Iranian Journal of Field Crops Research
Vol. 13, No. 4, Winter. 2016, p. 823-839

نشریه پژوهشهای زراعی ایران
جلد ۱۳، شماره ۴، زمستان ۱۳۹۴، ص. ۸۳۹-۸۲۳

Optimizing of Nitrogen, Phosphorus and Cattle Manure Fertilizers Application in Winter Wheat Production Using Response-Surface Methodology (RSM)

M. Jahan[1*]- M. Nassiri Mahallati[2]- H. Khalilzade[3]- R. Bigonah[4]- A. R. Razavi[5]

Received: 28-07-2014
Accepted: 21-12-2014

Introduction

It is estimated that up to 50 percent of applied nitrogen would drift from agricultural systems as gaseous compounds and other types of activated nitrogen (27 and 46). When applied in high amounts, up to 90% of phosphorous fertilizers could be fixed in soil together with metallic elements as insoluble forms leading to further phosphorus pollution (1). In many crops, low absorption efficiency of fertilizers is the main reason of losses through leaching, volatilization and diffusion of soluble chemical fertilizers which easily released to soil and air. It has been reported that between 18-41 percent of applied nitrogen retain in soil after crop harvesting (Fageria, 2014). Nitrogen losses happens in different ways as ammonium volatilization in lime soils (10-70%), denitrification (9-22%) and leaching (14-40%) (13).

Chemical fertilizers are widely used by farmers due to low costs, easy availability and easy applicability. Chemical fertilizers increase the rate of organic matter decomposition in soil, thus increase the amount of greenhouse gasses such as N, CO_2 released in air which aggravate global warning and climate change (2)

This research was aimed to emphasize on optimizing of chemical and organic fertilizer use in winter wheat production in Iran, study the trend of change in different N, P and cattle manure levels and their effects on wheat characteristics and its changes trend also, comparison of the effectiveness of manure by chemical fertilizer related to NUE and yield increase of wheat.

Materials and Methods

By conducting Box-Behnken design, it is possible to obtain the most information from the least operational practices due to distribution of experimental points through treatments confined. The design points were defined based on low and high levels of N (0, 300 kg ha^{-1}), P (0, 200 kg ha^{-1}) and manure (0, 30 tones ha^{-1}) as shown in Table 2. Manure was analyzed for N, P and K content (1.18% of N, 0.29% of P and 1.04% of K). The high and low levels of manure were determined based on nutrient content and local recommendations.

Response of measured variables (y) to experimental factors (X) was estimated by using second order polynomials with interaction (Equation 1):

$$y = \beta_0 + \sum_{i=1}^{m} \beta_i X_i + \sum_{i<j}^{m} \beta_{ij} X_i X_j + \sum_{i=1}^{m} \beta_{ii} X_i^2 \qquad (1)$$

Where β_0 is constant and β_i, β_{ij} and β_{ii} are coefficients for linear, interaction and quadratic terms, respectively.

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

$$Y = a_0 + a_1 X_1 + a_2 X_2 + a_3 X_3 + a_4 X_1^2 + a_5 X_2^2 + a_6 X_3^2 + a_7 X_1 X_2 + a_8 X_1 X_3 + a_9 X_2 X_3 \qquad (2)$$

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

The optimized rates of N, P and manure, determined considering 3 scenarios including: economic, environmental and eco-environmental, which seed yield, N loss and NUE and N loss were the main determining factors, respectively.

1, 2, 3, 4, 5- Associate professor, Professor, M.Sc. students, and Ph.D. student of Agroecology respectively, Department of Agronomy and Plant Breeding, College of Agriculture, Ferdowsi University of Mashhad, Iran
(*- Corresponding Author Email: jahan@um.ac.ir)

To obtain optimized levels, response-surface methodology was used. Finally, the fitted values compared to observed values then validity of regression models evaluated by *RMSE* test (Equation 3) and 1:1 regression line.

$$(\%)\ RMSE = \frac{100}{\bar{O}} \times \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \qquad (3)$$

Results and Discussion

Optimization of nitrogen, phosphorus and manure fertilization were done according to 3 scenarios of economic, environmental and eco-environmental. In economic scenario, wheat seed yield was considered as the main determining factor of optimized resource, thus the result showed by applying of 145.45 kg ha^{-1} N, 200 kg ha^{-1} P and 18.48 tones ha^{-1} manure, it would be attained the seed yield of 6500 kg ha^{-1} and dry matter yield of 13130 kg ha^{-1}. In eco-environmental scenario, the determining factor for optimizing resource was considered as nitrogen losses. The main objective of this scenario was reduction of environmental hazards resulted from the high rates of using of N, P and possibly manure, so, the economic yield had less importance. According to this scenario N application by 21.21 kg ha^{-1} with no use of P, plus 16.36 tones ha^{-1}of manure, minimize N losses (0 kg ha^{-1}). Considering the optimized amount of used resource in this scenario, seed yield, dry matter yield and NUE were estimated of 3160 kg ha^{-1}, 11692 kg ha^{-1} and 9.08 kg DM/kg N, respectively.

Under eco-environmental scenario the main determining factors for optimizing resource, were considered as NUE, N losses and seed yield. As applying of 144.73 and 34.3 kg ha^{-1} of N and P, respectively, and 30 tones ha^{-1} of manure, resulted in seed yield of 4031 and dry matter yield of 15311 kg ha^{-1}, respectively, which showed an increase of 36 percent for NUE compared to economic scenario (16.50 vs. 10.49.

Conclusions

The results of this study showed that N and P fertilizers which used for wheat production did not reflect the actual needs of different crops under different agro-climatic areas indeed, as it should be reconsidered. In this experiment, applying of 30 tones ha^{-1} of manure in eco-environmental scenario caused high availability of N, P and possibly other needed nutrients for plant, finally improved crop productivity. Moreover, trapped and retained nutrients in manure matrix which considered as an ecofriendly and low cost input, which simply preparable locally, improve effectiveness of chemical fertilizer in long term use.

Acknowledgements

Financial support of Ferdowsi University of Mashhad (ratified no. 19800) for conducting this experiment is acknowledged.

Keywords: ANUE, Box-Behnken design, Eco-Environmental scenario, Nitrogen losses, Seed yield