers (Hawkesford & Barraclough, 2011; Osborne, 2007). On the other hand, applying organic fertilizers in integration with chemical ones could be an efficient management practice to reduce application rate of chemical fertilizers and subsequently reduce their negative impacts on environment. Moreover, improved nutrient balance in soil and plant, enhance crop productivity and yield stability in intensified cultivation. Synchrony between application time and crop nutrient demand,

is an important factor, which reduce nitrogen losses (Gastal & Lemaire, 2002). Thus integrated use of slow release organic fertilizers such as manure could reduce N losses during crops cultivation (Emilsson *et al.*, 2007). In arid and semi-arid regions, N deficiency occurs faster than other nutrients and usually is due to low level of soil organic matter. It seems necessary to design cropping systems with high nutrient uptake and utilization efficiencies (Fageria, 2014; Cassidy *et al.*, 2013) considering global high demand for cereal in coming future. It is suggested to increase the mean efficiency of N utilization by 0.1-0.4 % annually (Doberman & Cassman, 2005). Improving N use efficiency, increases economic return and reduces the potential of environmental pollution (Fageria, 2014). To reach such goals, research priorities might be shifted from maximizing yield to developing methods for optimization of nutrients application.

Response Surface Methodology (RSM) was first introduced as optimization method for industrial use (Myers and Montgomery, 1995) however; this methodology could also be used in fertilizer optimization. Central Composite Design (CCD), which is the most popular RSM design, was implemented to design a series of tests with least number of experiments. This approach tries to investigate the effect of parameters involved (i.e. contact time, dosage, pH, initial concentration) on responses in a cost- and time-effective way. The CCD makes it feasible to observe the possible interaction of the parameters and their influences used RSM methodology to optimize N, water and plant density in canola cultivation. reported that the application of 93.48 kg N ha⁻¹ based on eco-environmental scenario was an optimized N use, was able to reduce environmental hazards and produced acceptable onion yield. It has been claimed that oxalic acid and lactic acid are the major acids responsible for enhancing the P solubilization .

This study was aimed to optimize the chemical and organic fertilizer use in winter wheat production and determine the best applicable scenario in Kashaf-rood watershed in northeast of Iran. It has also been studied the application trend of different N, P and cattle manure levels and their effects on wheat production. Furthermore, the effectiveness of manure compared to chemical fertilizer was studied based on NUE and wheat yield improvement.

2. Material and Methods

2.1. Site description

Field studies conducted during 2012-13 and 2013-14 growing seasons at the Research Station of Agriculture Faculty, Ferdowsi University of Mashhad, Iran (latitude: 36° 15' N; longitude: 59° 28' E; elevation: 985 m above sea level). Experiment station was located in Kashaf-rood watershed in northeast of the country in a semi-arid region with mean annual precipitation of 252 mm and temperature of 15 °C.

Soil samples were taken from 0-15 and 15-30 cm depths and analyzed for some physiochemical properties before beginning the experiment (Table 1). To determine soil nitrogen content, soil sampling was repeated at the end of growing season.

2.2. Experimental design

CCD (sometimes called Box-Behnken design) with two replicates was used for fitting response surface to experimental data (Tawfik *et al.*, 2017). Two years data were subjected to combined analysis after ensuring uniformity of the error mean squares. The results of combined analysis indicated that year $\times$ treatment interaction was not significant ($P > 0.05$), therefore the two years data were joined before exposing to response surface analysis.

The experimental factors were the combination of different amounts of nitrogen, phosphorus and cattle manure. The total number of experimental runs for a 3-factor CCD is 15 including 12 factorial points and 3 replications for center points.

Table 1. Soil properties of the experimental field (mean of two years).

Soil properties	Soil depth (cm)	
	0-15	15-30
Total N (%)	0.078	0.065
Available P (ppm)	19	15
Available K (ppm)	380	372
C/N	12.8	12.3
pH (saturation extract)	7.7	7.5
EC (dS m ⁻¹)	1.3	1.3
Water storage capacity (%)	22.3	20
Bulk density (g cm ⁻³)	1.34	1.41
Texture grade	Loamy-silt	Loamy-silt

By conducting CCD, it is possible to obtain all information from the least operational practices due to distribution of experimental points through treatments confined. The design points were defined based on the low and high levels of N (0, 300 kg ha⁻¹), P (0, 200

kg ha⁻¹) and manure (0, 30 t ha⁻¹) (Table 2). The N, P and K content of manure were determined as 1.18%, 0.29% and 1.04%, respectively. The high and low levels of manure were determined based on nutrient content and local recommendations.

Table 2. Actual and coded values of experimental factors for CCD.

Runs	Treatment values*			Coefficients		
	Nitrogen (kg ha ⁻¹)	Phosphorus (kg ha ⁻¹)	Manure (t ha ⁻¹)	Nitrogen (X ₁)	Phosphorus (X ₂)	Manure (X ₃)
1	300	0	15	+1	-1	0
2	150	0	15	0	-1	0
3	300	100	30	+1	0	+1
4	300	100	0	+1	0	-1
5	0	100	30	-1	0	+1
6	150	100	15	0	0	0
7	150	0	30	0	-1	+1
8	0	100	0	-1	0	-1
9	150	0	0	0	-1	-1
10	150	200	0	0	+1	-1
11	150	200	30	0	+1	+1
12	150	100	15	0	0	0
13	0	200	15	-1	+1	0
14	300	200	15	+1	+1	0
15	150	100	15	0	0	0

* +1, -1, and 0 indicates up, down and medium level of each factor

A normality test was already performed and transformation was also performed for numerical data where needed. To ensure uniformity of treatment variances, the Bartlett's test was used. Since there was no statistical difference between both years of data, the mean value of each trait was reported. Data analysis and graph plotting were performed using Minitab® Statistical Software Ver. 16.1.1, and Microsoft Excel Ver. 14

2.3. Crop management

Plots of 3 × 4 m with a distance of 1 meter between, to avoid nutrients mixing due to irrigation, were prepared. Each plot consists of 6 rows that

were arranged to sow wheat seeds on double side of rows. Manure was well mixed with soil one month before planting. The first N installment and the whole P amount were applied at sowing. The sowing dates (October 10, 2013-14) were the same for both years of experiment. Plots were immediately irrigated after sowing and after that irrigation continued at 10-day intervals. An eco-climate appropriate cultivar (Gascogne) was employed in this study. The plant density was 350 plants per square meter. Weeds were controlled two times during the growth period by hand. No agrochemical was used during soil cultivation, planting and growing season.

2.4. Measurements

Each plot was partitioned into two sections, one for seed yield and its components and the second section used for destructive time series sampling during the crop growth season. Before the final harvest, 5 plants from each plot were randomly selected and the number of fertile tillers was recorded. Seed yield was determined from 4 m² of each plot which was kept untouched, considering marginal effect. The air dried plants were weighed and biological yield (dry matter yield), seed yield and harvest index were also measured.

The N contents in plant tissue were measured using AOAC Official Method by a Kjelhdal Semi Automated Distillation Unit (Horwitz & Latimer, 2005). The total N was determined for each soil plot (AOAC official method 968.06 (4.2.04)). Nitrogen loss was calculated using Equation 1 (Jarvis *et al.*, 2011):

$$N_{\text{loss}} = N_{\text{initial}} + N_{\text{fertilizer}} - (N_{\text{plant}} + N_{\text{soil}}) \quad \text{Eq.1}$$

Where, N_{loss} : nitrogen loss (kg m⁻²), N_{initial} : soil available nitrogen content at the early season (kg m⁻²) which was calculated by: $N_{\text{Total End}} \times 0.03$
0.03= availability coefficient of total N in soil (as mineral for crop use) (Fageria, 2014).

$N_{\text{fertilizer}}$: applied nitrogen (kg m⁻²), N_{plant} : plant nitrogen content at the end of season, and N_{soil} : the available nitrogen content in soil after final harvest (kg m⁻²) which was calculated as:

$$N_{\text{Total End}} \times 0.03.$$

Agronomical nitrogen use efficiency (ANUE, kg Grain/kg $N_{\text{fertilizer}}$) was calculated using Equation 2 (Rathke *et al.*, 2006):

$$ANUE = \frac{Y_{\text{Grain}}}{N_{\text{initial}} + N_{\text{fertilizer}}} \quad \text{Eq.2}$$

Y_{Grain} : seed yield (kg m⁻²)

To determine relative water content (RWC) of leaves, the samples were prepared between 9:00 to 10:00 AM at flowering stage. The samples were submerged in distilled water for 6 hours and then turgor weight was measured and their dry weight were also recorded in after drying samples in 75 °C in oven. Finally RWC was calculated using Equation 3 (Kramer, 1988):

$$RWC = \frac{(FW - DW)}{(TW - DW)} \quad \text{Eq.3}$$

2.5. Statistical analysis

Response of measured variables (y) to experimental factors (X) was estimated using second order polynomials including the interaction (Equation 4):

$$y = \beta_0 + \sum_{i=1}^m \beta_i X_i + \sum_{i < j} \beta_{ij} X_i X_j + \sum_{i=1}^m \beta_{ii} X_i^2 \quad \text{Eq.4}$$

Where b_0 is constant and b_i , b_{ij} and b_{ii} are coefficients for linear, interaction and quadratic terms, respectively.

The result was a second order polynomial which describes the estimated of response (yield) as a function of inputs variables. Finally, after optimizing the resulted function and eliminating the low effect terms using statistical tests and criteria such as, F test, lack of fit test, coefficient of determination (R^2), a final function was calculated to predict yield and other expected variables as below (Equation 5):

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_1^2 + a_5X_2^2 + a_6X_3^2 + a_7X_1X_2 + a_8X_1X_3 + a_9X_2X_3 \quad \text{Eq.5}$$

In this function, Y is dependent variable, X_1 is N fertilizer, X_2 is P fertilizer, X_3 is manure, and a_0 to a_9 are coefficients. The equation is only functional in the defined range of input variables and would not predict the values out of the range.

The optimized rates of N, P and manure determined three scenarios including: economic, environmental and eco-environmental, in which seed yield, N loss, NUE and N loss were the main determining factors, respectively.

Response-surface methodology was used to obtain the optimized levels. Finally, the fitted values compared to observed ones and validity of regression models were evaluated by Root Mean Square Error (RMSE) (Equation 6) and 1:1 regression line.

$$RMSE(\%) = \frac{100}{O} \times \sqrt{\frac{\sum_{i=1}^n (P_i - O_i)^2}{n}} \quad \text{Eq.6}$$

The RMSE percentage states the different between predicted versus observed values. When $RMSE < 10\%$, prediction power of the used model is excellent, if $RMSE < 20\%$, prediction power of model is good, if $RMSE < 30\%$, it is considered as a poor prediction (Myers & Montgomery, 1995).

3. Results

The results for analysis of variance of the full quadratic regression for dependent variables have been presented in Table 3. The dependent variables were: seed yield, biological yield, fertile tiller numbers, RWCL, N loss and NUE. The seed yield linear effects for N and P were significant at 5%, and 1% probability level, respectively (data not shown).

Table 3. Regression coefficients of the fitted model.

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_1^2 + a_5X_2^2 + a_6X_3^2 + a_7X_1X_2 + a_8X_1X_3 + a_9X_2X_3$$

Coefficient	Response Variables					
	Seed Yield	Biological Yield	Fertile Tiller numbers	Relative Water Content	Nitrogen Losses	Agronomical Nitrogen Use Efficiency
a₀	2.939	15.11	2.863	78.97	65.5	12.64
a₁	0.03063	-0.0155	-0.00852	-0.0258	-0.136	0.0008
a₂	-0.01522	0.0077	-0.00836	-0.0821	0.640	0.0606
a₃	-0.0108	0.410	0.0203	-0.496	-11.36	-0.424
a₄	-0.000071	-0.000006	0.000023	0.000146	0.00298	0.000148
a₅	0.000118	-0.000094	0.000069	0.000274	-0.00306	-0.000326
a₆	-0.00078	-0.01059	-0.000067	0.00866	0.349	0.01252
a₇	-0.000045	0.000128	0.000023	-0.000247	-0.00073	0.000019
a₈	-0.000042	0.000117	0.000067	0.000297	0.00106	0.000604
a₉	0.000229	-0.001454	-0.000333	0.00220	0.0151	0.000577
R²	92.06	83.08	98.24	82.02	92.86	95.31

X_1 , X_2 and X_3 indicates independent variables: nitrogen fertilizer, phosphorus fertilizer and manure, respectively.

The second order effect was also significant for $N \times N$ and $P \times P$ on seed yield ($P \leq 0.01$), fertile tiller numbers ($P \leq 0.01$) and NUE ($P \leq 0.05$). However, the interaction of $N \times P \times \text{manure}$ was significant only for the number of fertile tiller ($P \leq 0.01$). The lack of fit of the regression model was not significant for the all studied traits. The regression coefficients of the fitted models for the studied traits have been presented in Table 3. The high coefficient of determination is indicated that the variances of the dependent variables were properly described by the full quadratic model used for response surface analysis (Table 3).

3.1. Seed Yield

The low RMSE indicated a good prediction ability of the model. Moreover, there was no significant differ

ence between slope and intercept of regression line compared to the 1:1 line (RMSE= 7.34; $R^2= 0.92$). The lowest SY (2350 kg ha^{-1}) obtained from the application of $0 \text{ kg ha}^{-1} \text{ N}$, $100 \text{ kg ha}^{-1} \text{ P}$ and 30 t ha^{-1} manure.

There was no significant $N \times P$ interaction effect on the SY. At any level of P fertilizer, SY response to N showed a quadratic trend with maximum yield achieved at 150 kg N ha^{-1} . However, the highest response of seed yield to P fertilizer was obtained at the highest level (200 kg P ha^{-1}) and as a result the maximum SY was observed by application of 150 and $200 \text{ kg ha}^{-1} \text{ N}$ and P , respectively, while applied manure was 15 t ha^{-1} (Figure 1). At any level of N, seed yield response was highest at high level of P (200 kg ha^{-1}). At high level application of N (300 kg ha^{-1}), seed yield decreased at any P levels (Figure 3).

Figure 1. Response surface of wheat seed yield in different nitrogen and phosphorus fertilization at the constant level of 15 t ha^{-1} of manure.

3.2. Biological Yield

Interaction effect of $P \times M$ was significant ($P \leq 0.05$) for BY (data not shown). At the high level of P fertilization (200 kg ha^{-1}), BY response to manure followed a

diminishing return and decreased when applied manure levels were above 15 t ha^{-1} . At no application of P, the highest BY was obtained when the maximum manure level (30 t ha^{-1}) was applied (Figure 2).

Figure 2. Response surface for biological yield in different phosphorus and manure fertilization at the constant level of 150 kg ha^{-1} of nitrogen.

3.3. Fertile tiller numbers

Increasing the application of both N and P, resulted in increased fertile tiller number per plant (not shown). The positive effect of N on plant growth only happens when adequate amounts of the other nutrients is available.

3.4. Relative Water Content (RWC)

RWC of leaves was positively related to the manure level, however, RWC negatively responded to the P application rate (not shown). RWC was dropped below 60% at the P rates higher than 200 kg ha^{-1} but

this response was moderated by increasing manure application. Apparently, with increasing P application a higher leaf expansion was taken place which was in turn led to the lower RWC. However, positive effects of manure on soil water retention is provided enough amount of water for sustaining leaf growth while keeping RWC at optimized level.

3.5. Nitrogen loss

Nitrogen loss (NL) positively responded to N application rate and manure level as well (Figure 3). The highest NL was achieved when N-fertilizer and manure were applied at the maximum levels.

Figure 3. Response surface for nitrogen losses of different nitrogen and manure fertilization levels at constant level of 100 kg ha^{-1} of phosphorus.

3.6. Agronomical Nitrogen Use Efficiency (ANUE)

ANUE decreased as a result of increasing in nitrogen and phosphorus application levels, although this increasing slope was higher at the mid level of P than of the low and the high levels (Figure 4).

The low RMSE (8.51; $R^2 = 0.92$) for regression line of the fitted versus observed values for NUE indicated the goodness of fit of the model. Moreover, no significant difference was observed between regression line

slope and intercept compared to the slope and intercept of 1:1 line (not shown).

RMSE values for response variables (6.35, 8.98 for BY and NL, respectively) showed goodness of fit of the related models (data not shown), moreover, coefficients of determination in respected models (0.92; 0.81; 0.92 and 0.92 for SY; BY; NL and ANUE, respectively) were confirmed the goodness of fit of the models.

Figure 4. Response surface for agronomical nitrogen use efficiency of different nitrogen and phosphorus fertilization levels at constant level of 15 t ha^{-1} of manure.

3.7. Resource Optimization

Optimization of nitrogen, phosphorus and manure fertilization were conducted according to the three scenarios of economic, environmental and eco-environmental. Under economic scenario, wheat seed

yield was considered as the main determining factor for resource optimization. The result showed that application of 145.4 kg ha⁻¹ N, 200 kg ha⁻¹ P and 18.4 t ha⁻¹ manure, could achieve a seed yield of about 6500 kg ha⁻¹ and a biological yield around 13130 kg ha⁻¹ (Table 4).

Table 4. Optimized values of nitrogen, phosphorus fertilizers and manure application for reaching the dependent variables based on evaluated scenarios.

Scenarios	Independent Variables (X)			Dependent Variable (Y)					
	Nitrogen (kg ha ⁻¹)	Phosphorus (kg ha ⁻¹)	Manure (t ha ⁻¹)	Seed Yield (kg ha ⁻¹)	Biological Yield (kg ha ⁻¹)	Fertile Tiller Numbers	Relative Water Content (%)	Nitrogen Losses (kg ha ⁻¹)	Agronomical Nitrogen Use Efficiency (kg DM/ kg N)
Economic	145.45	200	18.48	6500	13130	3.16	68.38	61.04	10.49
Environmental	21.21	0	16.36	3160	11692	3.03	72.79	0	9.08
Eco- Environmental	144.73	34.3	30	4031	15311	2.51	71.04	0	16.50

Under eco-environmental scenario, the determining factor for optimizing resource was considered as NL. The main objective of this scenario was reduction of environmental hazards resulted from high rates application of N, P and possibly manure, so, the economic yield had less importance. According to this scenario, N application by 21.2 kg ha⁻¹ with no application of P, plus 16.4 t ha⁻¹ of manure, minimized the NL (0 kg ha⁻¹). Considering the optimized amount of resource use in this scenario, seed yield, biological yield and ANUE were estimated about 3160 kg ha⁻¹, 11692 kg ha⁻¹ and 9.3 kg DM/kg N, respectively (Table 4). Under environmental scenario, the main determining factors for optimizing resource, were ANUE, NL and seed yield. Application of 144.7 and 34.3 kg ha⁻¹ of N and P, and 30 t ha⁻¹ of manure resulted in the seed

yield about 4031 and the biological yield of 15311 kg ha⁻¹, which showed 36% increase of ANUE compared to the economic scenario (16.50 vs. 10.49).

4. Discussion

Increased seed yield by higher levels application of fertilizers in the present study is in agreement with other studies. Osborne (2007) reported a positive and strong correlation between available N in soil and spring wheat seed yield. Seguel *et al.* (2016) reported the plant growth in acidic soil is limited by low levels of available P and the high presence of phytotoxic aluminum (Al³⁺), which causes deleterious effect on plant physiology. They also suggested that wheat shoot dry weight, root dry weight and root colonization were influenced

by wheat genotype/growth stages interaction and arbuscular mycorrhiza spores and P-ase activity were affected by wheat cultivar. Moraghebi *et al.* (2011) reported that increasing of N levels from 0 to 100 kg ha⁻¹ resulted in higher seed yield, protein percentage and biomass of wheat crop. Hatfield and Prueger (2004) reported that N fertilizer increased the yield of wheat seed through increasing seed numbers in spike and 1000 seeds weight. Mahmood *et al.* (2017) found a significant and positive correlation ($R^2= 0.52, 0.91$ and 0.55) among maize grain yield and available N, P and K content, in soil.

Higher levels of manure in soil usually lead to low pH (Mahmood *et al.*, 2017). On the other hand, P availability is highly dependent on soil pH (Mengel and Kirkby, 2001). It is widely accepted that the maximum P availability in the soil come through in pH range of 6.5-7.5 which meets the optimal needs of many plants. The soil temperature, CEC, and pH determine the availability of nutrients in the soil. Since pH levels control many bio-chemical processes that take place in the soil- specifically, plant nutrient availability- it is vital to maintain proper levels for plants to reach their full yield potential.

It could be explained that at high application rate of manure (30 t ha⁻¹), BY decreased at highest P fertilizer level due to pH limitation on P availability. Shah *et al.* (2016) reported increased dry matter of maize by application of manure. Organic matters, including cattle manure improve physiochemical properties of the soil mainly through buffering the pH. Hussain *et al.* (2016) reported the P application had significant effect on dry matter and other yield components of wheat. Sandana and Pinochet (2016) reported that there were differences between wheat, pea and lupin regarding their sensitivity to P deficiency and the strategies that these species developed to acquire P from soil. They also suggested considering these dif-

ferences could help improve fertilizer management strategies and optimize soil P use.

In present study, the positive effect of nitrogen on increasing fertile tiller numbers was clearly revealed at mid and high levels applications of phosphorus, but at zero application of phosphorus, no effect of N was observed. This was probably due to the limited effect of nitrogen in absence of phosphorus. The same result for N $\times$ P interaction was previously obtained for seed yield (Figure 1). N contributes in increased cell division, leaf area and its duration, increased tiller numbers and survival which eventually results the improvement of photosynthesis capacity and dry matter production (Davis *et al.*, 2002). Schlemmer *et al.* (2005) reported that N deficiency caused reduction of water potential and increased the amount of abscisic acid in leaves, thus play an important role in senescence process. They also reported that nitrogen increased RWC and plants with more water content, contained more chlorophyll. Temperature of root region could affect nitrate absorption. Since organic matter such as cattle manure could affect the soil water holding capacity, thus, it could affect retaining and nutrients uptake (nitrogen in particular) too (Sparling *et al.*, 2006; Kuepper, 2003). Increasing of NL by using high N-rates could be due to the lower N-absorption efficiency that was reported as almost 30-40% in study region (Rathke *et al.*, 2006). Higher soil water content due to manure application may negatively affect NL as a result of more N-leaching compared to the dry soils. Martinez-Lagos *et al.* (2015) reported that the slurry treated soil had greater net potential N mineralization than urea, which in turn results in lower rates of gross N immobilization and loss in time. They also suggested that for N fertilization amount determination, must consider the N which can be supplied by the soil mineralization in order to reduce N losses from the soil surface through different pathways particularly by NH₃ pathway. The results showed that to

avoid N-losses, the rate of nitrogen application should be recommended according to the applied manure. It is well known that ANUE decreases with the increment of N availability, (Dordas, 2011). Marino *et al.* (2004) reported that wheat NUE decreased by 60% (44.2 to 17.6 kg DM/kg N) when nitrogen application increased from 50 to 250 kg ha⁻¹. Moraghebi *et al.* (2011) reported that by increasing N application (0 to 160 kg ha⁻¹ of pure N), seed yield was increased but NUE and physiological nitrogen efficiency were significantly reduced.

As the law of diminishing returns states that in a production process, as one input variable is increased, there will be a point at which the marginal per unit output will start to decrease, holding all other factors constant, the NUE was not necessarily improved as a result of increased N application.

5. Conclusion

The results of this study showed that, N and P fertilizers which were used for wheat production have not reflected the actual needs of wheat. In this experiment, application of 30 t ha⁻¹ of manure under eco-environmental scenario caused high availability of N, P nutrients for plant, and improved crop productivity. Moreover, trapped and retained nutrients in manure matrix that is considered as an ecofriendly and low cost input that improved the effectiveness of chemical fertilizer.

Manure applying along with application of N and P fertilizers, open new perspectives to develop opportunities for organic fertilizers that could retain crop productivity at same level when chemical fertilizers are applied. Moreover, the use of manure is ecofriendly, low costs and enrich soil fertility. Considering the results, it seems that for the winter wheat production, the eco-environmental scenario had more advantages than other scenarios. Conducting this scenario in long

term can be promoting environment health, moreover promises sustainable production of wheat.

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