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Research Paper

Effect of coated urea and organic amendments on productivity, profitability, quality, and nutrient uptake in potato in alluvial soil of West Bengal

SUSMITA DAS[1], SUKANTA PAL[2], HIRAK BANERJEE[3] AND AMIT KUMAR[4]

Faculty of Agriculture, Bidhan Chandra KrishiViswavidyalaya, Nadia, West Bengal 741 252

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ABSTRACT

A two years study was carried out at the D block farm of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during *rabi* season of 2019–20 and 2020–21 to study the combined effect of coated urea fertilizer and organic manure on performance of potato cropgrown under newly formed alluvial soil conditions of West Bengal.The experiment was laid out in randomized complete block design (RCBD) with four replication and treatment comprised of five treatment combination such as T_1, Control plot (N_0); T_2, 100% RDN through neem coated urea (NCU); T_3, 75% RDN through NCU + 25% RDN through VC (vermicompost); T_4, 100% RDN through polymer sulphur coated urea (PSCU); T_5, 75% RDN through PSCU + 25% RDN through VC. The results showed that the application of 75% RDN (through PSCU) + 25% RDN through VC (10 Mg/ha) recorded significant impact on growth attributes, yield and nutrient uptake by potato. The highest taller plants (37.1 cm), maximum DMA (1024.7 g/m^2), LAI (3.74) and CGR (27.0 g/m^2/day), maximum tuber bulking rate (21.5 g/m^2/day), with highest B grade tubers (13.4 Mg/ha), maximum tuber yield (26.8 Mg/ha) and haulm yield (4.56 Mg/ha) were recorded in T_5 which was significantly higher than other treatments. Similarly, significantly highest amount of total NPK uptake by the crop (173.2, 55.9 and 585.3 kg/ha), protein yield (63.4 kg/ha), gross return (254.9 × 10^3/ha), net return (184.6 × 10^3/ha, B: C ratio (3.62) and AE (50.0 kg grain yield/kg N applied) and RE (26.2 kg N uptake/kg N applied) was recorded under T_5 which was statistically at par with T_3 and significantly higher than remaining treatments, respectively. was noticed under T_5 treatment as compared to the other treatments. Therefore, it is recommended to adopt a holistic nutrient management approach consisting of inorganic and organic in the proportion of 75% RDN (through PSCU) +25 % RDN through VC (10 Mg/ha) in split application of potato cultivation that optimizes the growth, yield, nutrient uptake and quality eventually enhancing the agricultural productivity, profitability, food security and sustainability.

Key words: Coated urea, Nutrient uptake, Organic manures, Productivity, Profitability, Quality

Potato (*Solanumtuberosum* L.) stands as one of the world's most vital food crops, serving as a primary source of nutrition and livelihood for millions. Its significance extends beyond sustenance, with economic implications ranging from local markets to global trade (Kumar *et al*., 2023). However, the sustainable cultivation of potatoes faces numerous challenges, including optimizing productivity, enhancing profitability, ensuring quality, and maximizing nutrient uptake efficiency (Dua *et al*., 2021). A developing country like India utilizes more nitrogenous fertilizers especially standard urea but get much lower efficiency, i.e., 20–35% only. Significant N loss to the environment, polluting air and water systems through ammonia (NH_3) volatilization, surface runoff, leaching and denitrification are recorded with the use of prilled urea (Biswas *et al*., Sarangi *et al*., 2020). The N loss can be especially high when dealing with potato due to high fertilizer and irrigation rates, as well as an inefficient root system (Hopkins *et al*., 2020). For the past few years in the Indo-Gangetic Plains (IGP), cultivators used to put the entire recommended dose of N as basal. Presently, various awareness campaigns regarding increased use efficiency of fertilizers led farmers to often split and apply 40 to 50% of the predicted N dose either before sowing or at plant emergence and remaining portion at the critical stages of crop growth. Because potato needs a steady supply of N throughout the growing season, it is recommended that N availability be synchronized with plant demand to maximize nitrogen use efficiency, yield, and tuber

[1]**Corresponding author's Email:** susmitadas282@gmail.com
[1]Assistant Professor, [2]Professor, [3]Assistant Professor, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal 741 252; [4]Scientist, ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim 737 102

quality henceforth reduces the labour cost, environmental degradability. In this context, the utilization of innovative agricultural inputs, such as coated urea and organic amendments, holds promise for addressing these multifaceted challenges. Slow-release or Controlled release nitrogen sources are components of Enhanced Efficiency Fertilizers (EEF), where the N is released into the soil through diffusion of the encapsulated inert material (Beig *et al*., 2020; Kaur *et al*., 2023). Neem oil coated urea works as nitrification resistant. The N proliferates slowly into the soil, leaches a smaller amount and had got insecticidal properties (Singh, 2019). Polymer sulphur coated urea (PSCU) is a diffusion controlled release product that is comprised of granulated N fertilizer with a thin polymer and sulphur coating surrounding each urea granule mostly affected by soil temperature and coating thickness (Ransom *et al*., 2020). Coating urea granules with materials such as polymers or sulfur inhibits nitrogen release, resulting in prolonged nutrient availability to crops. This controlled-release mechanism offers several advantages, including reduced nitrogen losses through volatilization and leaching, enhanced nutrient use efficiency, and minimized environmental impacts. Moreover, coated urea can contribute to more precise nutrient management, aligning fertilizer applications with crop demand and growth stages (Vejan *et al*., 2021; Manjappa *et al*., 2023).

Organic amendments including compost, manure, and biochar, represent another avenue for improving potato productivity, profitability, quality and nutrient uptake efficiency. Organic amendments offer numerous benefits, such as improving soil structure, enhancing water retention capacity, supplying essential nutrients, and fostering microbial activity. Furthermore, organic amendments can contribute to long-term soil fertility and resilience, reducing dependence on synthetic fertilizers and promoting sustainable agricultural practices (Yadav *et al*., 2017; Nallagatla *et al*., 2024). Vermicompost are enriched manures that act as a source of primary, secondary as well as micronutrients to the plants. This organic amendment are a constant source of energy for the heterotrophic micro-organisms to carry out the decomposition and assists in nutrient fixation or solubilization. Despite the individual merits of coated urea and organic amendments, their combined application holds potential synergistic effects on potato production. The integration of coated urea with organic amendments may offer complementary benefits, such as enhanced nutrient availability, improved soil health, and increased crop resilience to abiotic stresses. Moreover, the synergistic use of these inputs may result in more balanced nutrient supply, promoting optimal growth, development, and yield formation in potatoes (Sarkar *et al*., 2011). However, despite the growing interest in coated urea and organic amendments, there remains a notable gap in understanding their relative competency in augmenting potato productivity, profitability, quality, and nutrient uptake. Limited empirical evidence exists regarding the comparative efficacy of coated urea versus organic amendments and their combined application strategies in potato cultivation. Additionally, the economic feasibility and practical implications of adopting these technologies remain underexplored in many potato-growing regions. Therefore, this study aims to address these knowledge gaps by investigating the relative competency of coated urea, organic amendments, and their combination in enhancing the productivity, profitability, quality, and nutrient uptake of potato crops. Through a comprehensive field experiment, we seek to evaluate the individual and combined effects of these agricultural inputs on key performance indicators, including yield, marketable quality attributes, nutrient uptake efficiency, and economic returns. By elucidating the comparative efficacy and practical implications of coated urea and organic amendments, this study endeavors to provide valuable insights for potato growers, agronomists, and policymakers striving towards sustainable potato production systems.

MATERIALS AND METHODS

A field experiment for two years duration (*rabi* season of 2019–20 and 2020–21) has been conducted at the D-Block farm of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The experimental site is situated at a latitude of 22°98'N and longitude of 84°42'E, with an altitude of 9.50 m above mean sea level (MSL). This region has hot and humid climate. The temperature reached a maximum of 34°C in the month of May and minimum temperature got down to 23°C in the month of October during the crop growing season. The site receives an average annual rainfall of 1440 mm. The soil sample was collected before sowing of potato and analyzed therefore. The soil of the experimental site was clay loam texture having pb of 1.45 mg/m^3 with a neutral soil reaction, low levels of organic carbon (0.49%) and available N (205.3 kg/ha), high level of available P (28.8 kg/ha), and medium level of available K (175.5 kg/ha). The experiment was laid out in randomized complete block design (RCBD) with four replication and treatment comprised of five treatment combination such as T_1- Control plot (without N); T_2- 100% RDN through neem coated urea (NCU); T_3- 75% RDN through NCU + 25% RDN through vermicompost (VC); T_4- 100% RDN through polymer sulphur coated urea (PSCU); T_5- 75% RDN through PSCU + 25% RDN through VC. In accordance with the treatments, the fertilizers (NCU, PSCU, SSP and MOP) at the rate of 200 kg N/ha, 150 kg P/ha, 150 kg K/ha and manure (VC) at the rate of 10 Mg/ha was the prescribed fertilizer dose. The treatment regimen followed was the application of the entire phosphorus (P) and potassium (K) as basal. However, 75 percent of the recommended nitrogen (N) rate was mixed with soil as basal dose and 25 percent during first earthing up at 30 DAP. The harvesting of the *kharif* seasoned rice prior to potato planting was conducted on October 9, 2019 and October 17, 2020 respectively. Potato tubers (var. *kufri jyoti*) were taken out from cold storage and kept in the potato shed for seven days before planting to accelerate the sprouting. 2-2.5 Mg/ha of sprouted tubers was planted in the ridges and furrows with a spacing of 45 cm between the ridges and 20 cm among the plants. The ridging of land economies the use of irrigation and the furrows acts as drainage channels. The tubers were embedded into the soil on 18th, November 2019 and 22th, November 2020 respectively. The recommended agronomic practices were followed throughout the crop period. The net plot area was manually harvested for dry tuber yield assessment. The resulting tuber and haulm yield was then converted into Mg/ha. During harvest, samples of tubers from 10 plants of potatoes per plot were collected for chemical analyses. Samples of potato tubers were dried at an initial temperature of 70°C, and then dried at 105°C to a constant weight using the Willey mill with stainless steel blades. A modified version of the Kjeldahl method was used to estimate nitrogen (%) in tuber and haulm (Prasad *et al.*, 2006). Phosphorus concentration in tuber and haulm was determined by using the vanadomolybdophosphoric acid yellow colour method at 420 nm wavelength on a UV-VIS spectrophotometer (Prasad *et al.*, 2006). Potassium concentration in tuber and haulm was determined by flame photometer (Prasad *et al.*, 2006). Nutrient uptake was calculated by using the following expression:

NPK uptake (kg/ha) in tuber/haulm = [% NPK content in tuber/haulm × tuber/haulm yield (kg/ha)]

The content of protein in tuber was calculated from the nitrogen content with the use of the coefficient 6.25. Tuber protein yield has been calculated using the following formula:

Tuber protein yield (kg/ha) = Protein content (%) x tuber yield (kg/ha)/100

The total value of the output was quantified in monetary terms, and determined using the following formulas:

Gross returns (/ha) = Value of the tuber (/ha)
Net returns (/ha) = Gross returns (/ha) – Total costs (/ha)
B: C ratio = Net returns (/ha) /Total cost (/ha)

The data obtained from four separate replicates for each treatment were subjected to analysis using the general linear model procedures within the Statistical Analysis System 9.3 software package (SAS Institute, Cary, NC).

Table 1. Effect of coated urea and organic manure on the growth, quality, yield and economics of potato (pool data of 2019–20 and 2020–2021)

Treatment	Plant height harvest stage (cm)	DMA at harvest stage (gm^2)	Leaf area index at maximum growth stage	Crop growth rate at maximum growth stage (g/m^2/day)	Maximum Tuber bulking rate (g/m^2/day)	0–25g 'D' grade (Mg/ha)	26–50 g 'C' grade (Mg/ha)	51–75 g 'B' grade (Mg/ha)	> 75 g 'A' grade (Mg/ha)	Tuber yield (Mg/ha)	Haulm yield (Mg/ha)	Gross returns (× 10^3₹/ha)	Net returns (× 10^3₹/ha)	Benefit Cost: ratio
T_1	27.8	381.4	3.26	8.81	7.42	1.46	6.78	5.55	1.24	14.97	3.10	142.2	84.4	2.46
T_2	32.5	667.9	3.42	15.03	10.18	1.52	7.86	11.00	2.63	22.97	4.24	218.2	156.9	3.56
T_3	35.2	905.2	3.63	21.91	18.76	1.56	8.31	12.63	3.02	25.53	4.45	242.5	175.2	3.60
T_4	33.9	754.4	3.56	20.81	10.40	1.53	8.21	11.99	2.91	24.63	4.38	234.0	168.7	3.59
T_5	37.1	1024.7	3.74	27.01	21.51	1.60	8.55	13.41	3.24	26.83	4.56	254.9	184.6	3.62
SEm±	0.43	21.61	0.03	1.06	0.63	0.01	0.02	0.05	0.02	0.04	0.01	1.27	1.19	0.01
CD (P=0.05)	1.25	62.43	0.08	3.07	1.83	NS	0.07	0.15	0.07	0.18	0.04	4.50	4.34	0.04

T_1, [N0 + 100% PK]; T_2, 100% N (NCU) + PK; T_3, [75% NPK (N as NCU) + 25% N through VC]; T_4, 100% N (PSCU) + PK; T_5, [75% NPK (PSCU) + 25% N through VC]; DAP, days after planting; NS, non-significant at P=0.05

The significance of 'F' value was determined based on analysis of variance (ANOVA) for randomized complete block design. For conducting multiple comparisons of treatment means, the Least Significant Difference (LSD) test was employed at a significance level of 5% probability.

LSD= S.Ed. × t value at error degree of freedom, where, S.Ed.= Standard error of difference; t = value of percentage point of 't' distribution for error degrees of freedom at 5% level of significance.

RESULTS AND DISCUSSION

Growth attributes

The experimental result of two years pooled data explored variability in the growth attributes of potato and differed significantly with respect to the nutrient management options (Table 2). Plant height was highest in the treatment T_5 (37.1 cm) where 75% RDN through PSCU + 25% RDN through VC (10 Mg/ha) was used. It was statistically at par with T_3. Dry matter accumulation (DMA) reflects the growth, development and photosynthetic efficiency of the plants, ultimately determining the final crop yield. In our study, the DMA estimated at harvesting stage was highest in T_5 (1,025 g/m^2/day) and at par with T3 (905.2 g/m^2/day). The maximum leaf area index was noted in the T_5 (3.74) followed by T_3 (3.63) and T4 (3.56). The lowest plant height, dry matter accumulation, leaf area index, crop growth rate was recorded in treatment T_1. The growth parameters were profoundly lower in T_2 and T_4 where fertilization was with 100% of the recommended dose of chemical coated urea with no added organic manure. Potato demands high level of soil nutrients due to relative poorly developed and shallow root system. A good supply of nitrogen during the complete crop growth period for adequate vine and tuber development is necessary. Excessive N release from the conventional urea during early part of plant growth results in the delay of tuber initiation (tuberization) by 7 to 14 days, resulting in reduced tuber yields. PSCU with its integration of vermicompost exhibited an increase in plant height may be due to rapid elongation and multiplication of cell in the presence of adequate quantity of nitrogen (Barman *et al*., 2018). The rise in total dry matter can be attributed to the fact that PSCU promotes more NO_3^--N accumulation in the shoots, leaves and tubers. Moreover, the presence of sulphurin PSCU boosts up the utilization and uptake of N and K concentration in plants (Islam *et al*., 2014), presented a pattern that was nearly synchronized with the N uptake and accumulation from vegetative growth to tuber formation resulting in higher crop growth rate (Mahata *et al*., 2018). Also, compared to conventional fertilizers, this

Table 2. Effect of coated urea and organic manure on the growth, quality, yield and economics of potato (pool data of 2019–20 and 2020–2021)

Treatment	Plant height harvest stage (cm)	DMA at harvest stage (gm^2)	Leaf area index at maximum growth stage	Crop growth rate at maximum growth stage (g/m^2/day)	Maximum Tuber bulking rate (g/m^2/day)	0–25g 'D' grade (Mg/ha)	26–50 g 'C' grade (Mg/ha)	51–75 g 'B' grade (Mg/ha)	> 75 g 'A' grade (Mg/ha)	Tuber yield (Mg/ha)	Haulm yield (Mg/ha)	Gross returns (× 10^3₹/ha)	Net returns (× 10^3₹/ha)	Benefit Cost: ratio
T_1	27.8	381.4	3.26	8.81	7.42	1.46	6.78	5.55	1.24	14.97	3.10	142.2	84.4	2.46
T_2	32.5	667.9	3.42	15.03	10.18	1.52	7.86	11.00	2.63	22.97	4.24	218.2	156.9	3.56
T_3	35.2	905.2	3.63	21.91	18.76	1.56	8.31	12.63	3.02	25.53	4.45	242.5	175.2	3.60
T_4	33.9	754.4	3.56	20.81	10.40	1.53	8.21	11.99	2.91	24.63	4.38	234.0	168.7	3.59
T_5	37.1	1024.7	3.74	27.01	21.51	1.60	8.55	13.41	3.24	26.83	4.56	254.9	184.6	3.62
SEm±	0.43	21.61	0.03	1.06	0.63	0.01	0.02	0.05	0.02	0.04	0.01	1.27	1.19	0.01
CD (P=0.05)	1.25	62.43	0.08	3.07	1.83	NS	0.07	0.15	0.07	0.18	0.04	4.50	4.34	0.04

T_1, [N0 + 100% PK]; T_2, 100% N (NCU) + PK; T_3, [75% NPK (N as NCU) + 25% N through VC]; T_4, 100% N (PSCU) + PK; T_5, [75% NPK (PSCU) + 25% N through VC]; DAP, days after planting; NS, Non-significant at P > 0.05

treatment had a positive effect on the chlorophyll concentration and the photosynthetic rates resulting in leaf area expansion through facilitated vegetative growth (Agrawal *et al*., 2018).

Tuber quality

Quality attributes as shown in Table 2 revealed that the coated nitrogen sources and organic amendments had both non-significant and significant effect on potato tuber. The tubers were graded from A to D defining the superior to inferior quality on the basis of its fresh weight. The tuber yield of A, B and Cgrade significantly varied among the treatments except for D grade. The maximum tubers were found under B grade attaining a fresh weight between 51–75 g. Among the treatments, the highest tuber yield under A, B and C grade (3.24 Mg/ha, 13.4 Mg/ha, 8.55 Mg/ha respectively) were found in T_5. However, irrespective of grade, the lowest marketable yield was obtained in T_1. The increase in tuber yield under B grade might be due to the extended canopy life thereby prolonging the duration of tuber bulking, escalating both the number and weight of individual tubers in the medium and large grades at the expense of small tubers (Banerjee *et al*., 2016).

Yield

Nutrient management practices exerted a significant effect on tuber and haulm yield of potato (Table 1). The highest tuber yield was obtained with treatment T_5 (26.8 Mg/ha) and it was statistically at par with treatments T_3 (25.5 Mg/ha). The lowest tuber yield (14.9 Mg/ha) was obtained in the unfertilized N plot (T_1) which resulted in 79.8% lesser tuber yield. The sole NCU fertilized treatment T_2, and sole PSCU fertilized treatment T_4, had 16.8% and 8.9% respectively lesser yield compared to the INM treatment with PSCU and VC in T_5. The haulm yield followed the same trend and was significantly highest in T_5 (4.56 Mg/ha). T_3 recorded a haulm yield of 4.45 Mg/ha which was significantly at par with T_5. Nitrogen control plot (T_1) had acquired the lowest haulm yield (3.10 Mg/ha). The steady release of NO_3^-–N from PSCU causes more tuber formation than in those fed with NH_4^+–N which primarily influences the above ground biomass, dry matter, sugar content and tuber size. Furthermore, the humic acid from vermicompost enhances themicrobialactivity, keeps the soil pH within favourable range which helps the macronutrients solubilize faster and mobilize better (Song *et al*., 2014).

Economic returns

The economics as influenced by integrated nutrient management showed significantly highest amount of gross returns (254.9 × 10^3 ₹/ha), net return (184.6 × 10^3 ₹/ha) and B: C ratio (3.62) under 75% RDN through

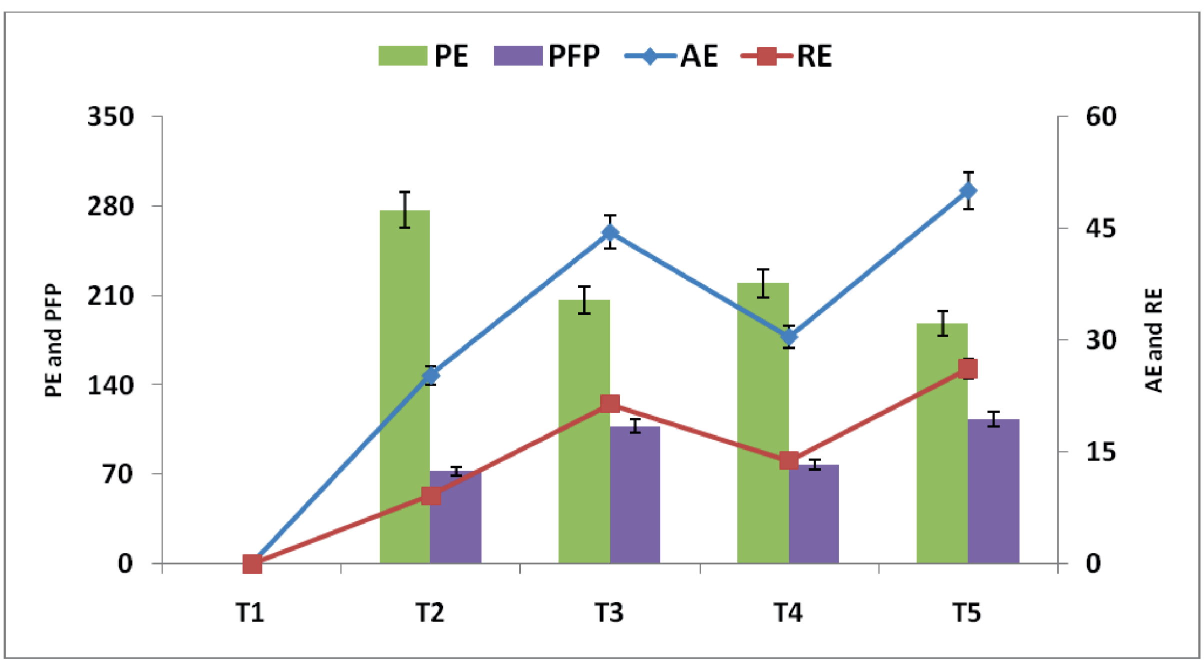

Fig. 1. Nitrogen use efficiency and its parameters as influenced by integrated nutrient management practices (pooled data of 2 years)
AE, Agronomic efficiency (kg grain yield/kg N applied); RE, recovery efficiency (kg N uptake/kg N applied); PE, physiological efficiency (kg yield/kg nutrient absorbed); Partial factor productivity [crop yield (kg)/unit of applied nutrient (kg)]; T_1, [N0 + 100% PK]; T_2, 100% N (NCU) + PK; T_3, [75% NPK (N as NCU) + 25% N through VC]; T_4, 100% N (PSCU) + PK; T_5, [75% NPK (PSCU) + 25% N through VC]

PSCU + 25% RDN through VC (10 Mg/ha) treatment which was significantly at par with 75 % RDN (through NCU + 25% RDN through VC (10 Mg/ha) in T_3 treatment, recording a gross returns (242.5×10^3 /ha), net return (175.2×10^3 /ha) and B: C ratio (3.60) respectively. The gross returns (142.2×10^3 /ha), net return (84.4×10^3 /ha) and B: C ratio (2.46) was lowest in control plot. The combined application of coated nitrogenous fertilizer and organic manure improved the above ground biomass and yield components like tuber number, average tuber weight. So, T_5 gave the highest volume of marketable and total tuber yield which maximized the profit, though the price of PSCU was much higher compared to NCU, the higher tuber yield might have compensated it (Gelaye, 2023).

Nutrient content (%) and uptake (kg/ha)

The coated urea and organic manure based nutrient management practices had significant effect on the NPK content and uptake by potato crop (Table 3). The T_5 treatment having 75% RDN (through PSCU) + 25% RDN through VC (10 Mg/ha) recorded significantly highest amount of nutrient content in tuber (0.38% N, 0.20% P, 1.49% K) and haulm (1.57% N, 0.08% P, 4.05% K) compared to the other treatments. The T_5 was statistically at par with T_3 where N got replaced by NCU along with VC in the same proportion recording a nutrient content of 0.35% N, 0.18% P, 1.45% K in tuber and 1.53% N, 0.07% P, 3.88% K in haulm. Indicating the positive effects of N and VC, the lowest NPK content in tuber (0.26% N, 0.14% P, and 1.33% K) and haulm (1.41% N, 0.03% P, and 3.58% K) was found in T_1. In case of NPK uptake by potato, similar trend was observed, where application of 75% RDN through PSCU along with 25% RDN through VC @ 10 Mg/ha (T_5) recorded highest total plant uptake (173.2 kg N/ha, 55.97 kg P/ha, 585.3 kg K / ha), followed by application of 75% RDN through NCU along with 25% through VC (10 kg/ha) (T_3) where 157.6 kg N/ha, 48.98 kg P/ha, 541.7 kg K/ha total plant uptake were observed. Both T_5 and T_3 remained statistically different to each other. No nitrogen input either as fertilizer or as manure in T_1 has resulted in lowest value of total plant uptake (81.9 kg N/ha, 21.0 kg P/ha, 309.6 kg K/ha). This may be attributed to the release pattern of N from PSCU at a controlled rate gradually into the soil in the form of NO_3^-–N over time up to tuber bulking phase, rather than its excess availability in the soil initially during the vine production phase which is common as in conventional urea and are more prone to lost through volatilization or leaching (Reetika *et al*., 2023). Moreover, compared to sole application of chemical fertilizers, the solubility action of organic acids derived from vermicompost produced during degradation of organic materials resulted into in-

Table 3. Effect of coated urea and organic manure on the nutrient uptake and protein yield of potato (pool data of 2019–20 and 2020–21)

Treatment	Nutrient content in tuber (%)			Nutrient content in haulm (%)			Nutrient uptake by tuber (kg/ha)			Nutrient uptake by haulm (kg/ha)			Total nutrient uptake by			Protein content	Protein yield
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K		
T_1	0.26	0.14	1.33	1.41	0.03	3.58	38.4	20.2	199	43.4	0.83	111	81.9	21.0	309.6	1.60	24.0
T_2	0.29	0.16	1.37	1.46	0.04	3.76	67.3	35.5	313	61.7	1.76	159	129.1	37.3	472.5	1.83	42.1
T_3	0.35	0.18	1.45	1.53	0.07	3.88	89.5	45.9	369	68.1	3.04	172	157.6	48.9	541.7	2.19	55.9
T_4	0.34	0.16	1.43	1.50	0.05	3.83	82.4	39.8	352	65.5	2.26	167	147.9	42.0	519.9	2.09	51.5
T_5	0.38	0.20	1.49	1.57	0.08	4.05	101.5	52.3	401	71.7	3.64	185	173.2	55.9	585.3	2.36	63.4
SEm±	0.00	0.00	0.01	0.01	0.00	0.01	0.93	0.75	1.44	0.25	0.11	0.80	0.98	0.83	2.08	0.02	0.58
CD (P=0.05)	0.01	0.01	0.02	0.02	0.01	0.04	3.05	2.45	4.69	0.81	0.36	2.62	3.21	2.69	6.77	0.08	1.90

T_1, [N0 + 100% PK]; T_2, 100% N (NCU) + PK; T_3, [75% NPK (N as NCU) + 25% N through VC]; T_4, 100% N (PSCU) + PK; T_5, [75% NPK (PSCU) + 25% N through VC]; DAP, days after planting; NS, Non-significant at $P > 0.05$

creased OC, CEC, available P and K and total N content of the soil (Wagari *et al*., 2022).

Protein content (%) and protein yield (kg/ha)

The results of the experiment revealed that the protein content and protein yield of potato were significantly influenced by the sole coated urea fertilization as well as fusion of coated urea and VC applied in different proportions (Table 3). It has been observed that the plots treated with INM (blend of coated urea and VC) reported maximum protein content and protein yield in potato compared to sole coated urea fertilization plot. The protein content (2.36%) as well as the protein yield (63.4 kg/ha) was maximum in T_5 containing 75% RDN through PSCU along with 25% RDN through VC (10 Mg/ha). However, the protein content (1.60 %) and protein yield (24.0 kg/ha) were observed to be minimum in control plot. Nitrogen is the precursor of protein and thus, higher protein content under application of coated urea along with vermicompost had caused better uptake of nitrogen as compared to application of sole coated urea (Biswas and Dutta, 2022). Similar study of protein yield was recorded by Singh *et al*. (2014).

Nutrient use efficiency

The coated urea and organic manure based nutrient management practices had significant effect on the nutrient use efficiency of crop (Figure 1). Among the different treatments, maximum AE (50.0 kg grain yield/kg N applied) and RE (26.2 kg N uptake/kg N applied) was recorded under T_5 which was statistically at par with T_3 and significantly higher than remaining treatments, respectively. It might be due to PSCU is a slow-release nitrogen fertilizer. This slow-release mechanism reduces nitrogen losses (e.g., from leaching or volatilization) and improves nitrogen availability to plants over a more extended period. This prolonged availability aligns more closely with the crop's nitrogen uptake pattern, enhancing nitrogen use efficiency (NUE). As a result, plants use more nitrogen for growth and grain production, thus increasing both agronomic and recovery efficiency (Reetika *et al*., 2023). The significant maximum PE (277 kg yield/kg nutrient absorbed) was found under T_2 followed by T_4 as compared to the remaining treatments, respectively because Due to its slow-release nature, neem-coated urea provides a steady supply of nitrogen that matches the crop's demand throughout different growth stages. This synchronization minimizes the risk of nitrogen excesses or shortages, allowing crops to maintain steady growth and optimize photosynthetic activity. As a result, the nitrogen absorbed is used more effectively for biomass and grain production, which increases PE (Singh *et al*., 2014). While, highest value of PFP (113 kg crop yield per kg of applied nutrient) was noticed under T5 which was statistically at par with T3 and significantly higher than other treatments. The combined use of an inorganic slow-release fertilizer (PSCU) with organic vermicompost leverages the strengths of both types of fertilizers. PSCU provides a steady and controlled nutrient release, while vermicompost enhances soil fertility, microbial activity, and nutrient cycling. This synergy leads to more efficient nutrient use and better crop yield outcomes compared to treatments relying solely on either organic or inorganic fertilizers. This improved efficiency in nutrient use translates into higher partial factor productivity (Hopkins *et al*., 2020; Gelaye, 2023).

The obtained results indicate that the selection of coated urea is important in relation to the use of organic manure for an appropriate integrated nutrient management in potato. Three-fourth part of the recommended dose of fertilizer as polymer sulphur coated urea and one fourth part of the recommended dose of fertilizer substituted with vermicompost applied in two splits as basal dose and one month after planting the tubers contributed to an increase in the growth attributes, yield, net return, NPK content as well as its uptake, true protein content and protein yield and AE. In the future, in order to economize the coated urea use, encapsulation of neem over the urea along with vermicompost could have equal potential as components to manage the nutrient needs of the potato in a combined manner.

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