International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 870-877
© 2018 IJCS
Received: 10-05-2018
Accepted: 12-06-2018

S Raghu
a) Crop Protection Division, ICAR-NRRI, Cuttack, Odisha, India
b) Department of Plant Pathology, UAS Dharwad, Karnataka, India

VI Benagi
Directorate of Research, UAS-Dharwad, Karnataka, India

VB Nargund
Department of Plant Pathology, UAS Dharwad, Karnataka, India

K Jayalakshmi
Department of Plant Pathology, UAHS-Shimoga, Karnataka, India

Correspondence
S Raghu
a) Crop Protection Division, ICAR-NRRI, Cuttack, Odisha, India
b) Department of Plant Pathology, UAS Dharwad, Karnataka, India

Effect of chemicals, bio control agents and soil amendments integrated in different management modules on plant growth, yield and incidence of fusarium wilt of chilli in Karnataka

S Raghu, VI Benagi, VB Nargund and K Jayalakshmi

Abstract
Field experiments was conducted for two seasons in two different locations of northern Karnataka to evaluate the efficacy of chemicals, bio control agents and soil amendment integrated in three management modules on incidence and management of fusarium wilt of chilli. The efficacy of these modules on plant growth and incidence of fusarium wilt was assessed. The experiments were conducted for two seasons in two different locations. The experiment was laid in randomized block design. Two varieties with differential disease reaction were taken for the experiment. Seed treatment of fungicides and bio control agents either alone or in combination was tested in nursery. Drenching of chemicals and bio control agents were made alone or in rotation with fungicides were done. The observations on plant growth parameters, disease incidence, per cent disease reduction, reduction in pathogen population and yield were recorded. Our results revealed that, significant increase in germination percent and plant growth parameters was recorded in module-III (adoptive module) with least death of the seedlings (9.04 and 8.96%). In the main field, module-III performed better with least disease incidence (15.80 and 12.67%) and highest yield (26.25 and 18.25 ton/ha) in both Sitara and Atirikta varieties. This module found best for two seasons in two different locations of Karnataka. The cost economics was also calculated and found that, highest cost benefit ratio (1:3.25 and 1:2.70 Rs) was obtained by following the adoptive module. There was significant reduction in pathogen population was also recorded from both the locations when compared with control treatment. Application of soil amendments like neem cake before transplanting also helps in controlling the disease and maintain soil health also.

Keywords: Fusarium wilt, chilli, management modules

1. Introduction

Chilli (*Capsicum annuum* L) occupies a premier place both as a spice and vegetable crop in most countries of the world and especially in Asia where the crop is used for many culinary purposes. India is the leading producer, consumer and exporter of chilli in the world with a production of 14.92 lakh tones from 7.74 lakh hectare area and a productivity of 1.92 MT/ ha (Anonymous, 2014) [2]. In India the states such as Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Odisha and Rajasthan are the major producers. Owing to the continuous monoculture and inappropriate package of practices followed by the farmers, diseases like Fusarium wilt becoming more and more serious from past few years especially in these states. The disease can have severe impact on crop growth from seedling up to harvesting stage. Various researchers have recorded different degrees of incidence from different agro-climatic regions of India with a range of 2-85 per cent. The disease causes 5- 57 % losses in major growing areas of south India (Raghu *et al.* 2013b) [20]. Loganathan (2013) [13] reported 10-80 per cent yield losses worldwide due to the disease. Devika Rani *et al.* (2007, 2009) [5, 6] recorded 20% yield loss where the crop is grown in black cotton soils. Almost all the commercial cultivars including famous Byadgi dabbi is highly susceptible to the disease posing a serious concern for the management of the disease. In India, different species of genus *Fusarium* such as *Fusarium oxysporum*, *Fusarium solani* are reported to induce the disease with other species *i.e.*, *F. moniliformae* and *F. Pallidoroseum* with sporadic appearance (Naik 2006, Devikarani 2007) [17, 5]. *Fusarium* spp. are of prime importance among the soilborne pathogens, and it is estimated that, they alone can cause an economic loss of 50-75% based on severity in different crops (Lewis and Papavizas, 1991) [12].

They can cause symptoms such as root rot, wilt, yellowing, stunting and seedling damping off. The pathogen can survive in soil for many years in the absence of host plant by forming resistant structures called chlamydospores. Consequently this pathogen is very difficult to predict, detect, diagnose and control (Astrom and Gerhardson, 1988) [3]. Drenching of chemicals are the only effective ways to manage this disease as the resistant varieties are scanty. Due to environmental concerns, researchers are focused on finding alternatives to chemical pesticides such as bio control agents and botanicals which are safe and ecofriendly for the suppression of this pathogen (Larkin *et al*. 1998) [11]. Alternate approaches including crop rotation, use of soil amendment, solarization, biofumigation, bio control agents, nutrient enriched composts are gaining considerable interest (Kirkegaard *et al*. 2000, Louws *et al*. 2010) [8, 14]. Looking into the scope for alternate approaches in fusarium wilt management, the present investigation was undertaken in farmers fields to assess the impact of chemicals, bio control agents and soil amendments integrated in different management modules (IDM) for the effective and eco-friendly management of this most destructive disease of chilli.

2. Materials and Methods

In order to assess the efficacy of three management modules, field experiments were conducted during *kharif* 2012 and 2013 in farmers' fields at Byadgi taluk of Haveri district (14^0 37.754^1 N, 75^0 25.545^1E and 656 m MSL) and Saundatti taluk of Belgaum district(15º86'786 N,74º84'047 E and 680 m MSL) of Karnataka. The soil was black cotton soil which was naturally infested with fusarium wilt and recorded more than 80 % of disease incidence for two consecutive years. Two susceptible varieties such as Sitara and Athirikta with differential reaction to the disease were taken for the experiment. Since the disease appears both in nursery and main field, the management was undertaken right from the nursery. The soil was well tilled and applied with FYM (25 ton/ha). The seeds of both the varieties were sown in nursery separately. Recommended dose of fertilizer (100:75:75 and 100:50:50 kg of N, P_2O_5, K_2O/ha for irrigated and rainfed conditions respectively) was applied to the field. 30 days old seedlings were transplanted in ridges at a spacing of 60x45 cm. each plot was of 10x10 mt size. The plots were irrigated timely and other intercultural operations were done as and when needed. All the treatments of each module were carried out as per time schedule. The observations like per cent germination, plant growth parameters, disease incidence and yield were taken and economics of different treatments were calculated in terms of benefit cost (C:B) ratio to find out the best module. The seeds of both the varieties were collected from the company dealers. The chemicals were purchased from local pesticide dealers, neem oil and neem cake were purchased from oil extraction mill and supplied as raw oil. Talc based formulations of bio control agents were collected from Institute of Organic Farming (IOF), University of Agricultural Sciences, Dharwad, Karnataka. The experiment was designed by following factorial RBD with three replications. The details of the treatments of nursery and main field experiments are furnished here under.

2.1 Treatments at Nursery

1. Module-I (Biological Module): Soil application of Neem cake @ 150 g/m^2 three days before sowing + Seed treatment with *Trichoderma harzianum* @ 10 g/kg of seeds- followed by drenching seedlings with *Trichoderma harzianum* @ 10 g/lit of water after seven and 20 days after sowing+ Spraying with Neem oil @ 5ml/lit of water.
2. Module-II (Chemical Module): Seed treatment with Thiram 37.5 + Carboxin 37.5 (Vitavaxx Power 75 % WP) @ 2.5 g/kg of seeds - followed by drenching seedlings with Metalaxil 4%+ Mancozeb 64% (Ridomil Gold 68 % WG) @ 3g/lit of water after seven days followed by drenching with copper oxy chloride @ 3g + Carbendazim @ 2 g/lit of water 20 days after sowing+ Spraying with Fipronil @1.0 ml/lit of water.
3. Module-III (Adoptive Module): Soil application of neem cake @ 150 g/m^2 three days before sowing + Seed treatment with Thiram 37.5 + Carboxin 37.5 @ 2.5 g/kg of seeds - followed by drenching seedlings with *Trichoderma harzianum* @ 10 g/lit of water after seven and 20 days after sowing + Spraying with Fipronil @1.0 ml/lit of water.
4. Untreated control.

2.2 Treatments at Main field

1. Module-I (Biological Module): Soil application with neem cake @ 20 g/spot (during transplanting) + root dipping of seedlings with *Pseudomonas fluorescens* @ 10 gm + raw neem oil @ 5ml/lit of water followed by drenching plants with *Trichoderma harzianum* @ 10 g/lit of water 15 and 45 days of transplanting + spraying with raw neem oil @ 5ml/lit of water followed by drenching with *Pseudomonas fluorescens* @ 10 g/lit of water after 30 and 60 days of transplanting + spraying with raw neem oil @ 5ml/lit of water.
2. Module-II (Chemical Module): Root dipping of seedlings with Thiram 37.5 %+ Carboxin 37.5% @ 2.5 gm + Imidachloprid @ 0.5 ml/lit of water followed by drenching plants Thiram 37.5 + Carboxin 37.5 @ 2.5 g/lit of water after 15 and 45 days of transplanting + spraying with Fipronil @ 1.0 ml/lit of water followed by drenching with Carbendazim 12 %+ Mancozeb 63 % @ 2.5 g/lit after 30 and 60 days of transplanting + spraying with Imidachlopriid @ 0.25 ml/lit +by spraying with propiconazole @ 1.5 ml/lit followed by spraying with Oberon 0.75ml/lit @ + spraying with hexaconazole @ 1.5 ml/lit during fruit maturity stage.
3. Module-III (Adoptive Module): Soil application with neem cake @ 20 g/spot (during transplanting) + root dipping of seedlings with *Pseudomonas fluorescens* @ 10 gm + raw neem oil @ 5ml/lit of water followed by drenching plants with Thiram 37.5 + Carboxin 37.5 @ 2.5 g/lit of water after 15 days and *Trichoderma harzianum* @ 10 g/lit of water after 30 days of transplanting + spraying with raw neem oil @ 5ml/lit of water followed by drenching with *Pseudomonas fluorescens* @ 10 g/lit of water after 30 days and Thiram 37.5 + Carboxin 37.5 @ 2.5 g/lit after 60 days of transplanting + spraying with Fipronil @ 1.0 ml/lit + spraying with propiconazole @ 1.5 ml/lit followed by followed by spraying with Oberon 0.75ml/lit @ + spraying with hexaconazole @ 1.5 ml/lit during fruit maturity stage.
4. Untreated control

2.3 Observations on growth, yield and disease incidence

The data on germination percent, plant vigor, number of plants died in nursery and percent disease incidence in main field initial and final population of fusarium was recorded one in 15 days during the imposition of treatments (15, 30,45, 60,75 and 90 DAT). Data on yield was recorded after each harvest of green fruits and cumulative yield after final harvest was used for economic analysis to estimate the cost benefit ratio of each module. The disease incidence (%) in each module was calculated by the following formula.

$$\text{Per cent disease incidence (PDI)} = \frac{\text{Number of plants infected}}{\text{Total number of plants observed}} \times 100$$

2.4 Biological assays of soil microbial population

The soil microbial populations of Fusarium in particular and total fungi in general were enumerated by serial dilutions on Fusarium specific Medium (NSM) (Nash and Synder, 1962) [18] and Martin's rose-bengal agar (Martin, 1950) [15], total bacteria on Nutrient agar, and total actinomycetes on Kenknight and Munaiers medium. Enumeration of each category of organisms was made from soil sample collected from each treatment. Serial dilutions of 10^{-4} to 10^{-6} were made as per the requirement. The Petri plates were incubated at ±27-30°C in a BOD incubator under a 12 h cycle of light and dark. Observations were recorded after 24 hours of incubation.

2.5 Statistical Analysis

Treatment effects on the percentage of emergence, root and shoot length, root and shoot weight root: shoot ratio, percent disease incidence (PDI), per cent reduction over control, yield were taken and were analyzed by analysis of variance (ANOVA). The data on per cent disease incidence in above said experiment was arcsine transformed before undergoing for statistical analysis.

3. Results

3.1 Effect of management modules on plant growth parameters in nursery

The present investigation was undertaken to evaluate the efficacy of three management modules under farmer's fields against fusarium wilt of chilli. The results of the present study revealed that, all the three modules were significantly effective in controlling the disease both under nursery and main field. All the three management modules significantly improved the germination percent when compared to control in both the test varieties. In nursery, module-III (Adoptive module) recorded significantly higher seed germination in both Sitara and Atirikta varieties (85.33 and 85.50 % respectively) when compared to control (26.08 and 38.00%). Module-III also recorded highest root length (12.00 cm & 11.75 cm), shoot length (15.33 cm & 14.33 cm), fresh root weight (0.85 g & 0.89 g), dry root weight (0.13g & 0.12 g), fresh shoot weight (6.83 g & 6.47g), dry shoot weight (0.42 g & 0.37g) in sitara and atirikta varieties respectively. The next best module was module-II (chemical module) followed by module-I (biological module). Module-III also recorded significantly lower seedling death (9.04 and 8.96% respectively) in both the varieties followed by module-II (Chemical module) when compared to the highest seedling death in control (25.00 and 20.54 % respectively) of both the varieties. We recorded a significant reduction in population of *Fusarium* spp. in all the treatments from 21.50 x 10^{-5} to 2.18-2.65x 10^{-5} cfu/g soil. There was slight increase in pathogen population in untreated control from 21.25 x 10^{-5} to 22.25 x 10^{-5} cfu/gm of soil (Table 1).

3.2 Response of modules in main field

In the main field we observed similar results where, module-III (Adoptive module) has recorded significantly lower disease incidence (16.10 and 14.22 % respectively) in both the varieties when compared to untreated control (65.88 and 54.91%). Similarly module-I (Biological module) and module-II (chemical module) also recorded significantly less disease incidence (23.09 and 19.16% in Sitara; 19.42 and 18.50% in Atirikta respectively). A significant reduction in pathogen population was also recorded in module-III (15.42 x 10^{-5} to 2.22 x 10^{-5}) which gave maximum disease reduction over control (78.62%). When two seasons were compared for the disease incidence, a significant reduction was recorded during 2013-14 when compared to 2012-13. Maximum yield was recorded in module-III (26.25 and 22.80 ton/ha respectively) followed by module-II (23.10 and 18.25 ton/ha) and module-I (18.20 and 16.25 ton/ha) in both the test varieties. The economic analysis of the modules were made and it was found that, significantly maximum benefit cost ratio (1:3.25 and 1: 2.70 Rs respectively) were recorded in module-III followed by module-II (1:2.16 and 1:3.00) and module-1 (Rs. 1:2.29 and 1:1.93). From the above results it is clear that, module-III (Adoptive module) which is an integration of both chemical and bio control agents is the most effective module in successful management of chilli fusarium wilt (Table 2).

3.3 Effect of different management modules on soil microbial population

There was significant variation between treatments when microbial populations were estimated before and after the imposition of treatments. The variation was also observed for the seasons (2012-13 and 2013-14). Total fungal counts were ranged from 18.25 to 40 x 10^4 CFU g^{-1} of soil in 2012/13 and between 14.50 to 38.50 x10^4 CFU g^{-1} of soil during 2013/14. Module-I (biological module) and Module-III (adoptive module) supported significant increase in soil beneficial micro organisms when compared to module-II (chemical module) over the two seasons. No significant variation was recorded in total bacterial counts in both the seasons of our study. The bacterial population was ranged between 14.50 and 23.50 x 10^5 CFU g^{-1} of soil in 2012/13 and between 12.50 to 30.25 x10^5 CFU g^{-1} of soil during 2013/14 respectively. Actinomycetes populations ranged between 13.50 and 22.50 x 10^4 CFU g^{-1} of soil in 2012/13 and between 4.40 to 18.50 x10^4 CFU g^{-1} of soil during 2013/14 (Table 3& Fig 8) From our observations it is clear that the soil microbial population was significantly varied due to the influence of management modules.

Table 1: Efficacy of different management modules on growth parameters and incidence of fusarium wilt of chilli in nursery

Varieties	Modules	Germination (%)	Root length (cm)	Root fresh weight (g)	Root dry weight (g)	Shoot length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Seedling death (%)	Initial population of Fusarium (cfu's/g x 10 ^{5} cfu's/g of soil)	Final population of (Fusarium of cfu's/g x 10 ^{5} cfu's/g of soil)
Sitara	Biological module	79.67	10.00	0.75	0.08	12.17	5.78	0.350	15.75 (23.38)*	21.25	2.18
	Chemical module	83.73	11.00	0.81	0.08	14.50	6.25	0.293	10.62 (19.02)	21.25	2.55
	Adoptive module	85.33	12.00	0.85	0.13	15.33	6.83	0.423	9.04 (17.50)	21.25	2.62
	Untreated Control	26.08	9.08	0.65	0.06	11.67	5.17	0.300	25.00 (30.00)	21.25	22.12
Atirikta	Biological module	81.17	11.33	0.73	0.09	12.50	6.29	0.367	10.58 (18.98)*	21.25	2.50
	Chemical module	81.67	11.17	0.79	0.09	11.00	6.30	0.380	10.67 (18.79)	21.25	2.55
	Adoptive module	85.50	11.75	0.89	0.12	14.33	6.47	0.393	8.96 (17.42)	21.25	2.65
	Untreated Control	38.00	9.00	0.66	0.06	11.00	5.37	0.333	20.54 (26.95)	21.25	22.25
C.D. at 5%	**Varieties**	**0.954**	**0.470**	**0.062**	**0.083**	**0.611**	**0.372**	**0.053**	**0.924**		
	Modules	**1.349**	**0.674**	**0.098**	**0.119**	**0.860**	**0.535**	**0.074**	**1.306**		
	Interaction (V X M)	**1.908**	**0.941**	**0.125**	**0.167**	**1.222**	**0.755**	**0.106**	**1.848**		

*Figures in the parenthesis are the arcsine values

Table 2: Efficacy of different management modules on incidence of fusarium wilt and yield of chilli in main field.

		Population of Fusarium cfu's/g x 10 ^{5} cfu's/g of soil) (Mean of two seasons)		Percent disease incidence					
Varieties	**Modules**	**Initial population**	**Final population**	**(2012/13)**	**(2013/14)**	**Mean disease incidence of two seasons**	**Percent reduction over control**	**Yield (t/ha)**	**B:C Ratio**
Sitara	Biological module	15.07	3.25	23.09 (27.66)	16.18 (23.72)	19.64 (26.31)	68.62	18.2	2.29
	Chemical module	15.53	2.52	19.16 (25.16)	13.17 (21.28)	16.17 (23.97)	74.17	23.1	3.00
	Adoptive module	15.42	2.22	16.10 (23.04)	10.66 (19.06)	13.38 (21.46)	78.62	26.25	3.25
	Un treated Control	14.01	16.9	65.88 (48.59)	59.31 (50.36)	62.47 (52.29)		5.25	
Atirikta	Biological module	14.82	3.57	19.42 (25.33)	13.53 (21.58)	16.47 (23.94)	69.38	16.25	1.93
	Chemical module	15.24	2.62	18.50 (24.71)	10.53 (18.93)	14.51 (22.39)	73.03	18.25	2.16
	Adoptive module	14.02	1.85	14.22 (21.65)	8.56(17.01)	11.39 (19.72)	78.83	22.8	2.70
	Un treated Control	15.22	16.50	54.91 (43.68)	52.69 (46.24)	53.80 (47.18)		6.00	
C.D. at 5%	**Varieties**			**0.350**	**0.480**				
	Modules			**0.455**	**0.679**				
	Interaction (V x M)			**0.640**	**0.960**				

*Figures in the parenthesis are the arcsine values

Table 3: Mean soil populations of *Fusarium solani* and other soil micro organisms in chilli field in two seasons as influenced by different management modules.

Varieties	Modules	*Fusarium solani* x 10 ^{5} cfu's/g of soil		Total bacteria x 10 ^{5} cfu's/g of soil		Total actinomycetes x 10 ^{4} cfu's/g of soil		Total fungi x 10 ^{4} cfu's/g of soil	
		2012-13	**2013-14**	**2012-13**	**2013-14**	**2012-13**	**2013-14**	**2012-13**	**2013-14**
Sitara	Biological module	15.07	3.25	15.25	12.50	13.50	8.50	28.50	25.25
	Chemical module	15.53	2.52	16.50	15.50	15.50	6.50	18.25	16.50
	Adoptive module	15.42	2.22	19.25	18.00	14.50	4.50	30.25	25.50
	Control	14.01	16.9	22.50	25.00	16.00	14.50	40.00	38.50
	Biological module	14.82	3.57	14.50	16.50	15.50	6.50	25.25	16.25
Atirikta	Chemical module	15.24	2.62	16.50	17.50	16.50	6.00	22.50	18.00
	Adoptive module	14.02	1.85	18.50	20.25	15.50	4.40	20.25	14.50
	Control	15.22	16.50	23.50	30.25	22.50	18.50	36.25	35.50

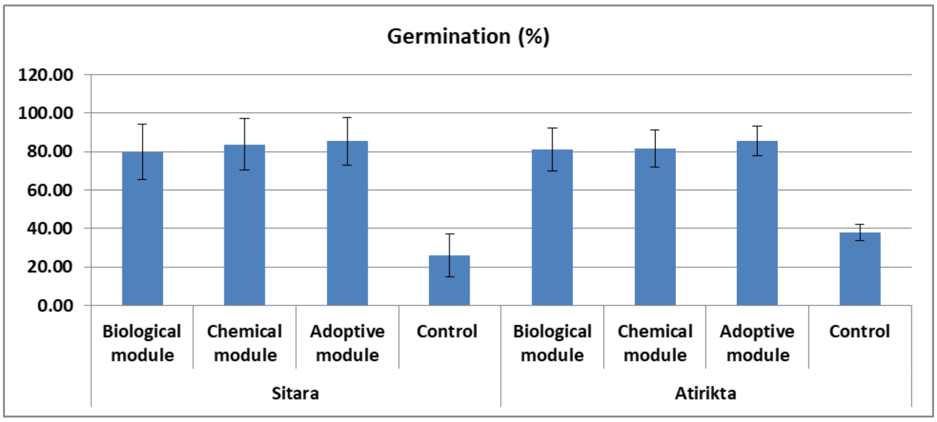

Fig 1: Effect of different management modules on germination of chilli seeds under nursery.

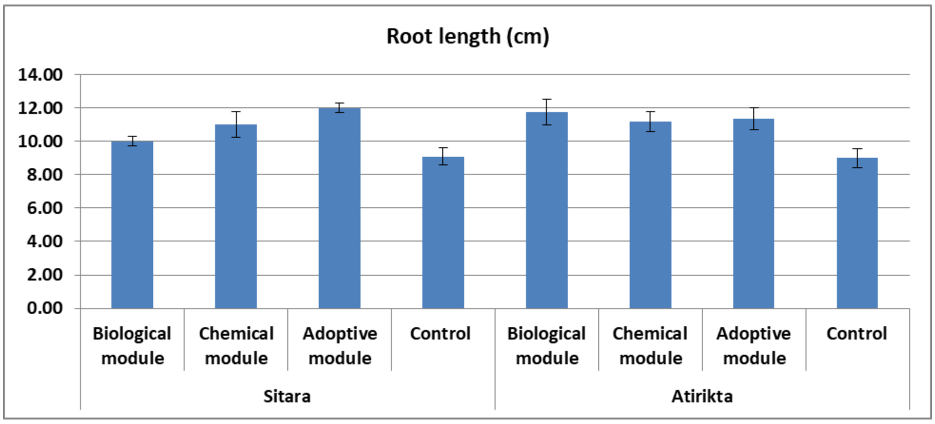

Fig 2: Effect of different management modules on root length of chilli seedling under nursery.

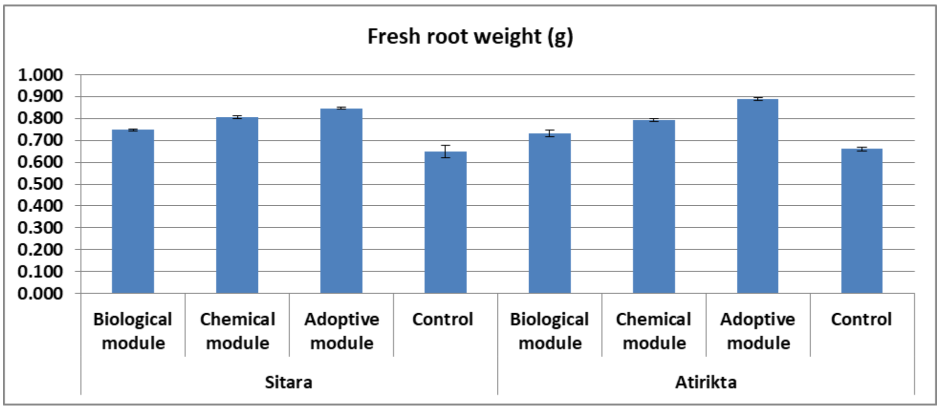

Fig 3: Effect of different management modules on fresh root weight of chilli seedling under nursery.

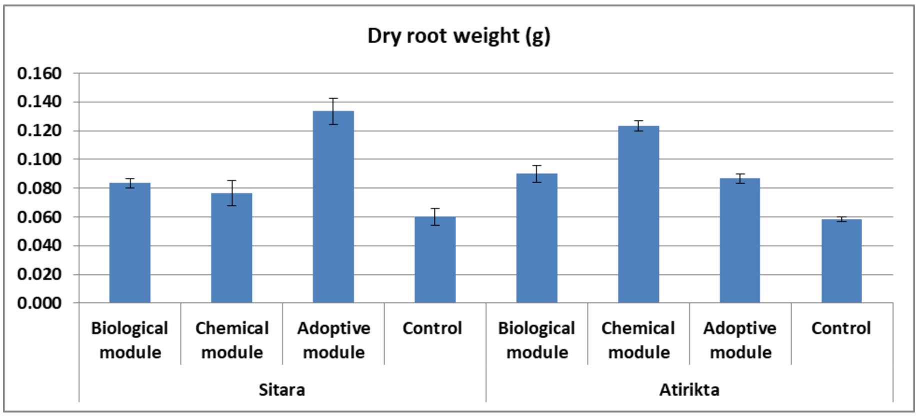

Fig 4: Effect of different management modules on dry root weight of chilli seedling under nursery.

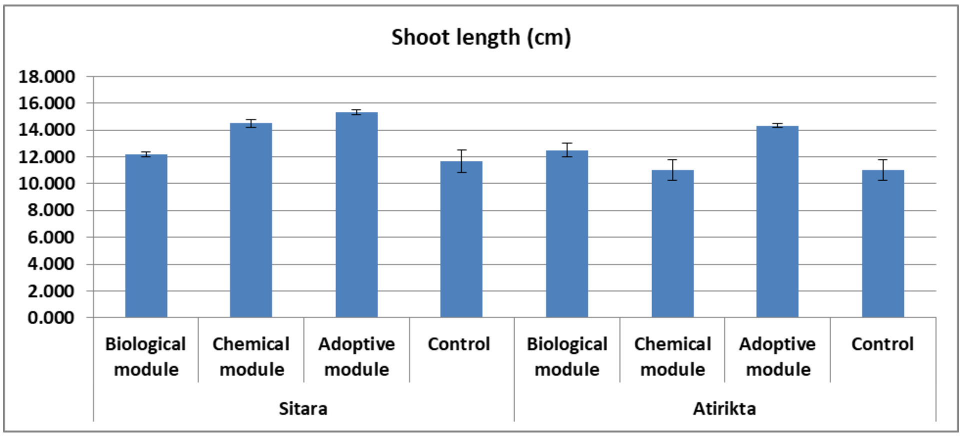

Fig 5: Effect of different management modules on shoot length of chilli seedling under nursery.

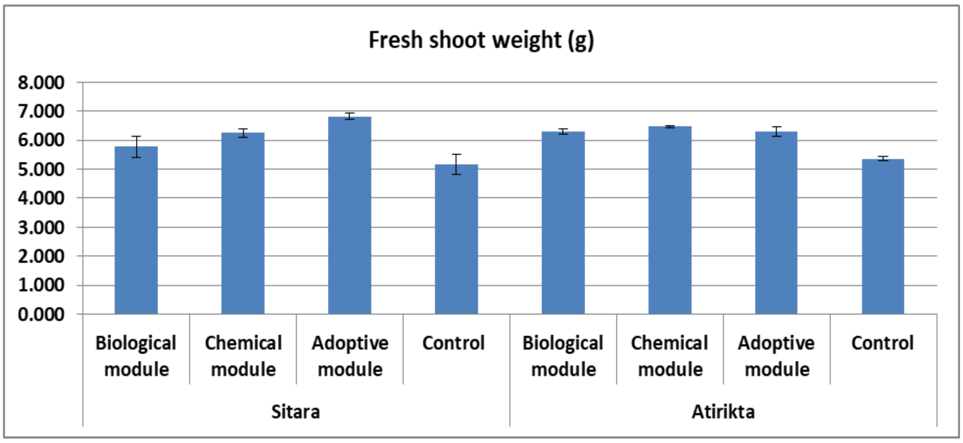

Fig 6: Effect of different management modules on fresh shoot weight of chilli seedling under nursery.

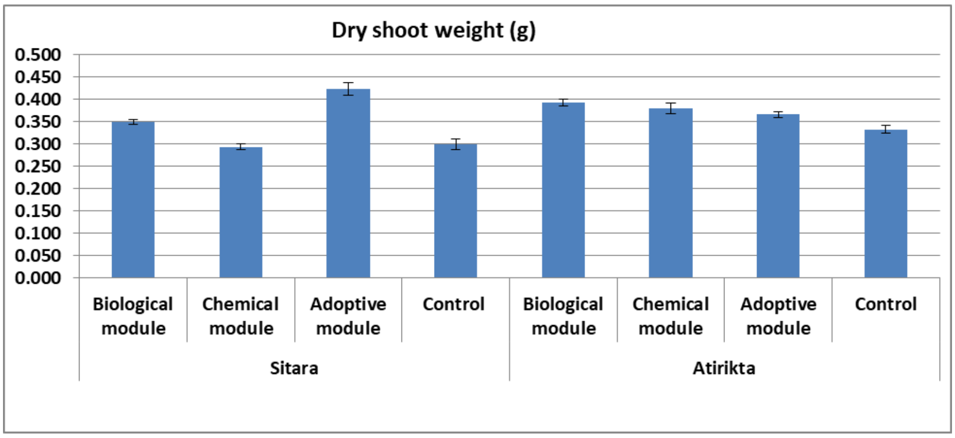

Fig 7: Effect of different management modules on dryshoot weight of chilli seedling under nursery.

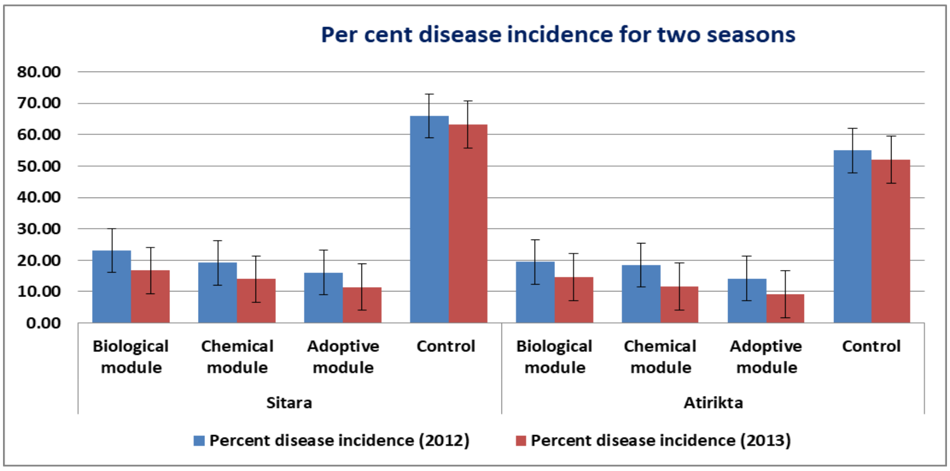

Fig 8: Effect of different management modules on disease incidence under main field

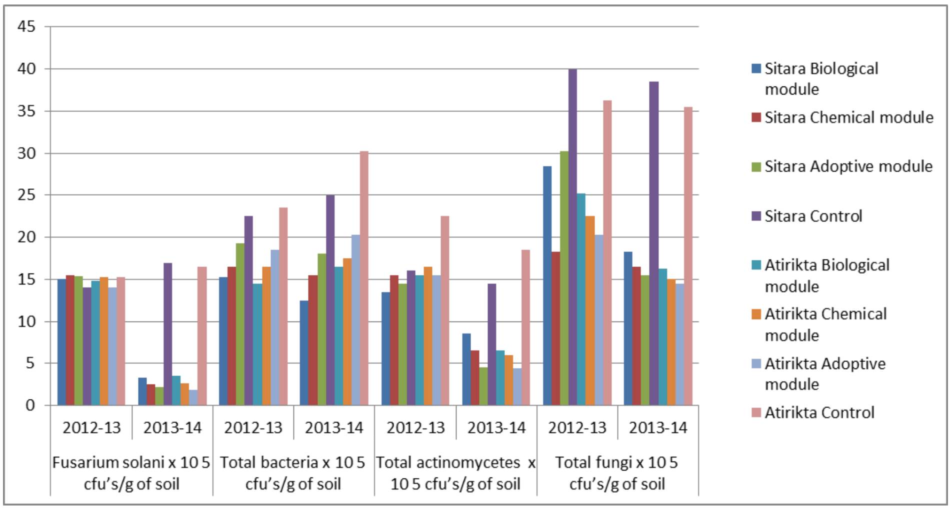

Fig 9: Soil populations of *Fusarium solani* and other soil micro organisms in chilli field in two seasons as influenced by different management modules.

4. Discussion

The main objective of the present investigation was to eco-friendly manage the chilli fusarium wilt disease which is the most destructive soilborne disease causing huge losses to growers. Here we integrated all the management options such as chemicals, bio control agents and soil amendments in different management modules by considering the beneficial aspects of these products. Bio control agents such as *viz. P. fluorescens*, *Trichoderma harzianum* (both are UAS Dharwad formulations) and neem based products like neem cake (commercial grade neem seed oil cake) (250 kg/ha) and neem oil were integrated with chemicals alone or in combination to check their efficacy against the disease.Our observations resulted that, integration of these options in rotation from the nursery onwards significantly manage the disease and also it gave good growth parameters (fig1 to 7) and highest green chilli yield (fig 8) and least disease incidence. Our results are also in confirmation with earlier workers like Tu (1987) [23] who developed integrated disease management modules to control Fusarium wilt and root rot of pea by integrating host resistance, tillage, use of green manure crop. Integration of chemicals and bio agents as seed treatment gave good germination and growth parameters of pea, least collar rot incidence (*F. solani f.sp. pisi*) and highest green pod yield (Kumar and Dubey 2001) [10]. Fungicide seed treatment prevents transmission of seed borne fungal pathogens and also control soil borne fungi which induce seed rots, pre- and post-emergence root, stem disease of young seedlings and causing poor seedling establishment. Field application of bio-pesticides like neem cake reduces soil-borne pathogens like *Fusarium* and promotes build-up of antagonistic organisms and promotes plant growth (Champawat and Sharma 2003, Altintas and Bal 2008) [4, 1]. Neem cake and neem oil application has been effective in checking pests and disease besides promoting plant growth (Rukmani and Mariappan, 1990) [22]. Chemical control of soilborne pathogens in vegetable crops is highly demanding because of the complexity of soil environment and biological differences among pathogens. In addition, only a limited number of registered products are available in the market to manage these plant pathogens. Products that effectively reduce soilborne pathogens of some crops by soil and plant applications are fungicides in the dicarboximide, benzimidazole and triazole chemical groups (Mihajlovic *et al.* 2010, Rekanovic *et al*. 2012, Vatchev and Maneva, 2012) [16, 21, 24].

There is an increasing tendency in crop protection to integrate different methods of control. Combining methods of control is at the heart of integrated pest management, and may result in either additive or synergistic effect. The expected benefit of this strategy is improved and sustainable control of pests and diseases. The goal of IPM methods is to employ measures that are more efficient, healthier, and more environmentally friendly in the long run, and to reduce the amount of pesticides used. Combined application of *Bacillus megaterium* with carbendazim has provided an effective control of Fusarium crown rot as well as root rot in tomato (Omar *et al.* 2006) [19]. The use of organic amendments to improve soil properties, plant health and yield has expanded in recent years. Organic amendments in combination with soil heating or solarization have the potential to improve crop health (Klein *et al.* 2007, Gamliel and Katan 2009) [9, 7]. The mechanisms by which bio control agents inhibit phytopathogenic fungi include, antibiotic production, production of bacteriocins, production of siderophores, production of hydrolytic enzymes like β-1,3-glucanses and chitinases, production of metabolites, phytoalexins, interference with quorum sensing, reduction of ethylene production and induced systemic resistance.

Our studies demonstrated the efficacy of an integration of chemicals, bio control agents and soil amendments such as neem oil cake provided a potentially useful, eco friendly and cost saving technology for the management of this destructive disease of chilli in particular and most of the soil borne pathogens in general. This will check the development of resistance by the pathogen to chemicals due to there continues use along with maintaining soil health and beneficial microbes. This module should be practiced at least for two to three years in order to manage the disease completely.

Conclusion

In the present experiment, we found that a significant increase in per cent germination and other plant growth parameters along with least disease incidence and highest yield in module-III (adoptive module) where we integrated both chemicals, bio control agents and soil amendments. This module found best for two seasons in two different locations of Karnataka. The cost economics was also calculated and found that, highest cost benefit ratio was obtained by following the adoptive module. There was significant reduction in pathogen population was also recorded from both the locations when compared with control treatment.

Acknowledgements
The author thankful to Department of Plant Pathology, College of Agriculture, University of Agricultural Sciences (UAS), Dharwad, Karnataka for providing laboratory facilities to conduct the experiments in partial fulfilment of Ph.D research work.

Reference

1. Altintas S, Bal U. Effects of the commercial product based on *Trichoderma harzianum* on plant, bulb and yield characteristics of onion. Sci. Hort. 2008; 116:219-222.
2. Anonymous. Directorate of Economics and Statistics for data till 2012-13 and National Horticultural Board, Ministry of Agriculture Publication. 2014; 2011-12, New Delhi.
3. Astrom B, Gerhardson B. Differential reactions of wheat and pea genotypes to root inoculation with growth-affecting rhizosphere bacteria. Plant and Soil. 1988; 109(2):263-269.
4. Champawat RS, Sharma RS. Integrated management of nursery diseases in brinjal, chilli, cabbage and onion. J Mycol Pl Pathol. 2003; 33:290-291.
5. Devika Rani GS, Naik MK, Patil MB, Prasad PS. Biological control of *Fusarium solani* causing wilt of chilli. Indian Phytopath. 2009; 62(2):190-198.
6. Devika Rani GS. Prevalence of wilt of chilli and assessment of population dynamics of *Fusarium* in predominant chilli (*Capsicum annuum* L.) growing regions of Karnataka. J Soil Biol Ecol. 2007; 27:50-61.
7. Gamliel A, Katan J. Control of plant disease through soil solarization. In D. Walters (Ed.), Disease Control in Crops. Edinburgh, UK: Wiley-Blackwell Publishing Ltd. 2009, 196-220.
8. Kirkegaard JA, Sarwar M, Wong PTW, Mead A, Howe G, Newell M. Field studies on the biofumigation of take-all by Brassica break crops. Aust. J Agric. Res. 2000; 51(4):445-456. doi:10.1071/AR99106
9. Klein E, Katan J, Austerweil M, Gamliel A. Controlled laboratory system to study soil solarization and organic amendment effects on plant pathogens. Phytopathol. 2007; 97(11):1476-1483. Pmid: 18943518.
10. Kumar D, Dubey SC. Management of collar rot of pea by the integration of biological and chemical methods. Indian Phytopath. 2001; 54:62-66.
11. Larkin RP, Roberts DP, Gracia-Garza JA. Biological control of fungal diseases. In: Fungicidal activity, chemical and biological approaches. 1998; (pp 141- 191), New York, NY: Wiley.
12. Lewis JA, Papavizas GC. Bio control of cotton damping-off caused by *Rhizoctonia solani* in the field with formulations of *Trichoderma* spp. and *Gliocladium virens.* Crop Protection. 1991; 10(5):396-402.
13. Loganathan M, Venkataravanappa V, Saha S, Sharma BK, Tirupathi S, Verma MK. Morphological, cultural and molecular characterizations of Fusarium wilt infecting tomato and chilli. Paper presented at National Symposiumon Abiotic and Biotic Stress Management in Vegetable Crops. 2013; (April 12-14, 2013), Indian Society of Vegetable Science, IIVR, Varanasi.
14. Louws FJ, Rivard C, Kubota C. Grafting fruiting vegetables to manage soil borne pathogens, foliar pathogens, arthropods and weeds. Sci. Hort. 2010; 127(2):127-146.
15. Martin JP. Use of acid rose bengal, and stre ptomycin in the plate method for estimating soil fungi. Soil Sci. 1950; 69:215-32, [Univ. California Citrus Experiment Station, Riverside, CA
16. Mihajlovic M, Rekanovic E, Potocnik I, Levic J. Osetljivost izolata *Fusarium graminearum* na difenokonazol i protiokonazol u kultiri "*in vitro*". In *Zbornik rezimea radova X savetovanja o zaštiti bilja*, Zlatibor. 2010; (str. 89-90). Beograd: Društvo za zaštitu bilja Srbije.
17. Naik MK. Wilt of chilli with special reference to cultural, morphological, molecular characterization and pathogenic variability of Fusarium isolates of India. In: Proc. Midterm Review Meeting of the Project held at Indian Institute of Vegetable Research, Varanasi, 2006.
18. Nash SM, Synder WC. Quantitative estmation by plate count of propagules of the bean root rot *Fusarium* in field soil. Phytopathol. 1962; 51:567-572.
19. Omar I, O'neill TM, Rossall S. Biological control of fusarium crown and root rot of tomato with antagonistic bacteria and integrated control when combined with the fungicide carbendazim. Plant Pathology. 2006; 55(1):92-99. doi:10.1111/j.1365-3059.2005.01315.x
20. Raghu S, Benagi VI, Nargund VB. Prevalence of wilt disease of chilli in major growing areas of south India. Proc. Nation. Symp. Pathogenom. Diagn. Manag. Pl. Dis., Cent. Tub. Crop. Res. Inst., 2013b, 32.
21. Rekanovic E, Potocnik I, Milijasevic-Marcic S, Stepanovic M, Todorovic B, Mihajlovic M. Toxicity of metalaxyl, azoxystrobin, dimethomorph, cymoxanil, zoxamide and mancozeb to *Phytophthora infestans* isolates from Serbia. J Environ. Sci. Heal, Part B. 2012; 47(5):403-409.
22. Rukmani S, Mariappan V. Influence of organic amendments with *Trichoderma viride* on the control of root rot of blackgram. Pl Dis Res. 1990; 5:244.
23. Tu JC. Integrated control of pea root rot disease complex in Ontario. Plant Dis. Sur. 1987; 71:9-13.
24. Vatchev T, Maneva S. Chemical control of root rot complex and stem rot of greenhouse cucumber in straw-bale culture. Crop Protection. 2012; 42:16-23.