Research Article

A Step towards the Sustainable Wheat Production with Integrated Nutrient Management Strategies under Pothwar Conditions

Muhammad Aqeel Sarwar[1]*, Abid Ali[2], Manzoor Hussain[2], Saadia[3], Muhammad Khubaib Abuzar[4], Ijaz Ahmad[5] and Sohail Latif[6]

[1]Crop Sciences Institute, National Agricultural Research Centre, Islamabad, Pakistan; [2]Groundnut Research Station Attock, Pakistan; [3]Gram Breeding Research Sub Station Attock, Pakistan; [4]Earth and Environmental Sciences Department, Bahria University, Islamabad; [5]Ecotoxicology Research Institute, NARC, Islamabad, Pakistan; [6]ARO, Research Farm Crops, Baldmas, District Kotli, AJ and K, Pakistan.

Abstract | Greater productions of cereals with excessive use of chemical fertilizers bring forth higher production cost and pollute the soil environment. Therefore, some alternative but sustainable, environment friendly and cost effective approaches of nutrient management can be a possible solution for these problems. So the present study was conducted at Agronomic Research Area, Groundnut Research Station Attock, Pakistan during rabi 2013-14 to check the effect of different integrated nutrients management strategies on the yield and quality of wheat. The experiment was laid out in randomized complete block design (RCBD) with factorial arrangement by using three replications. Treatments included different fertilizers combinations i.e (F_1) control, (F_2)100% recommended dose of NPK, (F_3) 75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure(PM), (F_4) 75% of recommended dose of NPK +3 t ha^{-1} farmyard manure (FYM) and(F_5) 75% of recommended dose of NPK + 4.5 t ha^{-1} press-mud (PrM) along with seed inoculants (I_1) *Azospirillum* and (I_2) *Azotobacter* separately for each plot. Data regarding yield, quality and nutrients use efficiency parameters were collected and analyzed. Results depicted that interactive effect of both the factors was non-significant for all the observed parameters. Considering the individual effect of fertilizer combinations, maximum number of productive tillers m^{-2} (392.3), number of grains per spike (45.27), 1000-grain weight (44.04 g), biological yield (14.11 t ha^{-1}), grain yield (5.40 t ha^{-1}) protein contents (12.52%), nitrogen (28.22kg kg^{-1}), phosphorus (34.85 kg kg^{-1}) and potassium (47.40 kg kg^{-1}) use efficiency were obtained with the treatment F_2 (100% recommended dose of NPK).While in seed inoculants, maximum values of yield and yield contributing parameters were obtained in I_1 (Inoculation with *Azospirillum*). However despite the better performance of F_2, economic analysis showed that maximum net income and benefit cost ratio were obtained where (F_3)75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure was applied. Therfore, it can be concluded that 75% recommended dose of NPK + 1.5 t ha^{-1} PM along with *Azospirillum* seed inoculation could be a better management approach for sustainable wheat production.

Received | September 12, 2017; **Accepted** | October 03, 2017; **Published** | March 13, 2018
***Correspondence** | Muhammad Aqeel Sarwar, Crop Sciences Institute, National Agricultural Research Centre, Islamabad, Pakistan; **Email:** maqeeluaf@gmail.com
Citation | Sarwar, M.A., A. Ali, M. Hussain, Saadia, M.K. Abuzar, I. Ahmad and S. Latif. 2018. A step towards the sustainable wheat production with integrated nutrient management strategies under pothwar conditions. *Pakistan Journal of Agricultural Research,* 31(1): 7-14.
DOI | http://dx.doi.org/10.17582/journal.pjar/2017/31.1.7.14
Keywords | Poultry manure, FYM, Press-mud, NPK, Wheat yield

Introduction

Wheat (*Triticum aestivum* L.) is an imperative staple food around the world (Wajid, 2004). Its importance has risen even more due to frequently experienced food shortages and its role in world trade. Among all the cereal crops it ranks first, contributing about 30% of all cereal food globally that makes available almost 20% of overall food calories directly or indirectly for the human body (Lal, 2007). Increasing wheat production is a challenge for the nations to fulfill food requirements by growing populations of the world (Abedi et al., 2012; Campuzano et al., 2012). Intensive production of food crops for this growing demand required increasing amounts of chemical fertilizers (Zhang et al., 2010). Modern agricultural practices have highlighted the widespread use of fertilizer and this technique has certainly increased economic yields in many countries in the last three decades (Jilani et al., 2007).

There are some problems associated to inorganic fertilizer such as their unavailability of fertilizer at the right time, ruining and high cost. Excessive use of chemical fertilizer causes soil, water and environmental pollution associated with health hazards (Elhassan et al., 2010). The use of natural fertilizers (organic manures and biofertilizers) is the need of time to sustain the crop productivity as there is gradual increase in prices and pollution caused by chemical fertilizers (Zaki et al., 2007). Being a renewable source of energy, organic fertilizer use has been revived worldwide. The nutrients release from organic manures is very slow but stored in the soil for a long time, that's why having residual effects for succeeding crops (Mahmoud, 2006; Bakry et al., 2009). On the other hand, application of biofertilizers increases efficiency of mineral nutrient and organic fertilizers but their sole application does not affect the crop yield significantly (Halim, 2009). Hence, biofertilizers could be a valuable source for improving the crop yield and fertility of soil on a sustainable basis.

Keeping in view the usefulness and specific benefits of mineral fertilizers and organic fertilizersfor crop and soil, the idea of integrated use of plant nutrient from various sources is being promoted in various croppingsystems.

Materials and Method

The experiment was conducted on a sandy clay loam soil at Agronomic Research Area, Groundnut Research Station Attock, Pakistan, to study the effect of integrated nutrient management in wheat. The climate of the region is semi-arid and subtropical. The experimental area is located at 31^0 North latitude and 73^0 East longitude with an altitude of 184 m on the globe. The experiment was conducted on sandy clay loam soil. Soil of the experimental area was quite uniform, so a composite and representative soil sample to a depth of 30cm was obtained with soil auger, prior to sowing of the crop. A soil sample was analyzed for its various physio-chemical properties (Table 1).

Table 1: *Physico-chemical analysis of soil.*

Determination	Unit	Value
EC	(dSm^{-1})	0.25
pH		7.9
Organic matter	(%)	0.61
N	(%)	0.038
P	(ppm)	11.5
K	(ppm)	145

The treatments included two seed inoculants i.e (I_1) *Azospirillum*(I_2) *Azotobacter* and different fertilizer levels i.e. (F_1)control, (F_2)100% recommended dose of NPK, (F_3) 75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure(PM), (F_4) 75% of recommended dose of NPK +3 t ha^{-1} farmyard manure (FYM) and(F_5) 75% of recommended dose of NPK + 4.5 t ha^{-1}press-mud (PrM). The inoculum (*Azospirillum* and *Azotobacter*) used in this study were taken from department of bacteriology, Ayub Agriculture Research Institute Faisalabad and were pre-isolated and characterized for their best activity from rhizospheric soil of wheat. Experiment was run in three replicates having a net plot size 7 m × 1.3 m.The crop was shown on 1st December 2014 using seed rate of 150 kg ha^{-1}in 22 cm apart rows with the help of a single row hand drill. Recommended dose of NPK @ 105-85-63 kg ha^{-1} was kept in mind to apply them according to the treatments. According to each treatment, amount of N, P and K dose were fulfilled through Urea, Diammonium Phosphate and Sulphate of potash along with different type of organic manures (PM, FYM and PrM). Whole P and K were applied at the time of sowing and nitrogen from urea was side dressed in two splits (at sowing and first irrigation). Whole calculated amount of poultry manure, FYM and press mud (according to respective treatment) was incorporated in the soil before pre-sowing irrigation (rauni).

Seed was treated with inoculants for each plot according to the treatments. All other agronomic practices were kept normal and uniform in the treatments. At the end of the growth period, different parameters number of productive tillers, grains per spike, 1000 grain weight, biological yield, grain yield, seed protein content, benefit cost ratio and nutrients use efficiency were studied using standard procedure. Total number of tillers were counted from 1 m^{-2} area from each plot at final harvest and number of grains per spike were counted and averaged from twenty spikes taken from each plot randomly. From the seed lot of every plot, five samples, each of 1000- grains were randomly taken, recorded their weight and then mean 1000-grain weight was computed. The biological yield for each experimental unit (7 m × 1.3 m) was noted and converted into kg ha^{-1} and after threshing grain yield in kg per plot was calculated then it was converted into kg ha^{-1}. While benefit cost ratio was calculated with the following formula.

$$BCR = \frac{Total\ Income}{Total\ Cost}$$

Physiological nitrogen use efficiency (kg grains kg^{-1} N)

The physiological nitrogen use efficiency (PHNE) was calculated as the yield obtained from the N (Yn) fertilized plot minus control (Yc), divided by nitrogen uptake in fertilized plot (NUf) minus nitrogen uptake by control (NUc) according to Hashemidezfooli et al. (1998).

$$PHNE = (Yn - Yc)/(NUf - NUc)$$

Agronomic nitrogen use efficiency (kg grains kg^{-1} N)

The agronomic N use efficiency (NUE): The agronomic N use efficiency was calculated as the yield obtained from the N (Yn) fertilized plot minus control (Yc), divided by a unit weight of the applied N fertilizer (Pw) according to Hashemidezfooli et al. (1998).

$$NUE = (Yn-Yc)/Nw$$

Agronomic Phosphorus use efficiency (kg grains kg^{-1} P)

The agronomic P use efficiency (PUE): The agronomic P use efficiency was calculated as the yield obtained from the P (Yp) fertilized plot minus control (Yc), divided by a unit weight of the applied P fertilizer (Pw) according to Fageria et al. (1977).

$$PUE = (Yp-Yc)/Pw$$

Agronomic potassium use efficiency (kg grains kg^{-1} K)

The agronomic K use efficiency (KUE): The agronomic K use efficiency was calculated as the yield obtained from the K (Yk) fertilized plot minus control (Yc), divided by a unit weight of the applied K fertilizer (Kw) according to Fageria et al. (1977).

$$KUE = (Yk-Yc)/Kw$$

The data was analyzed by using Fisher's analysis of variance technique and the difference among the treatment means were compared by using LSD at 5% probability level (Steel et al., 1997).

Results and Discussion

Production of fertile tillers is an important yield contributing parameter in wheat because more number of productive tillers results in higher yield. It was generally exposed that fertilizer levels and seed inoculants had significant effect on productive tillers. Comparison of individual treatment means (Table 2) indicated that maximum number of productive tillers were recorded in F_2(100% recommended dose of NPK) while it was statistically at par with F_3 where 75% recommended dose of NPK + 1.5 t ha-1 PM was applied. However, minimum number of productive tillers was observed in F_1 (control). In the same way maximum number of productive tillers were recorded with I_1 (*Azospirillum*).The maximum number of fertile tillers may be due to the fact that nutrient management through inorganic sources quickly supplies the essential nutrients to the plants. On the other hand, addition of organic matter through the combination improves the proportion of water stable aggregates of the soil. Similar results were also reported by Sarwar et al. (2008) and Shafi et al. (2012). De Freitas (2000) and Mohamed et al. (2010) also reported the similar trend of increasing number of productive tillers with *Azospirillum* inoculation. This increase in productive tillers might be due to its ability to produce more auxin as reported formerly.

The productive potential of a spike is measured in terms of number of grains per spike. Results (Table 2) showed that integrated nutrient management (fertilizer levels) and seed inoculants affected the number of grains per spike significantly. Maximum number of grain per spike were obtained with treatment F_2 (100% recommended dose of NPK) as compared to

Table 2: *Effect of different nutrient management approaches and seed inoculants on yield components, yield and quality of wheat.*

Treatments	Productive tillers (m^2)	Number of grains per spike	1000-grain wt. (g)	Biological yields (t ha^{-1})	Grain yield (t ha^{-1})	Protein contents (%)
F_1	198.8c	29.74 c	32.87 c	8.940 c	2.44 d	8.550 c
F_2	392.3 a	45.27 a	44.04 a	14.11 a	5.40 a	12.52 a
F_3	383.0 a	44.33 a	43.27 a	13.87 a	5.26 a	12.29 a
F_4	312.2 b	39.21 b	38.05 b	11.50 b	3.62 b	10.13 b
F_5	325.8 b	41.34 b	39.53 b	12.30 b	4.19 c	10.79 b
LSD value	33.03	2.29	2.53	1.03	0.14	1.45
I_1	335.7 a	40.77 a	40.36 a	12.54 a	4.45 a	11.04
I_2	309.2b	39.19 b	38.74b	11.75 b	3.91 b	10.67
LSD value	20.892	1.45	1.60	0.65	0.08	
Interaction	NS	NS	NS	NS	NS	NS

Means not sharing the same letters differ significantly at 5% probability level

F_1: *control;* **F_2:** *100% recommended dose of NPK;* **F_3:** *75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure;* **F_4:** *75% recommended dose of NPK + 3 t ha^{-1} FYM;* **F_5:** *75% recommended dose of NPK + 4.5 t ha^{-1} press-mud;* **I_1:** *Azospirillum;* **I_2:** *Azotobacter.*

control (F_1). Regarding seed inoculants higher value for number of grains per spike was recorded in I_1 (*Azospirillum*) than I_2 (*Azotobacter*). The probable reason could be that mineral fertilizer throughout the growing period did not put the plants in nutrient stress at any stage that attributed towards differences in number of grains spike^{-1} which resulted in maximum grain production. These results are supported by Iqbal et al. (2002). Microorganisms are involved in the production of indole acetic acid and cytokinins that increases the preserved matter by growing rhizomes and increasing leaf and root weight that result in to increasing number of reproductive organs such as grains. Similar results were also reported by Kandil et al. (2011).

Different fertilizer levels and seed inoculants significantly affected the 1000-grain weight (Table 2). Maximum 1000-grain weight was observed in F_2(100% recommended dose of NPK) which was statistically at par with F_3 (75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure). While, the minimum 1000-grain weight was observed in treatment F_1 (control). On the other hand maximum value for 1000-grain weight was observed in I_1 (*Azospirillum*) as compared to I_2 (*Azotobacter*). The increase in grain weight might be due to the availability of phosphorus and other micro elements during fertilization period that is vital for healthy spike development that means increase in grains weight as well. Similar results have also been reported by Diacono et al. (2013) who observed higher 1000-grain weight with the use of inorganic fertilizers. Regarding seed inoculants similar results were reported by Zaki et al. (2007).

Biological yield indicates the relative growth rate of plants as considered to net assimilation rate. Data regarding biological yield (Table 2) presented significantly effect of different fertilizer levels and seed inoculants. The mean comparison of treatments showed that highest value of biological yield was recorded where 100% recommended dose of NPK (F_2) was applied and it was statistically at par with treatment F_3 (75% recommended dose of NPK + 1.5 t ha^{-1} PM). In the mean time, minimum value for the parameter under study was observed with treatment F_1 (control). Similarly, significant improvement in biological yield was observed with seed inoculants. The value observed with the application of I_1 (*Azospirillum*) shows significant difference from I_2 (*Azotobacter*). The reason of increase in biological yield with the application of recommended dose of inorganic fertilizers is the acidification of soil which increases the availability of nutrients in early as well as later stages of growth. Our results are supported by the findings of Shafi et al. (2012). Regarding seed inoculants, increase in biological yield might be due to contributing effect of increased plant height, number of tillers and spike length with the same source (*Azospirillum*). Similar conclusions were also drawn by Kandil et al. (2011).

Grain yield is the end result of many complex morphological and physiological processes occurring during the growth and development of crop. Effect of fertilizer levels and seed inoculants on grain yield showed that both the factors had significant effect on the grain yield (Table 2). Data showed that highest grain yield was observed with the application of F_2 (100% recommended dose of NPK) that was statistically same with the treatment F_3 (75% recommended dose of NPK + 1.5 t ha^{-1} PM). While, the minimum value of grain yield was observed with control (F_1). In the same way maximum grain yield was recorded with I_1 (*Azospirillum*) and minimum grain yield was recorded with I_2 (*Azotobacter*). These results might be due to proper supply of nutrients from inorganic source of fertilizer during the plant development and also due to greater number of productive tillers, number of grains per spike and better grain development with the same treatment. Our results were in conformity of Weini et al. (2012) who also endorsed that increased rate of photosynthesis and utilization of assimilates obtained by the full dose of NPK resulted in heavier grains, thereby increased the grain yield. In case of seed inoculation the reason for increase in the grain yield is might be due to secretion of growth promoting phytohormones like auxins and gibberellins by *Azospirillum*. These results are in agreement with the findings of Kandil et al. (2011).

Seed protein content is the most important quality parameter affecting the nutritional value of crop. The results regarding the impact of different fertilizer levels and seed inoculants shows that fertilizer levels significantly affected the seed protein content % (Table 2). Highest value of seed protein content was obtained in F_2 (100% recommended dose of NPK) which was statistically at par with F_3 (75% recommended dose of NPK + 1.5 t ha^{-1}PM). Enhancement in grain protein was due to availability of nitrogen to plant at proper time and in proper proportion. It has also been reported that by increasing N supply through sole application of NPK protein content in seed also increased. This might have lead to accumulation of higher quantities of seed components like calcium carbonate and increased the lipid metabolism which helps in increasing the protein content in seed. These results are akin with findings of Roy and Singh (2006); Liu and Shi (2013).

Data regarding the effect of fertilizer levels on physiological nitrogen use efficiency (kg kg^{-1}) showed significant results (Table 3). Results shows that maximum physiological nitrogen use efficiency was obtained with F_4 (75% recommended dose of NPK + 3 t ha^{-1} FYM) and minimum value was recorded with F_1 (control). The combined use of organic and inorganic fertilizer reduces the N losses mainly results from denitrification, gaseous plant emission, volatilization, surface runoff and leaching, thus leading higher values of physiological nitrogen use efficiency. These values also confirm the previous study on combined use of organic and inorganic fertilizer (Metwally and Khamis, 1998; El-Sirafy et al., 2006; Tanveer et al., 2010).

It is clear from the results that fertilizer levels had significant effect on the agronomic nitrogen use efficiency (Table 3). Maximum increase in agronomic nitrogen use efficiency was observed with the treatment F_2 (100% recommended dose of NPK) which was statistically at par with F_3 (75% recommended dose of NPK + 1.5 t ha^{-1}poultry manure). The minimum value of agronomic nitrogen use efficiency was recorded in untreated (control). Enhancement in agronomic nitrogen use efficiency was due to availability of nitrogen to plant at proper time and in proper proportion through inorganic source of fertilizer. It has also been reported that N supply through combined use of organic and inorganic sources of fertilizer

Table 3: *Effect of different nutrient management approaches and seed inoculants on Nutrients use efficiency of wheat.*

Treatments	Physiological N use efficiency (kg kg^{-1})	Agronomic N use efficiency (kg kg^{-1})	Agronomic P use efficiency (kg kg^{-1})	Agronomic K use efficiency (kg kg^{-1})
F_1	00.00 b	00.00 d	00.00 d	00.00 d
F_2	33.29 a	28.22 a	34.85 a	47.40 a
F_3	34.02 a	26.61 a	33.17 a	44.69 a
F_4	40.59 a	10.23 c	14.91 c	17.36 c
F_5	38.98 a	15.09 b	20.53 b	23.87 b
LSD value	8.90	1.94	2.53	3.27

Means not sharing the same letters differ significantly at 5% probability level

F_1: *control;* **F_2:** *100% recommended dose of NPK;* **F_3:** *75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure;* **F_4:** *75% recommended dose of NPK + 3 t ha^{-1} FYM;* **F_5:** *75% recommended dose of NPK + 4.5 t ha^{-1} press-mud.*

Table 4: *Effect of different nutrient management approaches and seed inoculants on economic analysis of wheat.*

Treatment	Total expenditure ($Rs.ha^{-1}$)	Gross income ($Rs.ha^{-1}$)			Net income ($Rs.ha^{-1}$)	BCR
		Income from grains	Income from straw	Total		
I_1F_1	58018	80100	28815	108915	50897	1.88
I_1F_2	96581	170700	34297	204997	108416	2.12
I_1F_3	93312	166800	37017	203817	110505	2.18
I_1F_4	89112.5	115800	33872	149672	60560	1.68
I_1F_5	90462	133800	35020	168820	78357	1.87
I_2F_1	56608	66000	26435	92435	35827	1.63
I_2F_2	94841	153300	33660	186960	92119	1.97
I_2F_3	91512	148800	36210	185010	93497	2.02
I_2F_4	87642	101100	33107	134207	46565	1.53
I_2F_5	88812	117300	33957	151257	62445	1.70

gave maximum value of this parameter. While the lowest agronomic nitrogen use efficiency in F1 might be due to unavailability of nitrogen. These values are opposed by the findings of Haase et al. (2007), Pablo et al. (2008) who reported increase in nitrogen use efficiency with decreasing nitrogen levels.

Data about the agronomic phosphorus use efficiency indicates that it was significantly affected with different fertilizer levels (Table 3). The highest value for the parameter under study was observed in F_2 (100% recommended dose of NPK) which was statistically similar with F_3 (75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure). While minimum value was recorded in F_1 (untreated). However, no significant difference was observed with seed inoculants. Phosphorus play important role in various growth and developmental stages of wheat (root formation, stem formation, tillering capacity and ultimately grain formation) that may result higher agronomic phosphorus use efficiency in the treatment F_2. Uexkull and Mutert (1995); Eijk et al. (2006) on the base of their experimental results suggested that application of phosphorus at the initial stage brings forth higher production of a crop.

Data regarding agronomic potassium use efficiency is presented in Table 3. In general, it revealed that fertilizer levels showed a prominent increase in agronomic potassium use efficiency. The maximum increase in potassium use efficiency was obtained in response of F_2 (100% recommended dose of NPK) followed by F_3 (75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure) as compared to control. More uptake of potassium by plant, energy use efficiency would be more than low uptake of potassium. This increase in efficiency is due to its role in ATP synthesis that is the major component of conserving and transmission of energy. Potassium also play important role in osmotic potential and adjustment of turgor pressure via increasing size of cell (Sarmadnia and Kochaki, 1994).

Economic analysis is the criteria for basic determination of net benefits. It also helps the researcher to make recommendations to the farmers and to plan for further investigation. The cost of wheat production under local field conditions of Faisalabad, Pakistan in detail is given in Table 4. Different treatments of seed inoculants and fertilzer levels resulted in different net income (Rs. ha^{-1}) and benefit cost ratio. Data regarding economic analysis (Table 4) reveals that highest net return and benefit cost ratio were observed in I_1F_3 (seed inoculation with *Azospirillum* and 75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure).

Conclusion

It can be concluded that application of 75% recommended dose of NPK + 1.5 t ha^{-1} poultry manure along with *Azospirillum* seed inoculation would be a better and economical management approach for farming community for sustainable wheat production under pothwar conditions.

Author's Contribution

Muhammad Aqeel Sarwar conceived the idea, wrote abstract and provided technical input at every step. Manzoor Hussain did overall management and supervised the experiment. Abid Ali and Saadia conducted experiment and collected data. Muhammad Khubaib Abuzar did statistical analysis while Ijaz

Ahmad and Sohail Latif wrote the article.

References

Abedi, T., A. Alemzadeh and S.A. Kazemeini. 2010. Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. Aust. J. Crop Sci. 4: 384-389.

Bakry, M.A., M.M. Paraas and M.M. Abass. 2009. Effect of organic and inorganic soil ammendements combined with mineral fertilizers on the fertility of calcareous soil and its productivity. Minufiya J. Agri. Res. 34: 2243-2260.

Campuzano, G.E., G.A. Slafer and D.J. Miralles. 2012. Differences in yield, biomass and their components between triticale and wheat grown under contrasting water and nitrogen environments. Field Crops Res. 128: 167-179. https://doi.org/10.1016/j.fcr.2012.01.003

De-Freitas, J.R. 2000. Yield and nitrogen assimilation of winter wheat (*Triticum aestivum* L.) inoculated with rhizobacteria. Pedobiologia. 44: 97-104. https://doi.org/10.1078/S0031-4056(04)70031-1

Diacono, M., P. Rubino and F. Montemurro. 2013. Precision nutrient management of wheat; a review. Agron. Sust. Dev. 33: 219-241. https://doi.org/10.1007/s13593-012-0111-z

Eijk, V.D.D., B.H. Janssen and O. Oenema. 2006. Initial and residual effects of fertilizer phosphorus on soil phosphorus and maize yields on phosphorus fixing soils. A case study in south-west Kenya. Agric. Ecosys. Environ. 116: 104-120. https://doi.org/10.1016/j.agee.2006.03.018

Elhassan, G.A., M.E. Abdelgani, A.G. Osman, S.S. Mohamed and B.S. Abdelgadir. 2010. Potential production and application of biofertilizers in Sudan. Pak. J. Nut. 9: 926-934. https://doi.org/10.3923/pjn.2010.926.934

El-Sirafy, Z.M., H.J. Woodward and E.M. El-Norjar. 2006. Contribution of biofertilizer and fertilizer N to nutrient uptake and yield of Egyptian winter wheat. J. Plant Nut. 29: 587-599. https://doi.org/10.1080/01904160600564287

Fageria, N.K., V.C. Baligar and C.A. Jones. 1977. Growth and mineral nutrition of field crops. 2nd Ed. Marcel Dekker, Inc. NY, USA.

Haase, T., C. Schuler and J. Heb. 2007. The effect of different N and K sources on tuber nutrient uptake, total and graded yield of potatoes for processing. Europ. J. Agron. 26: 187-197. https://doi.org/10.1016/j.eja.2006.09.008

Halim, A.N.B. 2009. Effects of using enhanced biofertilizer containing N-fixer bacteria on patchouli growth. Thesis. Faculty of chemical and natural resources engineering university Malaysia Pahang. P145.

Hashemidezfooli, A., A. Koochaki and M.B. Avval. 1998. Crop 1 plant improvement (translation). Jehad Daneshgahi Mashad press. Mashad. Iran. Edition Number: 3: 964-6023-05-3.

Iqbal, A.S., M.K. Abbasi and G. Rasool. 2002. Integrated plant nutrition system (IPNS) in wheat under rainfed condition of Rawalkot Azad Jammu and Kashmir. Pak. J. Soil Sci. 21: 79-86.

Jilani, G., A. Akram, R.M. Ali, F.Y. Hafeez, I.H. Shamsi, A.N. Chaudhry and A.G. Chaudhry. 2007. Enhancing crop growth, nutrients availability, economics and beneficial rhizosphere microflora through organic and biofertilizers. Annals of Microbiol. 57: 177-183. https://doi.org/10.1007/BF03175204

Kandil, A.A., M.H. El-Hindi, M.A. Badawi, S.A. El- Morarsy and F.A.H.M. Kalboush. 2011. Response of wheat to rates of nitrogen, biofertilizers and land leveling. Crop Environ. 2: 46-51.

Lal, R. 2007. Anthropogenic influences on world soils and implications to global food security. Adv. in Agron. 93: 69-93. https://doi.org/10.1016/S0065-2113(06)93002-8

Liu, D. and Y. Shi. 2013. Effects of different nitrogen fertilizer on quality and yield in winter wheat. Ad. J. Food Sci. Tech. 5: 646-649.

Mahmoud, M.R. 2006. Residual effect of compost and biofertilizers on maize yield, and some soil chemical properties. Assi. J. Agric. Sci. 37: 87-200.

Metwally, S.M., and M.A. Khamis. 1998. Comparative effects of organic and inorganic nitrogen sources applied to a sandy soil on availability of N and wheat yield. Egypt. J. Soil Sci. 38: 35-54.

Mohamed, S.S., A.G. Osman, A.S. Abdalla and A.M.E. Rugheim. 2010. Response of wheat to biological and nitrogen fertilization. Uni. Kenya J. Agric. Sci. 18: 31-42.

Pablo, B.A.E., H. Echeverría, R.H.S. Rozas and H.F. Andrade. 2008. Nitrogen use efficiency in maize as affected by nitrogen availability and row spacing. Agron. J. 100: 1094-1100. https://doi.org/10.2134/agronj2006.0057

Roy, D.K. and B.P. Singh. 2006. Effect of level and time of nitrogen application with and without vermicompost on yield, yield attributes and quality of malt barley (*Hordeum vulgare*). Ind. J. Agron. 51: 40-42.

Sarmadnia, G. and E. Kochaki. 1994. Crop physiology. (Chapter 4). Mashhad University Publication.

Sarwar, G., H. Schmeisky, N. Hussain, S. Muhammad, M. Ibrahim and E. Safdar. 2008. Improvement of soil physical and chemical properties with compost application in rice-wheat cropping system. Pak. J. Bot. 40: 275-282.

Shafi, M., J. Bakht, F. Jalal, M.A. Khan and S.G. Khattak. 2012. Effect of nitrogen application on yield and yield components of wheat (*Triticum aestivum* L.). Pak. J. Bot. 43: 1471-1475.

Steel, R., J. Torrie and D. Dickey. 1997. Principals and procedures of statistics. A biometrical approach. 3rd Eds. McGraw Hifi Book Co. Inc., New York, USA.13: 1409-1414.

Tanveer, S.K., S. Yasmin, I. Hussain, M.Y. Mujahid, M. Munir and M. Asif. 2010. Wheat production and quality affected by combinations of different fertilizer NP and FYM in rainfed areas. Pak. J. Agric. Res. 23: 1-2.

Uexkull, V.H.R. and E. Mutert. 1995. Rehabilitation of anthropic savanna. In H. Tiessen, ed. Phosphorus in the global environment, pp 149-154. Chichester, UK, John Wiley.

Wajid, S.A. 2004. Modeling development, growth and yield of wheat under different sowing dates, plant populations and irrigation levels. Ph. D. Thesis, Department of Agronomy, University of Agriculture, Faisalabad.

Weini, W., L. Jianwei, R. Tao, L. Yinshui, Z. Juan, S. Wei and L. Xiaokun. 2012. Inorganic fertilizer application ensures high crop yields in modern agriculture. J. Food Agric. Environ. 10: 703-709.

Zaki, M., M. Nabila, S. Hassanein and K.M.G. Din. 2007. Growth and yield of some wheat cultivars irrigated with saline water in newly cultivated land as affected by biofertilization. J. Applied Sci. 36: 1121-1126.

Zhang, Q., Y. Chen, G. Jilani, I.H. Shamsi and Q. Yu. 2010. Model AVSWAT apropos of simulating non- point source pollution in Taihu lake basin. J. Hazard. Material. 174: 824-830. https://doi.org/10.1016/j.jhazmat.2009.09.127