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Study of Urea Embed Mesoporous Nano Silica on Yield and Yield Attributing Characters of Rice Grown in Mollisols

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ABSTRACT

Rice (*Oryza sativa* L.) is a stable food more than two billion people are getting 60-70 per cent their energy requirement from rice and its derived products. Present research investigated effect of urea embed mNS (embed in the mesoporousnano silica by simple immersion loading using aqueous solution and this formulation of nanofertilizer) on rice crop in pot experiment under polyhouse condition. Nine treatments consisted (T1: Control, T2:$N_{30}P_{60}K_{40}$, T3:$N_{60}P_{60}K_{40}$, T4:$N_{90}P_{60}K_{40}$, T5:$N_{120}P_{60}K_{40}$, T6:$N_{30(mNS)}P_{60}K_{40}$, T7:$N_{60(mNS)}P_{60}K_{40}$, T8:$N_{90(mNS)}P_{60}K_{40}$ and T9:$N_{120\,(mNS)}P_{60}K_{40}$) in three replications. In this study, the results revealed that the growth parameter, grain and straw yields as well as yield attributes (effective tillers, panicle length, grains per panicle and 1000-grain weight) were significantly affected by urea embed nano silica application. The highest grain and straw yields were recorded in treatment T9 giving 323.02 and 124.05 per cent more over control, due to exposure of urea embed mNS as compared to ordinary urea dose of chemical fertilizers. The sustained release of urea embedded mNSaccurs 7-8 days after exposure which is extraordinarily slow as compared to ordinary urea. These results are preliminary but promising and open the doors to use nanomaterials as an efficient nanofertilizer.

KEYWORDS

Rice, urea, mesoporousnano silica, yield and yield attributes.

INTRODUCTION

Currently, the global sustainability of agricultural production is jeopardized by increasing cost of agro chemical fertilizers. Moreover, inherent post-application losses consequently lead to severe underground water pollution. Therefore, new technology needs to be developed to enhance water and fertilizers use efficiency for reducing pollution and making agriculture more environmental friendly. In this regard, controlled release system of agrochemicals would be of great interest to the agriculture sector worldwide. Because, the limitation in arable lands and water resources, the development of agriculture sector is only possible by increasing of resource use efficiency with the minimum damage to soil through effective use of modern technology. Among these, nanotechnology has the potential to revolutionize the agriculture system, safety and security of water resources, energy conservation and numerous other areas (Miller *et al.*, 2005).

Rice (*Oryza sativa* L.) is the most widely consumed cereal in the world (Datta, *et al.*,2017) and it is major source of calories intake and the stable food for the more than three billion people in the world (Ullah, *et al.*, 2017). Studies have been conducted to improve rice production involving nano-materials (Huang *et al.*, 2014). Fertilizers have an important role in enhancing food production and quality especially after the introduction of high-yielding and fertilizer responsive varieties. Some studies already proved the significance of nano-fertilizers. Some beneficial effects include increased nutrient use efficiency, better yield and reduced soil pollution (Naderi *et al.*,2013). Rice yield largely depends on soil conditions and also on the supply of the available nutrients like nitrogen, phosphorus, potassium, sulphur and zinc (Masum *et al.*, 2013). Rice plants require large amounts of mineral nutrients including nitrogen for their growth, development and grain production (Ma, 2004).The development of efficient nitrogen management protocols requires recognizing cultivar differences and critical stages of crop growth that fertilization is necessary to avoid potential yield loss. Managing rice crop nitrogen nutrition is difficult because lowland rice crop culture leads to nitrogen losses through ammonia volatilization, nitrification, denitrification, leaching, and runoff, which decreases the availability of nitrogen for rice plants (Jianchang *et al.*,2017).

Fertilizer plays a pivotal role in agriculture production (35-40%). To enhance nutrient use efficiency and overcome the chronic problem of eutrophication, nanofertilizer might be a best alternative. Nanofertilizers are synthesized in order to regulate the release of nutrients depending on the requirements of the crops and it is also reported that nanofertilizers are more efficient than ordinary fertilizer (Liu *et al.*, 2006). Nanofertilizers could be used to reduce nitrogen loss due to leaching, emissions and long-term incorporation by soil microorganisms. They could allow selective release linked to time or environmental condition. Slow controlled release fertilizers may also improve soil by decreasing toxic effects associated with fertilizer over-application (Suman *et al.*, 2010). Studies have been conducted to improve rice production involving nano-materials (Huang *et al.*, 2014).

Nano structured formation through mechanisms such as targeted delivery or slow/controlled release mechanisms and conditional release could release their active ingredients in responding to environmental triggers and biological demands

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more precisely. Studies show that the use of nano fertilizers causes an increase growth characters,yield and yield attributes and minimizes the potential negative effects associated with over dosage and reduces the frequency of the application of chemical fertilizers. Hence, nanotechnology has a high potential for achieving sustainable agriculture, especially in developing countries.

MATERIALS and METHOD

Physiographic description of study area

Pantnagar is situated at 29º N latitude and 79.3º E longitude and with at an altitude of 243.8 m above the mean sea level in Tarai region of Uttarakhand, India. It is a hot humid subtropical region falls under the sub humid and subtropical climate zone with hot dry summers and cool winters. Generally, south west mansoon sets in the third or fourth week of June and continues up to the end of September with its peak in July. The mean annual rainfall is about 1400 mm, of which 80-90 per cent is received between June and September months. A pot experiment was carried out in polyhouse of college of agriculture, G.B.P.U.A&T Pantnagar, in rice crop variety PB-1(Pusa Basmati-1) with following 9 treatments included with 3 replications.

Treatments details

The treatment details are as follows : T1:Control, T2:N_{30} $P_{60}K_{40}$, T3:$N_{60}P_{60}K_{40}$, T4:$N_{90}P_{60}K_{40}$, T5:$N_{120}P_{60}K_{40}$, T6:$N_{30(mNS)}P_{60}K_{40}$, T7:$N_{60(mNS)}P_{60}K_{40}$, T8:$N_{90(mNS)}P_{60}K_{40}$ and T9:$N_{120(mNS)}P_{60}K_{40}$. Soil samples were collected from 0-15 cm of depth. The collected samples were brought to the soil science laboratory, Pantnagar and analyzed for the various physico-chemical properties by using standard methodology.The properties of soil is described in Table 1.

Table 1: Initial soil analysis for physico- chemical properties of soil

Property	Value
Soil texture class	Silty clay loam
Bulk density (g cm^{-3})	1.31
Particle density (g cm^{-3})	2.64
Porosity (%)	50.37
pH (1:2.5 soil: water suspension)	7.76
EC (dSm^{-1})	0.34
Organic carbon (%)	0.79
Available N (kg ha^{-1})	253.70
Available P (kg ha^{-1})	16.31
Available K (kg ha^{-1})	126.40
Total N (%)	0.127
Moisture content (%)	10.23

Mesoporusnano silica (mNS) as a carrier was used for loading of urea, Nitrogèn supplied through urea as per above treatment Phosphorus, potassium by single super phosphate (SSP) and muraite of potash (MOP) respectively. Recommended dose of NPK 120:60:40 for rice was used for fertilizer application.

Urea Loaded in Mesoporous Nano-Silica:-

Urea, the most used nitrogen fertilizer, was chosen a model molecule to assess the loading and controlled release behaviour of mesoporous nano silica (mNS). To study the effects of solute concentration on the process, mNS (500mg) was suspended in 10 mL aqueous solutions of urea containing 1:2 w/v urea: water for time periods 90 min. The suspension was stirred at 300 rpm at room temp. After elapse of time interval, samples were centrifuged at 10,000 rpm for 10 min. Necessary dilution were done with water after which 1.0 mL of the supernatant was diluted with 4.0 mL of 10% *trichloroacetic* acid and reacted with 1.0 m L modified Ehrlich's reagent (modified by dissolving 5.0g *p-dimethylamino-benzaldehyde* in 20 mL of concentrated HCl, then adding 80 mL of water, UV/Vis absorbance of samples was measured using a UV/Vis spectrophotometer at 425 nm. The final concentration of urea in solution was determined using the regression equation for the line of best fit of urea calibration standards. The standards (5, 10, 20, 40, 60, 80, and 100 mg/100 mL were prepared by serial dilution of the urea stock solution 1000mg/100 mL).Blank solution was composed of 1.0 mL of pure water, 4.0 mL of 10% trichloroacetic acid and 1.0 mL of the modified reagent.The total amount of urea absorbed by the mNS as a functional of time was calculated as the difference between the initial and final urea concentration in solution.

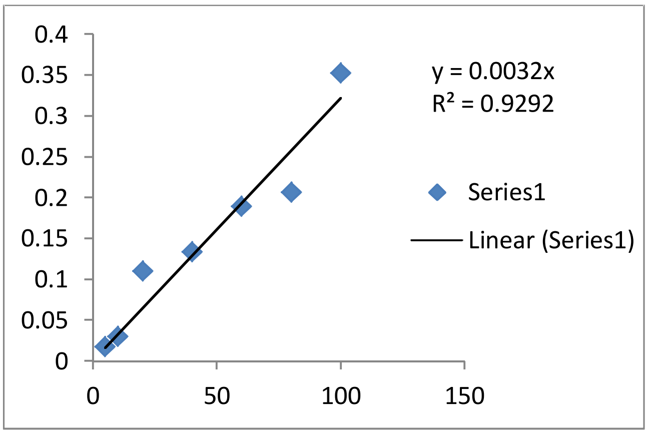

Fig. 1: Standard curve of urea concentration in mNS

Statistical analysis

The obtained experimental data were statistically analyzed by applying analysis of variance (ANOVA) technique (Panse, *et al.*, 1978).The difference among treatments were compared by applying "F"test of significance at 5 per cent level of significance (0.05 LSD).

RESULTS AND DISCUSSION

Plant growth parameters

The plant height data as affected by various treatments are summarized in (Table 2). All the treatments except T2 and T3 showed significantly higher plant height of rice at 60 DAT and maturity stage over control. T9 ($N_{120(mNS)}$ P_{60} K_{40}) recorded highest plant height giving 8.85 and 15.31% more plant height in rice as compared to control at 60 DAT and maturity stage respectively. However, T8 ($N_{90\,(mNS)}$ P_{60} K_{40})and T9($N_{60(mNS)}$ P_{60} K_{40}) gave significantly more plant height than T4 (N_{90} P_{60} K_{40})and T3 (N_{60} P_{60} K_{40}) in rice crops at maturity stage. Increase in plant height might be due to continuous supply of nitrogen through urea embed nano silica which act as slow releasing fertilizer in comparison to ordinary nitrogen fertilizers. The treatments T8 and T9 in which nitrogen was applied through Urea embed mesoporous nano-silica (mNS) produced significantly higher number of tiller pot^{-1} as compared to T3 and T4 treatments in which nitrogen was applied through ordinary urea @60 and 90 $kgha^{-1}$ in both crops. The increase in number of tiller pot^{-1} was due to controlled release of nitrogen through urea embed nano silica. Significantly higher number of tillers pot^{-1} were observed with T8 and T9 treatment in which nitrogen was applied through urea embed nano silica @90 and 120 $kgNha^{-1}$ in comparison of N applied @120 kgN ha^{-1} through ordinary urea (T5). Statistically at par number of tiller pot^{-1} was found with treatment T8 and T9, where nitrogen was applied through embed urea @90 and 120 kgN ha^{-1}.Thus, nitrogen applied through urea embed nano silica showed almost similar results with respect to number of tiller pot^{-1} as observed with nitrogen applied @120 kg ha^{-1} through ordinary urea. These results are agreement with the findings of (Hossain *et al*., 2008), who reported that, release of nitrogen by urea hydrolysis has been controlled through the insertion of urease enzymes into mesoporous nano silica.

Table 2: *Effect of varying levels of N through urea and urea embedded nano silica on growth parameter of rice in normal alluvial soil*

Treatment	*Rice crop of growth parameter*		
	Plant height (cm) at 60DAT	*Plant height (cm) at maturity stage*	*Number of tillers/pot^{-1}*
Control (T1)	*83.567*	*86.433*	*37.667*
$N_{30} P_{60} K_{40}$ *(T2)*	*84.467*	*88.367*	*42.000*
$N_{60} P_{60} K_{40}$ *(T3)*	*84.967*	*90.200*	*44.667*
$N_{90} P_{60} K_{40}$ *(T4)*	*88.267*	*94.867*	*50.000*
$N_{120} P_{60} K_{40}$*(T5)*	*90.267*	*97.667*	*66.000*
$N_{30(mNS)} P_{60} K_{40}$ *(T6)*	*84.533*	*90.633*	*48.000*
$N_{60(mNS)} P_{60} K_{40}$ *(T7)*	*87.933*	*96.967*	*56.667*
$N_{90(mNS)} P_{60} K_{40}$ *(T8)*	*90.167*	*99.067*	*63.667*
$N_{120(mNS)} P_{60} K_{40}$ *(T9)*	*90.967*	*99.667*	*76.000*
SE(m) ±	*0.511*	*1.213*	*0.801*
C.D. ±5%	*1.531*	*3.631*	*2.399*

Yield attributing characters:

The data pertaining to various yield attributing characters viz. effective tillers per pot, panicle length (cm), grain per panicle and test weight (g) are given in Table 3. All the treatments showed significantly higher number of effective tillers pot^{-1}, panicle length, number of grain per panicle and test weight except T2 and T3 treatments in rice over control. The highest number of effective tillers pot^{-1} and other yield attributing characters was recorded by T9 ($N_{120\,(mNS)}\,P_{60}\,K_{40}$) giving 203.88 % more effective tillers pot^{-1}, 15.31% panicle length, 155.05% number of grain per panicle and 16.83% test weight higher over control. However, treatment T9 gave significantly higher number of effective tiller pot^{-1} and panicle length in rice as compared to T5. Furthermore, Nitrogen applied through urea embed nano-silica in treatment T8, T7 and T6 gave 18.89, 41.39 and 33.32 % higher effective tiller pot^{-1}, 15.56, 16.08 and 8.45 % more panicle length, 25.47, 25.76 and 10.22 % more number of grain per panicle and 9.61, 10.68 and 3.78 % more test weight as compared to T4, T3 and T2 treatments respectively in which nitrogen was supplied through ordinary urea.

The increases in number of effective tillers, panicle length , number of grain per panicle were significant with the application of nitrogen through ordinary urea and urea embed nano silica rice but significantly higher values of yield contributing characters were recorded with urea applied through nano silica as compared to nitrogen applied through ordinary urea. The increase in yield attributing characters might be due to encapsulation of urea with meso-porous nano silica which controlled the released of nitrogen through urea and reduce the loss of nitrogen by leaching in soil. Similarly, it supplies regularly nitrogen during growth period of crops. These results are agreement with the finding of DeRosa *et al*., 2010 who reported that, nano-fertilizers or nano-encapsulated nutrients might have properties that are effective to crops, released the nutrients on-demand, controlled release of chemicals fertilizers that regulate plant growth and enhanced target activity. Similar results to our findings, have also been reported by (Lavinsky *et al*., 2016) mentioned that nano silica act as carrier with ordinary fertilizer to enhance yield traits of rice.

Table 3: Effect of varying levels of N through urea and urea embedded nano silica on growth parameter of rice and wheat in normal alluvial soil

Treatment	Yield attributes of rice crop			
	Effective tiller pot^{-1}	Panicle length (cm)	Number of grain per panicle	1000 grain Weight(g) 19.6
Control (T1)	17.0	20.7	18.6	20.0
$N_{30} P_{60} K_{40}$ (T2)	31.0	23.6	29.3	19.6
$N_{60} P_{60} K_{40}$ (T3)	33.0	23.6	32.3	20.8
$N_{90} P_{60} K_{40}$ (T4)	42.3	25.7	36.6	21.5
$N_{120} P_{60} K_{40}$ (T5)	48.0	28.6	45.3	20.8
$N_{30(mNS)} P_{60} K_{40}$ (T6)	41.3	25.6	32.3	21.7
$N_{60(mNS)} P_{60} K_{40}$ (T7)	46.6	27.4	40.6	22.8
$N_{90(mNS)} P_{60} K_{40}$ (T8)	50.3	29.7	46.0	22.9
$N_{120(mNS)} P_{60} K_{40}$ (T9)	51.6	30.2	47.6	0.39
SE(m)±	0.76	0.59	1.73	1.19
C.D. ±5%	2.28	1.794	5.20	

Yields of rice

The results presented in Table 4 illustrated that the rice grain and straw yield was significantly influenced by urea embed nano silica application and significantly higher grain (5.887g pot^{-1}) and straw (11.277 g pot^{-1}) yields were recorded in treatment T9 ($N_{120\,(mNS)}\,P_{60}\,K_{40}$) and lowest grain (1.397 g pot^{-1}) and straw (5.030 g pot^{-1}) yields under control. However, significantly increase grain and straw yield in rice with treatments T5, T4, T3, and T2 gave 163.55, 194.24, 148.92 and 69.06 per cent more grain yields and 98.21, 88.07, 51.49 and 2.58 per cent more straw yield over control. Similarly, treatment T9 and T8 significantly differ from treatment T5 with higher grain and straw yields in which nitrogen applied

@120 kgha^{-1} by ordinary urea. Furthermore, application of nitrogen through urea embed nano silica in treatments, T9, T8, T7 and T6 gave 29.18, 42.05, 51.73 and 90.21 per cent more grain yields and 13.07, 17.33, 38.84 and 64.53 per cent more straw yields as compared to treatments T5, T4, T3 and T2 respectively, in which nitrogen applied through ordinary urea. Treatment T8 and T9 showed statistically at par grain and straw yield of rice where nitrogen applied through urea embed nano silica @ 90 and 120 kg ha^{-1} but it was significantly higher than treatments T4 and T5 in which nitrogen was applied @ 90 and 120 kg ha^{-1} through ordinary urea. Similarly, treatment T7 in which nitrogen was applied @60 kg ha^{-1} by urea embed nano silica gave significantly higher grain and straw yield as compared to treatment T3 where N was applied @60 kg ha^{-1} by ordinary urea. The treatments order of performance was T9 >T8 >T7 >T5 >T6 >T4 >T3 >T2 >T1in case of grain yield of rice and T9 >T8 >T7 >T5 >T4 >T6 >T3 >T2 >T1 in case of straw yield of rice.

Table 4: Effect of varying levels of N through urea and urea embedded nano silica on grain and straw yield of rice crop grown in normal alluvial soil

Treatment	Rice yield (g pot^{-1})		Harvest Index
	Grain yield	Straw yield	(H.I.)
Control (T1)	1.397	5.030	0.217
N_{30} P_{60} K_{40} (T2)	2.353	5.167	0.312
N_{60} P_{60} K_{40} (T3)	3.467	7.620	0.313
N_{90} P_{60} K_{40} (T4)	4.093	9.460	0.301
N_{120} P_{60} K_{40} (T5)	4.557	9.973	0.313
$N_{30(mNS)}$ P_{60} K_{40} (T6)	4.470	9.450	0.321
$N_{60(mNS)}$ P_{60} K_{40} (T7)	5.257	10.587	0.331
$N_{90(mNS)}$ P_{60} K_{40} (T8)	5.813	11.107	0.342
$N_{120(mNS)}$ P_{60} K_{40} (T9)	5.887	11.277	0.343
SE(m)±	0.146	0.284	0.001
C.D.	0.436	0.851	0.002

Harvest Index

Harvest index of rice crop is presented in table 4. All the treatments of urea embed nano silica were recorded significantly harvest index over control. Highest harvest index of 0.342 was recorded by treatment T9 ($N_{120(mNS)}$ P_{60} K_{40}).Whereas, treatment T4 and T9 gave statistically at par results among themselves. While T9 was significantly differ from T5 (N_{120} P_{60} K_{40}). Urea embed nano silica treatments registered more harvest index than ordinary fertilizer treatments.

Several studies proved the significance of nano fertilizers. Nano fertilizers controlled released of nutrients as required by the crops and it act as growth stimulator and carrier of nutrients absorption by plants. Increase in growth of plant with increase the yield attributing characters and yields. These results are in agreement with the findings of (Liu *et al.*,2009) who reported that nanofertilizer application increased crop yield by 20 - 40%. (Pati *et al.*, 2016), also reported that, significantly increased in grain and straw yields of rice with increasing silica level. The increases in both grain and straw yields might be attributed to the positive effect of nano silica applied with urea in increasing growth and yields components of rice (Prakash *et al.*, 2011).

It has been found by various workers that mNS loaded urea as a nanofertilizer has many positive effects on the growth and yield as well physiology and metabolism of different crops. (Singh *et al.*, 2006) suggested that the increased dry matter and yield in rice. The indirect effects of silicon also cause increase in growth and yield in cereals, (Mukkram *et al.*, 2006) also found that silicon increased growth and yield due to decreased Na^{+} uptake by crops under salt stress. The effects of different levels of Silicon in the form of Silicic acid have been investigated by many investigators. (Singh *et al.*, 2006) found that the 180 kg ha^{-1} of Silicon increased nitrogen and phosphate levels in the grain and straw of rice. This suggests that silicon in lesser amounts can be beneficial in increasing grain yield and growth of cereal crops. In the present study the Silicon levels of 0.25 and 0.50 per cent have been found positive effects while overdose not only found un-advantageous but also reduced growth and yield in wheat crop.

CONCLUSION

In this study, application of mNS with recommended dose of fertilizer positively affected growth characters, yield related traits and yield of rice. It concluded that application of mNS with recommended dose of chemical fertilizer were increased significantly yield and yield contributing characteristics of rice as comparison of ordinary fertilizer doses. It might be due to the sustained release of nanofertilizers occurs after exposure which is extraordinarily slow as compared to direct dose of urea. These results are preliminary but promising and open the doors to use nanomaterials as an efficient nanofertilizer.

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