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USE OF NATURAL NITROGEN STABILIZERS TO IMPROVE NITROGEN USE EFFICIENCY AND WHEAT CROP YIELD

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ABSTRACT. Complex nature of nitrogen fertilizer in soil and poor management practices are major causes of low fertilizer use efficiency in Pakistan. These factors further increases nitrogen losses in form of nitrate leaching and volatilization of ammonium, as well as nitric oxide which are burning economic and environmental threats. Keeping in view the demand of urea application in Pakistan and its low efficiency, we hypothized that appropriate urea management with neem formulations or biofertilizers can enhance the nitrogen use efficiency. We designed experiment with treatments: T_0 (N_0 application), T_1 (recommended nitrogen), T_2 (recommended nitrogen + biofertilizer), T_3 (recommended nitrogen + neem seed extract), T_4 (75% recommended nitrogen + biofertilizer), T_5 (75% recommended nitrogen + neem seed extract), T_6 (recommended nitrogen + biofertilizer + neem seed extract), T_7 (75% recommended nitrogen + biofertilizer + neem seed extract) in wheat crop. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangements. Different approaches for stabilized nitrogen fertilizer responded significantly for the wheat plant height, tillers per plant, number of grains per spike, 1000-grain yield, grain yield and harvest index. Result exhibited that wheat crop enhanced yield attributes and finally the yield under treatment T_6 and T_7 for both wheat cultivars. Treatments comparison with recommended nitrogen (T_1) revealed that all treatments with biofertilizer, as well as with neem seed, enhanced crop performance along with nitrogen use efficiency. It can be concluded that nitrogen fertilizer can be stabilized in the soil with the use of different natural products for sustainable crop production.

Keywords: field experiment; fertilizer; neem seed extract; biofertilizer; yield attributes.

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INTRODUCTION

Population pressure has increased the food demand, which in turn enhanced the flux of nitrogen application all over the world. Nitrogen fertilizer demand is increasing day by day and is expected to increase 1.4% in year 2018. Among Asian countries, Pakistan is at 4th for increasing demand of nitrogen fertilizer (FAO, 2015). Pakistan is already energy deficient country and has to invest lot of energy to manufacture fertilizer, which needs to reduce for better economy.

Most of Pakistan's cultivated area is deficient in nitrogen, which is heavily fertilized with urea for successful crop production (Shah *et al.,* 2012; Ehsanullah *et al.,* 2012; Ali and Noorka, 2013). Nitrogen is major essential nutrient applied in crop production as it limited in agricultural soils and needs to be supplemented (Kawakami *et al.,* 2013). Various nitrogenous sources are being used like ammonium nitrate, nitrophos, but urea is extensively used due to its higher nitrogen contents (Soares *et al.,* 2012). But applied nitrogen is not fully utilized by the crop plants as lot of portion is being wasted by leaching or volatilization. Nitrogen use efficiency is very low and reaches up to 33% in cereals production worldwide (Raun and Johnson, 1999). Most dominant nitrogenous fertilizer is urea in most of the countries due to higher nitrogen percentage, low cost, no storage risk and can be applied in variety of crops. But the nitrogen use efficiency of urea-nitrogen is low as 20-50% in most of soils (Singh, 2016).

When urea applied in the soil, many chemical and biological reactions takes place which transform the nitrogen into different forms and reduces the availability for crops. Urea hydrolyzed into Ammonium by urease enzyme and then by nitrifying bacteria into nitrate nitrogen. These urea products can be absorbed by plants or losses in the ammonia gas and nitrate as leaching. Loss of nitrogen not only decreases the nitrogen use efficiency, enhance input cost but also a climatic threat in global warming. Big portion of greenhouse gasses are emitted from agriculture, which is 80% and 50%, respectively (IPCC, 2007).

Many products have been developed as nitrification inhibitors, which inhibit or delay the nitrogen transformation process and improve the nitrogen availability to plants. These products include N-(n-butyl) thiophosphorictriamide (NBPT), phenyl phosphorodiamidate (PPD), phenyl mercuric acetate (PMA), dicyandiamide (DCD), hydroquinone (HQ) (Khan *et al.,* 2013). These products are highly expensive, which cannot be affordable for the farmers of developing countries, like Pakistan.

Some plant extracts having similar mode of action to enhance the nitrogen use efficiency and also being used in developing countries like India. These products are cheaper and easily available, which can attract the farming community to save the expensive fertilizer.

Neem is widely growing tree in tropical and subtropical areas of Australia, America, asia, Africa and have nitrification inhibitor properties (Schmutterer, 1990). Studies showed that neem seed contain nitrification inhibitor coumpounds, like Epinimbin, Deacetyl, Salanin and Azadirachtin, which enhances the nitrogen use efficiency when applied along with urea (Singh and Singh 1986). Neem oil and cake can be used as nitrification inhibitors in crop production to enhance nitrogen use efficiency, which was reported many years back in 1970 (Bains *et al.,* 1971). Neem oil or neem cake coated urea can enhance the crop productivity by minimizing nitrogen losses (Prasad *et al.,* 2002). Complex nature of nitrogen fertilizer in soil and poor management practices are major causes of low fertilizer use efficiency in Pakistan. These factors further increases nitrogen losses in form of nitrate leaching and volatilization of ammonium, as well as nitric oxide, which are burning economic and environmental threats. On the basis of satisfied results of use of neem oil and neem cake along with year fertilization, Indian government recently allowed to fertilizer industries for urea coating (Singh, 2016). In Pakistan, no work has been reported yet by fertilizer industries at commercial level to facilitate the farmers. Keeping in view the demand of urea application in Pakistan and its low efficiency, we hypothised that appropriate urea management with neem formulations can enhance the nitrogen use efficiency.

MATERIAL AND METHODS

This field trial was laid out at Agronomic Research Area, Department of Agronomy, Bahauddin Zakariya University, Multan (71.50^o E, 30.2^o N and 129 meters above sea level) during Rabi season, 2016-2017. The environment area is semi-arid and subtropical. The experimental zone was constant, and soil was silty clay and saline in nature. Soil assessment was directed to determine the fertility status and other physicochemical properties of soil, which are given below. When physical analysis was conducted sand was 27.77%, silt 52.6%, clay 19.6%, and saturation percentage was 38%. Also, textural class was silty, clay, loam.

During the chemical analysis, the soil pH was 7.5, EC was 3.51 ds m^{-1}, organic matter was 0.85%, which is very low, total nitrogen was 0.05% it is also low, available phosphorous concentration was low, which is 7.43 ppm, available potassium was 126.00, which are in medium quantity. Experiment was comprised with two factors: Factor A: cultivars; V1: Galaxy-2013, V2: Faisalabad-2008 and Factor B: nitrogen management: T0 = Control, T1 = recommended nitrogen (120 kg ha-1), T2 = recommended nitrogen (120 kg ha-1) + biofertilizer, T3 = recommended nitrogen (120 kg ha-1) + neem seed extract, T4 = 75% recommended nitrogen + biofertilizer, T5 = 75% recommended nitrogen + neem seed extract, T6 = recommended nitrogen + biofertilizer + neem seed extract and T7 = 75% recommended nitrogen + biofertilizer + neem seed extract. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangements having net plot size 2 m × 2 m and replicated eight times. Water control was kept in main plots, seed size in sub plots. Two varieties are used for sowing.

Rouni irrigation of about 10 cm was practical to plot to produce profitable surrounds for seedbed preparation. When the soil reached to workable state, seedbed was organized by generous soil two cultivations with tractor-mounted plough and planking is done in field.

Sowing was done on Nov. 22, 2016 on seedbed by using hand drill with 125 kg kg ha^{-1} seed rate having row to row distance of 25 cm. Fertilizers were applied 120 and 100 kg ha^{-1} of nitrogen (N) and phosphorus (P), respectively, by using urea and DAP. Biofertilizer and neem seed extract was applied in changed treatments to stabilize nitrogen. Half dose of nitrogen and whole phosphorous were applied at sowing by drill and the remaining nitrogen was side dressed in 1st irrigation and also Biofertilizer and neem seed extract was applied with 1st irrigation. Irrigations were given rendering to the treatments and all further agronomic performs were retained constant to protect crop from weeds, insects and diseases. Matured crop was collected on April 14, 2017.

RESULTS

Yield and yield attributes

Different approaches for stabilized nitrogen fertilizer responded significantly for the wheat plant height, tillers per plant, number of grains per spike, 1000-grain yield, grain yield and harvest index. Both varieties responded similarly to different treatments, while significant difference was recorded for various treatments, as well as for the interaction of treatments and cultivars. As far as interaction concern for treatments and cultivars, maximum plant height was recorded in treatment T_6 (92.4, 91.87) and T_7 (90.700, 90.227) for cultivar V_1 as well as for cultivar V_2, respectively. Minimum plant height was recorded in T0, where we did not apply the nitrogen fertilizer. But, if we compare the treatments with the recommended nitrogen then it seems that all treatments with biofertilizer, as well as with neem seed extract increases the plant height. It might be due the less wastage of nitrogen fertilizer in the atmosphere, as well as in the leaching process.

Similarly, the other yield parameters responded significantly to all nitrogen management treatments. Tiller per plant, grains per spike, 1000-grain weight was improved in treatment of T_6 (recommended nitrogen+ biofertilizer + neem seed extract) and T_7 (75% of recommended nitrogen+ biofertilizer + neem seed extract) in both cultivars. These treatments were also at par with T_2 and T_3, in which we applied the recommended nitrogen along with biofertilizer, as well as with neem seed extract.

Treatment comparison for grains per panicle and spikelets per spike exhibited those treatments T_2, T_3, T_6 and T_7 were found at par, as compared with other treatments. This treatment group significantly improved the grains, as well spikelets per spike. In case of 1000-grain weight, heavier grains were recorded in treatment T_6 and T_7, which were further at par with T_3 treatment. Treatment comparison for grain yield proved that Treatment T_7V_1 was found superior, which was further at par with T_7V_2, T_2V_1, T_2V_2. Harvest index showed a very clear picture of results. It's a basically, ratio of biological yield with grain yield, which shows overall crop performance that how crop actively translocate the biomass toward grains. Treatment comparison reveals that treatment T_6 and T_7 along with both cultivars significantly improved the harvest index (*Table 1*).

In other words, we can say that crop matured with recommended nitrogen along with biofertilizer and neem seed extract and crop matured with reduced dose of nitrogen but along with biofertilizer and neem seed extract found very active in translocation of assimilates.

DISCUSSION

Nitrogen is called as king pin in nutrients, just because of its higher application and demand in successful crop production. Pakistan has emerged as 4^{th} largest consumer of nitrogen fertilizer in world ranking (FAO, 2015).

The nitrogen use efficiency of urea-nitrogen is low as 20-50% in most of soils (Singh, 2016), so the farmers can't afford the wastage of expensive fertilizer, especially in developing countries like in Pakistan. When urea applied in the soil, many chemical and biological reactions takes place, which transform the nitrogen into different forms and reduces the availability for crops. Urea hydrolyzed into ammonium by urease enzyme and then by nitrifying bacteria into nitrate nitrogen. These urea products can be absorbed by plants or losses in the ammonia gas and nitrate as leaching. Loss of nitrogen not only decreases the nitrogen use efficiency, enhance input cost, but also a climatic threat in global warming. Big portion of greenhouse gasses are emitted from agriculture, which is 80% and 50%, respectively (IPCC, 2007).

Experimental results revealed that nitrogen efficiency can be enhanced with sensible combination with other stabilized compounds (*Fig. 1*). We used the biofertilizer and need seed extract in combination with nitrogen fertilizer. Both compounds significantly improved the performance of yield dependent factors, like productive tillers, grains per panicle, grains per spike and grain weight. This effect shows that biofertilizer enhanced the availability of nitrogen as it may faster the decomposition of organic matter present in the soil. All combinations along with biofertilizer improved the crop performance, as compared with sole application of nitrogen fertilizer. Namvar *et al.* (2013) suggested applying inorganic along with organic fertilizer for better crop yield and conserving environment. Biofertilizer plays significant role in nitrogen fixation and production of growth regulators, which not only improve the crop production, but also reduce the environmental pollution (Saini *et al.,* 2004; Namvar *et al.,* 2012; Rana *et al.,* 2012). *Azotobacter* sp. and *Azospirillum* sp. are two widely used nitrogen fixing agents, which can contribute up to 0-60 kg N/ha (Vessey, 2003).

Neem seed extract also resulted in better performance of wheat crop. Neem is a widely grown tree in tropical, as well as in subtropical regions of the world. This plant have miracles properties in case of soil nutrients, especially the nitrogen management.

It was first time reported in year 1970s that neem seed has tremendous potential as natural nitrification inhibition process (Bains *et al.,* 1971).

Table 1 - Yield and yield attributes effected with stabilized nitrogen application among different wheat cultivars

Treat-ments	Plant height (cm)	Tiller per plant	No. of spikelet per spike	No. of grains	1000-grain weight (g)	Grain yield (g/m^{-2})	Harvest index
T_0V_1	78.5 h	4.7 d	13.8 e	41.3 h	45.8 h	420.2 h	0.35 g
T_0V_2	77.9 h	4.3 d	13.8 e	41.0 h	45.6 h	398.0 h	0.34 g
T_1V_1	86.3 ef	6.7 c	15.9 d	49.3 g	49.4 g	515.5 de	0.43 g
T_1V_2	86.0 ef	6.7 c	15.9 d	48.0 g	49.6 g	490.2 ef	0.42 g
T_2V_1	87.9 cd	8.0 ab	17.7 ab	54.0 bcd	51.5 def	553.1 b	0.47 c
T_2V_2	86.9 de	8.0 ab	17.5 b	53.5 cd	51.9 cde	527.8abc	0.46 c
T_3V_1	88.2 c	7.7 b	17.4 b	54.4 bc	52.5 abc	545.8 dcd	0.46 d
T_3V_2	88.4 c	8.0 ab	17.5 b	54.5 abc	52.3 bcd	498.3 efg	0.47 d
T_4V_1	85.6 fg	6.0 c	16.8 c	51.5 f	50.7 f	495.9 ef	0.42 e
T_4V_2	85.3 fg	6.7 c	16.8 c	51.8 ef	51.1 ef	469.3 g	0.43 d
T_5V_1	85.4 fg	6.3 b	16.8 c	53.2 cde	51.1 ef	522.4 df	0.41 d
T_5V_2	84.8 g	6.0 c	16.8 c	52.8 def	51.2 ef	492.4 efg	0.42 e
T_6V_1	92.4 a	8.7 a	17.9 a	55.0 ab	52.8 abc	572.1 ab	0.50 a
T_6V_2	91.9 a	8.7 a	17.9 a	55.3 ab	53.4 a	522.1 def	0.49 a
T_7V_1	90.7 b	8.3 ab	17.9 a	55.5 a	52.0 ab	568.9 ab	0.48 ab
T_7V_2	90.2 b	8.6 a	17.9 a	55.2 ab	53.1 ab	546.0 bc	0.49 a

V_1: Galaxy-2013, V_2: Faisalabad-2008, T_0 = Control, T_1 = recommended nitrogen (120 kg ha^{-1}), T_2 = recommended nitrogen (120 kg ha^{-1}) + biofertilizer, T_3 = recommended nitrogen (120 kg ha^{-1}) + neem seed extract, T_4 = 75% of recommended nitrogen + biofertilizer, T_5 = 75% of recommended nitrogen + neem seed extract, T_6 = recommended nitrogen + biofertilizer + neem seed extract and T_7 = 75% of recommended nitrogen + biofertilizer + neem seed extract

Neem seed can be applied in the form of seed extract, seed oil and seed cake. Studies shows that all different product have increased significance crop performance when applied in soil along with fertilizer. On the base of these results, government of India has allowed the fertilizer industries to coad urea with neem seed oil (Singh, 2016). Urea coated with nimin, a product of neem plant, inhibit the urea nitrification and results similar to inorganic nitrification inhibitors (Majumdar, 2005).

This characteristic of neem plant, not only improve the nitrogen use efficiency, but can also be helpful in emission of green house gasses, like N_{20} in the atmosphere (Akiyama *et al.,* 2010).

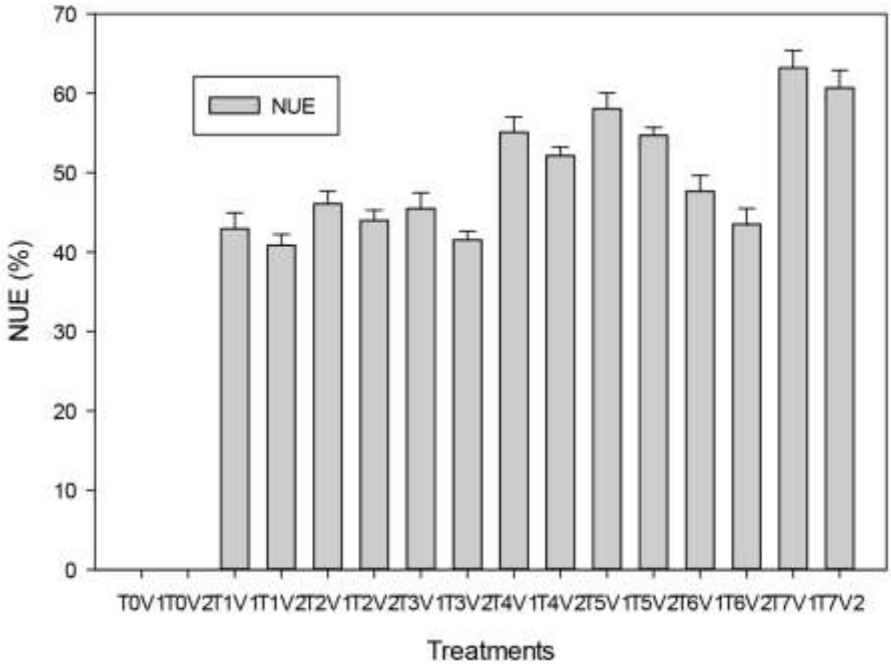

Figure 1 - Nitrogen use efficiency (%) effected with stabilized nitrogen application in different wheat cultivars

V_1: Galaxy-2013, V_2: Faisalabad-2008, T_0 = Control, T_1 = recommended nitrogen (120 kg ha^{-1}), T_2 = recommended nitrogen (120 kg ha^{-1}) + biofertilizer, T_3 = recommended nitrogen (120 kg ha^{-1}) + neem seed extract, T_4 = 75% of recommended nitrogen + biofertilizer, T_5 = 75% of recommended nitrogen + neem seed extract, T_6 = Recommended nitrogen + biofertilizer + neem seed extract and T_7 = 75% of recommended nitrogen + biofertilizer + neem seed extract

CONCLUSIONS

Crop matured with recommended nitrogen along with biofertilizer and neem seed extract, and crop matured with reduced dose of nitrogen, but along with biofertilizer and neem seed extract (75% of recommended nitrogen + biofertilizer + neem seed extract) resulted almost in similar way for crop performance.

So, it can be concluded that with application of suggested treatment, nitrogen fertilizer can be saved, as well as its efficiency can be improved with the addition of biofertilizer and neem seed extract during fertilization in the field.

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