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Management of Basal Stem Rot (*Ganoderma* Wilt) in Coconut with Effective Bioagents under Field Condition

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A B S T R A C T

Among the various fungal diseases affecting coconut palm, basal stem rot (BSR) or wilt or root rot caused by *Ganoderma* spp. *viz*., *G. lucidum*, *G. applanatum G. boninense*, etc., is the most destructive especially in the lighter soils of Andhra Pradesh. Keeping in view the minimal use of fungicides, the present investigation was taken up to develop an ecofriendly biocontrol management package against the basal stem rot disease by exploring the efficacy of native biocontrol agents under field conditions. The experiment was initiated during September 2014 at P. Gannavaram village of East Godavari District of Andhra Pradesh to standardize the dosage, frequency and method of application of effective biocontrol agents, *Trichoderma reesei*, *Pseudomonas fluorescens* and neem cake (5 kg/palm/year) and compared with root feeding of Hexaconazole @3ml/100ml of water/palm/quarter and micronutrient application @1kg/palm/year. Among all the treatments tested, soil application of talc based formulation of 125g of *Trichoderma reesei* and 125 g of *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year was found effective in reducing the disease index from 28.44 to 4.23 within a period of three (2014-2017) years and also found the increasing trend of the nut yield under field conditions.

Introduction

Coconut palm (*Cocos nucifera*, L.) is an important plantation crop of India and often described as 'Kalpavriksha' because of the multifarious uses of every part of it in the commercial sector. Coconut is grown in almost 94 countries in the world of which 90% of the production comes from Asian and Pacific countries. Andhra Pradesh occupies fourth position in coconut growing area and production (1.15 lakh ha; 1378 million nuts) after Kerala, Karnataka and Tamil Nadu with a productivity of 11957 nuts/ ha (2016-17).

In Andhra Pradesh, East Godavari (50,490 ha), West Godavari (21, 818 ha), Srikakulam (14,753 ha) and Visakhapatnam (7300 ha) districts occupy major area in forefront in coconut cultivation. (www.cdb.nic.in).

Coconut palms are normally affected by various insect pests and diseases resulting into reduction in yields. Among the various fungal diseases affecting coconut palm, basal stem rot (BSR) or wilt or root rot caused by *Ganoderma* spp. *viz*., *G. lucidum*, *G. boninense*, *G. applanatum* etc., is the most destructive. *Ganoderma* spp. has a wide host range attacking a variety of palms and several forest, avenue and fruit trees. According to Naidu *et al.,* (1986), hosts belonging to 19 families, 36 genera and 48 species have been reported to be affected by *Ganoderma* spp. Coconut palms in the age group of 10–30 years are easily attacked by the pathogen.

Ganoderma is a soil-borne pathogen and it survives well in the soil for a long time. The formation of chlamydospores during adverse conditions helps survival of pathogen and chlamydospores become more resistant to environmental factors than basidiospores and could be responsible for dissemination of the disease. Irrigation water and rain water help in the spread of the fungus from one field to another.

Though, several researchers (Bhaskaran *et al.,* 1994 and Srinivasulu *et al.,* 2001) have reported different practices for the management of the disease, not much work has been done relating to the aspects of integrated disease management practices against *Ganoderma* under field conditions with bioagents. Keeping in view the minimal use of fungicides, the present investigation was taken up to develop an ecofriendly integrated disease management package against the basal stem rot disease by exploring the efficacy of native biocontrol agents under field conditions.

Materials and Methods

Studies on management of basal stem rot by using effective bioagents under field conditions was initiated with the new treatments in the selected garden at *P. Gannavaram* village of East Godavari District (variety: East coast tall) of Andhra Pradesh under All India Co-ordinated Research Project on Palms at Horticultural Research Station, Ambajipeta centre which is situated at 16.61308^{o} N latitude and 81.89399 ^{o} E longitudes and at an altitude of 14 m above mean sea level. There is a growing demand for biologically based soil borne pathogen management practices.

The experiment was carried out with 12 treatments (including control) as scheduled below from September 2014 to march 2017 for standardization of dosage, frequency and method of application of *Trichoderma reesei*, *Pseudomonas fluorescens* along with neem cake (5kg/palm/year), root feeding with Hexaconazole @3ml/100ml of water/palm/quarter and micronutrient application @1kg/palm/yr. Pre and post treatment data was recorded from the treated palms at regular intervals by recording the linear spread of the *Ganoderma* disease in coconut palms and also nut yield. The data was analyzed statistically as per the procedure given by Gomez and Gomez (1984).

Trees showing *Ganoderma* symptoms were randomly selected and each tree was considered as a replication, likewise five replications were maintained for each treatment

Results and Discussion

Earlier results revealed the native *Trichoderma* spp *viz., T. viride, T. harzianum* and *T. hamatum* were found to inhibit basal stem rot pathogens *viz., Ganoderma applanatum* and *G. lucidum* to an extent of 63 to 84% under *in vitro* conditions (Srinivasulu *et al.,* 2002). Studies further proved that neem cake is a suitable substrate for mass

multiplication of native *Trichoderma* spp (Srinivasulu *et al.,* 2004). Further, neem cake has an advantage of inhibiting the growth of *Ganoderma* sp

Among the treatments evaluated, T_9 Treatment (Soil application of talc based formulation of 125 g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of neem cake/palm at yearly interval was found to be the best treatment by reducing the disease index from 28.44 to 6.20 during September 2014 to March 2016 (Table 1).

T_9 treatment was on par with T_3 treatment *i.e* soil application of talc based formulation of 125 g of *Trichoderma reesei* + 5 kg of neemcake/palm at yearly interval followed by T_4 treatment (soil application of talc based formulation of 125 g of *Pseudomonas fluorescens* + 1.25 kg of neemcake/palm at quarterly interval) and showed a disease index reduction of 6.20, 6.36 respectively (Table 1).

Similar studies was carried out by Srinivasulu and Raghava Rao (2009), and reported that the application of *Trichoderma* spp. caused lysis of mycelium of *Ganoderma lucidum*. Furthermore, they have found that the application of *T. harzianum*/*T. viride*/*T. hamatum* pasted over bleeding patches and soil application of the bioagents @ 50 g in 5 kg neem cake has reduced the perimeter of the *Ganoderma* wilt patches on coconut trees.

Similarly, during 2016-17 season, T_9 Treatment, soil application of talc based formulation of 125 g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of neemcake/palm at yearly interval was found to be the best treatment among all the treatments and reduced the disease index from 5.12 to 4.23 (Table 2). T_9 Treatment was followed by T_3 treatment (soil application of talc based formulation of 125 g of *Trichoderma reesei* + 5 kg of neemcake/palm at yearly interval), T_4 (Soil application of talc based formulation of 125 g of *Pseudomonas fluorescens* + 1.25 kg of neemcake/palm at quarterly interval) that showed 4.80, 5.36 reduction in disease index (Table 2). Studies conducted by earlier work indicated that rate of organic amendment can strongly influence the quality and subsequent crop performance in the field as well as rhizosphere bacterial communities (Allison *et al.,* 2011).

In respect of nut yield, the pooled analysis from Sept. 2014 to March 2017 (Figure 1) clearly showed that increasing trend in bioagents applied treatments.

Among all the treatments evaluated, T_9 treatment, soil application of talc based formulation of 125 g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of neemcake/palm at yearly interval showed the highest nut yield (78 nuts/palm/year) followed by T_3 treatment, (soil application of talc based formulation of 125 grams of *Trichoderma reesei* + 5 kgs of neemcake/palm at yearly interval) which was recorded 73 nuts/palm/year and the lowest nut yield was recorded in T_{12} (Control) treatment (26 nuts/palm/year).

The pooled analysis data (Table 3) clearly showed that T_9 treatment, soil application of talc based formulation of 125 g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of neemcake/palm at yearly interval showed the lowest disease index of *Ganoderma* wilt 5.43 ± 0.48 and was followed by T_3 treatment, (Soil application of talc based formulation of 125 grams of *Trichoderma reesei* + 5 kgs of neemcake/palm at yearly interval), T_4- (Soil application of talc based formulation of 125 grams of *Pseudomonas fluorescens* + 1.25 Kg of neemcake/palm at quarterly interval) that showed reduction in disease index of 5.61± 0.96 and 5.63 ± 0.35 respectively.

Table.1 Disease index data of *Ganoderma* wilt in coconut at P. Gannavaram village September 2014 to March 2016

S. No	Treatment	Pre-treatment September (2014)	March 2015	June 2015	September 2015	December 2015	March 2016
T_1	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 1.25 kg of Neem cake/ palm at quarterly interval	31.58	14.76	13.80	13.80	14.16	12.6
T_2	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 2.5 kg of Neem cake/ palm at six monthly interval	33.30	15.98	15.92	14.12	14.24	14.12
T_3	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 5 kg of Neem cake/ palm/year	35.78	8.48	7.40	6.30	6.72	6.20
T_4	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 1.25 kg of Neem cake/ palm at quarterly interval	22.86	6.84	5.90	5.60	5.40	6.36
T_5	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 2.5 kg of Neem cake/ palm at six monthly interval	26.12	26.72	27.32	25.52	24.68	24.2
T_6	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year	25.16	29.72	31.04	29.00	26.40	31.88
T_7	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* +1.25 kg of Neem cake/ palm at quarterly interval	28.76	26.88	28.2	25.80	24.60	26.08
T_8	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* +2.5 kg of Neem cake/ palm at six monthly interval	23.91	16.16	15.56	14.24	16.40	16.40
T_9	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year	28.44	7.28	6.08	5.12	5.24	6.20
T_{10}	Root feeding of 1 ml of Hexaconazole in 100 ml water thrice in a year	30.14	25.56	28.68	26.52	27.92	15.76
T_{11}	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year+ Root feeding with 1 ml Hexaconazole/100ml thrice in a year + Micronutrient application @1kg/palm/year	18.16	14.16	13.80	12.84	12.84	11.92
T_{12}	Control	33.6	32.28	33.00	33.00	33.96	35.28
SEM+			16.63	17.66	17.57	17.03	18.49
CD (P=0.05)		**NS**	5.81	6.17	6.14	5.98	6.46

Table.2 Disease index data of *Ganoderma* wilt in coconut at P. Gannavaram village April 2016 to March 2017

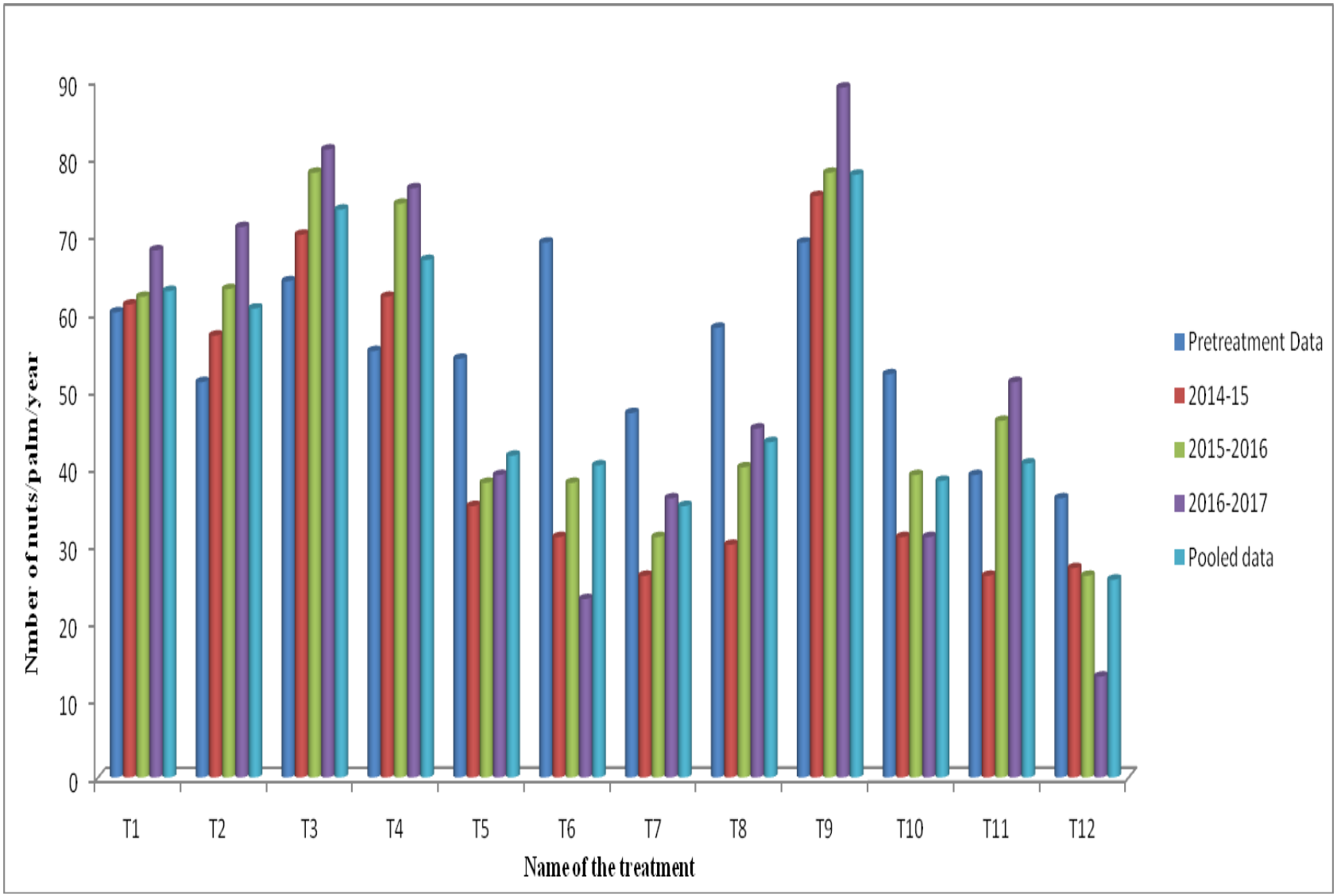
S. No	Treatment	Pre-treatment April (2016)	June 2016	September 2016	December 2016	March 2017
T_1	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 1.25 kg of Neem cake/ palm at quarterly interval	16.56	12.33	12.15	12.20	12.55
T_2	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 2.5 kg of Neem cake/ palm at six monthly interval	17.98	12.41	11.94	11.80	11.80
T_3	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 5 kg of Neem cake/ palm/year	9.52	5.20	4.20	3.20	2.80
T_4	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 1.25 kg of Neem cake/ palm at quarterly interval	8.84	5.60	5.20	4.40	5.36
T_5	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 2.5 kg of Neem cake/ palm at six monthly interval	36.52	21.75	21.46	21.46	22.13
T_6	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year	38.78	31.88	29.93	32.89	36.5
T_7	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* +1.25 kg of Neem cake/ palm at quarterly interval	31.53	25.80	25.70	27.87	29.15
T_8	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* +2.5 kg of Neem cake/ palm at six monthly interval	14.40	15.16	14.19	13.91	12.60
T_9	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year	12.92	5.12	5.36	4.28	4.23
T_{10}	Root feeding of 1 ml of Hexaconazole in 100 ml water thrice in a year	30.14	12.57	13.05	12.81	11.97
T_{11}	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year+ Root feeding with 1 ml Hexaconazole/100ml thrice in a year + Micronutrient application @1kg/palm/year	18.16	11.08	12.6	11.64	11.22
T_{12}	Control	19.28	35.74	35.98	36.25	36.65
	SEM+		16.38	20.1	18.9	20.06
	CD (P=0.05)	NS	5.75	7.05	6.63	7.04

Table.3 Pooled analysis of disease index data of *Ganoderma* wilt in coconut at P. Gannavaram village over the years from 2014 to 2017

S. No	Treatment	Mean of three years pooled data of *Ganoderma* wilt disease index
T_1	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 1.25 kg of Neem cake/ palm at quarterly interval	13.15 ± 0.49
T_2	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 2.5 kg of Neem cake/ palm at six monthly interval	13.59 ± 0.84
T_3	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 5 kg of Neem cake/ palm/year	5.61 ± 0.96
T_4	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 1.25 kg of Neem cake/ palm at quarterly interval	5.63 ±0.35
T_5	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 2.5 kg of Neem cake/ palm at six monthly interval	23.92 ±1.15
T_6	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year	31.03 ± 1.41
T_7	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* +1.25 kg of Neem cake/ palm at quarterly interval	26.68 ± 0.73
T_8	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* +2.5 kg of Neem cake/ palm at six monthly interval	14.74 ±0.60
T_9	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year	5.43 ± 0.48
T_{10}	Root feeding of 1 ml of Hexaconazole in 100 ml water thrice in a year	19.43 ± 3.75
T_{11}	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year+ Root feeding with 1 ml Hexaconazole/100ml thrice in a year + Micronutrient application @1kg/palm/year	12.46 ± 0.54
T_{12}	Control	34.68 ± 0.82

Means of pooled disease index data of *Ganoderma* wilt ± Standard errors are shown

Fig.1 Nut yield data in *Ganoderma* wilt effected gardens in coconut at P. Gannavaram village over the years from 2014 to 2017



Details of treatments imposed in integrated disease management against *Ganoderma* wilt disease

T_1	**Soil application of talc based formulation of 125g of *Trichoderma reesei* + 1.25 kg of Neem cake/ palm at quarterly interval**
T_2	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 2.5 kg of Neem cake/ palm at six monthly interval
T_3	Soil application of talc based formulation of 125g of *Trichoderma reesei* + 5 kg of Neem cake/ palm/year
T_4	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 1.25 kg of Neem cake/ palm at quarterly interval
T_5	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 2.5 kg of Neem cake/ palm at six monthly interval
T_6	Soil application of talc based formulation of 125g of *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year
T_7	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* +1.25 kg of Neem cake/ palm at quarterly interval
T_8	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* +2.5 kg of Neem cake/ palm at six monthly interval
T_9	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year
T_{10}	Root feeding of 1 ml of Hexaconazole in 100 ml water thrice in a year
T_{11}	Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year+ Root feeding with 1 ml Hexaconazole/100ml thrice in a year + Micronutrient application @1kg/palm/year
T_{12}	Control

Earlier results revealed that, application of two biocontrol agents together, a yeast (*Pichia guilermondii*) and a bacterium (*Bacillus mycoides)* resulted in better suppression of *Botrytis cinerea*, and also reduced the variability of disease control (Guetsky *et al.*, 2001). Hence, application of more than one biocontrol agent is suggested as a reliable means of reducing the variability and increasing the reliability of biological control (Shtienberg and Elad, 2002).

T_{11} Treatment, Soil application of talc based formulation of 125g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of Neem cake/ palm/year+ root feeding with 1 ml Hexaconazole/100ml thrice in a year + micronutrient application @1kg/palm/year showed disease index of 12.46 ± 0.54, this results revealed that hexaconazole effect on the biocontrol agents at field conditions. Earlier results revealed that systemic fungicide Hexaconazole was found incompatible with the biocontrol agents (*Trichoderma harzianum*) under *in vitro* conditions (Priti and Venkataravanappa, 2017). Bindu Madhavi *et al.*, (2011) reported that Hexaconazole @ 5% EC showed 94.4 % inhibition effect on *Trichoderma viride* under *in vitro* conditions.

Studies conducted by earlier workers indicated that the bacteria and fungi from the rhizosphere and belonging to a wide variety of genera have the potential to suppress diseases caused by a diversity of soil-borne

plant pathogens. Some of these, especially *Pseudomonas* spp and *Bacillus* spp. significantly suppressed the disease and increases the yield of crops in field trials (Van Peer and Schippers, 1992). It is very difficult to eliminate or completely suppress *Ganoderma* since it is a soilborne fungus. Under these circumstances, environment friendly, safe and less expensive methods like biocontrol measures have great relevance in disease management. Therefore, it is necessary to go for a biocontrol approach by the use of effective native biological agents against the Basal stem rot disease (*Ganoderma* wilt) to manage the malady. In the present study, soil application of talc based formulation of 125 g each of *Trichoderma reesei* and *Pseudomonas fluorescens* + 5 kg of neemcake/palm at yearly interval was effective in managing the Basal stem rot disease (*Ganoderma* wilt) by stimulating plant defensive mechanisms with the use of effective native biocontrol agents in the soil.

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