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Revealing enhanced yield and economic resilience in onion through biofertilizers, humic acid and GA_3

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Abstract
The research was conducted at the Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agriculture, Jabalpur, Madhya Pradesh, during the Rabi season of 2022-23. A Randomized Completely Block Design (RCBD) was employed, consisting of twelve distinct treatments (including biofertilizers, GA_3, humic acid and a control), with each treatment replicated three times. The objective of this study was to assess the impact of these treatments on onion yield and economic outcomes. It is noteworthy that the combination of Azotobacter, Azospirillum, GA_3 and humic acid resulted in significant enhancements across various yield parameters, such as polar diameter (5.51 cm), equatorial diameter (5.68 cm), neck thickness (0.97 cm), average bulb weight (69.40 g), bulb yield per plot (14.85 q/ha) and marketable yield per hectare (243.77 q/ha). Notably, Treatment T_{10}, which incorporated all these components, yielded the highest net returns (Rs. 259497.00) with a benefit-cost ratio of 2.44. This indicates the economic viability of utilizing these inputs in onion cultivation. Conversely, the control plot (T_{12}) demonstrated limited economic gains, thereby underscoring the effectiveness of the treatments under investigation.

Keywords: Biofertilizers, GA_3 and humic acid, yield parameters, azotobacter and Azospirillum, economic outcomes and onion cultivation

Introduction
The onion, known scientifically as *Allium cepa* L., is a herb with a distinct round shape. It belongs to the Alliaceae family and the Allium genus. Its culinary value is highly regarded worldwide, and it is consumed throughout the year. From an agricultural perspective, onions serve a dual purpose as both vegetables and spice crops. India is a major contributor to global onion cultivation and export, ranking second only to China. The characteristic pungency of onions is due to a compound called allyl-propyl-disulphide ($C_6H_{12}S_2$), while their colours, whether red or yellow, are influenced by anthocyanin and quercetin. Though there are variations among different onion varieties, a typical nutritional profile consists of 86.6% moisture, 11.6% carbohydrates, and a combination of trace elements (Raj *et al*., 2004) [9].

Modern agricultural practices emphasize the use of biofertilizers to enhance crop yield sustainably across various farming conditions. Research conducted by (Vijayakumar *et al*. 2000 and Ramakrishnan and Thamizhiniyan 2009) [11, 10] highlights the positive effects of biofertilizers on crop vigour and yield. For example, the introduction of PSB bio-fertilizer has resulted in yield increases ranging from 10 to 30%. Application of Azospirillum not only promotes plant growth but also reduces the need for nitrogenous fertilizers by 20-30%. This leads to improved nutrient absorption, enhancing soil fertility and ultimately resulting in higher crop yields (Bhati *et al*., 2018) [2] In the context of onion cultivation, both GA_3 and humic acid play vital roles. GA_3 stimulates stem growth and bulb enlargement, while humic acid improves soil quality, facilitates nutrient uptake and promotes a balanced microbial environment. This overall improves yield and the quality of onion bulbs (Yubaraj *et al*., 2023) [4].

Materials and Methods
The research was conducted at the experimental fields of the Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, College of Agriculture, situated in Jabalpur, Madhya Pradesh. This investigation took place during the Rabi season of 2022-23, using the 'Bhima Shakti' onion variety. A chosen Randomized Completely Block Design was implemented. To ensure robustness, each of the 12 treatments was replicated three times.

Each experimental plot had dimensions of 3 meters by 2 meters, with a gap of 1 meter between replications. Within each plot, the plants were spaced 10 cm apart, with rows separated by 15 cm. Detailed information regarding the specific treatments and their respective designations can be found below in Table 1 and Figure 1.

Table 1: Detailed Overview of Treatment Descriptions

Treatments No.	Treatment Details
T_1	RDF (NPKS:100:50:50:40 Kg/ha)
T_2	RDF + Azotobacter (5 kg/ha)
T_3	RDF + Azospirillum (5 kg/ha)
T_4	RDF + GA_3 (100 ppm)
T_5	RDF + Humic acid (2 kg/ha)
T_6	RDF + Azotobacter + Azospirillum
T_7	RDF + GA_3 + Azotobacter
T_8	RDF + GA_3 + Azospirillum
T_9	RDF + GA_3 + Humic acid
T_{10}	RDF + GA_3 + Azotobacter + Azospirillum + Humic acid
T_{11}	RDF + Humic acid + Azotobacter + Azospirillum
T_{12}	Control

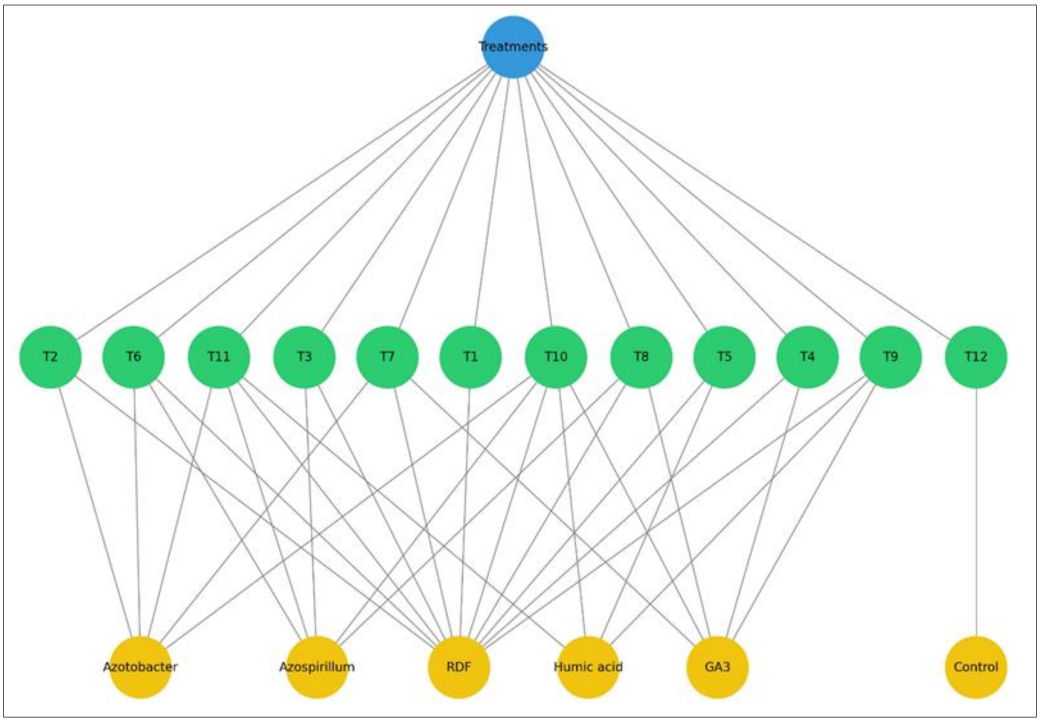


Fig 1: Insight into Treatment Approaches

Results and Discussion
Effect on yield attributes

This study examined the impact of various treatments, including RDF (Recommended Fertilizer Dose), GA_3 (Gibberellic Acid), Azotobacter, Azospirillum and Humic acid, on the characteristics and yield measurements of onion bulbs. The treatment T_{10}, which consisted of RDF, GA_3, Azotobacter, Azospirillum and Humic acid, resulting in enlarged plant cells and improved overall plant structure, affecting both their polar and equatorial measurements, consistently outperformed the others. Specifically, it recorded the largest polar diameter of onion bulbs at 5.51 cm, in contrast to the control group (T_{12}) which recorded the smallest at 3.88 cm. Similarly, T_{10} showed peak values in equatorial diameter (5.68 cm) and neck thickness (0.97 cm), with T_{11} following closely behind. In terms of average bulb weight, T_{10} emerged as the frontrunner at 69.40 g, while T_{12} fell behind at 56.11 g. Significantly, when assessing yields, T_{10} consistently delivered superior results, both per individual plot (14.85 kg) and on a hectare scale (247.44 q/ha). Furthermore, in terms of marketable yields, T_{10} reached a peak of 243.77 q/ha, in stark contrast to T_{12}'s lowest point of 178.75 q/ha. Overall, these findings highlight the effectiveness and success of the T_{10} treatment in enhancing onion cultivation outcomes, leading to increased yields and improved marketability.

The combined utilization of RDF, GA_3, Azotobacter, Azospirillum and Humic acid substantially increased onion bulb measurements, amplifying both the vertical and horizontal diameters to 5.51 cm and 5.68 cm, respectively. This significant growth can be attributed to the enhanced performance of biofertilizers, GA_3 and humic acid, optimizing both resource allocation and light absorption. In contrast, the untreated control samples exhibited smaller diameters, measuring 3.88 cm and 4.36 cm (Yadagiri *et al*., 2017) [13].

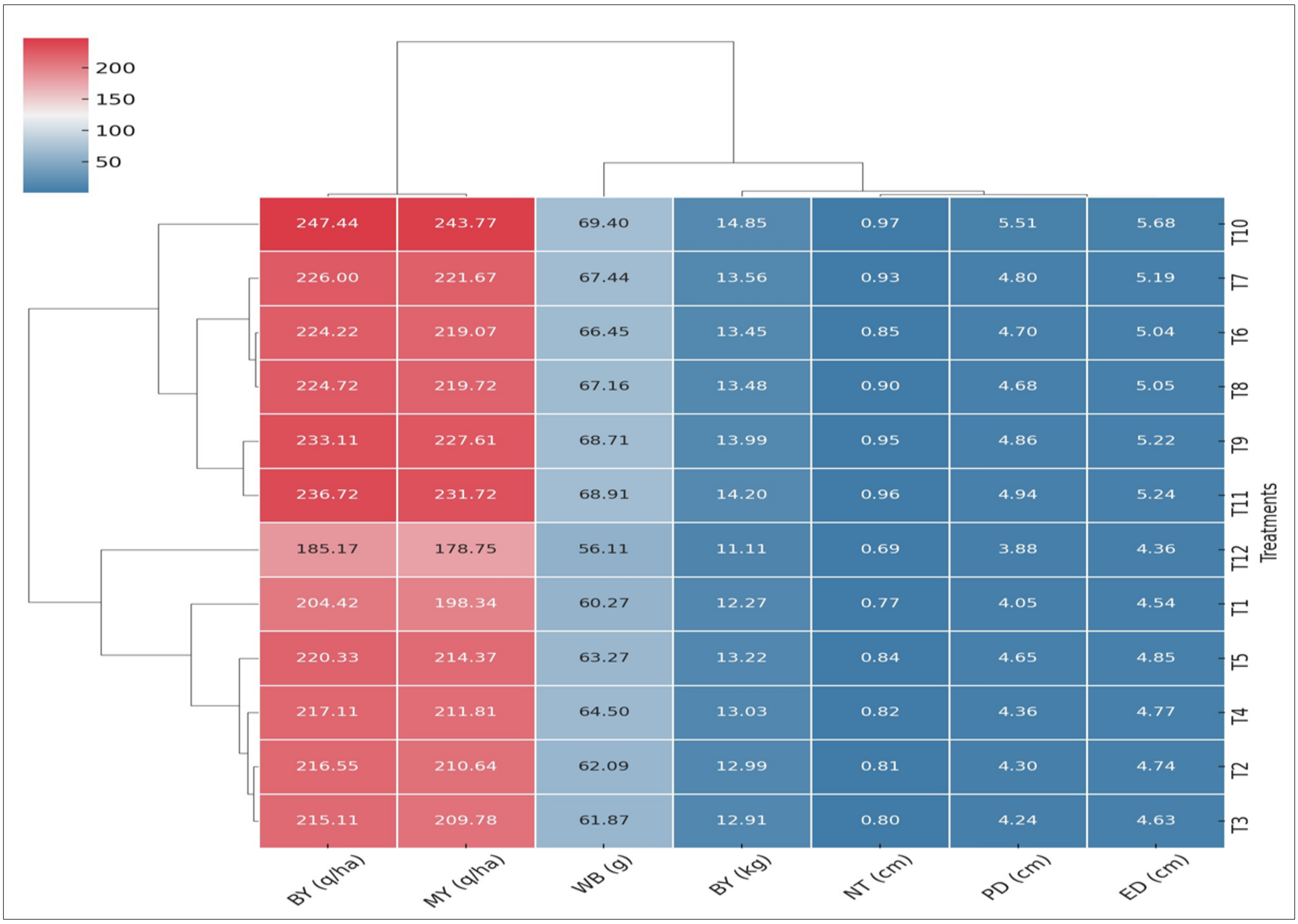
Interestingly, this comprehensive treatment resulted in noticeable changes in neck thickness, with T_{10} and T_{11} recording peak thicknesses of 0.97 cm and 0.96 cm, respectively. These measurements highlight increased cellular activities, such as elongation, division and tissue expansion (Banjare *et al*., 2015) [1]. The applied treatments also played a crucial role in determining bulb weight, with T_{10} producing the largest bulbs, weighing 69.40 g, closely followed by T_{11} at 68.91 g. The control group, T_{12}, only yielded bulbs weighing 56.11 g (Kumar *et al*., 2019b and Hore *et al*., 1988) [8, 6].

Furthermore, the synergistic interaction of GA_3, Azotobacter, Azospirillum and Humic acid strengthened onion plants in terms of vigour, nutrient assimilation, and overall yield potential (Waghmode *et al*., 2010 and Jamir *et al*., 2013) [12, 7]. Specifically, T_{10} demonstrated excellent yield metrics, both per individual plot (14.85 kg) and per hectare (247.44 q), with T_{11} showing similar results, while the control T_{12} lagged significantly behind in terms of yield (Waghmode *et al*., 2010 and Jamir *et al*., 2013) [12, 7]. In relation to marketability, T_{10}'s yield dominated at 243.77 q/ha, while T_{12} performed poorly with only 178.75 q/ha, highlighting the transformative effect of the treatment on improving onion productivity (Table 2 and Figure 2).

Effect on economics

A thorough evaluation of different treatments economic aspects delved into essential economic indicators, such as the overall cultivation expenses, gross earnings, net gains and the associated benefit-cost ratios. The benchmark for optimal economic feasibility relied on treatments that showcased strong net profits along with appealing benefit-cost ratios. Treatment T_{10} (which combined RDF, GA_3, Azotobacter, Azospirillum and Humic acid) notably stood out in terms of economic prudence, registering an impressive net gain of Rs. 259,497 per hectare. Treatment T_{11} (which integrated RDF, Humic acid, Azotobacter and Azospirillum) closely followed, achieving a commendable net profit of Rs. 241,735 per hectare. In contrast, treatment T_{12} (Control) lagged behind with a net return of Rs. 169,782 per hectare. Additionally, T_{10} secured the top spot with a benefit-cost ratio of 2.44, solidifying its financial effectiveness, while T_{11} closely trailed with a ratio of 2.28. In stark contrast, the control treatment, T_{12}, recorded the lowest ratio at 1.73. These financial metrics emphasize the significant economic advantages offered by T_{10}, positioning it as the preferable choice for enhancing onion farming yields.

A more in-depth financial assessment across different treatments highlighted distinct variances in crucial metrics. The overall cultivation cost, encompassing all expenses incurred throughout the experimental phase, was deduced. Subsequent net profits were determined and the benefit-cost ratio was calculated by comparing the net gains against the cultivation expenditure. The standout treatment, T_{10}, which included RDF, GA_3, Azotobacter, Azospirillum and Humic acid, emerged with an impressive profit margin of Rs. 264,997.00. In comparison, the control scenario (T_{12}) significantly lagged behind, realizing a profit of Rs. 179,402.00. Notably, T_{10} showcased the highest B:C ratio at 2.49 (Table 3 and Figure 3). These outcomes echo the findings of (Hafez and Geries 2019 and Bhavana *et al.* 2022) [5, 3] emphasizing the economic strength of Treatment T_{10}.



Where BY= bulb yield (q/ha), MY= marketable yield (q/ha), WB = weight of bulb (g), BY = bulb yield (kg/plot), NT = neck thickness (cm), PD = polar diameter (cm) and ED = equatorial diameter (cm)

Fig 2: Visualization of Yield Determinants: Exploring Patterns through Heat Mapping

Table 2: Effect of biofertilizer, GA_3 and humic acid on yield parameters in onion (*Allium cepa* L.)

S. No.	Treatment	Polar Diameter (cm)	Equatorial Diameter (cm)	Neck Thickness (cm)	Weight of bulb (g)	Bulb Yield(kg)	Bulb yield (q/ha)	Marketable yield (q/ha)
T_1	RDF (NPKS: 100:50:50:40 Kg/ha)	4.05	4.54	0.77	60.27	12.27	204.42	198.34
T_2	RDF + Azotobacter (5 kg/ha)	4.30	4.74	0.81	62.09	12.99	216.55	210.64
T_3	RDF + Azospirillum (5 kg/ha)	4.24	4.63	0.80	61.87	12.91	215.11	209.78
T_4	RDF + GA_3 (100 ppm)	4.36	4.77	0.82	64.50	13.03	217.11	211.81
T_5	RDF + Humic acid (2 kg/ha)	4.65	4.85	0.84	63.27	13.22	220.33	214.37
T_6	RDF + Azotobacter + Azospirillum	4.70	5.04	0.85	66.45	13.45	224.22	219.07
T_7	RDF + GA_3 + Azotobacter	4.80	5.19	0.93	67.44	13.56	226.00	221.67
T_8	RDF + GA_3 + Azospirillum	4.68	5.05	0.90	67.16	13.48	224.72	219.72
T_9	RDF + GA_3 + Humic acid	4.86	5.22	0.95	68.71	13.99	233.11	227.61
T_{10}	RDF + GA_3 + Azotobacter + Azospirillum + Humic acid	5.51	5.68	0.97	69.40	14.85	247.44	243.77
T_{11}	RDF + Humic acid + Azotobacter + Azospirillum	4.94	5.24	0.96	68.91	14.20	236.72	231.72
T_{12}	Control	3.88	4.36	0.69	56.11	11.11	185.17	178.75
	Sem±	0.26	0.21	0.04	0.22	0.29	4.85	3.06
	CD at 5%	0.77	0.63	0.12	0.67	0.85	14.24	8.78

Table 3: Effect of biofertilizer, GA_3 and humic acid on economic parameters of onion (*Allium cepa* L.)

S. No.	Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
T_1	RDF (NPKS: 100:50:50:40 Kg/ha)	1,03,395	297515	194120	1.88
T_2	RDF + Azotobacter (5 kg/ha)	104245	315960	211715	2.03
T_3	RDF + Azospirillum (5 kg/ha)	104395	314665	210270	2.01
T_4	RDF + GA_3 (100 ppm)	103713	317710	213997	2.06
T_5	RDF + Humic acid (2 kg/ha)	103995	321555	217560	2.09
T_6	RDF + Azotobacter + Azospirillum	105245	328605	223360	2.12
T_7	RDF + GA_3 + Azotobacter	104563	332505	227942	2.18
T_8	RDF + GA_3 + Azospirillum	104713	329575	224862	2.15
T_9	RDF + GA_3 + Humic acid	104313	341415	237102	2.27
T_{10}	RDF + GA_3 + Azotobacter + Azospirillum + Humic acid	106163	365660	259497	2.44
T_{11}	RDF + Humic acid + Azotobacter + Azospirillum	105845	347580	241735	2.28
T_{12}	Control	98,348	268130	169782	1.73

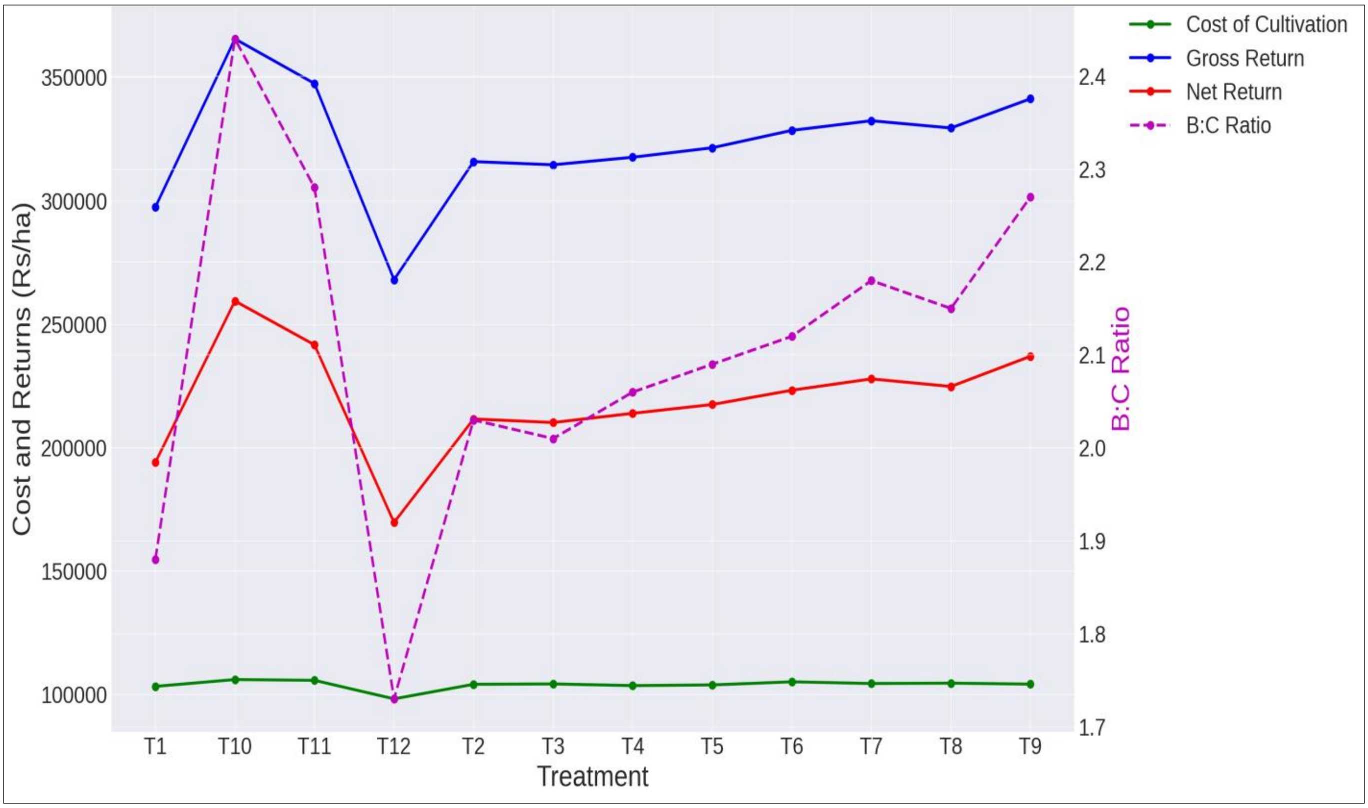


Fig 3: Economic Metrics and Analysis of Onion Production

Conclusion
The study on the 'Bhima Shakti' onion variety suggests that emphasizing key yield determinants, such as polar diameter, equatorial diameter, neck thickness and average bulb weight, can optimize yield, reaching up to 247.44 q/ha. Economically, the synergistic application of Azotobacter, Azospirillum, GA_3 and humic acid showcases a notable Benefit-Cost Ratio (B:C) of 2.44, aligning with a peak marketable yield and a net gain of Rs. 259,497.00. These findings indicate that the integrated approach could significantly elevate crop productivity and economic returns in onion cultivation.

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