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Effect of different NPK fertilizers on growth, yield and quality of rabi onion (*Allium cepa* L.)

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ABSTRACT

A field experiment was conducted during rabi 2025–26 at the Horticulture Research cum Instructional Farm, Department of Vegetable Science, IGKV, Raipur (C.G.), to work out how graded fertility levels shape the growth, yield and bulb quality of onion cv. Nasik Red. Eight treatments – T_1 : 0:0:0 (control), T_2 : 100:60:80 (RDF), T_3 : 120:60:80, T_4 : 140:60:80, T_5 : 140:80:80, T_6 : 140:80:100, T_7 : 160:80:80 and T_8 : 160:80:100 kg N:P₂O₅:K₂O ha⁻¹ – were laid out in a Randomized Block Design with three replications. Every growth and yield attribute measured – plant height, leaf number, neck length and thickness, bulb diameter, weight, volume, grading and marketable/total yield – responded significantly to fertility level and peaked around T_6 (140:80:100 kg NPK ha⁻¹), which produced the tallest canopy by 90 DAT along with T_7 , the heaviest bulb (72.95 g), the largest share of Grade A produce (58.30%) and the highest marketable (199.04 q ha⁻¹) and total yield (203.97 q ha⁻¹). By contrast, total soluble solids (9.33–9.77 °Brix) and ascorbic acid (5.11–5.68 mg 100 g⁻¹) were statistically unaffected by fertilizer dose, indicating that quality in this trial was set by factors other than NPK supply. These results identify 140:80:100 kg N:P₂O₅:K₂O ha⁻¹ as the fertility level that most consistently maximizes growth and marketable yield without altering bulb quality.

Keywords: Onion, *Allium cepa*, Fertility levels, NPK, Growth, Yield, Bulb quality

1. Introduction

Onion (*Allium cepa* L.) occupies a larger area in India than any other bulb vegetable, and the country's 2023–24 harvest of about 242.4 lakh tonnes made it the world's second-largest producer after China (Anon., 2024a) [1]. Within Chhattisgarh, the crop still occupies only about 22.7 thousand hectares (Anon., 2024b) [2], modest for a state whose rabi conditions otherwise suit it well. Onion carries a shallow, sparsely branched root system confined mostly to the top 30 cm of soil, so its performance depends heavily on the grower getting the level and balance of applied nutrients right rather than on soil reserves alone (Brewster, 2008) [3]. Nitrogen underpins leaf expansion and the length of the bulb-filling period, phosphorus supports early root and bulb initiation, and potassium is widely regarded as the nutrient that determines bulb firmness, size and keeping quality (Thangasamy *et al.*, 2019) [4].

A number of trials have already linked NPK dose to onion yield (Meena *et al.*, 2019; Patel *et al.*, 2023) [5, 6], but growth and quality are less often reported parameter-by-parameter from the same trial, even though a grower choosing a fertility level needs to know exactly which attributes respond, by how much, and why, rather than a single pooled verdict. Because Chhattisgarh soils of this type are characteristically nitrogen-deficient yet potassium-rich, a recommendation imported from elsewhere may not suit local conditions. The present study was accordingly framed around two linked objectives – to find out the effect of different NPK levels on the growth and yield of rabi onion, and to find out the effect of different NPK levels on the quality of rabi onion – examining each growth, yield and quality attribute individually so that the physiological basis of the response could be identified for each in turn.

2. Material and Methods**2.1 Experimental site and season**

The trial was conducted during rabi 2025–26 at the Horticulture Research cum Instructional Farm, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, located between 21°23' and 22°33' N and around 81°65' E at 298.15 m amsl, within the Chhattisgarh Plains zone of Agro-climatic Zone-7. The soil was clay loam (locally 'Kanhari'), neutral in reaction (pH 7.09), low in available nitrogen, medium in available phosphorus and organic carbon, and high in available potassium.

2.2 Treatments and design

Eight fertility levels were evaluated in a Randomized Block Design with three replications: T_1 : 0:0:0 (absolute control), T_2 : 100:60:80 (recommended dose of fertilizer, RDF), T_3 : 120:60:80, T_4 : 140:60:80, T_5 : 140:80:80, T_6 : 140:80:100, T_7 : 160:80:80 and T_8 : 160:80:100 kg N:P₂O₅:K₂O ha⁻¹, supplied as urea, di-am

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monium phosphate and muriate of potash. Phosphorus and potassium were applied in full at planting; nitrogen was split, half at basal and the remainder in two equal top-dressings at 30 and 45–50 days after transplanting (DAT). Forty- to forty-five-day-old seedlings of cv. Nasik Red were transplanted on 16 December 2025 at 15 × 10 cm spacing in plots of 2 × 2.25 m, and the crop was harvested on 6 April 2026 (114-day duration).

2.3 Observations

Plant height and leaf number were recorded on five tagged plants per plot at 30, 60 and 90 DAT. At harvest, neck length and thickness were measured on five randomly drawn bulbs per plot with a digital vernier caliper, and days to maturity were counted from transplanting to the stage at which about half the plants in a plot had shown natural neck fall. Equatorial and polar diameter, average bulb weight, bulb volume (water displacement) and bulb dry matter (oven-dried at 65 ± 2 °C) were likewise recorded on five bulbs per plot. Bulbs were graded by equatorial diameter into Grade A (> 4.5 cm), Grade B (3.5–4.5 cm) and Grade C (2.5–3.5 cm), undersized (< 2.5 cm), bolted, double and rotten bulbs were weighed separately; marketable yield combined Grades A–C and total yield added the unmarketable fraction. Total soluble solids were read on an ERMA hand refractometer (°Brix) and ascorbic acid was estimated by titration against 2,6-dichlorophenol indophenol dye (mg per 100 g fresh weight). Data were analysed by ANOVA following Panse *et al.* (1967) [7], with treatment means compared by critical difference (CD) at $p = 0.05$.

3. Result and Discussion

3.1 Growth parameters

3.1.1 Plant height (cm)

Plant height increased significantly with fertility level at every stage of growth. At 90 DAT it ranged from 44.95 cm under the unfertilized control (T_1) to a maximum of 63.75 cm under T_7 , with T_8 (62.21 cm) and T_6 (59.17 cm) close behind (Table 1). Nitrogen is a constituent of chlorophyll, amino acids and nucleic acids, and its ready availability under the higher doses would have accelerated cell division and cell

elongation in the intercalary meristem of the pseudostem, translating into taller plants; adequate phosphorus and potassium further support this by sustaining root activity and turgor-driven cell expansion. Similar height gains with increasing NPK have been reported by Meena *et al.* (2019) [5] and Kumar *et al.* (2021).

3.1.2 Number of leaves per plant

Leaf number followed a closely related but not identical trend, peaking under T_6 (10.03 leaves plant⁻¹) rather than under the highest-nitrogen treatments T_7 (9.80) and T_8 (9.87), against a minimum of 5.80 under T_1 . Leaf initiation depends on the rate of primordia differentiation at the shoot apex, which is promoted by nitrogen and phosphorus together; once nitrogen supply exceeds what phosphorus and potassium can support in balanced proportion, as in T_7/T_8 , the crop appears to favour elongation of existing leaves over initiation of new ones, so leaf number plateaus slightly ahead of plant height. A comparable pattern of nutrient-balance-dependent leaf production was reported by Patel *et al.* (2023) [6].

3.1.3 Neck length and neck thickness (cm)

Neck length and thickness at harvest were both maximum under T_6 (4.23 and 1.86 cm, respectively) and minimum under T_1 (2.03 and 1.07 cm). Neck dimensions are governed largely by the vascular and parenchymatous tissue that later collapses during curing; higher potassium availability under T_6 is known to strengthen cell walls and regulate the water relations of this tissue, producing a firmer, thicker neck that only later shows the characteristic collapse (neck fall) associated with maturity.

3.1.4 Days to maturity

Days to maturity increased steadily with fertility level, from 107.6 days under T_1 to 115.1 days under T_8 . Continued nitrogen availability, especially the split top-dressings at 30 and 45–50 DAT, keeps the foliage photosynthetically active and delays the onset of leaf senescence and neck fall that mark physiological maturity; the same nitrogen-linked delay in maturity has been reported by Muluneh *et al.* (2024) [8] and Borse *et al.* (2015) [9].

Table 1. Growth attributes of rabi onion at 90 DAT / harvest as affected by fertility levels

Treatment	N:P ₂ O ₅ :K ₂ O (kg/ha)	Plant height 90 DAT (cm)	Leaves per plant (no.)	Neck length (cm)	Neck thickness (cm)	Days to maturity
T_1	0:0:0 (Control)	44.95	5.8	2.03	1.07	107.6
T_2	100:60:80 (RDF)	51.42	6.4	3.17	1.15	109.13
T_3	120:60:80	54.03	7	3.37	1.27	108.8
T_4	140:60:80	56.91	7.6	3.77	1.36	112.87
T_5	140:80:80	57.03	8.4	3.73	1.75	111.1
T_6	140:80:100	59.17	10.03	4.23	1.86	111.87
T_7	160:80:80	63.75	9.8	3.83	1.9	113.73
T_8	160:80:100	62.21	9.87	4.13	2.03	115.13
$SEm_{\pm}$	–	2.73	0.25	0.28	0.11	1.52
CD ($p = 0.05$)	–	8.29	0.76	0.86	0.33	NS

3.2 Yield parameters

3.2.1 Equatorial and polar diameter of bulb (mm)

Equatorial diameter increased from 37.83 mm under T_1 to a maximum of 48.75 mm under T_6 , while polar diameter followed the same order, rising from 33.07 to 45.94 mm. Bulb enlargement in onion proceeds through swelling of the fleshy storage-leaf bases, a process driven by cell expansion under adequate potassium-mediated turgor pressure and by the photosynthate supply made available through greater leaf area under higher nitrogen; the combined effect of the two nutrients acting together, rather than either alone, likely explains why

diameter peaked at the balanced T_6 dose rather than at the highest-nitrogen treatments, consistent with Bhardwaj *et al.* (2024) [10].

3.2.2 Average bulb weight (g) and bulb volume (mL)

Average bulb weight rose from 54.58 g under T_1 to 72.95 g under T_6 , and bulb volume from 179.67 to 223.67 mL over the same range. Bulb weight and volume are direct outcomes of dry-matter partitioning into the storage leaves; since photosynthate supply, not sink capacity, is usually limiting in onion, the larger leaf area and longer vegetative duration recorded under T_6 (Section 3.1) would have supplied more assimilate to the developing bulb over a longer filling period, in agreement with Singh *et al.* (2025) [11].

3.2.3 Grading of bulbs (%)

The proportion of Grade A bulbs rose from 36.86% under T_1 to 58.30% under T_6 , while the combined share of undersized, bolted, double and rotten bulbs fell from 7.04% under T_1 to its lowest point, 4.44%, under the same treatment. Since grading is based directly on equatorial diameter, the larger average bulb size under T_6 mechanically shifts more of the crop into the Grade A bracket; the parallel decline in defective bulbs suggests that balanced NPK nutrition also reduces the physiological stress – particularly potassium deficiency, which is linked to bolting and double centres – that produces such defects, a pattern also noted by Wabalepatil *et al.* (2023) [12] and Faldu *et al.* (2023) [13].

3.2.4 Marketable, unmarketable and total bulb yield ($q\ ha^{-1}$)

Marketable yield rose from 104.89 $q\ ha^{-1}$ under T_1 to a maximum of 199.04 $q\ ha^{-1}$ under T_6 , and total yield from 110.18 to 203.97 $q\ ha^{-1}$ over the same range, with T_6 statistically on par with T_5 , T_7 and T_8 . Unmarketable yield, in contrast, stayed low and fairly flat across treatments (4.29–6.35 $q\ ha^{-1}$), showing no consistent trend with fertility level. Because marketable yield is the arithmetic product of bulb weight, grading outcome and plant population, it necessarily inherits the gains already described for bulb size and grading; that yield essentially plateaued from T_6 onward, despite T_7 and T_8 carrying 20 $kg\ ha^{-1}$ more nitrogen, indicates the crop's response to added fertilizer had already saturated by this dose – additional nitrogen beyond T_6 appears to have been only partially converted into extra bulb bulk, a ceiling effect also observed by Gour *et al.* (2023) and Kaur *et al.* (2023) [14].

Table 2. Bulb dimensions, grading and yield of rabi onion as affected by fertility levels

Treatment	Equat. diam. (mm)	Polar diam. (mm)	Avg. bulb wt. (g)	Bulb volume (mL)	Grade A (%)	Marketable yield (q/ha)	Total yield (q/ha)
T_1	37.83	33.07	54.58	179.67	36.86	104.89	110.18
T_2	42.37	38.75	60.55	200	47.53	171.16	177.51
T_3	43.38	40.02	63.38	183.67	50.53	183.01	189
T_4	45.07	41.84	65.69	212	53.4	192.89	197.37
T_5	46.35	43.2	67.91	219	55.37	197.26	201.55
T_6	48.75	45.94	72.95	223.67	58.3	199.04	203.97
T_7	46.58	44.25	69.4	221.33	57.17	195.7	199.32
T_8	44.94	41.98	70.7	219.33	53.43	193.11	198.23
$SEm_{\pm}$	1.94	1.6	2.45	8.32	1.79	5.69	6.01
CD ($p = 0.05$)	5.87	4.86	7.42	25.22	5.42	17.26	18.24

3.3 Quality parameters

3.3.1 Total soluble solids ($^{\circ}Brix$)

TSS varied narrowly between 9.33 $^{\circ}Brix$ (T_4) and 9.77 $^{\circ}Brix$ (T_8), with no significant difference among treatments. TSS in onion bulbs is contributed mainly by sugars accumulated through photosynthesis and by sulphur-containing flavour compounds, both of which are more closely tied to genotype, irradiance and curing conditions than to the range of NPK levels tested here; the absence of a fertility effect on TSS in this trial matches the findings of Selvaprabu *et al.* (2024) [15].

3.3.2 Ascorbic acid content ($mg\ 100\ g^{-1}$)

Ascorbic acid content ranged from 5.11 $mg\ 100\ g^{-1}$ (T_8) to 5.68 $mg\ 100\ g^{-1}$ (T_2), again without significant differences among treatments. Ascorbic acid synthesis in onion is regulated primarily through the hexose-sugar pathway and is strongly influenced by light intensity during bulb development rather than by soil nitrogen, phosphorus or potassium status directly, which is consistent with the non-significant response recorded here and with the similar finding of Tiwari *et al.* (2024).

Table 3. TSS and ascorbic acid content of rabi onion bulbs as affected by fertility levels

Treatment	N:P ₂ O ₅ :K ₂ O (kg/ha)	TSS ($^{\circ}Brix$)	Ascorbic acid (mg/100 g)
T_1	0:0:0 (Control)	9.63	5.29
T_2	100:60:80 (RDF)	9.57	5.68
T_3	120:60:80	9.4	5.15
T_4	140:60:80	9.33	5.54
T_5	140:80:80	9.47	5.4
T_6	140:80:100	9.53	5.26
T_7	160:80:80	9.6	5.43
T_8	160:80:100	9.77	5.11
$SEm_{\pm}$	–	0.22	0.12
CD ($p = 0.05$)	–	NS	NS

4. Conclusion

Considered parameter by parameter, fertility level acted on rabi onion cv. Nasik Red through a coherent physiological chain: nitrogen-driven vegetative growth (height, leaf number) built the leaf area that supplied assimilate for neck, bulb and yield development, while potas-

sium reinforced cell turgor and tissue strength across the neck and bulb; both effects converged on T_6 (140:80:100 $kg\ N:P_2O_5:K_2O\ ha^{-1}$), which returned the best or near-best value for almost every growth and yield attribute measured, with T_7/T_8 adding cost without a matching gain. Bulb quality – TSS and ascorbic acid – was governed by factors outside this nutrient window and remained unaffected

throughout. A fertility level of 140:80:100 kg N:P₂O₅:K₂O ha⁻¹ is therefore recommended for maximizing the growth and yield of rabi onion in the Chhattisgarh plains, with multi-location and multi-season confirmation advisable before wider recommendation to farmers.

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