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**Vidya SP**  
Ph.D. Scholar, Department of  
PSMAC, College of Horticulture,  
UHS Campus, Bengaluru,  
Karnataka, India

**Maruthi Prasad BN**  
Assistant Professor, Department  
of PSMAC, College of  
Horticulture, UHS Campus,  
Bengaluru, Karnataka, India

**Jayappa J**  
Professor, Department of  
Entomology, College of  
Horticulture, UHS Campus,  
Bengaluru, Karnataka, India

**Shankarappa TH**  
Professor, Dept. Agriculture  
microbiology, College of  
Horticulture, Bengaluru,  
Karnataka, India

**Fakrudin B**  
Professor and University Head,  
Dept. of Biotechnology and Crop  
Improvement, College of  
Horticulture, UHS Campus,  
Bengaluru, Karnataka, India

**Venkatesha J**  
ICAR-Emeritus Scientist, Dept.  
of PSMAC, College of  
Horticulture UHS Campus,  
Bengaluru, Karnataka, India

**Corresponding Author:**  
**Vidya SP**  
Ph.D. Scholar, Department of  
PSMAC, College of Horticulture,  
UHS Campus, Bengaluru,  
Karnataka, India

## Influence of PGPM and INM on yield and economics of black turmeric (*Curcuma caesia* Roxb.)

**Vidya SP, Maruthi Prasad BN, Jayappa J, Shankarappa TH, Fakrudin B and Venkatesha J**

### Abstract

Black turmeric (*Curcuma caesia* Roxb.) is a perennial herb belongs to Zingiberaceae family, usually found in N-E and Central India. It is an endangered species which includes many medicinal properties which possess several uses in pharmaceutical and cosmetic industry. The studies on agronomical requirements of the crop are scarce. Hence the present study on "Influence of PGPM and INM on yield and economics in black turmeric" was carried out at College of Horticulture, Bengaluru during 2 consecutive years *i.e.* 2020-21 and 2021-22. The study includes 14 treatments comprises different combination PGPMs, FYM and chemical fertilizers with two replications. The maximum fresh rhizome yield (13.32 kg plot<sup>-1</sup> & 15.90 t ha<sup>-1</sup>) was registered with the application of NPK (150: 125: 150 kg ha<sup>-1</sup>) + FYM (10 t ha<sup>-1</sup>) + Trichokavach (*Trichoderma asperellum*, *Pseudomonas fluorescens*, *Paecilomyces lilacinus* and 2% chitosan- soil application @ 75 g plot<sup>-1</sup> for 2 times at planting and 120 days after planting). Further, the same treatment registered significantly highest gross return (Rs. 31,80,000 ha<sup>-1</sup>), net return (Rs. 22,03,230 ha<sup>-1</sup>) and benefit: cost ratio (2.26) as compared to control.

**Keywords:** Black turmeric, INM, PGPMs, Trichokavach and EMC

### Introduction

Black turmeric (*Curcuma caesia* Roxb.) is a perennial herb belongs to Zingiberaceae family, usually found in N-E and Central India (Zaman *et al.*, 2013) [16]. It is an endangered species which includes many medicinal properties which possess several uses in pharmaceutical as well as cosmetic industry, is economically vital the growers (Mukunthan *et al.*, 2014) [5]. Rhizomes are bluish-black in colour which are bitter in taste and possess pungent smell and is largely exploiting in treatment of cancer, leprosy, haemorrhoids, asthma, fever, epilepsy, wound, vomiting, menstrual disorder, inflammation, skin diseases etc. (Zaman *et al.*, 2013) [16]. The oil of commerce contains about 30 constituents, representing 97.48% of the oil, major being camphor (28.3%), ocimene (8.2%), arturmerone (12.3%), 1, 8-cineole (5.3%), elemene (4.8%), bornylacetate (3.3%), borneol (4.4%), curcumene (2.82%) and arcurcumene (6.8%) as the main constituents. (Kumar and Dewangan, 2014) [4].

Black turmeric plants have short stem with large oblong leaves. It produces ovate pyriform or cylindrical or oblong rhizomes, which are often branched further having brownish yellow in colour exocarp (Swami *et al.*, 2021) [15]. The plant is native to India and South-East Asia and is being under cultivation in Ceylon, Belgium, Indonesia and India. In India its cultivation is confined to a small extent in West Bengal, Orissa, Madhya Pradesh, Uttar Pradesh, Chhattisgarh along with North Eastern Hilly Himalayan states (Nadkarni, 1976) [7]. It grows well in moist deciduous forest areas. It is flourishes in rich humid and clayey soils.

The combined application of organic and inorganic fertilizers known as "Integrated Nutrient Management" (INM) not only enhances the yield but also ensures the physical, chemical and biological property of soil which further add-on fertility, water holding capacity in addition to productivity of soil. The organic manures will aid to sustain nutrient equilibrium in soils while, the inorganic fertilizers readily furnish nutrient which might increase the initial growth in the crop eventually results in good growth, development and yield. Continuous use of inorganic fertilizers has emanated in ecological imbalance with consequent adverse effect to the soil.

Moreover, in recent days, bio-fertilizers have come out as promising component of plant nutrient supply system. The micro-organisms contribute much towards enhancing the fertility status of the soil besides augmenting yield as reported by Ray *et al.* (2000) [8].

### Material and Method

The study was conducted in college of Horticulture, Bengaluru-65 in 2 successive years *i.e.* 2020-21 and 2021-22. The area was ploughed well and divided into 28 raised beds with the size of 8.25m<sup>2</sup>. The design used for the study was randomized complete block design with 14 treatments along with 2 replications.

Healthy well matured seed rhizomes of about 20-40 g are treated with Bavistin (3g/ L of water) and Chloropyriphos (2 ml L<sup>-1</sup> of water) for 1 hour and shade dried the day before planting. The planting was done in the *karif* season by giving respective treatments according to the treatment details and spacing maintained was 45 cm X 30 cm.

The treatment details include, T<sub>1</sub> - EMC1- AM fungi- *Glomus* spp (1g plant<sup>-1</sup>), *Azospirillum*, *Pseudomonas fluorescens*, PSB (*Bacillus megaterium*) and KMB (*Frateruria aurantia*) @ 10 ml L<sup>-1</sup> each + FYM @ 10 t ha<sup>-1</sup>, T<sub>2</sub> - EMC2- AM fungi- *Glomus* spp (1g plant<sup>-1</sup>), *Azospirillum*, *Trichoderma*, PSB and KMB @ 10 ml L<sup>-1</sup> each + FYM (10 t ha<sup>-1</sup>), T<sub>3</sub> - EMC3- AM fungi- *Glomus* spp (1g plant<sup>-1</sup>), *Azospirillum*, *P. fluorescens*, *Trichoderma*, PSB and KMB @ 10 ml L<sup>-1</sup> each + FYM (10 t ha<sup>-1</sup>), T<sub>4</sub> - RDF as per turmeric POP + (FYM @ 10 t ha<sup>-1</sup>), T<sub>5</sub> - T<sub>1</sub> + 100% RDF, T<sub>6</sub> - T<sub>2</sub> + 100% RDF, T<sub>7</sub> - T<sub>3</sub> + 100% RDF, T<sub>8</sub> - T<sub>1</sub> + 75% RDF, T<sub>9</sub> - T<sub>2</sub> + 75% RDF, T<sub>10</sub> - T<sub>3</sub> + 75% RDF, T<sub>11</sub> - T<sub>3</sub> + 125% RDF, T<sub>12</sub> - T<sub>3</sub> + 150% RDF, T<sub>13</sub> - T<sub>4</sub> + Trichokavach (*T. asperellum*, *P. fluorescens*, *Paecilomyces lilacinus* and 2% chitosan- soil application @ 75 g plot<sup>-1</sup> for 2 times), T<sub>14</sub> - FYM @ 10 t ha<sup>-1</sup> (control).

Incorporation of FYM at the rate of 10 tonnes per hectare is common for all the treatment while preparing the beds. *Glomus* spp (1g plant<sup>-1</sup>) and trichokavach (at planting and 120 DAP at 75 g plot<sup>-1</sup>) as soil application and all other liquid bio fertilizers were used to treat the rhizomes for 1 hour before planting at the concentration of 10 ml per L of water and RDF (NPK @ 150:125: 150 kg ha<sup>-1</sup> as Urea, SSP and MOP) was practiced as per the treatment details in 4 splits at 30, 60, 90 and 120 DAP. Turmeric special (1kg 300 L<sup>-1</sup>) was sprayed as common application for all the treatments at 120 DAP.

The first irrigation was given immediately after planting and whenever there was no occurrence of rain, the crop was irrigated once in 3 days. Weeding operation carried out through hand weeding once in a month up to the crop covers the ground area completely, totally 4 weedings and 2 earthing ups at 30 and 150 DAP were done.

Observations like fresh rhizome yield was registered by taking the average fresh weight of rhizomes from each treatment and expressed in kilo grams per plot and estimated yield was calculated and given as tonnes per hectare and for calculating cost economics the prices of all the inputs used

including the labour cost that prevailed at the time of conduct of experiment were taken into account while working out the total cost for cultivation and expressed as rupees per hectare (Table 2). Gross income was considered on the basis of price fixed by University of Horticultural Sciences, Bagalkot *i.e.*, Rs. 200 per kg. Further the net income per hectare was calculated by taking into consideration of gross income and total costs per hectare by using bellowed formula.

**Net income** = Gross income - Total costs

The B: C ratio was calculated using the formula given below.

$$\text{Benefit: Cost ratio} = \frac{\text{Net returns (Rs. ha}^{-1}\text{)}}{\text{Total costs (Rs. ha}^{-1}\text{)}}$$

### Result and discussion

#### Fresh rhizome yield

The highest fresh rhizome yield (13.78 kg plot<sup>-1</sup> and 16.20 t ha<sup>-1</sup>) was reported in T<sub>13</sub> which was *on par* with T<sub>6</sub> and T<sub>9</sub>. While, the least fresh rhizome yield (8.63 kg plot<sup>-1</sup> and 8.63 t ha<sup>-1</sup>) was found in T<sub>5</sub> in first season while in second season, the maximum fresh rhizome yield (12.87 kg plot<sup>-1</sup> and 15.60 t ha<sup>-1</sup>) was found in T<sub>13</sub> which was *on par* with, T<sub>7</sub> and T<sub>10</sub>. Whereas, the minimum fresh rhizome yield (8.43 kg plot<sup>-1</sup> and 8.43 t / ha) was reported in T<sub>14</sub>. Further, the pooled data of both the seasons also registered the highest fresh rhizome yield (13.32 kg plot<sup>-1</sup> and 15.90 t ha<sup>-1</sup>) in T<sub>13</sub> which was *on par* with T<sub>6</sub>. Whereas, the least fresh rhizome yield (9.33 kg plot<sup>-1</sup> and 9.33 t ha<sup>-1</sup>) was reported in T<sub>5</sub> (Table I). The enhanced in yield was mainly as a consequence of aggregate of the plant growth characters as reported by Singh and Singh (2007) [14]. Ahirwar *et al.* (2015) [1] mentioned that, the positive effect of applied fertilizers on yield and yield parameters would be due to enhanced number of leaves and their size enhancement, enhanced photosynthates along with their effective transportation towards enlarging storage structure (rhizomes). The present results are similar with those of other workers, Kumar *et al.* (2013) [3] in Ashwaganda, Singh *et al.* (2015) [12] in ginger and Dodamani *et al.* (2017) [2] in turmeric.

#### Economics

The higher gross return (Rs. 31,80,000/ ha), net return (Rs. 22,03,230/ ha) and benefit cost ratio (2.26) was registered in T<sub>13</sub> followed by T<sub>6</sub>. Whereas minimum gross return (Rs. 22,32,000/ ha), net return (Rs. 12,58,230/ ha) and benefit-cost ratio (1.29) was reported in T<sub>5</sub> as enumerated in Table III. The maximum B: C ratio with this treatment is due to maximum yield as compare to all other treatments coupled with reduced cost of cultivation. The findings are in close conformity with Muthulakshmi and Saveetha (2009) [6], Singh (2012) [13] in turmeric, Shamrao *et al.* (2013) [11] in kashuri manjal and Shadap *et al.*, 2018 in ginger.

**Table 1:** Effect of PGPM and INM on yield

Treatments	Fresh rhizome yield (kg plot <sup>-1</sup> )			Estimated fresh rhizome yield (t ha <sup>-1</sup> )		
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
T <sub>1</sub>	11.50	8.90	11.50	8.90	11.50	8.90
T <sub>2</sub>	10.10	9.37	10.10	9.37	10.10	9.37
T <sub>3</sub>	10.33	9.06	10.33	9.06	10.33	9.06
T <sub>4</sub>	10.37	11.05	10.37	11.05	10.37	11.05
T <sub>5</sub>	8.63	10.03	8.63	10.03	8.63	10.03
T <sub>6</sub>	12.47	12.71	12.47	12.71	12.47	12.71

T <sub>7</sub>	8.76	11.55	8.76	11.55	8.76	11.55
T <sub>8</sub>	10.86	9.18	10.86	9.18	10.86	9.18
T <sub>9</sub>	12.42	9.30	12.42	9.30	12.42	9.30
T <sub>10</sub>	10.87	11.38	10.87	11.38	10.87	11.38
T <sub>11</sub>	10.44	10.40	10.44	10.40	10.44	10.40
T <sub>12</sub>	10.39	9.21	10.39	9.21	10.39	9.21
T <sub>13</sub>	13.78	12.87	13.78	12.87	13.78	12.87
T <sub>14</sub>	10.81	8.43	10.81	8.43	10.81	8.43
SEm±	0.82	0.52	0.82	0.52	0.82	0.52
CD @ 5%	2.51	1.6	2.51	1.6	2.51	1.6
CV	10.71	7.24	10.71	7.24	10.71	7.24

<p>T<sub>1</sub> - EMC1- AM fungi- <i>Glomus</i> spp (1g plant<sup>-1</sup>), <i>Azospirillum</i>, <i>Pseudomonas fluorescens</i>, PSB (<i>Bacillus megaterium</i>) and KMB (<i>Frateruria aurantia</i>) @ 10 ml L<sup>-1</sup> each + FYM @ 10 t ha<sup>-1</sup></p> <p>T<sub>2</sub> - EMC2- AM fungi- <i>Glomus</i> spp (1g plant<sup>-1</sup>), <i>Azospirillum</i>, <i>Trichoderma</i>, PSB and KMB @ 10 ml L<sup>-1</sup> each + FYM @ 10 t ha<sup>-1</sup></p> <p>T<sub>3</sub> - EMC3- AM fungi- <i>Glomus</i> spp (1g plant<sup>-1</sup>), <i>Azospirillum</i>, <i>P. fluorescens</i>, <i>Trichoderma</i>, PSB and KMB @ 10 ml L<sup>-1</sup> each + FYM @ 10 t ha<sup>-1</sup></p> <p>T<sub>4</sub> - RDF as per turmeric POP + FYM @ 10 t ha<sup>-1</sup></p> <p>T<sub>5</sub> - T<sub>1</sub> + 100% RDF</p> <p>T<sub>6</sub> - T<sub>2</sub> + 100% RDF</p>	<p>T<sub>7</sub> - T<sub>3</sub> + 100% RDF</p> <p>T<sub>8</sub> - T<sub>1</sub> + 75% RDF</p> <p>T<sub>9</sub> - T<sub>2</sub> + 75% RDF</p> <p>T<sub>10</sub> - T<sub>3</sub> + 75% RDF</p> <p>T<sub>11</sub> - T<sub>3</sub> + 125% RDF</p> <p>T<sub>12</sub> - T<sub>3</sub> + 150% RDF</p> <p>T<sub>13</sub> - T<sub>4</sub> + Trichokavach (<i>T. asperellum</i>, <i>P. fluorescens</i>, <i>Paecilomyces lilacinus</i> and 2% chitosan) -soil application @ 75 g plot<sup>-1</sup> for 2 times.</p> <p>T<sub>14</sub> - FYM @ 10 t ha<sup>-1</sup> (control).</p>
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**Table 2:** Cost of cultivation as influenced by PGPM and INM in Black turmeric (Rs ha<sup>-1</sup>)

Treatment	Land preparation	Bed preparation	Seed material and seed treatment	Sowing	Fertilizers	Bio-fertilizers	FYM	Turmeric special	Weeding	Earthing up	Plant protection	Harvesting and processing	Packaging material	Miscellaneous	Total
T1	4,800	7,000	8,78,000	2,750	-	21,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,61,125
T2	4,800	7,000	8,78,000	2,750	-	21,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,61,125
T3	4,800	7,000	8,78,000	2,750	-	25,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,65,125
T4	4,800	7,000	8,78,000	2,750	12,645	-	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,52,770
T5	4,800	7,000	8,78,000	2,750	12,645	21,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,73,770
T6	4,800	7,000	8,78,000	2,750	12,645	21,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,73,770
T7	4,800	7,000	8,78,000	2,750	12,645	25,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,77,770
T8	4,800	7,000	8,78,000	2,750	9,484	21,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,70,609
T9	4,800	7,000	8,78,000	2,750	9,484	21,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,70,609
T10	4,800	7,000	8,78,000	2,750	9,484	25,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,74,609
T11	4,800	7,000	8,78,000	2,750	15,806	25,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,80,931
T12	4,800	7,000	8,78,000	2,750	18,967	25,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,84,092
T13	4,800	7,000	8,78,000	2,750	12,645	24,000	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,76,770
T14	4,800	7,000	8,78,000	2,750	-	-	18,500	500	4,125	4,125	4,050	13,275	1,000	2,000	9,40,125

<p>T<sub>1</sub> - EMC1- AM fungi- <i>Glomus</i> spp (1g plant<sup>-1</sup>), <i>Azospirillum</i>, <i>Pseudomonas fluorescens</i>, PSB (<i>Bacillus megaterium</i>) and KMB (<i>Frateruria aurantia</i>) @ 10 ml L<sup>-1</sup> each + FYM @ 10 t ha<sup>-1</sup></p> <p>T<sub>2</sub> - EMC2- AM fungi- <i>Glomus</i> spp (1g plant<sup>-1</sup>), <i>Azospirillum</i>, <i>Trichoderma</i>, PSB and KMB @ 10 ml L<sup>-1</sup> each + FYM @ 10 t ha<sup>-1</sup></p> <p>T<sub>3</sub> - EMC3- AM fungi- <i>Glomus</i> spp (1g plant<sup>-1</sup>), <i>Azospirillum</i>, <i>P. fluorescens</i>, <i>Trichoderma</i>, PSB and KMB @ 10 ml L<sup>-1</sup> each + FYM @ 10 t ha<sup>-1</sup></p> <p>T<sub>4</sub> - RDF as per turmeric POP + FYM @ 10 t ha<sup>-1</sup></p> <p>T<sub>5</sub> - T<sub>1</sub> + 100% RDF</p> <p>T<sub>6</sub> - T<sub>2</sub> + 100% RDF</p>	<p>T<sub>7</sub> - T<sub>3</sub> + 100% RDF</p> <p>T<sub>8</sub> - T<sub>1</sub> + 75% RDF</p> <p>T<sub>9</sub> - T<sub>2</sub> + 75% RDF</p> <p>T<sub>10</sub> - T<sub>3</sub> + 75% RDF</p> <p>T<sub>11</sub> - T<sub>3</sub> + 125% RDF</p> <p>T<sub>12</sub> - T<sub>3</sub> + 150% RDF</p> <p>T<sub>13</sub> - T<sub>4</sub> + Trichokavach (<i>T. asperellum</i>, <i>P. fluorescens</i>, <i>Paecilomyces lilacinus</i> and 2% chitosan) -soil application @ 75 g plot<sup>-1</sup> for 2 times.</p> <p>T<sub>14</sub> - FYM @ 10 t ha<sup>-1</sup> (control).</p>
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**Table 3:** Effect of PGPM and INM on economics

Treatment	Cost of cultivation (Rs ha <sup>-1</sup> )	Gross return (Rs ha <sup>-1</sup> )	Net return (Rs ha <sup>-1</sup> )	B: C ratio
T1	9,61,125	24,34,000	14,72,875	1.53
T2	9,61,125	23,22,000	13,60,875	1.42
T3	9,65,125	23,14,000	13,48,875	1.40
T4	9,52,770	25,60,000	16,07,230	1.69
T5	9,73,770	22,32,000	12,58,230	1.29
T6	9,73,770	30,08,000	20,34,230	2.09
T7	9,77,770	24,30,000	14,52,230	1.49
T8	9,70,609	23,90,000	14,19,391	1.46
T9	9,70,609	25,88,000	16,17,391	1.67
T10	9,74,609	26,58,000	16,83,391	1.73
T11	9,80,931	24,90,000	15,09,069	1.54
T12	9,84,092	23,42,000	13,57,908	1.38
T13	9,76,770	31,80,000	22,03,230	2.26
T14	9,40,125	22,94,000	13,53,875	1.44

T <sub>1</sub> - EMC1- AM fungi- <i>Glomus</i> spp (1g plant <sup>-1</sup> ), <i>Azospirillum</i> , <i>Pseudomonas</i>	T <sub>7</sub> - T <sub>3</sub> + 100% RDF
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<i>fluorescens</i> , PSB ( <i>Bacillus megaterium</i> ) and KMB ( <i>Frateuria aurantia</i> ) @ 10 ml L <sup>-1</sup> each + FYM @ 10 t ha <sup>-1</sup>	T <sub>8</sub> - T <sub>1</sub> + 75% RDF
T <sub>2</sub> - EMC2- AM fungi- <i>Glomus</i> spp (1g plant <sup>-1</sup> ), <i>Azospirillum</i> , <i>Trichoderma</i> , PSB and KMB @ 10 ml L <sup>-1</sup> each + FYM @ 10 t ha <sup>-1</sup>	T <sub>9</sub> - T <sub>2</sub> + 75% RDF
T <sub>3</sub> - EMC3- AM fungi- <i>Glomus</i> spp (1g plant <sup>-1</sup> ), <i>Azospirillum</i> , <i>P. fluorescens</i> , <i>Trichoderma</i> , PSB and KMB @ 10 ml L <sup>-1</sup> each + FYM @ 10 t ha <sup>-1</sup>	T <sub>10</sub> - T <sub>3</sub> + 75% RDF
T <sub>4</sub> - RDF as per turmeric POP + FYM @ 10 t ha <sup>-1</sup>	T <sub>11</sub> - T <sub>3</sub> + 125% RDF
T <sub>5</sub> - T <sub>1</sub> + 100% RDF	T <sub>12</sub> - T <sub>3</sub> + 150% RDF
T <sub>6</sub> - T <sub>2</sub> + 100% RDF	T <sub>13</sub> - T <sub>4</sub> + Trichokavach ( <i>T. asperellum</i> , <i>P. fluorescens</i> , <i>Paecilomyces lilacinus</i> and 2% chitosan) -soil application @ 75 g plot <sup>-1</sup> for 2 times.
	T <sub>14</sub> - FYM @ 10 t ha <sup>-1</sup> (control).

## Conclusion

From the results, it is evident that the growth, yield and quality were remarkably affected by combined application of inorganic fertilizers, organic manures and bio fertilizers. The combined application of NPK (150: 125: 150 kg/ha) + FYM (10 t/ha) + Trichokavach (*T. Asperellum*, *P. flUoescens*, *Paecilomyces lilacinus* and 2% chitosan- soil application @ 75 g plot<sup>-1</sup> for 2 times at planting and 120 DAP) reported to be best for growth, yield and nutrient uptake and the same treatment reported in highest B: C ratio also (2.26) and was *on par* with the treatment T<sub>6</sub> (2.09).

**Abbreviations INM:** Integrated nutrient management.

**PGPM:** Plant growth promoting microorganism.

**EMC:** Effective microorganism combination.

**DAP:** Days after planting.

**FYM:** Farm Yard Manure.

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