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EFFECTIVENESS OF MICROBIAL CONSORTIA IN MANAGEMENT OF WILT DISEASE AND YIELD MAXIMIZATION IN TOMATO (*SOLANUM LYCOPERSICUM* L.)

Shashank Shekhar Singh[1]*, R.K. Singh[2] and J.K. Singh[1]
[1]Krishi Vigyan Kendra, Nawada – 805106, Bihar, India
[2]ICAR-National Research Centre on Pomegranate, Solapur- 413255, Maharashtra, India
*Corresponding author E-mail: shashanksiingh@gmail.com
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ABSTRACT

A two-year field study was conducted to evaluate the efficacy of microbial consortia in controlling wilt disease in tomatoes, comparing it with conventional chemical pesticide practices. The treatments included NRC Litchi Consortia/*Trichoderma* (T_2), ICAR-HIR Microbial Consortia/Arka Microbial (T_1), and Farmer's Practices (FP) relying on chemical pesticides. Results demonstrated that microbial consortia significantly delayed the onset of wilt and reduced wilt incidence at 45, 60, and 75 days after transplanting (DAT). T_2 showed the highest delay in first wilt incidence (40.84 DAT pooled data) and the lowest wilting rate by 75 DAT (2.67%), followed by T_1, while FP had the highest wilt incidence (19.10% by 75 DAT).Yield data further confirmed the superior performance of microbial consortia, with T_2 yielding 290.70 q/ha, followed by T_1 at 257.90 q/ha, both significantly outperforming FP (226.00 q/ha). Economic analysis revealed that despite similar cultivation costs, T_2 achieved the highest gross return (Rs. 5,23,260/ha) and net return (Rs. 4,79,675/ha), resulting in a benefit-cost ratio (BC) of 4.34, compared to 3.52 for FP. These findings highlight the potential of microbial consortia as a sustainable and economically beneficial alternative to chemical pesticide treatments in managing wilt disease in tomatoes.
Keyword **:** Wilting, Microbial Consortia, *Trichoderma,* Yield, Benefit-cost (BC)

Introduction

The tomato (*Solanum lycopersicum* L.), a prominent horticultural crop within the Solanaceae family, is highly valued for its abundant nutritional profile. It is particularly noted for being a rich source of essential vitamins, minerals, and bioactive compounds, many of which exhibit potent antioxidant properties. Renowned as one of the most widely consumed vegetables worldwide, the tomato is a key component in a diverse range of fresh, cooked, and processed dishes (Wang *et al.,* 2023). Although naturally a perennial herbaceous plant, it is largely grown as an annual crop, though some biennial and perennial varieties are cultivated. Tomatoes flourish in both tropical and temperate climates, with open-field cultivation common, while greenhouses are often utilized in temperate zones. As a member of the Solanaceae family, which includes several other economically important species, the tomato is grown extensively across the globe, serving both local markets and export demands (Poojitha, 2023). Tomatoes are a nutritional powerhouse, delivering a comprehensive range of essential vitamins and minerals that play a pivotal role in supporting overall health and well-being (Martinez *et al.,* 2024).

Numerous biotic factors have hindered tomato production, and despite significant efforts to enhance yield, its cultivation remains adversely affected. Among the most critical challenges are viral, bacterial, nematode, and fungal pathogens, which persist as major threats to tomato crop productivity. Among the various diseases affecting tomatoes, wilting stands out as one of the most destructive. The disease leads to swift and devastating wilting in host plants, resulting in significant economic losses. Although efforts have been made to control the disease using chemical treatments, soil amendments, resistant plant varieties, and various cultural practices, effective management remains elusive.

In contemporary agriculture, soil microbes are increasingly recognized as essential contributors to crop management strategies aimed at enhancing sustainability (Barea, 2015, Trivedi *et al.,* 2017 and Compant *et al.,* 2019). The employment of beneficial plant microorganisms as biological control agents (BCAs) offers a promising alternative to the excessive use of agrochemicals (Ab Rahman *et al.,* 2018; Randler-Kleine *et al.,* 2020). Recent years have witnessed a significant rise in the registration of microbial biocontrol agents globally, providing strong evidence of this trend (van Lenteren *et al.,* 2017). In this study, we examine the hypothesis that microbial consortia exhibit greater versatility compared to individual microbial inoculants, demonstrating enhanced functionality in the biocontrol of a broader spectrum of plant disease that is wilting and application techniques by integrating various modes of action. Therefore, this study was undertaken to explore disease management through the use of a consortium of biocontrol agents.

Material and Methods

The field experiment was conducted at Krishi Vigyan Kendra, Nawada, Bihar, during the 2022-23 and 2023-24 cropping seasons to evaluate the efficacy of microbial consortia in controlling wilt disease in tomato (*Solanum lycopersicum* L.). The experiment was carried out under rained conditions on sandy loam soil, representative of the regions agricultural environment. A randomized block design (RBD) was employed, comprising two treatments, a control, and ten replications for each treatment and in each replication there were 30 tomato plants. Treatment-1 (T_1) involved the application of ICAR-HIR microbial consortia (Arka Microbial), Treatment-2 (T_2) used the NRC Litchi consortia/ *Trichoderma*. The control plot did not receive any microbial input but applied farmer's practices chemical pesticides like Carbendazim and Mancozeb. The variety selected for the study was Kashi Amrit, a regionally adapted variety. In these treatments, part of the farm yard manure and vermicompost was mixed with the microbial consortia with proportion of 1 kg microbial consortia in 100 kg FYM and vermicompost and incubated for one week. The mixture was applied at planting holes near root zone at the time of planting with the dosage depended on the treatment. Data were collected on the initial plant population, first wilt incidence (DAT) and incidence of wilt disease at 15, 30, 45, 60, and 75 days after transplanting (DAT), alongside the crop yield and economics, measured at the end of the season.The variables observed were the percentage of plant infected by wilt disease (disease incidence). Statistical analyses were performed on the data to compare the efficacy of the treatments against the control. This provided insights into the potential of microbial consortia for effective wilt disease management in tomato crops under Nawada conditions.

Results and Discussion

The results collected from the present experimental design regarding initial plant population, first wilt incidence (DAT) and incidence of wilt disease at 15, 30, 45, 60, and 75 days after transplanting (DAT) characteristics is displayed in Table 1, which clearly demonstrated that the application of microbial consortium mixed with FYM and vermicompost significantly suppressed the wilt in tomato. Initial plant population was 300. The mean highestdays to first wilt incidence (40.40, 41.28 and 40.84) was obtained in treatment 2 (T_2) used the NRC Litchi consortia/ *Trichoderma* and mean minimal days to first wilt incidence (35.50, 38.70 and 37.10) was found in treatment 1 (T_1) used the ICAR-HIR microbial consortia (Arka Microbial), correspondingly for the years 2022-23 , 2023-24 and pooled data. Whereas the Farmer's practices (FP) treatment, using chemical pesticides, had the highest first wilt incidence at (30.60, 28.30 and 29.45) correspondingly for the years 2022-23 , 2023-24 and pooled data.

Trichoderma species are widely recognized for their multifunctional role in plant protection, including antagonistic activity against a variety of soil-borne pathogens through mechanisms such as mycoparasitism, where they directly attack and degrade fungal pathogens, and the production of antifungal metabolites (Harman *et al.,* 2004).

Woo *et al.,* (2014) reported that *Trichoderma* spp. can induce systemic resistance in plants, thereby enhancing the plant's defence mechanisms, reducing disease incidence, and delaying pathogen attacks, which is evident in the results from T_2. *Trichoderma* also promotes plant growth by producing hormones like auxins and cytokinins, which improve root development and nutrient uptake (Contreras-Cornejo *et al.,* 2009). This dual role of controlling pathogens while promoting healthier plants likely contributed to the longer time to first wilt incidence.

The wilting percentages observed at 15 and 30 days after treatment (DAT) offer valuable insights into the initial impact of the microbial consortia and chemical interventions. At 15 and 30 DAT, none of the treatments exhibited any noticeable signs of wilting, which likely indicates that the plants were either in the early phases of disease progression or that the treatments had effectively mitigated wilt at this preliminary stage. These early results demonstrate the superior efficacy of microbial consortia in reducing wilt pressure from an early stage of crop growth. The wilting percentages recorded at 45, 60, and 75 days after treatment (DAT) reveal a clear distinction in the efficacy of the different treatments.

By 45 DAT, the NRC Litchi Consortia/ *Trichoderma* (T2) demonstrated the lowest wilting incidence at 2.08%, 2.20% and 2.14% correspondingly for the years 2022–23, 2023–24 and pooled data followed closely by the IIHR Consortia (T_1) at 3.30%, 3.0% and 3.15% correspondingly for the years 2022–23, 2023–24 and pooled data .While the Farmer's practices (FP) showed a significantly higher wilting rate of 8.65%, 8.30% and 8.48% correspondingly for the years 2022–23, 2023–24 and pooled data. Similar studies have confirmed *Trichoderma*'s efficacy in delaying wilt and other soil-borne diseases in various crops. Yadav *et al.,* (2021) noted significant reductions in disease incidence when *Trichoderma* was applied in litchi orchards, citing its ability to not only control Fusarium wilt but also enhance soil microbial diversity, contributing to overall plant health.

As the crop progressed to 60 DAT, the T_2 treatment continued to exhibit superior disease suppression, with a wilting percentage of only 2.80%, 2.15% and 2.28% correspondingly for the years compared to T_1 with 3.68%, 3.48% and 3.58% correspondingly for the years 2022–23, 2023–24 and pooled data and FP which recorded 11.84%, 11.19% and 11.52% correspondingly for the years 2022-23, 2023-24and pooled data wilt incidence. The disparity in performance became more pronounced as the treatments extended to 75 DAT, where T_2 maintained its lead with a wilt percentage of 2.85%, 2.48% and 2.67%, correspondingly for the years 2022-23, 2023-24and pooled data followed by T_1 at 4.52%, 4.62% and 4.57% correspondingly for the years 2022-23, 2023-24and pooled data. In contrast, the FP treatment resulted in the highest wilting percentage of 19.20%, 19.00% and 19.10% correspondingly for the years 2022-23, 2023-24 and pooled data. Mukherjee *et al.,* (2013) further explain that *Trichoderma*-based biocontrol agents are less prone to lead to resistance compared to chemical fungicides. *Trichoderma* adapts well to various soil environments, making it a sustainable solution for long-term crop protection. Additionally, it can thrive in the rhizosphere, where it competes with pathogens for nutrients and space, further suppressing disease outbreaks (Kashyap *et al.,* 2017)

The yield data collected from the various treatments further highlights the benefits of microbial consortia over conventional chemical treatments (Table 2). The highest yield (288.90 q/ha, 292.50 q/ha and 29.07 q/ha) was observed in the in treatment 2 (T_2)used the NRC Litchi consortia/ *Trichoderma* correspondingly for the years 2022-23, 2023-24and pooled data. This indicates that the T_2 treatment not only reduced wilt incidence but also contributed to enhanced overall plant vigour and productivity. The treatment 1 (T_1) used the ICAR-HIR microbial consortia (Arka Microbial) followed closely, with a yield of 254.90 q/ha, 260.90 q/ha and 257.90 q/ha correspondingly for the years 2022-23, 2023-24 and pooled data. In contrast, the Farmer's practices (FP) treatment, which relied on chemical pesticides, resulted in the lowest yield of data (219.80 q/ha, 232.20 q/ha and 226.00. q/ha) correspondingly for the years 2022-23, 2023-24and pooled data. Indicating that chemical pesticides, while controlling pests, do not offer the broader benefits to plant health and yield observed with microbial consortia (Mukherjee *et al* .,2013).

T_1 (IIHR Consortia) and T_2 (NRC Litchi Consortia/*Trichoderma*) have identical costs of cultivation. Both treatments incurred a cost of Rs. 120,700/ha correspondingly for the years 2022-23, 2023-24and pooled data, while the Farmer's practices (FP) treatment had a lower cost of Rs. 115,700/ha correspondingly for the years 2022-23, 2023-24 and pooled data. The identical costs for T_1 and T_2 suggest that the implementation of both microbial consortia treatments requires a similar level of investment in terms of material costs and labour. This includes the preparation and application of microbial inoculants, which are mixed into the soil near the root zone to maximize their effectiveness in promoting plant health and controlling disease.

The gross return results underscore the economic viability of the microbial consortia treatments compared to traditional chemical practices. Among the treatments, treatment 2 (T_2) used the NRC Litchi consortia/ *Trichoderma* provided the highest gross return as well as net return, amounting to Rs. 5,23,260.00/ha and Rs. 4,79,675/ha respectively reflecting its ability to enhance both yield and profitability. This significant return is directly attributed to the higher yield achieved by this treatment, making it a highly productive option for farmers. The treatment 1 (T_1) used the ICAR-HIR microbial consortia closely followed, with a gross return of Rs. 4,64,220.00/ha and net return of Rs.

4,13,289/ha.In contrast, the Farmer's practices (FP), which relied on chemical pesticides (Carbendazim and Mancozeb), resulted in the lowest gross return of Rs. 4,06,800.00/ha Net return of Rs. 3,62,875/ha. While this treatment incurred the least cultivation costs, the lower yield and higher wilt incidence significantly reduced the overall economic returns.

The benefit-cost (BC) ratio serves as a critical metric for evaluating the economic viability of the different treatments applied in this study (Table 3). It compares the financial benefits derived from the yields of each treatment to the associated costs of cultivation, providing a clear picture of the profitability of each approach. The results revealed that the IIHR Consortia (T_1) and the NRC Litchi Consortia/*Trichoderma* (T_2) treatments yielded higher BC ratios compared to the Farmer's practices (FP).The BC ratio for T_2 was calculated at 4.34, indicating that for every unit of currency invested, the return was approximately 4.34 times the cost. This substantial ratio reflects not only the high yield of 290.70 q/ha but also the effective control of wilt, which ultimately contributes to increased profitability. Similarly, the T_1 treatment yielded a BC ratio of 3.85. The effectiveness of T_1 in reducing wilt incidence and promoting healthy plant growth contributed to its strong economic performance, demonstrating its value as a sustainable agricultural practice. In contrast, the Farmer's practices (FP) showed a lower BC ratio of 3.52, indicating less profitability. Although FP incurred lower cultivation costs, the significantly reduced yield of 226.00q/ha and higher wilting percentages ultimately led to diminished returns.

Conclusion

The study conclusively demonstrates the superior efficacy of microbial consortia over conventional chemical pesticide treatments in managing wilt disease in tomatoes, enhancing yield, and improving economic returns. Both the NRC Litchi Consortia/*Trichoderma* (T_2) and ICAR-HIR Microbial Consortia (Arka Microbial) (T_1) significantly delayed the onset of first wilt incidence and reduced the percentage of wilt over the growth period. In contrast, the Farmer's Practices (FP), reliant on chemical pesticides, exhibited earlier disease onset and higher wilting rates at each interval, indicating less effective disease control. Furthermore, microbial treatments not only suppressed disease but also enhanced plant vigour, reflected in substantially higher yields for T2 (290.70 q/ha) and T_1 (257.90 q/ha), compared to FP (226.00 q/ha). The cost of cultivation remained nearly identical across microbial and chemical treatments; however, the net return from microbial treatments was significantly higher due to the increased yield. T_2 achieved the highest net return (Rs. 4,79,675/ha) and benefit-cost (BC) ratio (4.34), making it a highly profitable alternative to conventional chemical treatments, which achieved a lower BC ratio of 3.52.In conclusion, the use of microbial consortia, particularly NRC Litchi Consortia/*Trichoderma* (T_2), offers a sustainable and economically viable alternative to chemical pesticides for managing wilt disease in tomato crops. The integration of microbial consortia with organic amendments such as FYM and vermicompost contributes not only to disease control but also to enhanced productivity and profitability, thus supporting a more resilient and sustainable agricultural system.

Table 1 : Effect of microbial consortia on initial Plant Population and Wilting percentage (DAT)

Technological options	Initial Plant Population	First wilt incidence (DAT)			Wilting percentage (DAT)											
					15	30	45			60			75		
		22-23	23-24	Pool			22-23	23-24	Pool	22-23	23-24	Pool	22-23	23-24	Pool
T1	**300**	35.50	38.70	37.10	0	0	3.30	3.00	3.15	3.68	3.48	3.58	4.52	4.62	4.57
T2	**300**	40.40	41.28	40.84	0	0	2.08	2.20	2.14	2.80	2.15	2.28	2.85	2.48	2.67
FP	**300**	30.60	28.30	29.45	0	0	8.65	8.30	8.48	11.84	11.19	11.52	19.20	19.00	19.10
CV	**-**	8.04	7.53	7.75	-	-	11.84	13.74	10.58	15.79	16.47	14.35	18.79	19.83	19.24
CD @ 5%	**-**	2.78	2.60	2.68	-	-	0.52	0.59	0.46	0.89	0.88	0.79	1.55	1.63	1.59

Table 2 : Effect of microbial consortia on Yield (q/ha) and Gross return (Rs. /ha.)

Technological options	Yield (q/ha)			Gross return (Rs. /ha.) @ Rs. 20/kg
	22-23	23-24	Pool	
T1	254.90	260.90	257.90	464220.00
T2	288.90	292.50	290.70	523260.00
FP	219.80	232.20	226.00	406800.00
CV	4.79	3.96	3.44	
CD @ 5%	11.55	9.81	8.42	

Table 3 : Effect of microbial consortia on Cost of cultivation, Net return and BC ratio

Technological options	Cost of cultivation (Rs / ha)		Pool Cost of cultivation (Rs / ha)	Net return (Rs)/ha	BC ratio
	22-23	23-24			
T1	120700	120700	120700	413289	3.85
T2	120700	120700	120700	479675	4.34
FP	115700	115700	115700	362875	3.52

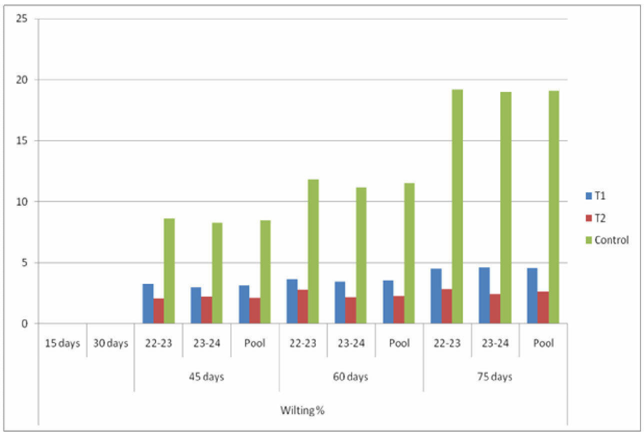

Fig. 1 : Percentage of wilt incidence

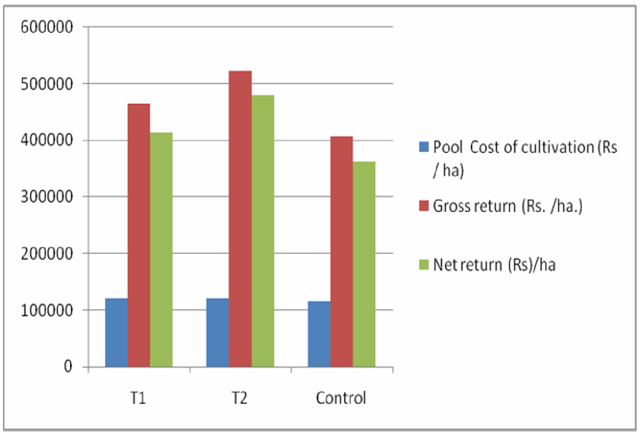

Fig. 4 : Cost of cultivation

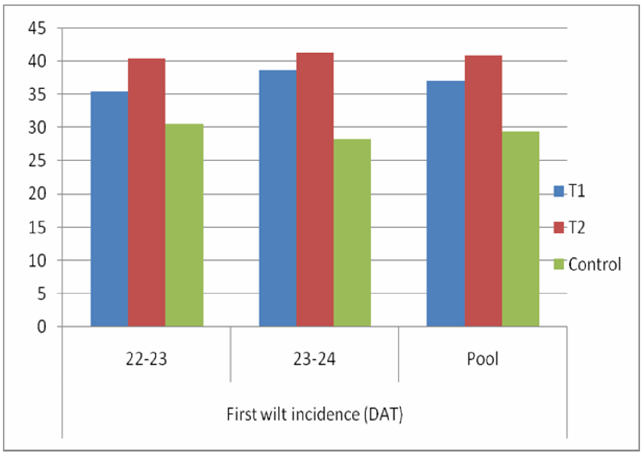

Fig. 2 : Days to first wilt incidence

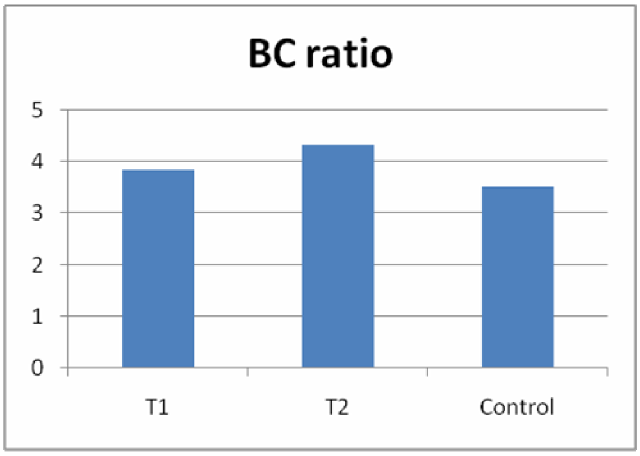

Fig. 5 : BC ratio

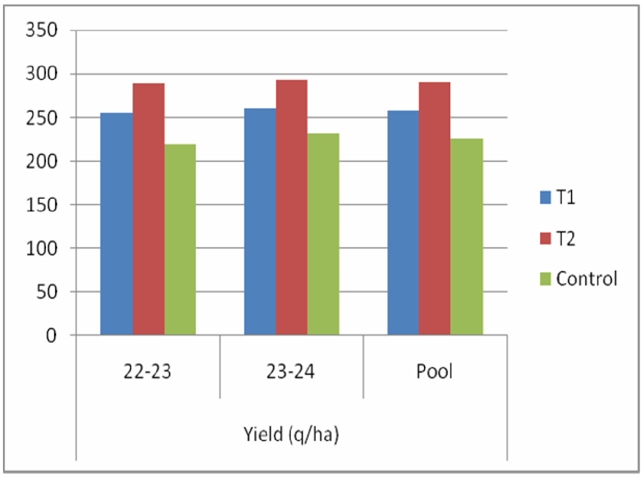

Fig. 3 : Yield (q/ha)

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