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Effect of NPK and organic manures on soil properties, growth and yield of potato (*Solanum tuberosum* L.) var. Kufri Badshah

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Abstract

A field trial was conducted during the Rabi season of 2025–26 at the Central Research Farm of the Department of Soil Science and Agricultural Chemistry, SHUATS, Prayagraj, to assess how the joint application of the recommended dose of NPK fertiliser (RDF) with two organic sources — poultry manure (PM) and city waste compost (CWC) — influences soil physical and chemical properties, vegetative growth, yield attributes and profitability of potato cv. Kufri Badshah. Eight treatments (absolute control, RDF alone, and RDF combined with PM or CWC at 5, 10 and 15 t ha⁻¹) were arranged in a Randomised Block Design with three replications. Integrated nutrient management consistently outperformed the control and sole mineral fertilisation: bulk and particle density declined while pore space, organic carbon and the availability of nitrogen, phosphorus and potassium increased after harvest, without pushing soil pH or electrical conductivity outside a safe range. Vegetative growth (plant height, branching and leaf number) and yield attributes (tubers per plant and tuber yield) improved correspondingly, with RDF + PM @ 15 t ha⁻¹ producing the highest tuber yield (36.30 t ha⁻¹), a 37.5% gain over the untreated control (26.40 t ha⁻¹). Economic appraisal showed that although organic amendments raised cultivation cost, they also raised gross and net returns, with RDF + PM @ 15 t ha⁻¹ giving the highest gross return and RDF + CWC @ 15 t ha⁻¹ giving the highest net return. The results support integrated use of poultry manure or city waste compost with recommended NPK, particularly RDF + PM @ 15 t ha⁻¹, as a productive and economically sound nutrient management option for potato in the alluvial soils of the middle Gangetic plains.

Keywords: Potato, integrated nutrient management, poultry manure, city waste compost, soil fertility, tuber yield, economics

1. Introduction

Agriculture remains central to the Indian economy, contributing roughly 17–18% of national GDP and sustaining the livelihoods of a large share of the rural population. Within this system, soil functions as far more than a rooting medium: its physical architecture, chemical status and biological activity together set the ceiling on crop productivity and on the long-term sustainability of farming systems. Decades of intensive cropping, heavy reliance on chemical fertiliser and inadequate return of organic matter have progressively eroded soil organic carbon and structural quality across much of the Indo-Gangetic plain, a trend widely recognised as a threat to future food security.

Potato (*Solanum tuberosum* L.) is among the most nutrient-responsive of India's field crops and one of the most important non-cereal contributors to farm income and food supply. Because tubers are harvested from below ground and develop rapidly during a short growth cycle, potato is particularly sensitive to the physical condition of the soil — bulk density, porosity and aeration directly govern stolon movement and tuber bulking — as well as to a steady, well-synchronised supply of nitrogen, phosphorus and potassium. Nitrogen drives canopy expansion and chlorophyll synthesis, phosphorus underpins root proliferation and energy transfer, and potassium regulates water relations and the translocation of photosynthate to the developing tubers; a shortfall or imbalance in any one of these can constrain yield even when the others are adequate.

Meeting the crop's nutrient demand from mineral fertiliser alone, however, does little to rebuild organic matter or improve the physical fabric of the soil, and in the long run can accelerate the

very degradation that limits productivity. Organic amendments such as poultry manure and city waste (municipal solid waste) compost offer a complementary route: besides supplying nitrogen, phosphorus, potassium and micronutrients, they add organic carbon, stimulate microbial activity and improve aggregation, porosity and water-holding capacity as they decompose. Combining such organic sources with the recommended dose of mineral fertiliser — the essence of integrated nutrient management (INM) — is widely reported to improve nutrient-use efficiency, soil health and crop performance relative to either input used alone, though the optimum organic source and rate are strongly site- and soil-specific.

Despite an extensive body of INM research on potato from other agro-climatic zones, comparatively little site-specific evidence exists for the sandy loam alluvial soils of the Prayagraj region under the locally grown variety Kufri Badshah, and few studies simultaneously track soil physical properties, soil chemical fertility, vegetative growth, yield attributes and the economics of cultivation within a single trial. The present investigation was therefore undertaken with the objectives of (i) evaluating the effect of recommended NPK fertiliser applied alone and in combination with graded levels of poultry manure and city waste compost on the physical and chemical properties of the soil; (ii) assessing the consequent response in plant growth and yield attributes of potato; and (iii) working out the cost of cultivation, returns and benefit–cost ratio of the different nutrient management options to identify a combination that is both agronomically effective and economically viable.

2. Materials and Methods

2.1 Site, climate and initial soil status

The trial was carried out during the Rabi season (November 2025 – February 2026) at the Central Research Farm of the Department of Soil Science and Agricultural Chemistry, Naini Agricultural Institute, SHUATS, Prayagraj (25°44' N, 81°50' E; ~98 m amsl), on nearly level, well-drained alluvial land of the Indo-Gangetic plain. The region has a subtropical climate; during the cropping period the maximum temperature ranged from about 22–34°C and the minimum from 6–18°C, with only minor rainfall. Pre-sowing composite soil samples (0–15 cm) showed a sandy loam texture (sand 65.3%, silt 19.1%, clay 15.6%), near-neutral reaction, non-saline status and low-to-medium fertility (Table 1), providing a baseline against which the treatment effects could be assessed.

Table 1: Initial physico-chemical properties of the pre-sowing experimental soil

Parameter	Value
Bulk density (Mg m^{-3})	1.29
Particle density (Mg m^{-3})	2.47
Pore space (%)	41.60
Water-holding capacity (%)	34.55
Soil pH (1:2.5)	6.94
Electrical conductivity (dS m^{-1})	0.29
Organic carbon (%)	0.40
Available nitrogen (kg ha^{-1})	252.2
Available phosphorus (kg ha^{-1})	14.25
Available potassium (kg ha^{-1})	185.2

2.2 Experimental design and treatments

The experiment followed a Randomised Block Design with eight treatments replicated three times (24 plots of 2 m × 2 m). Treatments comprised an absolute control, the full recommended dose of NPK fertiliser (RDF) alone, and RDF supplemented with poultry manure or city waste compost at three rates each (Table

2). Nitrogen, phosphorus and potassium were supplied through urea, di-ammonium phosphate and muriate of potash; the entire phosphorus and potassium dose and half the nitrogen were applied basally, with the remaining nitrogen top-dressed at earthing-up. Organic manures were incorporated uniformly about 15 days before sowing on a treatment-wise basis.

Table 2: Treatment details

Code	Treatment
T ₁	Absolute control
T ₂	100% RDF (NPK)
T ₃	RDF + Poultry manure @ 5 t ha ⁻¹
T ₄	RDF + Poultry manure @ 10 t ha ⁻¹
T ₅	RDF + Poultry manure @ 15 t ha ⁻¹
T ₆	RDF + City waste compost @ 5 t ha ⁻¹
T ₇	RDF + City waste compost @ 10 t ha ⁻¹
T ₈	RDF + City waste compost @ 15 t ha ⁻¹

2.3 Crop husbandry

Healthy, disease-free seed tubers (30–50 g) of Kufri Badshah, treated with a recommended fungicide, were sown on ridges in the first week of November 2025 after one deep ploughing and two harrowings. A light irrigation followed sowing, with subsequent irrigations at 7–10-day intervals and particular attention to the stolon-initiation and tuber-bulking stages. Two hand weedings/hoeings were carried out, combined with earthing-up at about 30 days after sowing (DAS), and standard plant-protection measures were applied uniformly to all plots to guard against late blight, early blight, aphids and cutworms. The crop was harvested at physiological maturity in the first week of February 2026.

2.4 Observations and statistical analysis

Plant height, number of stems/branches and number of leaves were recorded from five randomly tagged plants per plot at 30, 60 and 90 DAS. At harvest, the number of tubers per plant and plot/hectare tuber yield were determined, and post-harvest soil samples (0–15 and 15–30 cm) were analysed for bulk density, particle density, pore space, pH, electrical conductivity, organic carbon and available N, P and K following standard procedures (pH and EC — potentiometric/conductometric; organic carbon — Walkley–Black wet oxidation; available N — alkaline potassium permanganate; available P — Olsen's method; available K — flame photometry). Treatment economics were computed from prevailing input and output prices as cost of cultivation, gross return, net return (gross return minus cost of cultivation) and benefit–cost (B:C) ratio (net return ÷ cost of cultivation). All data were subjected to analysis of variance appropriate to a Randomised Block Design; treatment means were compared using the critical difference at the 5% level of probability.

3. Results and Discussion

3.1 Soil physical properties

Integrated application of organic manures with RDF produced a consistent, statistically significant improvement in soil physical condition relative to the control and to RDF alone (Table 3). Bulk density fell progressively with increasing rate of poultry manure or compost, from 1.27 Mg m^{-3} under RDF alone to a minimum of 1.18 Mg m^{-3} under RDF + PM @ 15 t ha⁻¹ at the 0–15 cm depth, while pore space rose correspondingly from about 45% in the control to nearly 49% under the same treatment. Particle density showed the same downward trend but over a much narrower range, consistent with its dependence on the soil's mineral composition rather than on management. These shifts are readily

explained by the addition of low-density organic material and by the stimulation of microbial activity and stable-aggregate formation during manure decomposition, which loosens compaction and opens macro- and micropore space for root growth, aeration and water movement — mechanisms consistent with those generally reported for integrated organic–inorganic nutrient management in field crops.

Table 3: Effect of NPK and organic manures on soil physical properties at 0–15 cm depth (post-harvest)

Treatment	Bulk density (Mg m ⁻³)	Particle density (Mg m ⁻³)	Pore space (%)
T ₁ – Control	1.26	2.36	45.03
T ₂ – 100% RDF	1.27	2.37	45.33
T ₃ – RDF+PM 5 t	1.23	2.33	46.82
T ₄ – RDF+PM 10 t	1.20	2.31	47.43
T ₅ – RDF+PM 15 t	1.18	2.30	48.80
T ₆ – RDF+CWC 5 t	1.24	2.34	46.96
T ₇ – RDF+CWC 10 t	1.21	2.31	46.89
T ₈ – RDF+CWC 15 t	1.19	2.29	47.67
CD (5%)	0.0072	0.033	1.61

3.2 Soil chemical properties

Soil reaction stayed close to neutral in every treatment, with the

control showing the highest pH (7.23) and RDF + CWC @ 15 t ha⁻¹ the lowest (7.08) at 0–15 cm — a small but statistically significant spread attributable to organic-acid release and nitrification during manure decomposition, well within the buffering capacity of the alluvial soil. Electrical conductivity likewise varied only slightly (0.372–0.414 dS m⁻¹) and never approached saline levels, indicating that repeated organic amendment did not risk salt build-up. Organic carbon, by contrast, responded strongly and positively: it rose from 0.412% in the control to 0.475% under RDF + PM @ 15 t ha⁻¹, reflecting direct organic-matter addition together with reduced decomposition losses under improved soil structure. The availability of all three major nutrients increased significantly with integrated nutrient management (Table 4). Available nitrogen was highest under RDF + CWC @ 15 t ha⁻¹ (282.3 kg ha⁻¹) against 208.7 kg ha⁻¹ in the control; available phosphorus and potassium were both highest under RDF + PM @ 15 t ha⁻¹ (26.3 and 235.8 kg ha⁻¹ respectively) against 18.7 and 190.3 kg ha⁻¹ in the control. The gradual mineralisation of organic manures, reduced leaching and volatilisation losses, and organic-acid-mediated release of fixed phosphorus and non-exchangeable potassium together explain this improved nutrient status, which in turn provided the physiological basis for the superior growth and yield recorded under these treatments.

Table 4: Effect of NPK and organic manures on soil chemical properties at 0–15 cm depth (post-harvest)

Treatment	pH	EC (dS m ⁻¹)	OC (%)	N (kg ha ⁻¹)	P (kg ha ⁻¹)	K (kg ha ⁻¹)
T ₁ – Control	7.23	0.372	0.412	208.73	18.70	190.32
T ₂ – 100% RDF	7.14	0.382	0.432	246.45	22.49	217.52
T ₃ – RDF+PM 5 t	7.15	0.406	0.454	252.62	23.46	224.03
T ₄ – RDF+PM 10 t	7.17	0.408	0.467	259.52	25.00	231.96
T ₅ – RDF+PM 15 t	7.20	0.412	0.475	273.25	26.34	235.78
T ₆ – RDF+CWC 5 t	7.14	0.408	0.445	269.69	22.93	219.86
T ₇ – RDF+CWC 10 t	7.12	0.411	0.454	276.26	24.25	227.12
T ₈ – RDF+CWC 15 t	7.08	0.414	0.468	282.25	25.12	234.76
CD (5%)	0.092	0.018	0.036	12.51	1.37	10.85

3.3 Vegetative growth

Plant height, branch number and leaf number all increased steadily from 30 to 90 DAS across treatments, and integrated nutrient management outperformed both the control and RDF alone at every stage (Table 5). Differences among treatments were modest at 30 DAS, when the crop still drew mainly on native soil fertility and basally applied fertiliser, but widened by 60–90 DAS as the organic sources continued to mineralise and supply nutrients. RDF + CWC @ 10 t ha⁻¹ produced the tallest plants at 90 DAS (28.70 cm) and the most branches (7.63), while RDF + CWC @ 15 t ha⁻¹ and RDF + PM @ 10 t ha⁻¹ produced the greatest leaf numbers; the control lagged behind on every parameter. Better nitrogen supply supported chlorophyll synthesis and canopy expansion, phosphorus favoured root proliferation and early establishment, and potassium supported efficient translocation, while the physical improvements described above (lower bulk density, higher porosity) allowed roots to exploit a larger soil volume — together accounting for the more vigorous canopy development under integrated treatments. Notably, the tallest and most heavily branched treatments were not always the highest-yielding ones, foreshadowing the yield results discussed next: vegetative vigour alone is not sufficient for maximum tuber production.

Table 5: Effect of NPK and organic manures on growth parameters at 90 DAS

Treatment	Plant height (cm)	Branches plant ⁻¹	Leaves plant ⁻¹
T ₁ – Control	24.70	5.97	20.16
T ₂ – 100% RDF	21.40	6.25	25.20
T ₃ – RDF+PM 5 t	28.50	6.15	30.23
T ₄ – RDF+PM 10 t	23.00	6.77	28.21
T ₅ – RDF+PM 15 t	27.30	7.42	30.62
T ₆ – RDF+CWC 5 t	20.60	6.91	29.47
T ₇ – RDF+CWC 10 t	28.70	7.63	31.72
T ₈ – RDF+CWC 15 t	23.90	7.23	27.35
CD (5%)	2.51	0.36	2.81

3.4 Yield attributes and tuber yield

Tuber number per plant and total tuber yield both responded strongly and significantly to integrated nutrient management (Table 6). RDF + PM @ 15 t ha⁻¹ gave the highest values for both — 12.52 tubers plant⁻¹ and 36.30 t ha⁻¹ — a yield gain of about 37.5% over the control (26.40 t ha⁻¹) and 31.5% over RDF alone (27.60 t ha⁻¹); RDF + CWC @ 15 t ha⁻¹ was the next-best treatment (34.90 t ha⁻¹). The yield advantage under T₅ reflects the cumulative effect of the improvements documented above: lower bulk density and greater pore space favoured root and stolon

proliferation, higher organic carbon and nutrient availability sustained metabolic activity through the season, and the resulting larger, longer-lived canopy generated more assimilate for translocation to the tubers. As with plant height, the treatment with the tallest canopy was not the highest yielder, underlining that efficient partitioning of assimilate toward tuber bulking — rather than vegetative size alone — determines final productivity under integrated nutrient management.

Table 6: Effect of NPK and organic manures on yield attributes

Treatment	Tubers plant ⁻¹	Tuber yield (t ha ⁻¹)
T ₁ – Control	8.24	26.40
T ₂ – 100% RDF	8.63	27.60
T ₃ – RDF+PM 5 t	9.75	29.45
T ₄ – RDF+PM 10 t	10.36	30.90
T ₅ – RDF+PM 15 t	12.52	36.30
T ₆ – RDF+CWC 5 t	9.50	28.70
T ₇ – RDF+CWC 10 t	10.14	30.45
T ₈ – RDF+CWC 15 t	12.05	34.90
CD (5%)	1.25	1.61

Table 7: Economics of potato cultivation under different treatments

Treatment	Cost of cultivation (₹ ha ⁻¹)	Yield (t ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio
T ₁ – Control	130,950	26.40	3,16,800	1,85,850	1.41
T ₂ – 100% RDF	141,167	27.60	3,31,200	1,90,033	1.34
T ₃ – RDF+PM 5 t	166,167	29.45	3,53,400	1,87,233	1.12
T ₄ – RDF+PM 10 t	191,167	30.90	3,70,800	1,79,633	0.93
T ₅ – RDF+PM 15 t	216,167	36.30	4,35,600	2,19,433	1.01
T ₆ – RDF+CWC 5 t	156,167	28.70	3,44,400	1,88,233	1.20
T ₇ – RDF+CWC 10 t	171,167	30.45	3,65,400	1,94,233	1.13
T ₈ – RDF+CWC 15 t	186,167	34.90	4,18,800	2,32,633	1.24

4. Conclusion

Under the sandy loam alluvial soils and Rabi-season conditions of Prayagraj, integrating recommended NPK fertiliser with poultry manure or city waste compost improved soil physical structure (lower bulk density, higher porosity), raised organic carbon and the post-harvest availability of nitrogen, phosphorus and potassium, and enhanced vegetative growth and tuber yield of potato cv. Kufri Badshah relative to an unfertilised control or to mineral fertiliser used alone, without adverse effects on soil pH or salinity. RDF combined with poultry manure at 15 t ha⁻¹ gave the best overall performance — the lowest bulk density, the highest organic carbon and available phosphorus, the highest tuber yield (36.30 t ha⁻¹) and the highest gross return — while RDF with city waste compost at 15 t ha⁻¹ was the most profitable option on a net-return basis. These findings support integrated nutrient management, and RDF + poultry manure @ 15 t ha⁻¹ in particular, as a productive and economically sound practice for potato cultivation in this agro-climatic zone; because the results derive from a single season and site, multi-season and multi-location confirmation would strengthen the recommendation before wider extension.

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