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Comparison of Conventional and Encapsulated Urea on Growth and Yield of Wheat (*triticum aestivum l.)*

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Abstract: Nitrogen (N) is necessary sustenance for healthy plant growth and its yield. Urea is a primary source of N in solid fertilizers. The hydrolysis rate of urea accelerates as it stays in surface application. However, Controlled-Release Fertilizers (CRF) has proven to reduce N losses, thereby increasing fertilizer efficiency. Wheat is the leading food grain of Pakistan occupying the largest area under single crop. It accounts for 9.6 percent of the value added in agriculture and 1.9 percent GDP. However, the production is recorded less as compared to previous years due to imbalance fertilizer application practices. The recommended doses of fertilizers may vary time to time for wheat. This study is therefore, planned to evaluate the method and appropriate rate of N for wheat, based on these specific objectives: 1) to evaluate an appropriate method and dose of N application for wheat and 2) to find out the effect of different N applications on growth and yield of wheat. In this regard, a field experiment was conducted at Wheat Section, Agriculture Research Institute Tandojam. There were 5 treatments examined on one variety (TD1) of wheat with three replications. The encapsulated urea was prepared manually in the laboratory of Department of Soil Science, Sindh Agriculture University Tandojam. Results revealed that wheat yield was markedly influenced by encapsulated urea as compared to surface applied urea. Maximum yield (40.5 % increment over control) was observed from encapsulated urea (N 140 kg ha^{-1}). However, the difference between the rates of N was non-significant ($p > 0.05$).

Keywords: Wheat, Encapsulated urea, Nitrogen, Yield

Introduction

Nitrogen (N) is one of the most important nutrients for plant growth and yield. Consistently it is required in larger amount than any other nutrients (Babar et al., 2016). It is commonly assumed that increasing application of N fertilizer is an effective way to improve crop yields. Though, N fertilizer application is an important practice for increasing crop efficiency in agricultural production (Wang et al., 2015; Behera et al., 2013), but its loss concern is a different scenario. The drawbacks of N fertilization for agricultural lands in excess of crop requirements may negatively affect groundwater, surface water, and the atmosphere through leaching, runoff, and volatilization of N (Drecht et al., 2003; Galloway et al., 2008). Moreover, low Nitrogen Use Efficiencies (NUEs) is an indication to lower economic returns for farmer's fertilizer investments. Pakistani soils are deficient in N therefore; urea turns into the most widely used nitrogenous fertilizer, due to its easily available approach and high N percentage (46%). Nitrogen losses upon surface application of urea have been reported worldwide. As urea applied in the form direct application, the amount of applied N is expected to loss more than 50% in the form of volatilization as NH_3 (Sommer et al., 2004). It is very important to overcome on N-losses. So that alleviates environmental pollution and increase N-efficiency (Chien et al., 2009). In this regard, controlled release urea is one of the appropriate solutions, as it expected to improve crop yield by reducing the hazardous emission of ammonia and nitrous oxide gases (NH_3, N_2O) from urea (Shaviv, 2005).

Thus the substitute for the conventional urea is to coat it, which harmonizes time, the release of nutrients and the sequential plant requirements. An effective method of justifying the problem is to develop slow-release urea. Much research has reported on the improved performance of the coated urea where a central part is encapsulated within an inert carrier (Han et al., 2009; Liu et al., 2008). The release and dissolution rates of water soluble fertilizers depend on the coating materials (Wu et al., 2008). The N losses to the environment may be reduced with the use of coated fertilizers (Sato and Morgan, 2008). The coated fertilizers offer low N volatilization (10 to 30%) when compared to the conventional fertilizers (Medina et al., 2008). Controlled release urea (CRU) was designed to release nutrients into the soil solution at rates which closely match the N demands of crops, which maximizes NUEs and reduces N losses (Shaviv, 2005). Therefore, its designed to release N in close association with the crop N requirement and it can reduce residual nitrates in soil solutions. CRU also requires only a single basal fertilization, thereby reducing labor and energy cost compared to split applications of urea (Ribeiro et al., 2016). The application of CRFs can potentially decrease fertilizer use by 20 to 30 percent of the recommended rate of a conventional fertilizer while obtaining the same yield (Trenkel et al., 2010).

Therefore, using controlled-release N fertilizer for wheat may be a cost-effective management practice that improves crop performance and possibly allows custom applicators to apply fertilizer once in the fall (Nelson et al., 2014). Wheat *(Triticum aestivum* L.) is the leading food grain of Pakistan occupying the largest area under a single crop. It accounts for 9.6 percent of the value added in agriculture and 1.9 percent GDP; In Pakistan wheat was cultivated on an area of 9052 thousand hectares with the total production of 25,750 million tons during 2016-17 (Pakistan Economic Survey 2016-17), this figure is actually less than the previous year. It is due to imbalance fertilizer practices. The recommended doses of fertilizers may vary time to time. The reasons are the lack of awareness and resources. Wheat is the most important cereal crop of Rabi season and self-sufficiency is a prerequisite for the sustainable food security. The food availability can be secured through increasing productivity, especially of small farmers who are majority in Pakistan and putting emphasis on major wheat growing districts (Mazhar et al., 2007).

Consequently, this study is proposed to evaluate the effect of surface applied and encapsulated urea on growth and yield of wheat under filed conditions of alkaline soils and to identify an appropriate recommendation of urea rate.

Method

Experimental Field and its preparation

Research trial was conducted at Wheat Section, Agriculture Research Institute (ARI), Tandojam, Sindh, Pakistan. Experimental plot was located on the latitude of 25°-24'54"N and longitude of 68°-32'11"E (Figure 1). A piece of 252 m^2 (18 m × 14 m) land was selected for this experiment. The area was equally being divided in 15 experimental units of 9 m^2 (3 m × 3 m). Experiment was laid out in Randomized Complete Block design with five treatments and three replications. Variety TD1 was used under test trial to observe its behavior towards capsulated urea along with different N-rates. Five Treatments combination was based on T_1 as control (No N-application), T_2 (surface application of N at the rate of 140 kg ha^{-1}), T_3 (surface application of N at the rate of 160 kg ha^{-1}), T_4 (encapsulated application of N at the rate of 140 kg ha^{-1}), T_5 (encapsulated application of N at the rate of 160 kg ha^{-1}). Each treatment also received recommended doses of P_2O_5 at the rate of 90 kg ha^{-1} and K_2O at the rate of 50 kg ha^{-1}. The urea in the form of capsulated coating was applied once at the time of sowing. Whereas, surface application of urea (one-third) applied at the time of seedbed preparation and remaining N was applied with subsequent irrigations. Phosphorus and potassium were applied as a full dose. The capsulated urea was prepared manually in the laboratory, Department of Soil Science, Sindh Agriculture University Tandojam. In this regard, the normal empty capsules were bought (to serve as coating material) from the chemical store to refill with urea fertilizer.

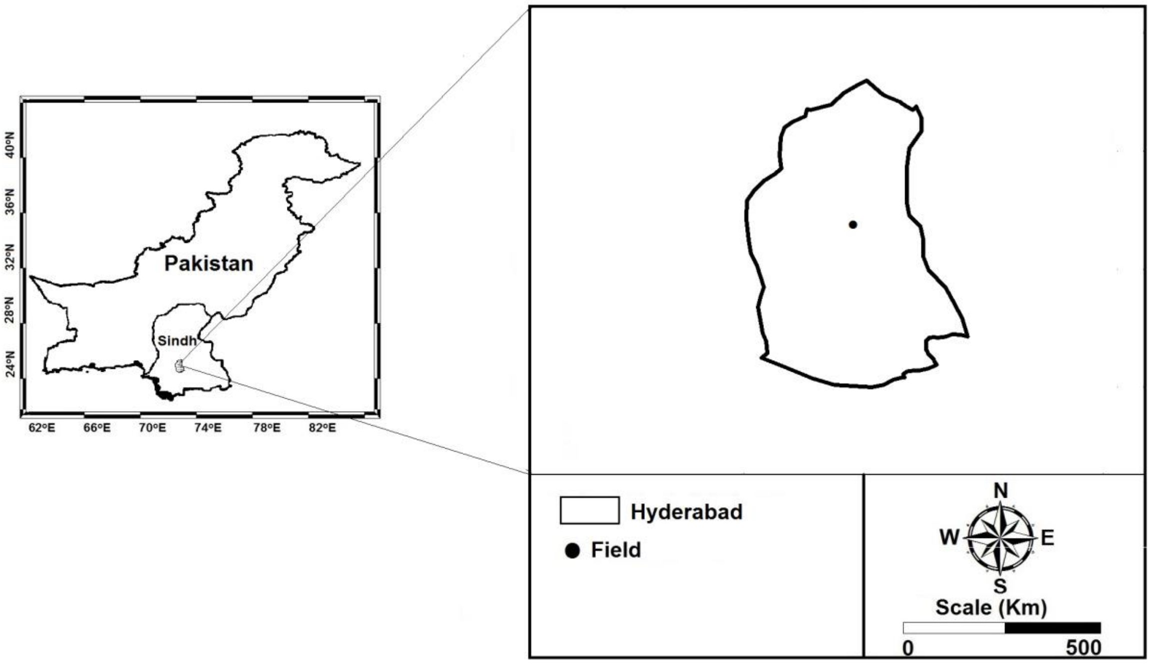

Figure 1. Experimental unit at Agriculture Research Institute Tandojam

The soil was well prepared by plowing and leveling the land to make a fine seedbed. Seed was sown with single coulter hand drill at the depth of 3 cm. The 360 counted numbers of wheat seeds were sown in each plot (This calculation was based on the recommended seed rate of particular variety; 50 kg acre^{-1}). The first irrigation was applied at the crown root initiation stage i.e., after three weeks of sowing. The subsequent irrigation was applied according to the need of crop.

Soil sampling and analysis

Soil samples were collected from sixteen different soil cores at the depth of 0-15 cm and 15-30 cm to make a representative soil sample. Samples were then brought to the laboratory for air-drying and grinding then passed through a 2mm sieve. Soil samples were placed in polyethylene bags for the further analysis. Soil texture done by using standard hydrometer method (Bouyoucos, 1962), soil pH and EC were measured in soil-water extract (1:5) by using digital pH and EC meters. Lime contents were determined by employing acid neutralization method discussed in practical agriculture chemistry (Kanwar and Chopra, 1959). Organic carbon was obtained by following Walkley black method (Jackson, 1959; Jackson and Barak, 2005) and N was analyzed by Kjeldhal method.

Observations to be recorded

Plant height (cm) was recorded at the time of maturity, Number of tillers plant^{-1}, 1000 grain weight (g), biomass (g m^{-2}) and Grain yield (kg ha^{-1}), were recorded accordingly. The data recorded, transmitted through the statistical analysis by using Statistix 8.1 software to find out the treatment effect. The means were compared with Tukey's range test (HSD)/ honest significant difference.

Results and Discussion

The effect of different rates and methods of application of urea on the growth and yield of wheat revealed the significant effects of encapsulated urea on the tiller production, plant height, seed index, wheat biomass and grain yield of wheat crop.

The soil characteristics before planting wheat crop are given in Table 1. According to the results, soil was slightly alkaline in nature (pH 7.8), low in OM (0.67 %) and found deficient in N contents (0.04 %). The soil was silty clay loam in textural class and found non-saline in nature.

Table 1. Soil physical and chemical properties before planting wheat crop

Physical properties	
Textural class	Silty Clay loam
Sand%	0.48
Silt%	41.27
Clay%	50.32
Chemical properties of soil	
Soil pH	7.8
OM%	0.67
$CaCO_3$%	7.4
EC dS/m	0.13
Total N%	0.04

Effect of Encapsulated urea on the growth and yield of wheat

The effect of method of urea application (direct and encapsulated urea) was analyzed on the growth and yield of TD1 (wheat variety). According to the observations made, it was noted that the various growth and yield parameters of wheat were highly affected by the method of urea application. Encapsulated urea (at the rate of 140 kg ha^{-1} (T_4)) gave the positive significant effect ($p < 0.05$) as compared to rest of the other treatments (Table 2). It was perceived that the difference between the rates of urea was non-significant ($p > 0.05$). The range values showed the difference of treatments in the various growth parameters of wheat as: number of tillers plant^{-1} 5.68 to 11.69, plant height 65.56 to 90.01 cm, seed index 34.02 to 45.87 g, biomass 653.0 to 1107.43 g plot^{-1}, grain yield 3240.11 to 5478.23 kg ha^{-1}. The results revealed are supported by Laghari et al, 2010, who have observed the significant effect of fertilizer use and management on three cultivars of wheat. Fertilizer rates and combinations affected on the growth and yield of different wheat varieties. They have reported that the N at the rate of 120 kg ha^{-1} enhanced the yield of TD1, However the higher rates of N were found non-significant on wheat variety TD1. Whereas, rest of the other two wheat varieties (Mehran-89 and TJ-83) showed the positive response in all aspects of growth and yield upon the higher fertilizer rates (180 N kg ha^{-1}). Tall plants, maximum nodes stem^{-1}, internode length, grain weight spike$^{-1,}$ seed index, prolonged maturity days and higher lodging tendency in Mehran-89 and TJ-83 were recorded under the highest rate of urea. The similar results were also obtained by Oad et al, 2007, who analyzed that the proper cultural practices can have positive results in terms of higher yield due to nutrients management.

Table 2. Effect of encapsulated urea on the growth and yield of wheat

Treatments	Tillers plant^{-1}	Plant height (cm)	1000 grain wt (g)	Wheat biomass (g m^{-2})	Grain yield (kg ha^{-1})
T1 Control	5.68 d	65.56 c	34.02 c	653.00 d	3240.11 d
T2 SN 140 kg ha^{-1}	7.28 bc	71.57 bc	38.89 b	790. 89 bc	4000.14 c
T3 SN 160 kg ha^{-1}	7.79 cd	75.13 b	39.52 b	824.13 b	4413.21 b
T4 CN 140 kg ha^{-1}	**11.54 a**	**89.97 a**	**45.42 a**	**1110.76 a**	**5410.23 a**
T5 CN 160 kg ha^{-1}	**11.69 a**	**90.01 a**	**45.87 a**	**1107.43 a**	**5478.23 a**
HSD (5%)	1.568	3.92	2.56	25.61	4.56

Means with the different letters in each of the column are significantly different at Tukey's (HSD) $p < 0.05$
*****SN= Surface Nitrogen
*CN= Capsulated Nitrogen

The rate of N remains fluctuating as the self-sufficiency in nitrogen use efficiency (NUE) is still beyond the range. Overall in Pakistan, a number of research trials have been conducted to evaluate the appropriate rate of N, but no makeable results have been achieved. In 2016, at the Northern areas of Pakistan a research experiment was conducted to evaluate proper rate of N along with the seed rate and number of irrigations. It was manifested from the results that as the N rate decreased the yield of wheat crop was also declined. However, the rate of 120 kg N ha^{-1} showed the positive effect on the increasing seed rate (60 kg ha^{-1}). Soils at northern areas of Pakistan are fertile but still the yield is not desirable (Shah et al, 2016). Therefore, it is required to analyze the actual myths behind the NUE. The conventional urea resulted in 1 - 60% of N losses in the form of ammonia volatilization and nitrous oxide emission, hence the solution is to eliminate this risk with the application of slow released urea (coated urea), that can capable to provide the nutrients at precise and tardy manner (Babar et al., 2016, Chien et al., 2009; Jiang et al., 2012; Shaviv, 2005). Coating of urea has proven the efficiency regarding N-uptake and minimizing NH_3 volatilization loss as reported in the laboratory studies (Babar et al., 2016). The growth parameters increment might be attributed with the adequate supply of N, that contributes in accelerated enzymatic activities (Khan et al., 2012). Since decades, it is realized that the hydrolysis rate of urea is faster if it would be applied in conventional form. Reports have mentioned that about 70% of the applied urea losses in different forms, the common one is ammonia volatilization loss (Fenn and Miyamoto, 1981). Current studies also observed that NUE was markedly affected when the urea was applied as surface application. Therefore, the highest yield value was observed under encapsulated urea. CRF (controlled release fertilizer) is a solution, as it assumes to improve crop yield by minimizing the hazardous emission of NH_3 and N_2O gases from the fertilizers (Shaviv, 2005).

Conclusion

Wheat yield of TD1 variety was expressively subjective towards encapsulated urea. The 40.5% yield increment was recorded under T4 (CN 140 kg ha^{-1}) and T5 (CN 160 kg ha^{-1}) respectively as compared to control (no nitrogen application). However, the difference between T4 and T5 was found non-significant ($p > 0.05$) therefore; the rate of urea can be adjusted at 140 kg ha^{-1} (encapsulated) to skip the price increment of fertilizer application.

Recommendations

It is recommended that urea can be applied in coating form as compared to surface application. In this regard, the coating materials can be changed accordingly. Natural products should be selected to see their effects on the hydrolysis rate of urea. To minimize the N-losses such coated urea fertilizers are suggested to apply. This study was concern only with one wheat variety which may be suggested to test on the other varieties as well as on the other crops too.

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