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Effect of Combined Application of Different Coated Urea on Soil Chemical and Biological Properties in Inceptisols of Varanasi

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ABSTRACT: The application of excess nitrogenous fertilizers can increase crop yield quickly, but they also could cause soil hardening and decrease soil organic matter and pH after a long period of application, resulting in loss of soil productivity. Therefore a sustainable approach is required that increases yield and maintains soil health. Keeping in view a research study was conducted in the glasshouse at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University in Varanasi on sandy clay loam soil with rice (var.HUR-105) to find out the influence of Polymer coated urea, Neem coated urea with FYM and PGPR on chemical properties and enzymatic activity in Inceptisol of Varanasi. The enzyme urease activity ranged from 151.77 to 242.25µg urea hydrolysed g^{-1} soil $h^{-1}$and enzyme dehydrogenase activity ranged from 41.98 to 112.20 µg TPF produced g^{-1} soil day^{-1} whereas enzyme alkaline phosphatase activity ranged from 52.08 to 98.27µg PNP produced g^{-1} soil h^{-1}.The soil available nitrogen, organic carbon, available potassium, available phosphorous were increased from 225.7 to 264.94 kg ha^{-1}, 0.39% to 0.57%, 14.50 to 22.30 kg ha^{-1}, 218.33 to 256.36 kg ha^{-1}. The enzymatic activity of soil was positively and significantly correlated with organic carbon as well nitrogen content of the soil.

Keywords: Polymer coated urea, Neem coated urea, Urease, Dehydrogenase, Alkaline Phosphatase

INTRODUCTION

The demand for food is increasing to feed the rising population, global rice production must be increased by about 1% annually to sustain economic developments (Huang *et al*., 2019). India contributes to nearly 16% of the world population. Intensification of rice cultivation is necessary to meet the food demand of the increasing human population, especially in India where approximately 80% of rice is grown and consumed (Kumar *et al.,* 2016). Fertilizers' application in a disproportionate way has caused the translocation of nitrogen (N) from farmlands into aquatic systems in paddy fields. Nitrogen, particularly in the form of nitrate, is simply soluble in soil pore water, and promptly infiltrates underneath the dynamic soil layer below crop root. The leaching of nitrogen may lessen soil fertility, expedite soil acidification and decrease crop yields.

Fertilizer manufacturers have concentrated in recent decades to produce slow-release and controlled-release fertilizers (SRFs/CRFs) as enhanced-efficiency nitrogen fertilizers (Halvorson *et al.*, 2014). The main advantage of using SRFs are (Akelah, 1996, Shaviv *et al*., 1993) (1) extending the durability of fertilizers by providing small amounts for a longer time; (2) lowering the number of fertilizer applications, generally to a single background application, by prolonging their time of action; (3) reducing costs by eliminating the repeated application (4) reducing environmental pollution by excess loss.

Plant growth-promoting rhizobacteria (PGPR) are beneficial bacteria that colonize plant roots and enhance plant growth by a wide variety of mechanisms. Biofertilization, root stimulation, rhizo-remediation, and plant stress management are direct mechanisms of plant growth promotion, while biological control mechanisms include disease reduction, antibiosis, induction of systemic resistance, and nutrient competition (Lugtenberg *et al*. 2009). PGPR has been shown to solubilize precipitated phosphates and enhance phosphate availability to rice that represents a possible mechanism of plant growth promotion under field conditions (Verma *et al.,* 2001).

Continuous excessive applications of mineral fertilizer can lead to nutrient accumulation in soil, and eventual P and N loss from soil to aquatic ecosystems. Therefore organic agriculture has been promoted as an alternative method of farming for the past two to three decades as a means of producing food sustainably while reducing the impact of agriculture on the environment (Seufert *et al.* 2012). Organic farming has an important role in producing healthy food through the exclusion of applications of synthetic chemicals (Micuti *et al.,* 2020). Organic farming without the use of synthetic fertilizers, pesticides, or genetically engineered crops simply cannot feed the projected 10 billion people for 2050 (Connor, 2013). Continuous use of chemical fertilizer causes deterioration of soil health. Therefore a midway path with a combination of both organic, inorganic as well as microbial approaches is used to achieve the goal of maximum production by retaining the values of sustainability, soil health, enzymatic activity, etc.

Soil enzymes produced by microbes play key roles in the biochemical functions of organic matter decomposition and nutrient cycling which are affected by land-use management (Waldrop *et al.*, 2004; Wang 2013). Soil enzymes reveal ecosystem perturbations, are sensitive to management choices, and have been used as indicators of biogeochemical cycles, organic matter degradation, and soil remediation processes. Thus, enzymes can indicate, along with other physical or chemical properties, soil quality (Lee *et al.,* 2020). Soil microbiological activity or enzymes activity plays a key role in nutrient transformation because it has a direct impact on soil organic matter mineralization. Soil enzymes can be used as biological indicators for diagnosing soil quality because of their stability and sensitivity; they can well indicate whether the biochemical reactions in the soil to which soil enzymes are involved are correctly performed (Yang *et al*., 2016; Liang *et al.*, 2014).

The fundamental objective of this study is to determine the effect of polymer-coated urea (PCU), neem coated urea (NCU), Farmyard manure (FYM) and PGPR on chemical properties and enzymatic activity of soil in lowland rice.

MATERIAL AND METHODS

A pot experiment on rice crop variety HUR105 had been conducted at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India (25.2645° N latitude, 82.9913° E longitude, and 75.7 m MSL) during the kharif season of 2017. Bulk surface soil samples (0-15 cm) were collected from the Agricultural Research Farm of the Institute of Agricultural Sciences for the pot experiment. The soil has a sandy clay loam texture and its physicochemical and biological properties are listed in Table 1.

The experimental study was laid out in a glass house with a complete randomized block (CRD) design having 13 treatments with 3 replications. The soil of the experimental site was air-dried and ground to pass through a 2 mm sieve. After processing filled in 10 kg earthen pots with a diameter of 30 cm lined by polythene. Treatments are given two different levels of nitrogen 535 mgpot^{-1} and 428 mgpot^{-1} supplied from different sources PCU, NCU with and without FYM and PGPR (mixture of *Azospirillum brasilense, Azotobacter chroococcum, Bacillus subtilis, Pseudomonas putida, Pseudomonas aeruginosa, Trichoderma harzianum, Pseudomonas fluorescence*). The thirteen treatment combinations are first treatment (T_1) is controlled with zero nitrogen (N_0), other from T_2 to T_7 treatment having the split application of two nitrogen levels 535 mg pot^{-1} and 438 mg pot^{-1} as 100% and 80% RDN with NCU and PCU [T_2 (100% of RDN through PCU Split), T_3 (80% of RDN through PCU 3 Split), T_4 (100% of RDN through NCU 3 Split), T_5 (80% of RDN through NCU 3 Split), T_6 (50% of RDN through PCU+ 50% of RDN through NCU 3 Split), T_7 (40% of RDN through PCU+40% of RDN through NCU 3 Split). Treatments T_8 to T_{13} comprises of two levels of basal dose of nitrogen 535 mg pot^{-1} and 438 mg pot^{-1} as 100%, 80% RDN with PCU and NCU mixed with FYM @ 10 t ha^{-1} and PGPR. T_8 (100% of RDN through PCU+ FYM @ 10 t ha^{-1} + PGPR), T_9 (80% of RDN through PCU+ FYM @ 10 t ha-1 + PGPR), T_{10} (100% of RDN through NCU + FYM @ 10 t ha^{-1} + PGPR), T_{11} (80% of RDN through NCU + FYM @ 10 t ha^{-1} + PGPR), T_{12} (50% of RDN through PCU+ 50% of RDN through NCU + FYM @ 10 t ha^{-1} + PGPR), T_{13} (40% of RDN through PCU+40% of RDN through NCU+ FYM @ 10 t ha^{-1} + PGPR). Treatment details are given in Table 2.

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

Particulars	Value
Soil pH (1:2.5 soil and water suspension)	8.1
Electrical conductivity (dSm^{-1})	0.22
Organic carbon (%)	0.46
Available Nitrogen (kg ha^{-1})	230.50
Available P_2O_5 (kg ha^{-1})	15.62
Available K_2O (kg ha^{-1})	225.18
Urease (µg urea hydrolysed g^{-1} soil h^{-1})	155.37
Dehydrogenase (µg TPF produced g^{-1} soil day^{-1})	43.25
Alkaline Phosphatase (µg PNP produced g^{-1} soil h^{-1})	53.86

Rice seedlings (25 days old of HUR-105 variety) were firstly dipped in PGPR consortium then three seedlings transplanted in each pot. Recommended dose of phosphorous from Single superphosphate 1.704 g pot^{-1} (16% P_2O_5) and potassium from muriate of potash (MOP) 0.303 g pot^{-1} (60% K_2O) just after puddling while nitrogen is given according to treatments split [tillering stage 28 days after transplanting(DAT) and vegetative stage 56 DAT] and basal after transplanting.

Soil samples collected 120 DAT (harvesting stage) from the surface (0-15 cm) in each pot. Excess water is drained, soil samples were taken in plastic bags and kept in a freeze at 40℃ temperature for a few days to stabilize the microbiological activity. Then it was analyzed for chemical properties and enzymatic activity. Dehydrogenase activity (DHA) was determined using the assay by Casida *et al.*, (1964). Alkaline phosphatase activity was determined according to the procedures of Tabatabai and Bremner (1969). The urease activity was assayed by the colorimetric method given by Zantua and Bremner (1975).

Table 2: Treatment details.

Treatment	Details of treatments
T_1	Control
T_2	100% of RDN through PCU Split
T_3	80% of RDN through PCU Split
T_4	100% of RDN through NCU Split
T_5	80% of RDN through NCU Split
T_6	50% of RDN through PCU+50% of RDN through NCU Split
T_7	40% of RDN throughPCU+40% of RDN through NCU Split
T_8	100% of RDN through PCU+ FYM @ 10 t ha^{-1} + PGPR Basal
T_9	80% of RDN through PCU+ FYM @ 10 t ha^{-1} + PGPR Basal
T_{10}	100% of RDN through NCU + FYM @ 10 t ha^{-1} + PGPR Basal
T_{11}	80% of RDN through NCU + FYM @ 10 t ha^{-1} + PGPR Basal
T_{12}	50% of RDN through PCU+50% of RDN through NCU + FYM @ 10 t ha^{-1} + PGPR Basal
T_{13}	40% of RDN throughPCU+40% of RDN through NCU+ FYM @ 10 t ha^{-1} + PGPR Basal

RESULT AND DISCUSSION

A. pH and EC

Application PCU and NCU in the soil resulted in an increased soil pH, but the increase was not significant. This indicates that the application of a high dose of PCU and NCU cause an increase in soil pH insignificantly. Lower pH (7.93) was observed in control (T_1) and a higher pH value of 8.2 was observed in T_2. Data about EC of soil has been representing that a non-significant increase in the EC of soil with the application of PCU, NCU, FYM and PGPR was observed.

B. Organic carbon, Available Nitrogen, Available Phosphorus and Available Potassium

The maximum organic carbon (Table 3) content (0.57%) was observed in T_{12}. While the application of PCU and NCU along with organic sources such as FYM and PGPR from T_8 to T_{13} increased the organic carbon content of the soil value from 0.52 to 0.57%. Total organic carbon and its different active and passive pools C fractions in soil were influenced significantly with the application of FYM with fertilizers (Pant *et al*. 2017). FYM provides more labile carbon, which can improve rice yield over the short term (Ghosh *et al*. 2021).

The available nitrogen content (Table 3) of post-harvest soil was increased with an increase in the application of PCU, NCU and FYM with PGPR. The available nitrogen content of soil ranged between 225.70 and 264.94 kg ha^{-1}. The minimum being in control T_1 225.70 kg ha^{-1} and maximum in treatment T_{12} 264.94 kg ha^{-1} followed by treatment T_8 262.94 kg ha^{-1}. The treatment T_{12} was 17.38% higher than treatment T_1 (control). Chen *et al.*, (2020) reported that the available nitrogen significantly increase in post-harvest soil by supplying controlled-release urea in rice.

Table 3: Effect of different levels of the recommended dose of nitrogen (RDN) through PCU and NCU on available pH, EC, organic carbon, N, P_2O_5, K_2O in post-harvest soil.

Treatment	pH	EC	OC (%)	Nkg ha^{-1}	P_2O_5kg ha^{-1}	K_2O kg ha^{-1}
T_1	7.93	0.19	0.39	225.7	14.50	218.33
T_2	8.2	0.2	0.44	260.64	20.81	254.61
T_3	8.17	0.19	0.4	246.18	18.43	247.39
T_4	8.18	0.19	0.45	255.41	20.20	253.82
T_5	8.17	0.19	0.4	241.16	18.28	245.08
T_6	8.11	0.21	0.44	261.16	20.28	256.59
T_7	8.19	0.21	0.4	246.07	18.90	245.83
T_8	8.16	0.19	0.52	262.94	21.15	255.23
T_9	8.14	0.2	0.51	247.33	19.15	250.22
T_{10}	8.12	0.21	0.52	257.82	20.27	253.19
T_{11}	7.98	0.22	0.51	247.85	18.37	247.64
T_{12}	8.14	0.23	0.57	264.94	22.30	256.36
T_{13}	8.15	0.21	0.50	248.62	19.97	248.95
SEm±	0.048	0.012	0.018	2.03	0.48	2.58
CD at 5%	NS	NS	0.054	5.95	1.42	7.55

The available phosphorus content (Table 3) of soil ranged between 14.50 and 22.30 kg ha^{-1}. The minimum being in control (T_1) is 14.50 kg ha^{-1} and the maximum (22.30 kg ha^{-1}) in treatment T_{12}. T_{12} has a PGPR application that solubilizes phosphorous. PGPR was also found to be promising in indole acetic acid production having an additional property of phosphate solubilization (Ashrafuzzaman *et al*. 2009).

Application of PCU with NCU increase the available potassium content of the soil, but the increase was statistically non-significant. The available potassium content of soil ranged between 218.33 and 256.36 kg ha^{-1}. The minimum being in control (T_1) was 218.33 kg ha^{-1} and the maximum (256.36 kg ha^{-1}) in treatment T_{12} followed by treatment T_8 (255.23kg ha^{-1}).

C. Soil Enzymatic activity

The urease activity (Table 4) in post-harvest soils of rice increased significantly in T_{12} (212.32 µg urea hydrolysed g^{-1} soil h^{-1}) due to combined application of polymer-coated urea and neem coated urea because it supplies urea till maturity stage and observed least in control T_1 151.77 (µg urea hydrolysed g^{-1} soil h^{-1}). Slow hydrolysis allows urea to remain in fertilized fields for a long period due to the reduced loss of ammonia via volatilization and increased soil pH caused by high amounts of ammonium accumulation on fertilizer microsite (Juneja *et al.*, 2011). Urease activity of PCU (T_2) was found 2.3% and 12.5% lower than NCU (T_4) and mixed doses of PCU and NCU with FYM and PGPR respectively. The same finding was reported by Bordoli *et al.*, (2020) that the SCU (starch-coated urea) treatment showed 28.29%, 22.95%, and 13.41% lower urease activity compared to NPK, NUA (normal urea alone) and NCU respectively.

Table 4: Effect of different levels of the recommended dose of nitrogen (RDN) through PCU and NCU on soil enzymatic activity in post-harvest soil.

Treatment	Urease (µg urea hydrolysed g^{-1} soil h^{-1})	Dehydrogenase (µg TPF produced g^{-1} soil day^{-1})	Alkaline Phosphatase (µg PNP produced g^{-1} soil h^{-1})
T_1	151.77	41.98	52.08
T_2	215.08	75.12	78.12
T_3	185.68	63.20	65.13
T_4	220.33	72.38	75.29
T_5	193.30	60.20	63.13
T_6	205.12	79.47	82.37
T_7	182.08	70.09	68.10
T_8	225.13	108.08	91.25
T_9	202.28	88.08	72.27
T_{10}	236.22	105.20	88.17
T_{11}	208.20	90.12	70.17
T_{12}	242.25	112.20	98.27
T_{13}	212.32	95.07	76.07
SEm±	2.80	1.19	1.13
CD at 5%	8.19	3.48	3.43

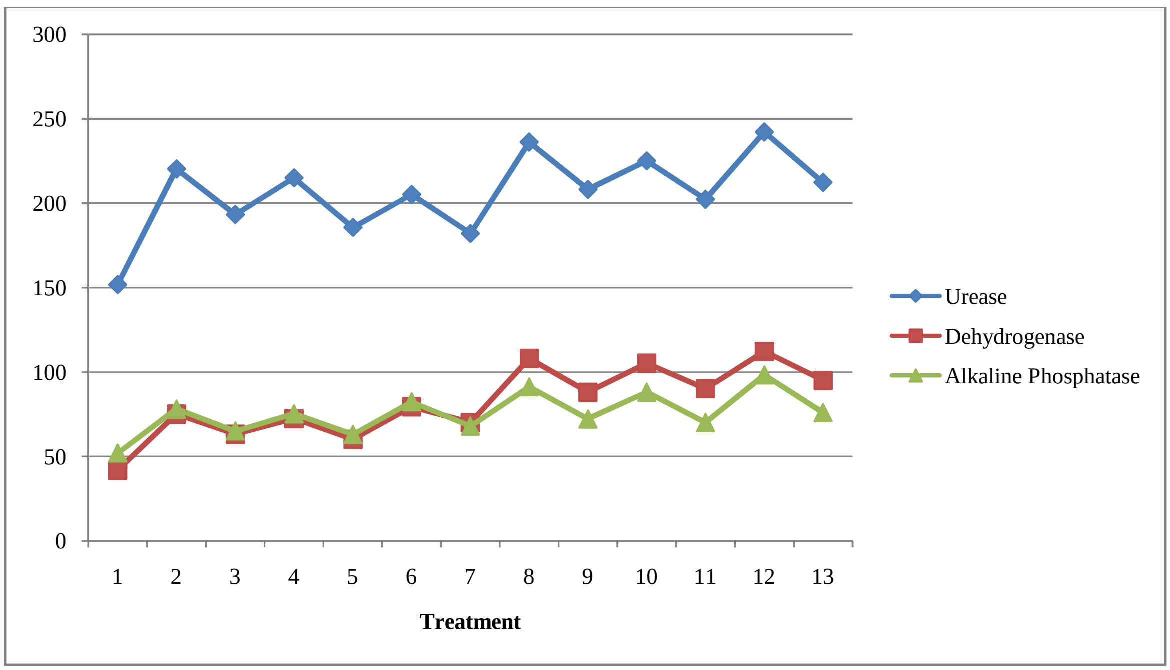

Fig. 1. Soil enzymatic activity in post-harvest soil.

Dehydrogenase activity (Table 4) observed maximum in T_{12} (112.20 µg TPF produced g^{-1} soil day^{-1}) and minimum in T_1 (41.98µg TPF produced g^{-1} soil day^{-1}). Dehydrogenase activity of soil increased due to the addition of organic carbon through organic manures (Kumar *et al.* 2014; Goutami *et al*. 2015). The activity of the dehydrogenase enzyme was strongly affected by organic manures. Generally, soil enzyme activities are related to soil organic matter content. Dehydrogenase activity was closely related to soil organic matter and microbial biomass under different ecosystems. Microbial population enhanced under the organic manure application which supplies higher organic carbon especially biological active phase of carbon acts as a source of energy for microbes in soil (Vishwanath *et al.,* 2020). Continuous application of inorganic fertilizer integrated with FYM improved the organic matter status of soils, which in turn enhanced the enzymatic activity (Biswas *et al*., 2018).

Alkaline phosphatase (Table 4) is an enzyme that has great importance in the transformation of organic phosphorus compounds to inorganic phosphorous which are easily taken by the plant (Maestre *et al.* 2011). A significant increase in alkaline phosphatase activity was recorded in treatment T_{12} (98.27 µg PNP produced g^{-1} soil h^{-1}) and the lowest activity was in T_1 (52.08 µg PNP produced g^{-1} soil h^{-1}) due to the application of organic matter which supplies organic phosphorous.

CONCLUSION

The main conclusion that can be drawn from this work is that conjoint application of PCU, NCU, FYM and PGPR resulted in an increment in enzymatic activity viz. urease, alkaline phosphatase and dehydrogenase increased to 12.5%, 25.79% and 20.15% in soil with certain changes in nitrogen, phosphorous and potassium. Conjoint application of slow-release fertilizers with FYM enhance the soil quality and health. Further studies are needed at abroad-scale with regards to establishing the most effective application rates and, the dynamics of nutrient release to synchronize the complex interaction of nutrient availability and plant demand.

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