Integrated management of fungal-nematode wilt complex disease of Bananacv. Ney Poovan (AB) caused by *Fusarium oxysporum*f. sp. *cubense*(E.F Smith) Snyder and Hansen and *Radopholussimilis*(Cobb and Thorne) under field conditions.

ABSTRACT

Banana (Musa spp.) belongs to the family Musaceae is the most important fruit crop in the world, serving as a staple food and source of income in many developing countries. There are several diseases recorded on Banana causing serious losses. Wilt complex disease caused by *Fusarium oxysporum* f. sp. *cubense* and *Radopholussimilis* is considered as a serious threat Banana cultivation. A field experiment was conducted in a randomised complete block design with susceptible Banana variety Nay Poovan (AB) to manage the fungal-nematode wilt complex using treatments of bioagents, organic amendments and chemicals in individual as well as in integrated approach. The experiment results revealed that, Carbendazim (262.73 cm) treated plants had good plant height and it was on par with combined treatments. Among combination treatments, T11 (Neem cake + FYM, Tv+Pf+Pl + Carbofuran + stem injection of Carbendazim at 5,7,9 months) gave maximum plant height (118.00, 195.27 and 262.60 cm). The least plant height was recorded in control 89.60 cm, 140.00 cm and 188.00 cm at 90, 180 days after planting and at harvest respectively. The final population of *R. similis* in soil was lowest in T11 (Neem cake + FYM, *Tv+Pf+Pl* + Carbofuran + stem injection of Carbendazim at 5,7,9 months) (6.33 /200 cc soil), followed by T6 (*T. viride* + *P. lilacinus*) (26.33 /200 cc soil), whereas control treatment has maximum (1382.00 /200 cc soil). Regarding wilt incidence, the plants treated with Neem cake + FYM, *Tv+Pf+Pl* + Carbofuran + stem injection of Carbendazimat 5, 7, 9 months (T11) recorded less incidence (11.12%) as compared to the maximum wilt incidence of 88.89 per cent in control treatment. The next best treatment was T10 (Carbendazim 17.67 %). Individual application the maximum number of hands per bunch, bunch weight and total yield per hectare was recorded in T10(Carbendazim) 13.80, 12.75 kg and 45.75 t/ha), T2(P. Fluorescens)(9.67, 9.73 kg and 36.05 t/ha) and least was recorded in T9 (Carbofuron) (8.75, 8.25 kg and 32.50 t/ha) compare to control. Among the combined treatments, the maximum number of hands per bunch (19.75), bunch weight (16.80 kg) and total yield per hectare (26.33 t/ha) was recorded in treatment T11 (Neem cake + FYM, *Tv+Pf+Pl* + Carbofuran + stem injection of Carbendazim at 5, 7, 9 months). The economic analysis revealed that, the T11 had recorded a

maximum benefit cost ratio of 4.26 followed by T10 – Carbendazim (3.96) percent incidence and the least benefit cost ratio was recorded by control (1.23).
Key words: Banana**,** *Fusarium, Radopholus*, disease management, wilt

INTRODUCTION

Banana (*Musa* spp.) belongs to family *Musaceae* is the most important fruit crop in the world, serving as a staple food and source of income in many developing countries. Banana is also the world's leading fruit crop and consequently an important export commodity for several agricultural based economies in Asia, America and African continents and represents the fifth most important agricultural crop in world trade (Aurore *et al.,* 2009). The genus *Musa* consists of giant herbs, ranging in height from 0.8 to 15 m. According to the use and genotype, Bananas can be divided into 3 categories: dessert and highland Bananas (AAA), plantains (AAB) and cooking Bananas (ABB) (Dadzie, 1998). Though, it has little fat and protein, it is a rich source of energy and contains all essential nutrients including minerals and vitamin A, B1, B2 and vitamin C and thus it is called as 'Apple of Paradise' and as well as 'Adams Fig' (Bose and Mitra, 2001).In India, Banana is the second most important fruit crop next to mango. Since, Banana is being used as food, fiber and for medicinal, cultural and industrial purposes and also gives high returns to small holders it is referred to as "Kalpatharu"- a plant of virtues. There are several fungal, bacterial, viral and nematode diseases recorded on Banana causing serious losses. Among these, Fusarium wilt complex caused by fungus (*Fusarium oxysporum* f. sp. *cubense*) and nematode (*Radopholussimilis*) is serious threat to the Banana cultivation (Ploetz and Pegg , 1990 ; Murali *et al.*, 2022)

The Fusaruiuminfects the roots of Banana plants, colonising the vascular system of the plants inducing characteristic symptoms of yellowing, pseudostemspiltting, drooping of leaves, wilting of the plant and eventually plant dies. It was first reported from South East Queensland, Australia in 1874 (Were*et al.*,2023;Bancroft, 1876). It became serious epidemic in Panama during 1890 and devastated Banana crop in Central American and Caribbean Banana industries (Stover, 1972).

In India occurrence of *R. similis* was first reported by from Kerala by Nair *et al*. (1966), the area of infestation has increased progressively over the years. Following its spread to the neighbouring states *viz*., Tamil Nadu (Rajagopalan and Chinnarajan, 1976), Karnataka (Venkaitesan, 1976), Maharashtra (Reddy and Singh, 1980), Williams *et al.* (2004) reported that, the most abundant root-parasitic nematode was *R. similis*and was most frequently

detected with Fusarium. All species of root-inhabiting nematodes and fungi were detected at high and low altitudes.Stover (1911) reported this disease in India for the first time. Uppal (1993) recorded the serious outbreak of Panama wilt disease in Pune. In India, the yield loss by this disease was estimated as 30 to 40 per cent and in South India alone from 20 to 90 per cent (Thangavelu *et al.*, 1999).NanjangudRasabale, which has been given the Geographical Indication tag in Karnataka, has been almost devastated by wilt diseases, caused by *F. oxysporium* f. sp. *cubense*. The disease was so severe that, it has reduced the area under cultivation of the crop from to about 100 acres in Mysore region (Reddy *et al.*,1992 ; Sowmya, 1993).

Global Banana production is seriously threatened by the re-emergence of wilt complex caused by fungus and nematode. Since, both the pathogens are soil borne in nature, once they enter into the soil, they can survive many years in the soil (Murali, 2016). As we all know that, the soil borne diseases are very difficult manage with single management component. Hence, in this experiment an effort was done with integrated approach for the management of wilt complex using plant extracts, bioagents and chemicals.

MATERIALS AND METHODS

An effort was made under field conditions to effectively manage the fungal-nematodewilt complex by soil application with commercially available plant productslikefarm yard manure,neem cake, bioagents like *Trichoderma viride, Pseudomonasfluorescens*,*Paecilomyceslilacinus*and chemicals like Carbofuran and Carbendazimboth individually and in integration.

Location of the experimental site:

Experiments was conducted in the garden of farmer Sri. Ramesh, Bikonahallivillage, Shivamogga (Tq. &District) of Karnataka. The field was heavily infested withFusarium and *R. similis*population density of more than one nematode per g soil *i.e*., 864nematode per 200 cc soil. Elakkibale, the succeptibe cultivar for Fusarium wilt was used forthis study.Farm was situated in agro climatic zone-VII (Southern Transition Zone) ofKarnataka state at 5804.245' North latitude and 75034' 35.15" East longitude at analtitude of 930 meters above the mean sea level.

Soil characteristics and Climatic conditions

Soil characteristics of the experimental location were sandy loam soil. Soils havemedium to high water holding capacity in the profile. Zone –VII has a semi-arid type of climate. Mean annual rainfall ranges from800 mm to 1000 mm with a normal rainfall of 830.00 mm and mean monthly maximumand minimum temperature are 32.75 °C and 19.25 °C respectively.

Field preparation

Experimental site was thoroughly ploughed to a fine tilth, harrowed andlevelled. Pits of 45 cm3 size were dug at a spacing of 1.8+1.2 x 1.8 m as a paired rowplanting. Uniform sized suckers of 1.2 kg each were planted after imposing differenttreatments to their respective pits.Normal package of practices like irrigation, fertilizer application and weedingwas done uniformly to all the plants by the farmer of the field.

Pre-treatment sampling

In order to assess the initial population of nematodes in soil, pre-treatmentsampling was taken up separately for each plot, rhizosphere soil samples collected fromplants at the corner and from the centre of plot were pooled. Out of this thoroughlymixed soil, an aliquot of 200cc was used for population assessment. These soil sampleswere processed and nematodes were extracted as explained earlier.

Experimental details

Crop : Banana
Cultivar : Ney Poovan (AB)
Design : RCBD
Size of the plot: 1.2 x 1.8m
Treatments : 12
Replications : 3
Number of plants per replication: 18

List 1. List of treatments and their details

Treatments	Treatment Details
T_1	*Trichoderma viride* @ 50 g/plant
T_2	*Pseudomonas fluorescens* @ 50 g/plant
T_3	*Paecilomyceslilacinus* @ 50 g/plant

T_4	Neem cake @ 250 g/plant
T_5	*T.viride*@ 25 g/plant + *P. fluorescens* 25g/plant
T_6	*T. viride* @ 25 g/plant + *P.lilacinus* @ 25g/plant
T_7	*P. fluorescens* @ 25 g/plant + *P.lilacinus*@ 25 g/plant
T_8	Carbofuran (20 g/plant) + Carbendazim (0.2 %)
T_9	Carbofuran 3G @ 20 g/plant
T_{10}	Carbendazim 50 % WP @ 0.2% as drenching
T_{11}	Neem cake + *Tv+Pf+Pl* + FYM + Carbofuran + Stem injection of Carbendazim (at 5, 7, 9 months)
T_{12}	Stem injection of Carbendazim 50 % WP
T_{13}	Untreated Control

The talc based formulations of *T. viride, P. fluorescens* and *P. lilacinus* were obtained from Indian Institute of Horticultural Research (IIHR), Bangalore.

The treatments are applied in two splits, one at the time of planting and anotherat six months after planting. In the first split application, full dose of bioagents, plantextracts and 50 per cent of carbofuran were applied at the time of planting andremaining 50 per cent of Carbofuran was applied at six months after planting. Thetreatment T_{12}, stem injection of Carbendazim @ 2 per cent was done at 5, 7, 9months. Injection of 2 per cent Carbendazim was done at an angle of 45^0 to the stem ofBanana with the help of stem injector at two feet above the soil surface. Oneinjection it releases 5 ml of solution approximately, if stem is smaller one injection wasdone, for bigger stems two injections were done at opposite directions.

Observations recorded:

The observations like plant height, girth of pseudostem, number of functional leaves, number of hands/bunch, weight of bunch (kg)nematode population before the treatment imposition, nematode population at monthly intervals, final nematode population, number of lesions per plant, root lesion indexNumber of wilted plants, per cent disease incidence, length of Psuedostem splitting and vascular discoloration index were recorded.vascular discoloration index was calculated by using 1-6 scale given by Orjeda (1998).

List 2.Vascular discoloration index

Vascular discolouration	Scale
Corm completely clean, no vascular discolouration	1
Isolated points of discolouration in vascular tissue	2
Discolourationupto 1/3rd of vascular tissue	3
Discolouration between 1/3rd and 2/3rd vascular tissue	4
Discolouration more than 2/3rd of vascular tissue	5
Total discolouration of vascular tissue	6

Analysis of data

The data obtained in present investigation for various parameters were subjected to ANOVA for a completely randomized design for *in vitro* studies and Randomized complete block design for *in vivo* studies (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The bio-agents (*Trichoderma viride, Pseudomonas fluorescens* and *Paecilomyceslilacinus*), organic amendment (Neem cake) and chemicals (Carbofuran and Carbendazim) were evaluated separately and in combination for the management of fungal-nematodewilt complex in Banana. Pairing and prolinage and rhizome dipping @ 0.1 per cent Carbendazim was the common for all treatments except control. The observations were recorded on plant height, number of leaves and pseudostem girth at 90, 180 days after planting and at harvest were given in the Table 1.

Effect of integrated approaches on plant growth parameters

Plant height

The individual treatments of bioagents, organic amendment and chemicals were not significantly different over control at 90, 180 days after planting. At harvest, Carbendazim (262.73 cm) treated plants had good plant height and it was on par with combined treatments.

Among combination treatments, T_{11} (Neem cake + FYM, *Tv+Pf+Pl*+ Carbofuran + stem injection of Carbendazim at 5,7,9 months) gave maximum plant height (118.00, 195.27 and 262.60 cm) and it was on par with T_8 (Carbofuran + Carbendazim) (113.27, 182.40 and

252.07 cm), T_7 (*P. fluorescens* + *P. lilacinus*) (104.67, 172.40 and 238.87 cm), T_5 (*T. viride*+ *P. fluorescens*) (104.53, 167.87 and 235.40 cm) and T6 (*T. viride*+ *P. lilacinus*) (101.87, 163.20 and 224.40 cm) at 90, 180days after planting and at harvest respectively.The least plant height was recorded in control 89.60 cm, 140.00 cm and 188.00cm at 90, 180 days after planting and at harvest respectively.The present findings are in confirmation with Dinesh *et al.,* (2014) whoconducted experiment on Fusarium wilt complex of Banana and revealed that, combined application of Carbofuran + Carbendazim gave maximum plant height,number of functional leaves and pseudostem girth. The alternative to above treatmentwith the similar efficacy was *T. viride*+ *P. fluorescens* + *P. lilacinus*with a higher plantheight, number of functional leaves and pseudostem girth at 90, 180 days after plantingand at harvest respectively.

Number of leaves

Among the individual treatments, the number of functional leaves wasmaximum in plants treated with Carbendazim (9.02, 12.47 and 11.36). Amongindividual bioagents and organic amendment, the plant treated with *P. fluorescens*(7.21, 9.32 and 8.56) followed by *P. lilacinus*(6.55, 7.87 and 7.03), *T. viride*(6.33,8.40 and 7.65) and neem cake (7.61, 9.30 and 7.96) and which were on par with eachother at 90, 180 days after planting and at harvest respectively.Among combination treatments, the plant treated with T11 (Neem cake + FYM,*Tv*+*Pf*+*Pl*+ Carbofuran + stem injection of Carbendazim at 5,7,9 months)hadmaximum number of functional leaves at 90 (9.96), 180 days after planting (13.80) andat harvest (14.09) and it was on par with T8(Carbofuran + Carbendazim)9.24, 11.87 and12.76 at 90, 180 DAP and harvest respectively.The lowest number of leaves was observed in control 90 (4.96), 180 days afterplanting (6.75) and at harvest (4.66).Senthil Kumar *et al.*(2008a;b) reported maximum plant growth intreatment with *P. fluorescens B13* isolate. The soil application of *P. fluorescens* @ 10g/plant recorded increased plant growth and yield. Further, Jonathan *et al.* (2009) observed significantly enhanced the growth and fruit yield with combined applicationof *P. fluorescens* (Pfbv22) and *B. subtilis* (Bbv57).

Pseudostem girth

The individual treatments of bioagents, organic amendments and chemicalswere not found to be significantly different in Pseudostem girth over control at 90, 180days after planting and at harvest. But among individual treatments, the plants treatedwith Carbendazim (24.22, 51.06 and 84.06 cm) had maximum pseudostem girth at 90,180 days after planting and at harvest respectively and it was on par with combinedtreatments.Among combination treatments, T11 (Neem cake + FYM, *Tv+Pf+Pl*+Carbofuran + stem injection of Carbendazim at 5,7,9 months)had maximum girth of28.10, 54.09 and 86.12 cm at 90, 180 days after planting and at harvest respectivelyand it was on par with T8 (Carbofuran + Carbendazim) (26.17, 52.03 and 82.04 cm),T5 (*T. viride*+ *P. fluorescens*) (24.09, 43.11 and 70.04 cm), T6 (*P. fluorescens* + *P.lilacinus*) (23.23, 42.55 and 69.21 cm), and T7 (*T. viride*+ *P. lilacinus*) (23.17, 42.49and 71.39 cm) at 90, 180 days after planting and at harvest respectively.The minimum pseudostem girth was noticed in control plants at 90 (15.27 cm),180 days after planting (30.33 cm) and at harvest (51.03 cm).*T. viride*was also found effective against wilt. The improved plant growth bythis bioagent is in confirmation with findings of Thangavelu and Mustaffa (2010) theyfound that soil application of *T. viride*significantly reduced the external (up to 78%)and internal symptoms (up to 80%) of *Fusarium* wilt of Banana and increased the plantgrowth significantly under field conditions.The effect of *P. lilacinus*in managing the *R. similis*and improving the growthof Banana is in confirmation with findings of Kilama *et al.* (2007); Mendoza *et al.* (2007); Marimuthu and Murugesan (2008).

Effect of integrated approaches on nematodes population in root and soil ofBanana infected with Fusarium and *R. similis*under field conditions.

The population of *R. similis*in soil differed significantly among thetreatments compared to control.Among individual treatments, the lowest multiplication of *R. similis*wasobserved in Carbofuran and it was on par with *P. lilacinus*and *P. fluorescens*. It wasfollowed by *T. Viride*and neem cake. The population of *R. similis*in roots differedsignificantly among the treatments compared to control.Observation on *R. similis*population in soil (200 cc) and root (5g) was recordedat harvest and are presented in Table 2.

Final population *R. Similis*in root and soil

The final population of *R. similis*in soil was lowest in T11 (Neem cake + FYM,*Tv+Pf+Pl*+ Carbofuran + stem injection of Carbendazim at 5,7,9 months) (6.33 /200cc

soil), it was on par with T6 (*T. viride*+ *P. lilacinus*) (26.33 /200 cc soil), T7 (*P.fluorescens* + *P. lilacinus*) (28.00 /200 cc soil), T8(carbofuran + Carbendazim)(52.67/200 cc soil), *P. lilacinus*(63.67 /200 cc soil), carbofuran (63.33 /200 cc soil), *P.fluorescens* (72.67 /200 cc soil) and T5 (*T. viride*+ *P. fluorescens*) (71.67 /200 cc soil)compared to control (1382.00 /200 cc soil).The final population of *R. similis*in roots was minimum in T11 (Neem cake +FYM, *Tv*+*Pf*+*Pl*+ Carbofuran + stem injection of Carbendazim at 5,7,9 months)(5.33 /5 g root) and was on par with T7 (*P. fluorescens* + *P. lilacinus*) (14.67 /5 g root),T5 (*T. viride*+ *P. fluorescens*) (17.33 /5 g root), T3 (*P. lilacinus*(28.33 /5 groot)) and T6 (*T. viride*+ *P. lilacinus*) (32.00 /5 g root) as compared to control (348.33/5 g root).The results obtained in current investigation were upholded by the resultsobserved by Shreenivasa*et al.* (2005); Shanthi and Rajendran (2006); Senthil Kumar *et al.* (2008a); Jonathan *et al.* (2009); and Shanthi and Sivakumar (2011).

Number of lesions per plant and lesion index

The lowest number of lesion and lesion index (4.07 and 0.67) was observed inT9carbofuran followed by T11 (Neem cake + FYM, *Tv*+*Pf*+*Pl*+ Carbofuran + stem injection of Carbendazim at 5,7,9 months)(9.47 and 0.87) and T8 (carbofuran + Carbendazim) (12.50 and 1.07) and these were on par with each other. The next best treatment in reducing the lesions and lesion index was T6 (*T. viride*+ *P. lilacinus*) (24.33 and 1.60) which was on par with, T7 (*P. fluorescens* + *P. lilacinus*) (25.33 and 1.73), T5 (*T. viride*+ *P. fluorescens*) (31.93 and 1.87) and *P. lilacinus*(30.87 and 1.87) respectively.

Effect of integrated approaches on wilt incidence

The results indicated that, the plants treated with Neem cake + FYM, *Tv*+*Pf*+*Pl*+ Carbofuran + stem injection of Carbendazimat 5, 7, 9 months (T11) recorded very lesswilt incidence (11.12%) as compared to the maximum wilt incidence of 88.89 per centin control treatment. The next best treatment was T10(Carbendazim 17.67 %) followed by the T8(carbofuron + Carbendazim), whichrecorded the wilt incidence of 22.22 per cent. It was on par with T5(*T. viride*+ *P.fluorescens*) (27.78%) and T7 (*P. fluorescens* + *P. lilacinus*) (33.33%). Even though,individual application of bioagents and organic amendments were significantly reducedthe wilt incidence over control, but the efficacy was less compared to their combinedapplication.

Rhizome discolouration index (RDI) and Vascular discolouration index (VDI)

Based on the rhizome discolouration index (RDI) and Vascular discolouration index (VDI), the plant treated with T_{11} (Neem cake + FYM, *Tv+Pf+Pl+* Carbofuran + stem injection of Carbendazim at 5, 7, 9 months)showed very lowest rhizome discolouration and vascular discolouration (1.27 RDI and 0.53 VDI respectively). It was followed by T_8(carbofuran + Carbendazim) (2.67 and 1.07) and T_{10} (Carbendazim) (3.07, 1.67) compared to almost complete discolouration of rhizome and vascular region with a RDI of 6.33 and VDI of 5.80 respectively in control. Individual application of *P. fluorescens* (5.47), *T. viride*(6.13), and *P. lilacinus*(6.20), carbofuran (6.13) and neem cake (6.27) showed higher rhizome discolouration and it was on par with control (6.33). But based on VDI, significant difference was observed in plants applied with *P. fluorescens* (3.60), *T. viride*(3.67), and *P. lilacinus*(4.40) individually with lower vascular discolouration compared to complete vascular discolouration in control treatment (5.80).

Effects integrated approaches on yield parameters and economic benefit ofdisease management

All the treatments recorded increased yield parameters viz., number of handsper bunch, bunch weight, total yield per hectare and higher net income and benefit: costratio compared to control. The data is presented in Table 3.Individual application the maximum number of hands per bunch, bunch weightand total yield per hectare was recorded in T10(Carbendazim) 13.80, 12.75 kg and 45.75t/ha), T2(*P. Fluorescens*)(9.67, 9.73 kg and 36.05 t/ha) and least was recorded inT9(carbofuron) (8.75, 8.25 kg and 32.50 t/ha) compare to control.Among the combined treatments, the maximum number of hands per bunch(19.75), bunch weight (16.80 kg) and total yield per hectare (26.33 t/ha) was recordedin treatment T11 (Neem cake + FYM, *Tv+Pf+Pl+* Carbofuran + stem injection ofCarbendazim at 5, 7, 9 months). The next best treatment was T8(carbofuran +Carbendazim)with higher number of hands per bunch (17.50), bunch weight (15.20 kg)and total yield per hectare (24.73 t/ha).Present findings were in confirmation earlier results reported by Roy *et al*. (1998), Raguchander*et al.* (1998), Raguchander*et al.* (2001), Shamarao*et al.* (2001), Thangavelu (2002) and Saravanan *et al.* (2003). Roy *et al*. (1998) reported that dipping disease-free Banana suckers in 0.2 percent solution of carbendazim for 45 min was effective in reducing disease intensity ofwilt complex disease.

The efficacy of *P. fluorescens* and *T. viride*in reducing the wilt disease complex was also reported by Raguchander*et al.* (1998), who reported that, *T. viride*and *P. fluorescens*

were equally effective in reducing growth of Fusariumunder *in vitro*. Dipping of Banana suckers in the suspension of *P. fluorescens* or *T. viride*effectively reduced the *Fusarium* wilt incidence and produced the highest yield under field conditions. Further, Raguchander*et al.* (2001) observed, capsule application of *P. fluorescens* at 3 and 5 months after planting recorded the lowest wilt incidence. Further, Shamarao*et al.* (2001) showed that, the *T. viride*, *P. fluorescens* and *B. thuringiensis*, MPG-3 and carbendazim were all effective against Fusarium.Saravanan *et al.* (2003) recommended the basal application of neem cake + sucker dipping *P. fluorescens* + soil application of *P. fluorescens* at 3, 5 and 7 months after planting showed the greatest suppression of Panama wilt disease under field condition.

The reasons for the reduced wilt incidence and severity and increased yield may attributed to the *Trichoderma* spp. involved in the reduction of *Fusarium* wilt severity by mycoparasitism, spatial and nutrient competition, antibiosis by enzymes and secondary metabolites, and induction of plant defence system. The fluorescent *pseudomonads* produced secondary metabolites like phenazine, 2,4- diacetylphloroglucinol, pyocyanine, pyoluteorin and pyrrolnitrin which were involved in suppression of root diseases causing pathogens (Ayyadurai *et al*., 2006) and the developing *P. lilacinus*kills the nematode by feeding on its body contents. In effect, the *P. lilacinus*acts as a parasite on all the stages of nematode.The pre-colonization with *P. fluorescens* reduced Fusariumcolonization. Massive depositions of unusual structures at sites of fungal entry clearly indicated that bacterized root cells were signalled to mobilize a number of defense structures for preventing the spread of pathogen in the tissue (Sukhada *et al.*, 2004).

The economic analysis for integrated management revealed that, the T_{11} had lowest wilt incidence (11.11 %) and recorded benefit cost ratio of 4.26. The next best treatment was T_8 (Carbofuran + Carbendazim) with a wilt incidence of 22.22 per centB: C ratio of 3.82 and the least benefit cost ratio was recorded by control (1.23). It was apparent that, the application of T_{11} (Neem cake + FYM, *Tv+Pf+Pl*+ Carbofuran + stem injection of Carbendazim at 5, 7, 9 months)was most effective in improving plant growth, fruit yield and in reducing nematode population, root lesion index, wilt incidence and wilt severity and also maximum net and additional returns.The combined action of these three bioagents against Fusarium and*R. similis*helpedtremendously for the management of wilt complex in Banana under *in vitro* and *in vivo.*The amount of disease suppression obtained with a biological control agent depends onthe density of the agent, the density of the pathogen, and how efficiently individualunits of

the agents render units of the pathogen ineffective. In our study, an inoculumdose of 10 g of talc formulation per plant was optimum.

CONCLUSION

Finally, it may be concluded that, soil borne pathogens like *Fusarium oxysporum*f.sp.*cubense*and*Radopholussimilis*cannot be kept under control with just a single management strategy. In the present study an integrated approach was attempted to manage this disease, with mixtures of biocontrol formulations which showed significant reduction in the disease incidence. The application of *T. viride*, *P. fluorescens* and *P. lilacinus*in combination is highly useful in managing the *Fusarium- R. similis*wilt complex in Banana.Integration of biocontrol withagronomic practices may also improve the efficacy of the biocontrol organisms and thehealth of the host plants, which may be sensitive to environmental changes.More research is needed to integrate previous advancements with consideration of disease management, host genetics, identification of resistant sources and the biology of *F.oxysporum*f. sp. *cubense*and *R. similis* and rhizosphere microbe interactions which influence the wilt complex.

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Table 1: Effect of integrated approaches on plant growth parameters of Banana infected with Fusariumand *R. similis* wilt complex under field conditions.

Sl. No.	Treatments	Plant height (cm)			Number of leaves			Pseudostem girth (cm)		
		90 DAP	180 DAP	At harvest	90 DAP	180 DAP	At harvest	90DAP	180 DAP	At harvest
1	T_1 - *T. viride*	101.47*	161.27	220.67	6.33	8.40	7.65	18.44	36.17	58.29
2	T_2 - *P. fluorescens*	99.53	162.07	223.60	7.21	9.32	8.56	19.33	37.09	60.07
3	T_3 - *P. lilacinus*	98.13	156.13	213.53	6.55	7.87	7.03	17.42	38.32	57.43
4	T_4 - Neem cake	95.53	151.27	206.07	7.61	9.30	7.96	16.46	35.09	58.35
5	T_5 - *Tv+Pf*	104.53	167.87	235.40	8.44	10.09	11.58	24.09	43.11	70.04
6	T_6 - *Tv+Pl*	101.87	163.20	224.40	8.65	9.96	9.24	23.23	42.55	69.21
7	T_7 - *Pf+Pl*	104.67	172.40	238.87	9.11	10.45	10.03	23.17	42.49	71.39
8	T_8 – Carbofuran + Carbendazim	113.27	182.40	252.07	9.24	11.87	12.76	26.17	52.03	82.04
9	T_9 - Carbofuran	91.07	157.47	211.33	6.03	9.33	7.54	19.22	37.13	59.02
10	T_{10} - Carbendazim	97.80	170.40	242.73	9.02	12.47	11.36	24.22	51.06	84.06
11	T_{11} – Neem cake + *Tv+Pf+Pl* Carbofuran + Stem injection of Carbendazim (at 5, 7, 9 months)	118.80	195.27	262.60	9.96	13.80	14.09	28.10	54.09	86.12
12	T_{12} Stem Injection ofCarbendazim	101.73	146.20	212.20	8.05	10.26	9.55	22.12	48.16	80.22
13	T_{13} - Control	89.60	141.00	188.00	4.96	6.75	4.66	16.76	31.24	48.26
	S. Em ±	**5.38**	**10.48**	**14.26**	**0.31**	**0.37**	**0.36**	**1.54**	**1.66**	**2.24**
	CD @ 5%	**15.71**	**30.58**	**41.61**	**0.95**	**1.23**	**1.21**	**4.51**	**4.85**	**6.54**

Note: * Indicate the mean values of replications of respective treatments,DAP- Days after planting

Note : *Tv- Trichoderma viride, Pf- Psuedomonas fluorescens* and *Paecilomyceslilacinus*

* Pairing and prolinage and rhizome dipping @ 0.1 % Carbendazim is common for all treatments except control

Table 2: Effect of integrated approachesonNematode population, lesion index and wilt parameters of Banana.

Sl. No.	Treatments	Final nematode population		Number of lesions	Lesion index	Wilt incidence (%)	% decrease over control	RDI	VDI
		Soil (200 cc)	Roots (5 g)						
1	T_1 - ***T. viride***	298.43	131.00	70.47	3.00	56.33 (48.62)	36.63	6.11	3.67
2	T_2 - ***P. fluorescens***	72.67	41.33	59.80	2.80	53.56 (47.02)	39.74	5.37	3.60
3	T_3 - ***P. lilacinus***	63.67	28.33	30.87	1.87	67.44 (55.18)	24.13	6.10	4.40
4	T_4 - Neem cake	414.67	188.00	76.27	3.20	65.67 (54.11)	26.12	6.27	5.67
5	T_5 - ***Tv+Pf***	71.67	17.33	31.93	1.87	26.78 (31.15)	69.87	5.03	2.20
6	T_6 - ***Tv+Pl***	26.33	32.00	24.33	1.60	37.89 (37.98)	57.34	5.83	3.13
7	T_7 - ***Pf+Pl***	28.00	14.67	25.33	1.73	32.33 (34.62)	63.63	5.10	3.27
8	T_8 - Carbofuran + Carbendazim	52.67	112.33	12.50	1.07	21.22 (27.42)	76.13	2.67	1.07
9	T_9 - Carbofuran	63.33	81.33	4.07	0.67	76.78 (61.17)	13.62	6.13	5.53
10	T_{10} - Carbendazim	502.00	334.67	94.93	3.27	17.67 (24.85)	80.12	3.01	1.67
11	T_{11}- Neem cake + ***Tv+Pf+Pl*** + FYM Carbofuran + Stem injection of Carbendazim (at 5, 7, 9 months)	6.33	5.33	9.47	0.87	11.12 (19.47)	87.49	1.27	0.53
12	T_{12} Stem injection of Carbendazim	528.67	202.67	80.40	3.13	36.11 (36.92)	59.38	3.07	1.71
13	T_{13} - Control	1382.00	348.33	97.40	3.40	88.89 (70.50)	0.00	6.33	5.80
	S. Em ±	**31.45**	**12.14**	**4.42**	**0.16**	**2.02**	**-**	**0.25**	**0.22**
	CD @ 5%	**90.86**	**35.56**	**12.90**	**0.47**	**5.89**	**-**	**0.74**	**0.65**

Note :*Tv- Trichoderma viride, Pf- Psuedomonas fluorescens* and *Paecilomyceslilacinus,* DAP- Days after planting

* Pairing and prolinage and rhizome dipping @ 0.1 % Carbendazim is common for all treatments except control.

Table 3: Effect of integrated approacheson yield parameters of Bananainfected withFusariumand*R. similis* wilt complex under field conditions and their economic analysis.

Sl. No.	Treatments	Wilt incidence (%)	Number of hands /bunch	Bunch weight (kg)	Yield(t/ha)	B:C ratio
1	**T_1 - *T. viride***	56.33 (48.62)	9.50	9.28	16.52	2.44
2	**T_2 - *P. fluorescens***	53.56 (47.02)	10.75	9.36	15.48	2.01
3	**T_3 - *P. lilacinus***	67.44 (55.18)	9.76	9.30	15.07	1.96
4	**T_4 - Neem cake**	65.67 (54.11)	8.75	9.25	14.20	1.73
5	**T_5- *Tv+Pf***	26.78 (31.15)	12.72	12.80	19.39	3.67
6	**T_6- *Tv+Pl***	37.89 (37.98)	12.27	11.50	18.84	3.49
7	**T_7- *Pf+Pl***	32.33 (34.62)	11.90	11.25	18.27	3.37
8	**T_8– Carbofuran + carbendazim**	21.22 (27.42)	17.50	15.20	22.73	3.82
9	**T_9- Carbofuran**	76.78 (61.17)	18.75	8.25	13.61	1.41
10	**T_{10}- Carbendazim**	17.67 (24.85)	13.80	12.75	20.11	3.96
11	**T_{11}–Neem cake + *Tv+Pf+Pl* carbofuran + Stem injection of carbendazim (at 5, 7, 9 months)**	11.12 (19.47)	19.75	16.80	26.33	4.26
12	**T_{12} Stem injection of carbendazim**	36.11 (36.92)	10.25	9.26	18.93	3.68
13	**T_{13}- Control**	88.89 (70.50)	6.24	4.96	12.06	1.23
	S. Em ±	**2.02**	**0.43**	**0.35**	**1.31**	
	CD @ 5%	**5.89**	**1.25**	**1.03**	**3.83**	

Note: *Tv- Trichoderma viride, Pf- Psuedomonas fluorescens* and *Pl- Paecilomyceslilacinus*

* Pairing and prolinage and rhizome dipping @ 0.1 % Carbendazim is common for all treatments except control