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Optimizing NPKS dosages for better morphological and yield traits of onion (*Allium cepa*) in *rabi* season in Jharkhand

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Abstract

The experiment was conducted to evaluate the impact of varying NPKS dosages on morphological characteristics, quality and yield of onion (*Allium cepa* L.) cv. Pusa Madhavi during *rabi* season of 2024-2025 under agroclimatic conditions of Hazaribagh, Jharkhand. Randomized block design with nine treatments with variable dosages of NPKS, replicated six times was used. Analysis of variance revealed significant differences across treatment combinations. Application of N:P:K:S @ 140:112:112:56 kg/ha (T_5) recorded the maximum number of leaves and plant height \60 days after transplanting, number of scales/ bulb, total soluble solids and neck thickness of the bulbs at harvesting. The treatment also produced the maximum weight for ten bulbs which was found statistically at par with application of N:P:K:S @ 130:104:104:52 kg/ha (T_4). Moreover, highest total yield/ plot was recorded in T_4, followed by T_5, while the lowest yield was observed in T_9. The increasing levels of NPKS dosages promotes vegetative growth and bulb weight. However, T_4 resulted in the highest yield/ plot with a comparatively lower fertilizer dosage than T_5, making it potentially superior for maximizing growth and productivity of onion in Jharkhand.

Key words: Chotanagpur Plateau, Morphology, Nutrient Management, Quality, Yield.

Onion (*Allium cepa* L.) is one of the most important bulb crops cultivated in India. It belongs to the family Alliaceae, with a somatic chromosome number of 2n=2x=16 (Bal and Pal, 2020; Pal *et al.,* 2026). In India, Maharashtra, Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu, Punjab, Haryana, Rajasthan, Uttar Pradesh, Bihar and West Bengal are the main onion-producing states (Tripathi *et al.,* 2017). It is cultivated in four different seasons, early-*kharif, kharif,* late-*kharif* and *rabi*. *Rabi* season onion is main crop as it can be stored for a longer period with proper storage facilities and has comparatively more area under cultivation. In India, it is grown in 1.54 million ha area with a production of 24.267 million tonnes and average productivity of productivity 15.76 tonnes/ha. While, in Jharkhand, it covers an area of 18.56 thousand ha with a production of 307.25 thousand tons, resulting in an average productivity of 16.55 tonnes/ ha (MA&FW, 2024). Thus, it is evident that though onion is grown in a relatively less area, its productivity in Jharkhand marginally supersedes that of national productivity, predominantly due to adoption of *kharif* onion in some districts, leading to better yield realization per unit area. However, small and marginal farmers grow *rabi* onion without application of recommended dosage of fertilizers, leading to poor productivity and quality. Other factors contributing to the low production are undulating topography, stony soil profile, poor water-holding capacity, lack of irrigation facility. A good agricultural practice, along with proper nutrient management, can boost the productivity as well as area expansion of *rabi* onion in Jharkhand as well as in the other parts of the Chotanagpur plateau region. Application of recommended dosage of fertilizers also results into thinner neck, reduces sprouting and thereby increases storage life of bulbs. Although, a common dose of NPKS of 100:80:80:40 kg/ha exists for *rabi* onion (Thamburaj and Singh, 2014), however, the recommended dosage varies across soil types and its inherent fertility status. Keeping these facts in mind, the experiment was conducted to standardize the recommended fertilizer dosage for *rabi* onion.

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MATERIALS AND METHODS

The field experiment was conducted at ICAR-Indian Agricultural Research Institute, Hazaribagh, Jharkhand, during *rabi* season of 2024-2025. The experimental site is located in the Chotanagpur Plateau region at 24.2851°N latitude, 85.3600°E longitude at approximately 387.51 meters above mean sea level. The soil of experimental plot had a pH of 5.27 and EC of 0.035 ds/m. The available NPK of experimental plot was approximately 124.38, 14.48 and 120.50 kg/ ha, respectively. The experiment was laid down in a randomized block design with nine treatments (with variable dosage of N:P:K:S, replicated six times with each plot size of 1.0 m ×1.5 m. The details of treatment combinations evaluated have been presented in Table 1. The calculated dosage of nitrogen, phosphorus, potassium and sulphur was applied in the form of urea, single super phosphate, muriate of potash and wettable

Table 1: Variable dosage of NPKS evaluated

Treatment	N:P:K:S dosage (kg/ ha)				N:P:K:S dosage (g/ 1.5 m2)				Urea, SSP, MOP and wettable sulphur (80%WP) (g/ 1.5 m2)			
	N	P	K	S	N	P	K	S	Urea	SSP	MOP	Sulphur
T_1	100	80	80	40	15.00	12.00	12.00	6.00	33.00	75.00	19.20	7.50
T_2	110	88	88	44	16.50	13.20	13.20	6.60	36.30	82.50	21.12	8.25
T_3	120	96	96	48	18.00	14.40	14.40	7.20	39.60	90.00	23.04	9.00
T_4	130	104	104	52	19.50	15.60	15.60	7.80	42.90	97.50	24.96	9.75
T_5	140	112	112	56	21.00	16.80	16.80	8.40	46.20	105.00	26.88	10.50
T_6	90	72	72	36	13.50	10.80	10.80	5.40	29.70	67.50	17.28	6.75
T_7	80	64	64	32	12.00	9.60	9.60	4.80	26.40	60.00	15.36	6.00
T_8	70	56	56	28	10.50	8.40	8.40	4.20	23.10	52.50	13.44	5.25
T_9	60	48	48	24	9.00	7.20	7.20	3.60	19.80	45.00	11.52	4.50

sulphur (80%WP). Onion, variety Pusa Madhavi was used. The 45 days old seedlings were transplanted to main plots by maintaining a spacing of 15 cm between rows and 10 cm between plants, accommodating 100 plants in each plot. The half amount urea along with the entire quantity of SSP, MOP and elemental Sulphur was applied as the basal dose to each plot before transplanting. The remaining half amount of nitrogen was applied 26 days after transplanting. The plots were irrigated immediately after transplanting as well as when required to maintain sufficient moisture conditions to enable proper growth and development. Two hand weeding and hoeing were carried out, first at 25 days after transplanting and the other at 50 days after transplanting. After attaining more than 70% neck fall, bulbs were harvested. Recommended cultural practices were adopted for raising a healthy crop stand (Thamburaj and Singh 2014; Tripathi and Lawande 2019).

The plant height at 60 days after transplanting (DAT) was measured from the base of the plant to tip of the longest leaves using a measuring scale and number of leaves were counted simultaneously. At the time of harvesting, number of marketable bulbs were counted/ plot by discarding the undesired bulbs and yield/ plot was recorded. The bulbs were shifted to shade after six days of field curing following wind-row method. The neck thickness was measured using a digital vernier caliper 7 days after harvest. The bulbs were cut longitudinally into two halves and number of scales/ bulb were counted. The half-cut pieces were then crushed using a mortar and pestle to extract the juice for the estimation of total soluble solids and was expressed in °Brix, using a hand-held refractometer at room temperature. Ten bulbs were randomly selected from each plot for calculating average weight of ten bulbs. The data were analyzed using KAU Grapes Software Packages (Gopinath *et al.* 2021) at 5% level of significance.

RESULTS AND DISCUSSION

The analysis of variance depicted significant differences across the treatment combinations. The number of leaves/ plant at 60 days after transplanting (DAT) ranged from 10.667 in (T_9) to 12.302 (T_5) (Table 2). The performance of the other treatments, *viz.* T_1, T_2, T_3, T_6, T_7 and T_8 were found statistically similar to each other, while performance of T_5 was statistically superior to other treatments. The overall mean for this trait was recorded as 11.14. The number of leaves/ plant is a key determinant for yield of onion as it directly influences the photosynthesis. Generally, nitrogen promotes vegetative growth in plants. It was overserved that increasing levels of nitrogen increased the vegetative growth manifested in terms of number of leaves at 60 DAT. Previously, a similar increase in number of leaves/ plant was observed in onion by Vani *et al.* (2018) and Dhakad *et al.* (2019); Gour *et al.* (2023); Wabalepatil *et al.* (2023); Kumar *et al.* (2024) and Prakash *et al.* (2024).

Significant differences were also observed for plant height at 60 DAT in all treatment combinations. The mean plant height was 50.81 cm, with a maximum of 63.413 cm in T_5 and a minimum of 40.505 cm in T_9 (Table 2). The performance of T_9 was found statistically inferior among all other combinations, whereas T_5 was statistically superior over others. Thus, results indicated that variable application of macronutrients like NPKS significantly alters vegetative growth of onion plants. A consistent supply of a relatively higher quantity of nutrients promotes more plant height in onion. The plant height showed increasing trend with increase in application of the dosage of nitrogen, phosphorus, potassium and sulphur. Kumar *et al.* (2019) also found greater plant height in onion both at 45 and 90 DAT with application of 125 kg nitrogen and 50 kg each of phosphorus and potassium/ ha and by Gour *et al.* (2023) by application of 120:60:80:40 kg/ ha.

Significant differences were also observed for number of marketable bulbs/ plot. It was maximum in treatment T_6 (96.33 g), whereas treatment T_1 (control) was the lowest performing among all combinations (Table 2). The treatment combinations T_4, T_5, T_7, T_8 and T_9 were statistically at par with treatment T_6. The overall mean across the treatment combinations for this trait was recorded as 93.41 g. The coefficient of variation for this trait, *i.e.* 3.342% suggests good experimental precision with low variability among treatment combinations. The number of bulbs/ plot is another important determinant to maximize the return in onion production. Increase in marketable bulb yield was also observed by Dhakad *et al.* (2019) by applying 125:50:50 kg of chemical NPK fertilizers along with 20 tonnes of FYM/ ha over the other treatments comprising either similar or less dosage of NPK applied through organic inputs.

The highest neck thickness (14.892 mm) was observed in treatment T_5, which was statistically superior to lowest-performing treatment, T_9 (11.75 mm) (Table 2). The neck thickness in treatment T_4 (14.483 mm) was statistically at par with that of T_5, indicating no statistical difference between these treatments. The performance of T_3 showed intermediate neck thickness (13.557 mm), whereas T_1, T_2, T_6, T_7 and T_8 statistically inferior to highest performing treatment T_5. The performance of treatment T_9 was least in magnitude (11.795 mm) among all treatment combinations. The thickness of the neck at the time of harvest depends primarily on number of leaves/ plant and thickness of the leaves at harvest. A low to moderate neck thickness is generally desired as in minimizes moisture loss and prevents entry of pathogenic microorganisms, leading to longer post-harvest life. However, with increasing levels of nitrogen application, neck thickness increases correspondingly with increase in the leaf thickness and number of leaves/ plant. In our study, a similar trend was observed for this trait. The maximum neck thickness observed in T_5 seems primarily due to application of higher quantity of nitrogen over other treatments. These findings are in accordance with that of Dhakad *et al.* (2018), Kumar *et al.* (2024) and Swain *et al.* (2025).

The number of scales/ bulb ranged from 9.028 to 13.25, with an overall mean value of 10.67 (Table 3). The highest number of scales/ bulb was recorded in T_5, which was statistically superior over the other treatments. The treatment T_9 had the least number of scales/ bulb. It is evident from the data that, the number of scales/ bulb gradually increased with increase in fertilizer dosage from the RDF, while it decreased gradually with reduction in fertilizer dosage. Gour *et al.* (2023) recorded a similar trend. Kumar *et al.* (2024) recoded maximum number of scales/ bulb when onion crop was applied with 75% NPK of recommended dosage along with 25% FYM.

The total soluble solid content showed significant variations across treatment combinations with variable dosage of NPKS. The magnitude of TSS ranged from 9.778° Brix to 12.500° Brix, with an overall mean value of 11.24° Brix (Table 3). The treatment, T_5, showed maximum TSS value of 12.500° Brix, followed by 12.383° brix in T_4. A gradual decreasing trend of TSS was observed among treatment combinations T_3, T_2, T_1, T_6, T_7, T_8 and T_9 along with decrease in applied NPKS

Table 2: Effects of variable dosage of NPKS on plant morphological traits

Treatment	Traits observed#			
	No. of leaves at 60 DAT	Plant height (cm) at 60 DAT	No of marketable bulbs/ plot (g)	Neck thickness (mm)
T_1 (N:P:K:S @ 100:80:80:40 kg/ ha)	11.023c	48.733e	89.333c	12.907cd
T_2 (N:P:K:S @ 110:88:88:44 kg/ ha)	11.080c	51.448d	92.333bc	13.010cd
T_3 (N:P:K:S @ 120:96:96:48 kg/ ha)	11.123c	54.603c	91.667bc	13.557bc
T_4 (N:P:K:S @ 130:104:104:52 kg/ ha)	11.708b	57.548b	94.667ab	14.483ab
T_5 (N:P:K:S @ 140:112:112:56 kg/ ha)	12.302a	63.413a	93.500ab	14.892a
T_6 (N:P:K:S @ 90:72:72:36 kg/ ha)	10.855c	49.978de	96.333a	12.698cd
T_7 (N:P:K:S @ 80:64:64:32 kg/ ha)	10.843c	46.943f	94.500ab	12.833cd
T_8 (N:P:K:S @ 70:56:56:28 kg/ ha)	10.738c	44.090g	94.000ab	12.330cd
T_9 (N:P:K:S @ 60:48:48:24 kg/ ha)	10.667c	40.505h	93.833ab	11.795d
Overall Mean	11.14	50.81	93.41	13.16
S.E. (m) ±	0.172	0.608	1.274	0.449
C.D. ($P \leq 0.05$)	0.491	1.739	3.64	1.282
C.V. (%)	3.772	2.933	3.342	8.345

#Values followed by different letters indicate significant ($p \leq 0.05$) differences

Table 3: Effect of variable dosage of NPKS on bulb yield and quality traits

Treatment	Traits observed#				
	No of scales per bulb	TSS (°Brix)	Weight of 10 bulbs (g)	Yield (kg/plot)	Yield (tonnes/ha)
T_1 (N:P:K:S @ 100:80:80:40 kg/ ha)	10.350e	11.233d	620.000d	4.207d	28.043d
T_2 (N:P:K:S @ 110:88:88:44 kg/ ha)	10.992d	11.617c	700.000c	4.580c	30.533c
T_3 (N:P:K:S @ 120:96:96:48 kg/ ha)	11.575c	11.967b	750.167b	4.787c	31.912c
T_4 (N:P:K:S @ 130:104:104:52 kg/ ha)	12.317b	12.383a	839.167a	5.598a	37.323a
T_5 (N:P:K:S @ 140:112:112:56 kg/ ha)	13.250a	12.500a	856.167a	5.212b	34.745b
T_6 (N:P:K:S @ 90:72:72:36 kg/ ha)	9.862f	11.058d	582.000e	3.762e	25.077e
T_7 (N:P:K:S @ 80:64:64:32 kg/ ha)	9.377g	10.475e	524.833f	3.488ef	23.255ef
T_8 (N:P:K:S @ 70:56:56:28 kg/ ha)	9.335g	10.177f	483.833g	3.300f	22.000f
T_9 (N:P:K:S @ 60:48:48:24 kg/ ha)	9.028g	9.778g	451.333h	2.627g	17.510g
Overall mean	10.67	11.24	645.27	4.17	27.822
S.E. (m) ±	0.152	0.064	8.277	0.102	0.678
C.D. (P≤0.05)	0.433	0.184	23.659	0.291	1.939
C.V. (%)	3.479	1.404	3.142	5.973	5.973

#Values followed by different letters indicate significant ($p \leq 0.05$) differences

dose. The TSS showed lowest coefficient of variation (%), suggesting a clear consistent effects of treatment combinations on the performance of this trait. The results of our study are in accordance with that of Brinjh *et al.* (2014), Behairy *et al.* (2015), Barman *et al.* (2023) and Getanesh *et al.* (2025).

The weight of ten bulbs ranged between 451.333 g to 856.167 g, with a mean value of 645.27 g (Table 3). The highest average bulb weight was recorded in treatment combination T_5. However, performance of T_4 was statistically at par with that of T_5. Further, these two treatment combinations (T_5 and T_4) were statistically superior to all the other treatments, indicating the influence of increasing fertilizer doses on dry matter accumulation in bulbs. The balanced supply of phosphorus and potassium helps in better energy transfer and cell expansion that ultimately led to better bulb size and bulb weight. Similarly, application of more quantity of NPKS in T_5 maximized weight of 10 random bulbs. The results are in line with that of Bhardwaj and Parashar (2024).

The highest yield/ plot (5.598 kg) was recorded with T_4 followed by T_5 (5.212 kg) (Table 3). However, lowest yield was recorded in treatment combination T_9 (2.627 kg), with an overall mean value of 4.17 kg, making them potential nutrient combinations for yield in *rabi* season where adoption of T_4 has been found to produce more yield over T_5 with comparatively lesser quantity of fertilizers. Similar performance was also observed for yield/ hectare. The results corroborate with that of Bhardwaj and Parashar (2023). The results of our study are also in accordance with that of Tesfay and Girmay (2019).

AUTHOR CONTRIBUTION

Dr. Saheb Pal conceptualized the experiment. Mr. Gourab Saha, Ms. Ananya Maji, Mr. Raj Kumar, Ms. Loino K. Chishi and Ms. Shilpa Singha conducted the experiment with assistance from Drs. Saheb Pal, Krishna Prakash and Shantesh R. Kamath. Dr. Saheb Pal wrote the manuscript. All authors have read and commented on the manuscript.

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DECLARATION

The authors declare that they do not have any conflict of interest.

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