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Microbial inoculants and *Trichoderma viride* consortia for growth promotion and disease management in ginger

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Abstract

A study was conducted to evaluate the effect of microbial inoculants consortia on ginger under field conditions. Three biofertilizers comprising of *Azospirillum lipoferum* (nitrogen fixer KAU-AZO), *Bacillus megaterium* (phosphate solubilizer KAU-PSB), *Bacillus sporothermodurans* (potash solubilizer KAU-KSB) and two biocontrol agents namely, *Pseudomonas fluorescens* (KAU-PF) and *Trichoderma viride* (KAU-TV) were used in the study. Compatibility studies revealed that all the isolates were compatible with each other. However, *P. fluorescens* and *T. viride* were incompatible with each other under *in vitro.* Under field evaluation, consortia of microbial inoculants performed better than the single inoculants in terms of yield and disease management. The organic *Adhoc* package recorded the minimum incidence of rhizome rot (2.09 %) among all the treatments. However, KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV recorded the minimum rhizome rot (5.23%) incidence among the consortia. In the case of *Rhizoctonia* leaf blight disease, consortia of KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF showed the minimum incidence (5.21%). In general, consortium of *A. lipoferum*, *B. megaterium* (PSB), *B. sporothermodurans* (KSB) and *T. viride* was the most efficient for plant growth promotion and disease management in ginger.

Keywords: compatibility, consortia, disease management, field conditions, ginger, microbial inoculants, yield

Introduction

Ginger is one of the major spice crops of Kerala and is used as a fresh vegetable and dried spice, since time immemorial. Several factors *viz.,* environmental degradation, loss of ecosystem components, climate change, pest and disease incidence hinder the production and the major one is its susceptibility to various diseases. This has led to the use of a heavy dose of fungicides and antibiotics for the management of biotic stress. Ginger is also a highly nutrientdepleting crop, which demands the use of high doses of organic manure and chemical fertilizers. Although chemical fertilizers and pesticides are highly effective, their continuous use has led to many environmental problems. Increased use of inorganic fertilizers has created environmental issues such as air pollution, reduced biodiversity, suppressed ecosystem function, and deterioration of soil and ground water quality. Moreover, indiscriminate use of agrochemicals for the control of pathogens is causing serious ecological, economic, and social problems. Alternative approaches are therefore needed to minimize the use of chemical fertilizers, fungicides, antibiotics and insecticides, since ginger is directly consumed. Dutta *et al*. (2003) reported that the use of organic fertilizers together with chemical fertilizers showed positive effect on microbial biomass and soil health. Therefore, emphasis should be given to the organic cultivation of ginger by minimizing chemical fertilizers and pesticides. Microbial inoculants are formulations of beneficial microorganisms used to promote plant growth and manage plant diseases.

The quantum of plant growth-promoting activities is better in consortia or mixed cultures than a single strain (Bashan *et al*. 2004). Sarma & Anandaraj (1998) suggested the consortium approach for disease management in plantation and spice crops. Sarma *et al.* (2000) have established the biocontrol consortium for black pepper, ginger, and cardamom. Introduction of nitrogen fixers, phosphate solubilizing bacteria (PSB), and potash solubilizing bacteria along with biocontrol agents will not only supply the primary nutrients to the plants but also manage the diseases with multiple actions. The treatments with biofertilizers improved the rhizome quality by increasing the oleoresin content in the rhizome. *Azotobacter* not only fixed N, but also produced anti-fungal antibodies which inhibited the growth of several pathogenic fungi in the root region and hence improved root growth and crop nutrition which improved the quality of the product (Subba Rao 2001). N10 (*Pantoea*, sp.) and SJN5 (*Arthrobacter)* showed biocontrol efficacy and reduced disease incidence by 39.98% and 45.61%, respectively. Moreover, N10 and SJN5 promoted root length by 25.5% and 26.6% shoot dry weight by 12.5% and 20.1% and root dry weight by 15.4% and 17.9%, respectively. Therefore, a single formulation consisting of both biofertilizer and biocontrol agents would be an ideal technology for plant growth promotion and disease management in the present-day agriculture. Hence, a study was undertaken to evaluate the bioinoculant consortia for organic cultivation of ginger and identify a consortium for plant growth promotion and disease management in ginger under field condition.

Materials and methods

Collection of microbial strains

The efficient cultures of microbial inoculants *viz., Azospirillum lipoferum, Bacillus megaterium* (PSB), *Bacillus sporothermodurans* (KSB), *P. fluorescens,* and *T. viride* of KAU were obtained from the repository of the Department of Agricultural Microbiology, College of Agriculture, Vellayani, Thiruvanthapuram. The media used for the maintenance of isolates were Okon's nitrogen-free media for *A. lipoferum,* Pikovskaya's agar for *B. megaterium*, Glucose Yeast Calcium agar media for *B. sporothermodurans*, King's B agar for *P. fluorescens* and potato dextrose agar for *T. viride*.

Compatability studies among the microbial cultures

The compatibility among the bacterial isolates was tested by the cross streak method using nutrient agar media (Raja *et al*. 2006), and compatibility between bacteria and fungus was studied by dual culture technique (Morton & Strouble, 1955) using potato dextrose agar media. The carrier-based inoculants were prepared by blending vermicompost with the respective culture broth (Zaidi *et al* 2014) and it was applied to the soil. The population of bacteria was maintained at 10^8 cfu ml^{-1} and 10^6 cfu ml^{-1} in case of fungus.

Field evaluation of microbial inoculant consortia for plant growth promotion and disease management

The experiment was conducted at the College of Agriculture, Vellanikkara, Kerala Agricultural University. The plot was located at 10.550708 latitude, 76.27398 longitude and 31.0 m MSL elevation. The initial soil physiocochemical parameters were as follows: Soil pH: 5.6, organic carbon: 1.4 %, available nitrogen: 230.3 kg ha^{-1}., available phosphorus: 50.13 kg ha^{-1} and available potassium: 203.1 kg ha^{-1}. The ginger plants were maintained in a randomized complete block design (RCBD) and 'Himachal' variety was used as it has less fibre and gives good quality gingerol for oleoresin production.

The incidence of rhizome rot was estimated in each field following the formula: (Number of diseased plants / Total number of plants **x** 100) (Sagar *et al.* 2008). The characteristic initial symptom of rhizome rot appearance was yellowing of leaves and in the early stages, a few tillers showed symptom of yellowing. The leaves showed drooping, withering and drying. The infected shoot could be easily pulled out from the soil. The rhizome showed water-soaked and mushy appearance. Per cent disease incidence of *Rhizoctonia* leaf blight was estimated as per Chiang (2017): Per cent disease incidence = (Number of diseased leaves/ Total number of leaves) × 100. In the case of *Rhizoctonia* leaf blight, the lesions were usually observed on the leaf sheaths although leaf blades also get affected. Initially, lesions were small, ellipsoid or ovoid, and greenish-gray. Under favorable conditions, they enlarge and may coalesce to form bigger lesions with irregular outline.

A bed of size 2 x 1 m^2 with a spacing of 25 x 25 cm was adopted. The treatments applied were as follows:

T_1: *Azospirillum lipoferum*

T_2: *Bacillus megaterium*

T_3: *Bacillus sporothermodurans*

T_4: *Pseudomonas fluorescens*

T_5: *Trichoderma viride*

T_6: *Azospirillum lipoferum + Bacillus megaterium + Bacillus sporothermodurans*

T_7: *Azospirillum lipoferum + Bacillus megaterium + Bacillus sporothermodurans + Pseudomonas fluorescens*

T_8: *Azospirillum lipoferum + Bacillus megaterium + Bacillus sporothermodurans + Trichoderma viride*

T_9: Organic Adhoc package (KAU, 2009)

T_{10}: Control

Before planting, the seed rhizomes were soaked in a solution containing *Pseudomonas fluorescens* @ 20 g l^{-1} for 30 min and dried under shade. FYM / compost was applied @ 25 t as basal and 3 t ha^{-1} each at 60 days after planting and 120 days after planting. FYM, *Trichoderma*, neem cake mixture @ 100 g $plant^{-1}$ were applied in the planting pit at the time of planting. *Azospirillum* was applied @ 2.5 kg ha^{-1}. The same dose was repeated at 120 days after planting.

Farmyard manure was applied in all the treatments @ 30 t ha^{-1}. Treatments T_1 to T_8 were applied @ 160 g $2m^{-2}$ and T_9 as per KAU POP (2011) recommendation. Observations on the number of days taken for germination, germination percentage, number of tillers, plant height, rhizome yield, and disease incidence were recorded. The data were analyzed using the statistical package MSTAT-C (Freed 1986) and Duncan's Multiple Range Test (Duncan 1955).

Results and discussion

Microbial consortia can consist of two or more strains that are either closely or distantly related (Ramírez-López *et al*. 2019; ElMaaloum *et al.* 2020) that provide an overall additive or synergistic effect. In the present studies the different isolates of KAU-AZO, KAU-PSB, KAU-KSB, KAU-PF, and KAU-TV were subjected to a compatibility test. It was observed that all the bacterial cultures tested were mutually compatible with each other (Fig 1). Fitriatin & Nurmala (2019) reported that

P-solubilizers such as *Pseudomonas mallei, P. cepaceae, Aspergillus niger*, *Penicillium* sp., and N fixing bacteria namely *Azotobacter chroococum, Azospirillum* sp. were synergistic and did not antagonist to each other and hence, consortia of P-solubilizers and N-fixing bacteria can be used for agricultural purposes. In a similar study, Raja *et al.* (2006) reported compatibility of *A. lipoferum, B. megaterium* var *phosphaticum*, and *P. fluorescens* among each other. Khorshidi (2011) also reported that *P. fluorescens* and *A. lipoferum* were compatible with each other which are in agreement with present results. KAU-TV and KAU-PF were incompatible with each other (Fig 2). It contradicts Manjula *et al*. (2004) findings, who reported *in vitro* compatibility of *P. fluorescens* and *Trichoderma* sp. in dual culture and found that *P. fluorescens* did not affect the growth of *Trichoderma* sp. or vice versa. In the present study, KAU-PF and KAU-TV were incompatible which might be attributed to the action of organic volatiles produced by KAU-PF that might have inhibited the mycelial growth of the fungus. The consortium KAU-AZO + KAU-PSB+KAU-KSB showed their compatibility with KAU-TV. The compatibility of *T. viride* with *Azospirillum* under *in vitro* has already been reported (Sankar and Jayarajan, 1996) which is in agreement with the present studies.

Based on the compatibility studies, the consortia consisting of biofertilizers alone and biofertilizer cum biocontrol agents were selected for the field evaluation. Consortia including biocontrol agents KAU-PF and

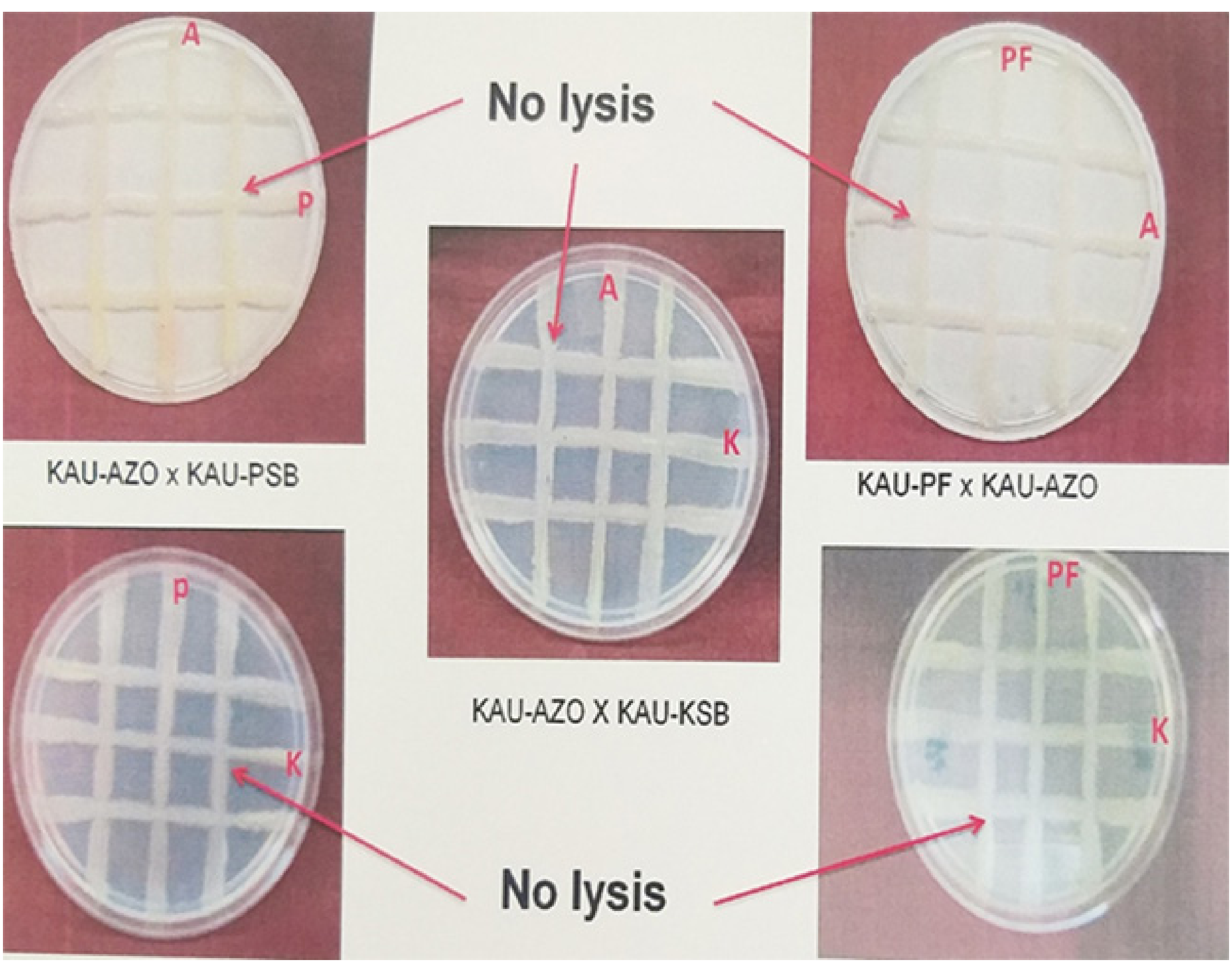

Fig 1. *In vitro* evaluation of compatability between bacteria and bacteria

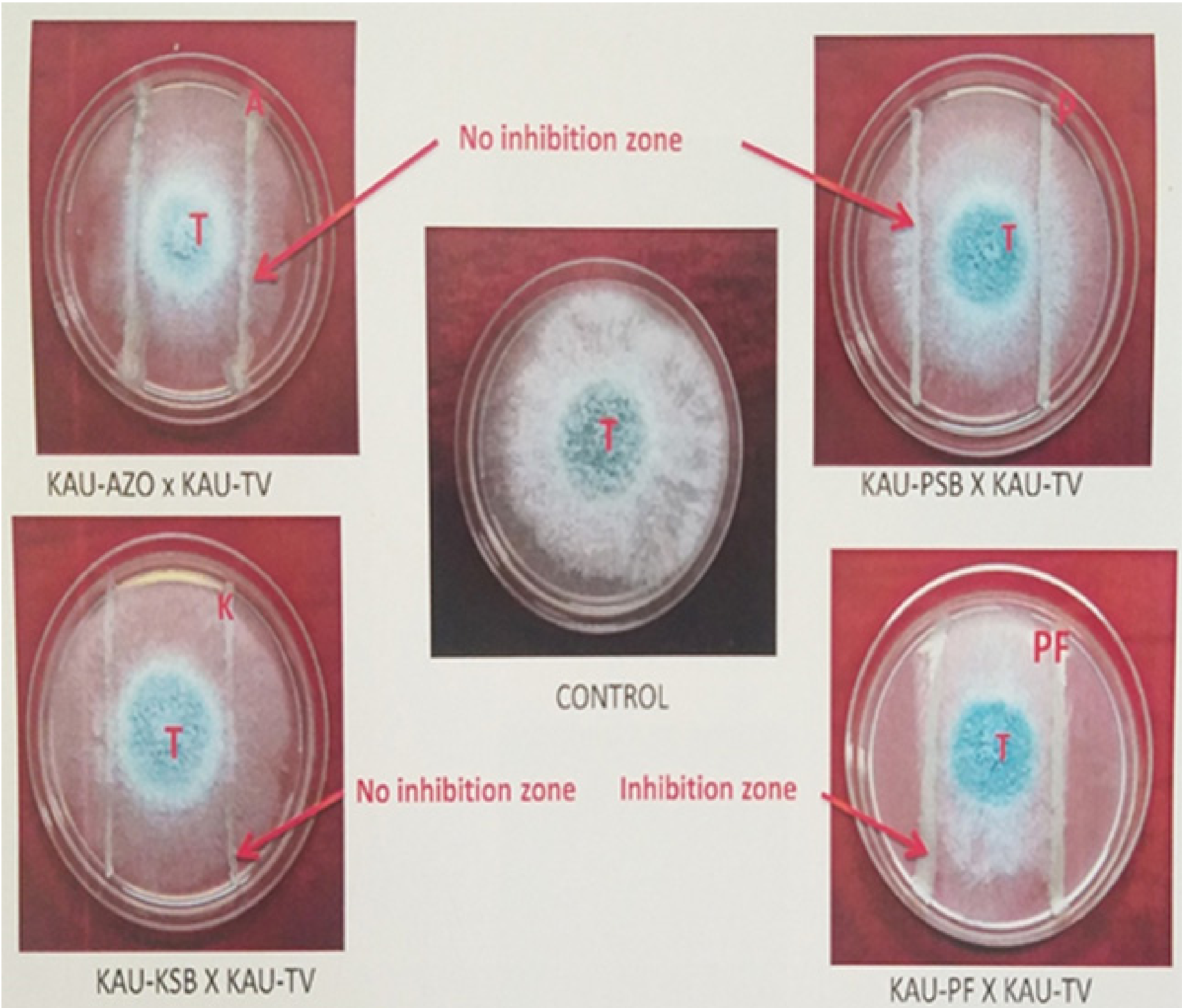

Fig 2. *In vitro* evaluation of compatability between bacteria and *Trichoderma viride*

KAU-TV were not selected for further studies as both were incompatible with each other. The consortia selected were KAU-AZO +KAU- PSB + KAU-KSB, KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF and KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV.

The effect of biofertilizers alone and its consortia were evaluated under field conditions using ginger crop. The number of days taken for sprouting ranged between 16-20 days for different treatments. However, no significant differences were observed among the treatments in number of days taken for sprouting. The minimum number of days (16.67) was recorded in the case of KAU-PF. Selvakumar (2009) reported *Pseudomonas* and *Bacillus* can produce phytohormones like indole acetic acid (IAA) and gibberellic acid (GA3) that increases uptake of water and nutrients, per cent germination and rate of germination, plant biomass and nutrient uptake. Among the consortia, both KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF and KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV recorded the highest germination (91.67%). The increase in germination percentage after five days of consortial inoculation in the soil might be due to the production of indole acetic acid. The highest plant height was recorded in the case of plants inoculated with organic *adhoc* package (KAU 2009) (32.7% over control) followed by KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV (20.5% increase over control) and KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF (20.4% increase over control) and the consortia treated plants performed better than individual inoculants (Table 1). Among the consortia, the plant height was highest (74.86 cm) in the case of KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV (20.5% increase over control). This might be due to the optimum supply of nutrients from organic sources. Microbial inoculants might have helped in the better uptake of nutrients, more synthesis of nucleic and amino acids, amide substances and formation of meristematic tissues thereby increased the growth of plants which is in agreement with the findings of Saxena *et al*. (2001) in soybean.

The maximum numbers of tillers were recorded in the treatment KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV (Table 2). Sumathi *et al*. (2011) reported that co-inoculation of *A. lipoferum, T. viride, B. megaterium, P. fluorescens* resulted in maximum plant height in turmeric. Similarly, Nath and Korla (2000) reported higher tiller and leaf production per plant in ginger due to the influence of biofertilizers which support the positive effect of biofertilizer in the present study.

Among the consortia based treatments, maximum rhizome yield per bed (57.6% increase over control) was observed in KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV (Table 3) followed by KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF (55.5% increase over control). This

Table 1. Effect of consortia and individual bioinoculant on plant height (cm)

Treatment	Plant height (cm)					Per cent increase over control
	Months after planting					
	1	2	3	4	5	
T_1: KAU-AZO	14.96^{bc}	27.61^{e}	36.04^{f}	59.74^{bcd}	72.23^{cd}	16.2
T_2 : KAU-PSB	13.37^{c}	26.23^{ef}	35.71^{f}	55.61^{de}	71.13^{de}	14.5
T_3 : KAU-KSB	15.24^{bc}	23.233^{f}	32.54^{g}	50.21^{ef}	65.67^{ef}	5.7
T_4 : KAU-PF	16.14^{abc}	28.68^{de}	37.5^{ef}	59.08^{cd}	72.73^{cd}	17.0
T_5: KAU-TV	16.68^{abc}	31.72^{cd}	39.42^{e}	60.95^{bcd}	73.78^{bcd}	18.7
T_6 : KAU-AZO + KAU-PSB + KAU-KSB	18.15^{ab}	32.16^{bcd}	39.34^{e}	61.03^{bcd}	73.55^{bcd}	18.4
T_7 : KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF	17.62^{ab}	33.56^{abc}	39.72^{e}	61.94^{bc}	74.80^{bcd}	20.4
T_8 : KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV	18.21^{ab}	35.65^{ab}	43.08^{d}	62.03^{bc}	74.86^{bcd}	20.5
T_9 : Organic adhoc package (KAU, 2009)	18.80^{ab}	37.04^{a}	51.15^{a}	68.17^{a}	82.45^{a}	32.7
T_{10}: Control	13.51^{c}	22.97^{f}	31.57^{g}	48.09^{f}	62.15^{f}	0
CD (0.05)	4.08	3.78	2.57	5.99	6.33	

Values are mean of 32 rhizomes planted in 3 beds per season

KAU-AZO : *Azospirillum lipoferum*
KAU-PF : *Pseudomonas fluorescens*
KAU-PSB : *Bacillus megaterium*
KAU-TV : *Trichoderma viride*
KAU-KSB : *Bacillus sporothermodurans*

Table 2. Effect of consortia and individual bio inoculants on number of tillers

Treatment	Months after planting		
	2 *	4	6
T_1: KAU-AZO	1.52	6.21^{bcd}	6.33^{cde}
T_2: KAU-PSB	1.50	5.67^{cd}	6.09^{de}
T_3: KAU-KSB	1.56	5.38^{d}	5.89^{ef}
T_4: KAU-PF	1.55	5.81^{bcd}	5.92^{ef}
T_5: KAU-TV	1.53	6.25^{bcd}	6.70^{cde}
T_6 : KAU-AZO + KAU-PSB + KAU-KSB	1.72	6.23^{bcd}	6.87^{cd}
T_7 : KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF	1.78	6.53^{abcd}	6.94^{bcd}
T_8 : KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV	1.81	6.72^{abcd}	7.06^{bc}
T_9 : Organic *adhoc* package (KAU, 2009)	1.78	7.93^{a}	8.14^{a}
T_{10}: Control	1.41	5.33^{d}	5.18^{f}
CD (0.05)	NS	1.43	0.79

Values are mean of 32 rhizomes planted in 3 beds per season
* No significant difference
KAU-AZO: *Azospirillum lipoferum*
KAU-PF : *Pseudomonas fluorescens*
KAU-PSB : *Bacillus megaterium*
KAU-TV : *Trichoderma viride*
KAU-KSB : *Bacillus sporothermodurans*

Table 3. Effect of consortia and individual bio inoculants on rhizome yield

Treatment	Yield (kg 2m^2)	Percent increase over control
T_1: KAU-AZO	3.08	30.5
T_2: KAU-PSB	2.70	14.4
T_3: KAU-KSB	2.40	1.7
T_4: KAU-PF	2.86	21.2
T_5: KAU-TV	3.18	34.7
T_6: KAU-AZO + KAU-PSB + KAU-KSB	3.43	45.3
T_7 : KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF	3.67	55.5
T_8 : KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV	3.72	57.6
T_9: Organic *Adhoc* package (KAU, 2009)	4.59	94.5
T_{10}: Control	2.36	0
CD (0.05)	1.56	

Values are mean of 32 rhizomes planted in 3 beds per season
KAU-AZO : *Azospirillum lipoferum.*
KAU-PF : *Pseudomonas fluorescens*
KAU-PSB : *Bacillus megaterium*
KAU-TV : *Trichoderma viride*
KAU-KSB : *Bacillus sporothermodurans*

might be due to the optimum supply of nutrients from organic sources and bioinoculants which increased the plant growth. Chandrashekhar and Hore (2019) reported maximum number of primary fingers (3.84), weight of primary fingers (45.67g), length of primary fingers (4.36 cm), length of secondary fingers (9.09 cm), breadth of secondary fingers (6.61 cm), rhizome yield (26.43 t ha^{-1}) and oleoresin (6.86) content in ginger in NPK 100% + *Azotobacter* + PSB + K mobilizer. Asokan *et al*. (2002) and Sreekala (2004) reported increased yield in ginger due to the addition of farmyard manure and biofertilizers which improved soil fertility. Based on the overall biometric and yield parameters, KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV performed better among the consortia in the present study. However, Organic Adhoc package (KAU 2009) performed better than the consortia treatments.

One of the major constraints in ginger cultivation is the disease incidence. In the present study, diseases observed were rhizome rot caused by *Pythium* sp. and *Rhizoctonia* leaf blight by *Rhizoctonia solani* (Table 4). The treatment (Organic *Adhoc* package) recorded a minimum incidence of rhizome rot (2.09 %) among all the treatments. However, KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV recorded the minimum rhizome rot incidence (5.23%) among the consortia under study. Tripathi & Singh (2021) reported that ginger rhizome

Table 4. Effect of consortia and individual bio inoculants on percent incidence of rhizome rot and *Rhizoctonia* leaf blight

Treatment	Percent incidence					
	Rhizome rot			*Rhizoctonia* leaf blight		
	3 MAP	4 MAP	5 MAP	3 MAP	4 MAP	5 MAP
T_1: KAU-AZO	5.21^{a} (2.37)	5.23^{a}(2.37)	8.37^{abc}(2.97)	4.17(2.14)	5.21(2.15)	7.29(2.73)
T_2: KAU-PSB	4.17^{ab} (2.14)	5.23^{a}(2.27)	8.37^{abc}(2.97)	4.17(2.14)	8.35(2.94)	10.43(3.27)
T_3: KAU-KSB	5.21^{a} (2.15)	5.23^{a}(2.37)	7.33^{a}(3.3)	4.17(2.14)	8.35(2.89)	9.39(3.12)
T_4: KAU-PF	2.78^{abc}(1.87)	3.14^{abc}(1.91)	6.28^{abc}(2.6)	1.04(1.92)	4.17(1.92)	5.18(2.5)
T_5: KAU-TV	0.00^{c} (0.7)	1.04^{c}(1.12)	6.28^{abc}(2.55)	2.08(1.51)	6.26(2.6)	6.26(2.6)
T_6 : KAU-AZO + KAU-PSB + KAU-KSB	2.7^{abc}(1.)	4.19^{ab}(2.4)	7.33^{abc}(2.7)	3.13(1.4)	7.30(2.71)	9.39(3.04)
T_7 : KAU-AZO + KAU-PSB + KAU-KSB + KAU-PF	4.17^{ab} (2.14)	5.23^{a}(2.3)	6.28^{abc}(2.5)	2.08(1.1)	4.17(2.14)	5.21(2.37)
T_8 : KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV	3.13^{ab} (1.91)	3.14^{abc}(1.91)	5.23^{a}(2.37)	5.21(2.15)	6.26(2.55)	6.26(2.55)
T_9 : Organic *adhoc* package (KAU, 2009)	0.00^{c} (0.7)	1.04^{c}(1.12)	2.09^{d} (1.51)	1.04(1.11)	3.13(1.74)	4.17(1.97)
T_{10}: Control	6.25^{a} (2.55)	6.28^{a}(2.6)	9.42^{ab}(3.12)	7.30(2.71)	9.39(3.12)	12.51(3.59)
CD (0.05)	3.7	2.9	4.23	NS	NS	NS

Values are mean of 32 rhizomes planted in 3 beds per season

MAP: Months after planting

Figures in parenthesis are square root transformed values

KAU-AZO : *Azospirillum lipoferum.*

KAU-PF : *Pseudomonas fluorescens*

KAU-PSB : *Bacillus megaterium*

KAU-TV : *Trichoderma viride*

KAU-KSB : *Bacillus sporothermodurans*

treatment by copper hydroxide and its soil drenching effectively controlled rhizome rot disease (67%) with reduced disease incidence (4.6%) followed by *T. viride* which controlled the disease by 53.5% and reduced the disease incidence by 6.8% (over local check) which are in agreement with the present study where the *T. viride* in combination with NPK biofertilizers could effectively control the disease in ginger. Gupta *et al.* (2010) also reported the effectiveness of *Trichoderma* spp. against many fungal diseases particularly rhizome pathogens. *Trichoderma* strains establish long-lasting colonization of plant roots and penetrate the epidermis and produce or release compounds that induce localized or systemic plant resistance responses (Harman 2004). In a similar study, it was reported that rhizome treated with the *Trichoderma* sp. significantly reduced rhizome rot incidence and also increased the yield (Ram *et al.* 2000). *T. viride* produced non-volatile substances that inhibited the growth of the ginger rhizome rot pathogens viz. *P. myriotylum* and *F. solani* (Rathore *et al.* 1992). These results are in accordance with the present studies. However, the incidence of leaf blight was the lowest in the Organic Adhoc package at 4.17%.

The ginger plants treated with consortia AZO + KAU-PSB + KAU-KSB + KAU-PF also recorded the minimum incidence (5.21%) of *Rhizoctonia* leaf blight among the consortia. The incidence of the disease was lowest (15.63%) in seed treatment (TD) and soil application of *P. fluorescens* and *T. harzianum* consortia mass cultured in the mixture of vermicompost and mustard oil cake (Bora *et.al*. 2016), *P. fluorescens* is known to exhibit strong antifungal activity mainly through the production of antifungal metabolites. Nandakumar *et al.* (2001) reported two *P. fluorescens* strains, (PF1 and FP7) which inhibited the mycelia growth of sheath blight fungus *R. solani* and increased the seedling vigor of rice plants and yield. Biofertilizers improve soil health and provide protection against drought and some soil-borne diseases (Ellafi *et al.* 2010). In the present study, it was found that KAU-PF was more effective in the management of leaf diseases, whereas consortia with *T. viride* were effective in the control of rhizome rot incidence.

As ginger is highly amenable to organic inputs, organic cultivation of ginger must be encouraged as the ginger is directly consumed. The present study indicated that ginger plants inoculated with microbial inoculants consortia performed better than the individual microbial inoculants. The consortia of microbial inoculants treated plants were on par based on most of the parameters, but T_8 KAU-AZO + KAU-PSB + KAU-KSB + KAU-TV performed better among the consortia used.

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