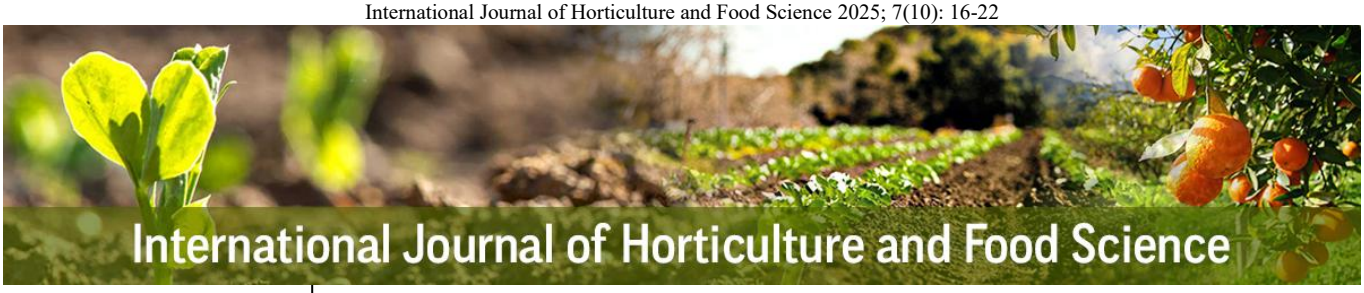

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Expression of quantitative and qualitative traits in post kharif onion (*Allium cepa* L.) grown using non-chemical amendments in Eastern Indian Plateau

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Abstract
A field trial comprising five onion varieties and three non-chemical nutrient sources was conducted at the organic experimental farm of RKMVERI, Ranchi, during post-kharif season. The experiment was conducted for two consecutive years (2022-23 and 2023-24) and was designed using a FRBD spread across 45 experimental plots [five varieties, viz., V1(Sukh Sagar), V2(Agrifound Dark Red), V3(N-53), V4(Pusa Sona), & V5(Pusa Riddhi); and three treatments, namely, T_1 (NCSN-1), T_2 (NCSN-2), & T_3 (NCSN-3) with three replications each]. Several growth, yield, and quality attributes were considered for evaluation. Results showed that growth and yield attributes of five onion varieties were significantly influenced by T_1, where Jeevamrutha was used as non-chemical amendment, but the quality-contributing traits were greatly influenced by T_2, where a biodynamic formulation (BD-501) was applied as foliar feeding. Findings also revealed that Agrifound Dark Red, N-53, and Sukh Sagar are the best- performing post-kharif onion varieties for the eastern Indian plateau.

Keywords: Onion, Jeevamrutha, BD-501, growth, yield, quality

1. Introduction
India is the global leader in onion production, with an annual production of 302.81 lakh tonnes, followed by the mainland China with 248.60 lakh tonnes [12]. Onion is an indispensable and important vegetable item that is used in every kitchen; therefore, its constant demand always remains throughout the year. It is basically grown as a rabi crop in the eastern Indian plateau after the harvesting of kharif paddy. The variety grown in the kharif season requires shorter photoperiod than rabi season crops. The day length requirement varies: for short-day varieties, it's less than 12 hours; for intermediate-day varieties, it's between 12 and 14 hours; and for long-day varieties, it's more than 14 hours for bulbing [35]. Growers of the eastern Indian plateau generally tend to grow the crop either in a very traditional manner without considering its seasonal and nutrient requirements or on a very limited commercial scale using indiscriminate application of agro-chemicals. Consequently, on one hand, there is reduced yield [41], but on the other hand, quality deteriorates [38]. In this context, non-chemical growing approaches have been prioritized to counteract yield reduction and chemical hazards. Besides, the eastern Indian plateau is home to a remarkable tribal population with a very poor economic background; therefore, non-chemical growing approaches incorporating own-farm resource-based organic and biodynamic formulations may be the most suitable production intervention for tribal growers in the region. Jeevamrutha is an organic liquid formulation made of cow dung and cow urine that is rich in plant nutrients and plant growth enhancers [30, 43]. Its efficacy on the growth and productivity of vegetables, including onions [23, 31], has been evidenced in various research findings [9, 8, 14, 17, 39]. Biodynamic farming is regarded as "above and beyond organic" [6]. The fundamental distinction between the two systems is due to the biodynamic agriculture's specific preparation [2]. Growth and yield improvement in various horticultural crops through biodynamic farming have been investigated by several researchers. For instance, higher yields have been observed in cauliflower, cabbage, gooseberry, and mango [34], better growth and yield in cumin [37], and improved onion yield [34]. Additionally, biodynamic agriculture has been shown to restore normal antioxidant production in plants, thereby increasing the nutritional value of biodynamic fruits and vegetables [15, 31].

Examples include the highest polyphenol concentration in lettuce [18], the highest total phenolic content in red beets [5], and mangoes [24]. There is a strong correlation between varieties and growing seasons on the growth, yield, and quality of onions [10]. Besides, different onion varieties respond differently to various organic nutrient sources [11, 32]. Considering the above valuable information, the present investigation was designed to evaluate the interaction effect of onion varieties under different chemical-free organic treatments during the late kharif season in the eastern Indian plateau, focusing on growth, yield, and quality-contributing traits of the crop.

Materials and Methods

The experiment was conducted at the organic experimental farm of the university, located at 23.23°N latitude and 85.23°E longitude, at Morabadi, Ranchi, Jharkhand, India. Late kharif season of the experimental site with average temperature regimes of 140-200C (minimum) and 220-270C (maximum) for 2022-23 and 2023-24 was chosen to conduct the experiment.

Details of the experiment

Three treatments [T_1 (NCSN-1) = FYM @ 10 t.ha-1 (as basal application) + Jeevamrutha @ 500 litre ha-1 thrice at 15 days interval starting 30 DAT (as soil drenching in split applications); T_2 (NCSN-2) = FYM @ 10 t.ha-1 (as basal application) + Bio-Dynamic (BD-501) @ 3% thrice at 15 days interval starting 30 DAT (as a foliar spray in split applications); T_3 (NCSN-3) = Without any organic or bio-dynamic inputs (therefore, organic by default as control)] and five varieties [V1 (Sukh Sagar), V2 (Agrifound Dark Red), V3 (N-53), V4 (Pusa Sona), & V5 (Pusa Riddhi)] with three replications were basic experimental compositions of the study. Accordingly, forty-five experimental plots of 3.0 m x 2.0 m were laid out through Factorial Randomized Block Design (FRBD) considering the crop spacing (15 cm x 10 cm). Different growth [Plant height (cm), No. of leaves. plant-1, Leaf length (cm), and Leaf area (cm2)], yield [Equatorial diameter of bulb (cm), Polar diameter of bulb (cm), Average bulb weight (g), and Bulb yield (t.ha-1)], and quality [TSS (0Brix), Total sugar (%), Reducing sugar (%), and Ascorbic acid (mg.100g-1)] contributing traits of the crop varieties were evaluated under several non-chemical sources of plant nutrients. Forty-five days old seedlings were transplanted [7] into the experimental plots. Subsequently, growth, yield, and quality attributes were recorded at 75 days after transplanting, at harvest, and immediately after harvest, respectively. Necessary crop husbandry practices, such as weeding and irrigation, were performed as needed. No severe incidences of insect-pests or diseases occurred during the experimentation period in both years.

Preparation of Jeevamrutha and BD-501

Jeevamrutha is a fermented organic liquid manure prepared by mixing cow dung, cow urine, and water in a 1:1:20 ratio, with 1 kg of molasses and 1 kg of gram flour added per 100 litres of finished product to enrich its nutrients and beneficial microbes. Adding a handful of soil, preferably from a garden, enhances microbial populations. Indigenous cow dung and urine are preferred. The mixture is stirred with a wooden ladle for 2-3 minutes, twice daily (morning and afternoon), in clockwise and anti-clockwise directions. It is ready for application after 2-3 days of fermentation, depending on the prevailing weather conditions especially the temperature.

BD-501 was prepared by filling cow horns with silica powder paste and burying them in a pit during the descending moon phase in March-April. After six months of incubation, the horns were unearthed in October-November during the ascending moon phase. The light yellowish silica powder was then extracted and stored in glass jars near a sunny window. For application, 30 g of horn silica (BD-501) was mixed with 1 litre of water to create a 3% solution for foliar feeding.

Methods adopted for measuring growth and yield parameters

Growth parameters recorded at 75 DAT: Plant height measured from ground level to the tip of the longest leaf in five tagged plants per plot, averaged and recorded in cm. The number of fully opened leaves was counted on five selected plants per plot 75 days after transplanting, then averaged and expressed as the number of leaves per plant. The leaf length of five tagged plants was measured at 75 DAT, and the average value was recorded as leaf length in cm. Leaf area was measured in five tagged plants randomly using a digital leaf area meter, and the average value was calculated and expressed in cm^2.

Yield attributes recorded at harvest: The equatorial diameter of five randomly selected onion bulbs at harvest was measured using slide calipers, and the average was calculated and expressed in cm. Similarly, the length of five randomly selected bulbs was measured between both polar ends, and the average was calculated as the polar diameter and expressed in cm. The weight of five randomly selected harvested bulbs from each plot was measured using a digital weighing machine, and the average was calculated and expressed in grams (g). The bulbs were harvested from each plot, and the total bulb weight was recorded using a digital balance. Bulb yield per hectare was calculated based on the yield per plot and expressed in tonnes per hectare (t.ha-1).

Methods used for analyzing quality traits

Following bulb quality parameters were analyzed immediately after harvest: Total soluble solids (TSS) in onion bulb samples were measured using an ERMA Hand Refractometer (0-32° Brix), with values corrected to 20°C. Total sugar content was determined by the Anthrone method and expressed as a percentage (%). Reducing sugar content was measured using Fehling's test and expressed as a percentage (%). Ascorbic acid content was determined by dye titration [20] and expressed in mg.100g-1.

Statistical methods used in the study

Data from two consecutive years of experimentation (2022-23 and 2023-24) were analyzed statistically using Analysis of Variance (ANOVA) [13]. Differences were tested for significance using Fisher and Snedecor's F-test at $P \leq 0.05$. Critical differences (CD) were determined at a 5% significance level using Fisher and Yates' table, and interpretations were drawn based on pooled mean values.

Results and Discussion

Non-chemical plant nutrient sources significantly influenced growth, yield, and quality traits in onion varieties, as

presented in the following tables and discussed below.

Growth parameters

Plant height differed significantly (P≤0.05) among treatments, varieties, and their interactions (Table 1). The highest plant height (44.00 cm) was recorded in T_1, while among varieties, V1 (39.98 cm) performed best. All varieties performed better in T_1 compared to the other two treatments, with T_3 consistently yielding the lowest plant height across all varieties. The superior performance of T_1 may be attributed to the microbial activity in Jeevamrutha, promoting growth substances and nutrient availability. Enhanced soil microbial activity likely improved soil physical properties (granulation, friability, and porosity), creating a balanced nutritional environment [22, 42]. These findings align with previous studies [11, 23].

Number of leaves per plant differed significantly ($P \leq 0.05$) among treatments, with T_1 recording the highest value (8.14). Among varieties, V1 had the maximum (6.96). However, interactions between varieties and treatments were non-significant (Table 1). These findings well matched with the previous studies [3, 16]. The highest number of leaves per plant in T_1 may be attributed to the enhanced nutrient supply from the liquid organic formulation, Jeevamrutha.

Leaf length differed significantly among treatments and varieties, but their interaction was non-significant (Table 1). T_1 recorded the highest leaf length (48.03 cm), while V2 showed the maximum (43.69 cm) among varieties. Jeevamrutha positively influenced all varieties, leading to better performance of all varieties under T_1 treatment condition.

Although leaf length is a varietal trait, certain varieties like Agrifound Dark Red (V2) excelled under favourable non-chemical nutrient supply conditions.

Leaf area differed significantly among treatments and varieties, but their interaction was non-significant (Table 1). Leaf area ranged from 34.82 to 104.03 cm² among treatments and 56.68 to 83.28 cm² among varieties. These findings align with previous studies [33].

Yield traits

Equatorial diameter of bulbs differed significantly among treatments, varieties, and their interactions (Table 2). T_1 recorded the largest diameter (5.85 cm), followed by T_2 (5.41 cm) and T_3 (4.89 cm). Among varieties, Agrifound Dark Red (V2) had the largest bulb diameter (5.76 cm). The application of Jeevamrutha likely enhanced bulb size by providing a balanced nutrient supply and growth-promoting substances [30] [43]. Its positive impact on onion growth and productivity has been previously reported [23] [31]. Polar diameter of bulbs differed significantly among treatments and varieties, but their interaction was non-significant (Table 2). T_1 recorded the highest polar diameter (5.00 cm), while among varieties, Sukh Sagar (V1) had the maximum (4.72 cm). These findings align with previous studies [1]. The superior performance under T_1 may be attributed to Jeevamrutha's potential to supply more plant-available nitrogen, consistent with reports that nitrogen fertilizers enhance polar diameter [36, 44].

Bulb weight differed significantly among treatments and varieties (Table 2). T_1 recorded the highest average bulb weight (50.29 g), followed by T_2 (40.33 g) and T_3 (25.08 g). Jeevamrutha likely enhanced bulb weight due to its superior organic nutrient supply potentiality followed by the biodynamic formulation (BD-501). While V1 (41.41 g), V2 (41.89 g), and V3 (41.66 g) showed statistically similar effects, the lower performance of V4 (35.68 g) and V5 (32.19 g) led to significant varietal differences. These findings align with previous studies on kharif-grown onions [26]. The interaction between treatments and varieties was non-significant (Table 2).

Bulb yield differed significantly among treatments and varieties, but their interaction was non-significant (Table 2). T_1 recorded the highest average bulb yield (31.78 t.ha-1), while T_3 had the lowest (15.06 t/ha). Among varieties, V2 yielded the highest (26.44 t.ha-1), followed by V3 (25.87 t.ha-1) and V1 (25.80 t.ha-1), with V5 (Pusa Riddhi) recording the lowest (19.53 t.ha-1). These results highlight Jeevamrutha's potential for enhancing non-chemical onion production in the eastern Indian plateau. The findings on onion bulb yield under organic management practices align with previous studies [4, 45].

Quality attributes

Quality contributing traits of bulbs harvested from five onion varieties as influenced by the non-chemical sources of plant nutrients are discussed below:

Total Soluble Solids (TSS) is a key quality attribute of onion, directly linked to its processing value. Treatments and varieties showed significant differences ($P \leq 0.05$), but their interaction was non-significant (Table 3). T_2 recorded the highest TSS (13.91°Brix), statistically similar to T_1 (13.07°Brix). Among varieties, V5 (Pusa Riddhi) had the highest TSS (14.13°Brix), while V1 (Sukh Sagar) recorded the lowest (11.32°Brix). The higher TSS in organically produced onions suggests their suitability for processing. Although non-significant but higher level of TSS in T_2 with all varietal interactions showed potential for enhancing TSS via biodynamic formulation (BD- 501), while T_1 interactions highlighted Jeevamrutha's role in improving TSS, likely due to enhanced nitrogen supply [27, 28]. Higher level of TSS as recorded in the present investigation align with previous studies [29, 40].

Total sugar content differed significantly among treatments and varieties as well as their interactions (Table 3). T_2 recorded the highest total sugar (6.05%), followed by T_1 (5.89%), while T_3 had the lowest (5.16%). Among varieties, Pusa Riddhi (V5) had the highest total sugar (6.38%), while N-53 (V3) recorded the lowest (4.92%). These findings align with previous research findings [25].

Reducing sugar content differed significantly among treatments and varieties, but their interaction was non-significant (Table 3). T_3 recorded the highest reducing sugar content (3.01%). Among varieties, V5 (Pusa Riddhi) had the highest reducing sugar content (3.05%). The higher levels of reducing sugars may be attributed to the immediate measurement just after the harvest as earlier findings revealed that reducing sugar content in onion bulbs decreases during storage [21]. Ascorbic acid content differed significantly among treatments and varieties (Table 3). T_2 recorded the highest content (14.59 mg.100g-1), followed by T_3 (14.00 mg.100g-1), while T_1 had the lowest (13.77 mg.100g-1). Among varieties, V1 (Sukh Sagar) recorded the highest content (14.82 mg.100g-1), followed by V5 (Pusa Riddhi) with 14.36 mg.100g-1, while V3 (N-53) had the lowest (13.48 mg.100g-1). These findings align with previous research showing that organically managed soils, with lower nitrogen availability, often result in higher ascorbic acid content in crops compared to conventionally fertilized crops [19].

Table 1: Effect of different non-chemical sources of nutrients and varieties on growth attributes of onion

Parameters	Observations were recorded at 75 DAT			
	Plant Height (cm)	No. of Leaves. Plant-1	Leaf Length (cm)	Leaf Area (cm2)
Non-chemical sources of nutrients (T)				
T_1 (NCSN-1)	44.00	8.14	48.03	104.03
T_2 (NCSN-2)	34.36	6.67	35.41	62.89
T_3 (NCSN-3)	36.47	6.16	28.48	34.82
SEm (±)	1.47	0.19	1.46	2.77
CDP≤0.05	3.54	0.45	3.51	6.65
Varieties (V)				
V1 (Sukh Sagar)	39.98	6.96	37.82	66.31
V2 (Agrifound Dark Red)	39.89	6.83	43.69	83.28
V3 (N-53)	39.76	6.85	38.85	72.90
V4 (Pusa Sona)	37.49	6.73	34.84	56.68
V5 (Pusa Riddhi)	34.93	6.71	31.34	57.06
SEm (±)	1.04	0.05	1.03	1.96
CDP≤0.05	2.50	0.13	2.48	4.70
Interaction (T x V)				
T_1V1	45.65	8.48	48.31	99.15
T_1V2	50.23	8.14	55.94	135.35
T_1V3	45.57	7.75	48.91	108.03
T_1V4	41.28	8.23	46.68	89.74
T_1V5	37.30	8.09	40.30	87.87
T_2V1	35.81	6.13	36.90	62.54
T_2V2	32.34	6.16	42.68	76.09
T_2V3	36.54	6.33	36.81	71.15
T_2V4	35.83	6.07	31.10	51.21
T_2V5	33.30	6.06	29.57	53.45
T_3V1	38.49	6.27	28.25	37.25
T_3V2	37.11	6.19	32.45	38.42
T_3V3	37.17	6.47	30.84	39.51
T_3V4	35.37	5.88	26.74	29.08
T_3V5	34.20	5.98	24.13	29.85
SEm (±)	0.93	0.98	2.22	4.21
CDP≤0.05	2.24	NS	NS	NS

Note(s): NS= Non-significant; T_1 (NCSN-1) = FYM @ 10 t.ha-1 (as basal application) + Jeevamrutha @ 500 litre.ha-1 thrice at 15 days interval starting 30 DAT (as soil drenching in split applications); T_2 (NCSN-2) = FYM @ 10 t.ha-1 (as basal application) + Bio-Dynamic (BD-501) @ 3% thrice at 15 days interval starting 30 DAT (as a foliar spray in split applications); T_3 (NCSN-3) = Without any organic or bio-dynamic inputs (therefore, organic by default as control).

Table 2: Effect of different non-chemical sources of nutrients and varieties on yield attributes of onion

	Equatorial	Observations were recorded at harvest		
Parameters Diameter of Bulb (cm)		**Polar Diameter of Bulb (cm)**	**Average Bulb Weight (g)**	**Bulb Yield (t.ha-1)**
Non-chemical sources of nutrients (T)				
T_1 (NCSN-1)	5.85	5.00	50.29	31.78
T_2 (NCSN-2)	5.41	4.39	40.33	25.60
T_3 (NCSN-3)	4.89	4.38	25.08	15.06
SEm (±)	0.21	0.17	1.52	0.96
CDP≤0.05	0.49	0.42	3.65	2.31
Varieties (V)				
V1 (Sukh Sagar)	5.50	4.72	41.41	25.80
V2 (Agrifound Dark Red)	5.76	4.56	41.89	26.44
V3 (N-53)	5.45	4.62	41.66	25.87
V4 (Pusa Sona)	5.18	4.62	35.68	23.11
V5 (Pusa Riddhi)	5.05	4.43	32.19	19.53
SEm (±)	0.15	0.06	1.07	0.68
CDP≤0.05	0.36	0.14	2.58	1.63
Interaction (T x V)				
T_1V1	6.05	5.10	53.11	32.85
T_1V2	6.39	5.07	61.78	39.16
T_1V3	5.84	5.08	50.02	30.46
T_1V4	5.68	4.98	45.66	30.21
T_1V5	5.28	4.75	40.89	26.21
T_2V1	5.50	4.57	41.08	26.19
T_2V2	5.68	4.41	38.38	24.14
T_2V3	5.41	4.35	47.49	29.96
T_2V4	5.28	4.40	39.31	26.18

T_2V5	5.20	4.24	35.37	21.54
T_3V1	5.30	4.51	30.04	18.36
T_3V2	5.25	4.19	25.51	16.01
T_3V3	5.31	4.44	27.49	17.18
T_3V4	4.99	4.47	22.05	12.93
T_3V5	4.95	4.29	20.30	10.84
SEm (±)	0.13	0.11	0.96	0.61
CDP≤0.05	0.32	NS	NS	NS

Note(s): NS= Non-significant; T_1 (NCSN-1) = FYM @ 10 t.ha-1 (as basal application) + Jeevamrutha @ 500 litre.ha-1 thrice at 15 days interval starting 30 DAT (as soil drenching in split applications); T_2 (NCSN-2) = FYM @ 10 t.ha-1 (as basal application) + Bio-Dynamic (BD-501) @ 3% thrice at 15 days interval starting 30 DAT (as a foliar spray in split applications); T_3 (NCSN-3) = Without any organic or bio-dynamic inputs (therefore, organic by default as control).

Table 3: Effect of different non-chemical sources of nutrients and varieties on quality attributes of onion.

Parameters	Analyses were conducted immediately after the harvest			
	TSS (0Brix)	Total Sugar (%)	Reducing Sugar (%)	Ascorbic Acid (mg.100g-1)
Non-chemical sources of nutrients (T)				
T_1 (NCSN-1)	13.07	5.89	2.17	13.77
T_2 (NCSN-2)	13.91	6.05	3.01	14.59
T_3 (NCSN-3)	11.93	5.16	1.87	14.00
SEm (±)	0.41	0.22	0.11	0.24
CDP≤0.05	1.03	0.52	0.29	0.58
Varieties (V)				
V1 (Sukh Sagar)	11.32	5.35	2.14	14.82
V2 (Agrifound Dark Red)	13.43	6.05	2.89	13.73
V3 (N-53)	13.08	4.92	1.86	13.48
V4 (Pusa Sona)	12.89	5.79	2.01	14.20
V5 (Pusa Riddhi)	14.13	6.38	3.05	14.36
SEm (±)	0.35	0.15	0.16	0.28
CDP≤0.05	0.85	0.37	0.39	0.71
Interaction (T x V)				
T_1V1	11.24	5.49	2.28	15.75
T_1V2	13.78	6.21	3.15	11.18
T_1V3	13.39	4.72	1.80	14.10
T_1V4	12.73	6.04	2.89	14.08
T_1V5	14.22	6.97	2.09	13.73
T_2V1	12.64	5.52	2.18	15.16
T_2V2	14.32	6.53	3.07	15.00
T_2V3	14.41	5.41	2.06	12.96
T_2V4	13.38	5.89	1.97	13.83
T_2V5	14.79	6.91	2.37	15.98
T_3V1	10.08	5.05	2.14	13.56
T_3V2	12.20	5.41	2.34	15.01
T_3V3	11.43	4.63	2.03	13.37
T_3V4	12.55	5.45	3.11	14.68
T_3V5	13.37	5.25	2.05	13.37
SEm (±)	1.71	0.14	0.97	0.34
CDP≤0.05	NS	0.33	NS	NS

Note(s): NS= Non-significant; T_1 (NCSN-1) = FYM @ 10 t.ha-1 (as basal application) + Jeevamrutha @ 500 litre.ha-1 thrice at 15 days interval starting 30 DAT (as soil drenching in split applications); T_2 (NCSN-2) = FYM @ 10 t.ha-1 (as basal application) + Bio-Dynamic (BD-501) @ 3% thrice at 15 days interval starting 30 DAT (as a foliar spray in split applications); T_3 (NCSN-3) = Without any organic or bio-dynamic inputs (therefore, organic by default as control).

Conclusion

The study concludes that growth and yield attributes of five onion varieties were significantly influenced by T_1 (Jeevamrutha as a non-chemical amendment), while quality traits were enhanced by T_2 (biodynamic formulation BD-501 as foliar feeding). Agrifound Dark Red (V2), N-53 (V3), and Sukh Sagar (V1) emerged as top-performing post-kharif onion varieties for the eastern Indian plateau, with bulb yields of 26.44, 25.87, and 25.80 t.ha^{-1}, respectively.

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