

Evaluation of different integrated disease management approaches for Rhizome rot of Ginger (*Zingiber officinale* Roscoe.) caused by *Ralstonia solanacearum* (Smith.) under field conditions.

Abstract

Ginger (*Zingiber officinale* Rosc.,) is a slender herbaceous perennial plant ~~belongs~~ ~~belonging~~ to the family Zingiberaceae is an important commercial spice and medicinally important crop grown for its aromatic and medicinal values. India is the largest producer of ginger and accounts for about 1/3rd of ~~the~~ total world output. Ginger is grown in Kerala, Karnataka, West Bengal, Andhra Pradesh, Orissa, Arunachal Pradesh, Sikkim and other parts of India. The production of ginger is greatly influenced by a number of diseases caused by bacteria, fungi, viruses, mycoplasma, and nematodes. ~~Main-The main diseases-disease~~ of ginger ~~are-is~~ bacterial wilt caused by *Ralstonia solanacearum*, which ~~cause-causes~~ yield loss ~~of~~ up to 80 ~~per-cent~~ percent. A field experiment was conducted with integrated approaches to manage the ginger rhizome rot caused by *R. solanacearum* (Smith). The experiment was laid out with ~~a~~ Randomized Completely Block Design (RCBD) including nine treatments and four replications. The experiment results revealed that, rhizome treatment with Streptocycline @ 0.5 g + COC @ 3.0 g/l of water + soil application with neem cake 3q/ha followed by drenching with bleaching powder (33%) @ 2.0 g/l + Metalaxyl MZ @ 1.0 g/lit for water three ~~time-times~~ at 20 days intervals + Ginger special spray 45 DAS, starting with ~~the~~ initiation of the disease was significantly most effective and recorded a higher yield of 110.27 q/ha with least disease incidence of disease (14.23 %). Integrated management of rhizome rot of ginger through soil solarization revealed that, among the different treatments, the treatment treated with soil solarization + rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/lit of water + Soil application of *Pseudomonas fluorescens* @ 10 kg along with 25t FYM /ha recorded higher yield of 115.23 q/ha with less ~~per-cent~~ percent disease incidence (8.20 %).

Keywords: ~~Integrated,~~ *Ralstonia solanacearum*, Ginger, Rhizome rot, soil solarization.

Introduction

~~India is considered as the “magical land of spices”; no other country in the world has such a diverse variety of spice crops as India. Ginger (*Zingiber officinale* Roscoe.) is an economically important spice and medicinal crop of India. The production of ginger is influenced largely by a~~

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~~number of diseases caused by bacteria, fungi, viruses, mycoplasma and nematodes. Main diseases of ginger are bacterial wilt caused by *Ralstonia solanacearum*, rhizome rot caused by *Pythium* species, *Fusarium* species, *Sclerotium* species, *Pseudomonas* species and others (Dake and Edison, 1989; Senapati and Ghose, 2005; Paret *et al.*, 2010; Sharma *et al.*, 2010; Kavyashree, 2009).~~

Bacterial rhizome rot is a serious disease ~~and that~~ has drastic effects on ~~crop crops~~ and eventually leads to yield loss ~~of~~ up to 80 ~~per cent percent~~ (Smith *et al.*, 1995; Denny, 2006). It is a soil-borne bacterium, ~~which that~~ belongs to the beta-proteobacteria and ~~is~~ responsible for bacterial wilt on more than 200 plant species from 50 botanical families, including important crops such as potato, tomato, eggplant, pepper, tobacco, and banana. In fact, bacterial wilt is considered the single most destructive bacterial plant disease because of its extreme aggressiveness, wide geographic distribution, and unusually broad host range (Meng, 2013). It is manifested initially by foliar yellowing and later ~~water soaked water-soaked~~ lesions ~~appears appear~~ on the collar of the pseudostem which extend to rhizomes and leaves resulting in ~~the~~ rotting of ~~the~~ rhizome and drying of the entire plant. The disease is both seed and soil-borne (Bhai *et al.*, 2005).

Bacterial rhizome rot of ginger was reported by Orian (1953) for the first time ~~from~~ ~~in~~ Mauritius. Later on, the disease was reported ~~from in~~ Hawaii (Ishii and Aragaki, 1963), Malaya (Jamil, 1964), and Australia (Hayward *et al.*, 1967) although the disease occurred in India since ~~the~~ middle of ~~the~~ 29th century, but Mathew *et al.*, reported it from Kerala in 1979. Supriadi (2000) reported that bacterial wilt causes losses ~~of~~ up to 75 billion ~~rupee rupees~~ per year. Therefore, the present study was undertaken to manage the rhizome rot with special emphasis on *R. solanacearum* through different integrated disease management approaches.

Soil solarization is a soil ~~disinfestations disinfection~~ practice and ~~the~~ main benefits of solarization are pathogen and disease control and yield increase (Katan, 1981). It is essentially a hydro-thermal disinfection accomplished by covering moist soil with transparent polyethylene film during the ~~period periods~~ of high temperature and intense solar radiation. It aims to eradicate or reduce ~~soil borne soil-borne~~ inoculum, prior to planting. The final goal is to achieve an economic reduction in disease incidence for at least one season (Katan, 1981). Solarization is non-hazardous, more economical, and leaves no residue (Katan *et al.*, 1976).

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Materials and Methods

A field experiment was conducted in ~~farmers farmers'~~ ginger ~~field field~~ at Bikonahalli village of Shivamogga where ~~the~~ highest disease incidence was observed. Integrated approaches were made under field ~~condition conditions~~ in relation to ~~manage managing~~ the rhizome rot of ginger.

The trial was laid out in a Randomized completely block design (RCBD) with four replications with ~~the~~ plot size of 14.2X14.2 meter. The variety Himachal was used (Plate 1a). All the recommended ~~package~~ ~~packages~~ and practices of Ginger production were followed ~~to~~ ~~for~~ all treatments except ~~the~~ control treatment. The details of the treatments ~~were~~ ~~are~~ given in ~~the~~ table 1.

Soil solarization as a component in ~~the~~ integrated disease management with special reference to *Ralstonia solanacearum*.

Soil solarization is a method of ~~soil disinfection~~ ~~soil disinfection~~ based on its solar heating by mulching a soil with a transparent polyethylene during the hot season, thereby controlling ~~soil borne~~ ~~soil borne~~ pathogens and disease control are attributed to microbial, chemical, and physical processes in addition to the thermal killing. Soil solarization was achieved by mulching with a transparent polythene sheet ~~for~~ around 45 days during the summer season to the specific treatment. The experiment was conducted in the sick plots of rhizome rot at ZARS, College of Agriculture, Shivamogga, and healthy rhizomes of variety Himachal were used. The details of the treatments ~~were~~ ~~are~~ given in ~~the~~ table 2.

Plots were prepared after pre-monsoon shower in the first week of April. The beds in the plot meant for solarization were immediately covered with transparent polythene sheets of thickness 150µm and the sides were sealed. The non-solarized plots were also maintained without polythene tarping. After solarization, the beds were imposed with the treatments with best components of all bactericides *i.e.*, rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/l of water, soil application bioagents *i.e.* *P. fluorescens* and FYM..

The following soil solarization procedure was followed in the experiment.

1. The land to be solarized was thoroughly cultivated and then leveled so as to minimize protrusions as clods, stubble and stones to prevent tearing of the sheet.
2. 40-50 mm irrigation was given before mulching.
3. Clear, transparent polythene sheet of 150µm thickness was used.
4. The polythene sheet was applied immediately after irrigation and when it was least windy.
5. Solarization was conducted for six weeks during April to May.
6. All free edges were buried and the soil around them compacted so as to prevent escape of heated air or moisture.

Observations

The observations ~~pertaining to~~ ~~about~~ the incidence and severity of the disease were recorded using the ~~per cent~~ ~~percent~~ disease incidence formula and PDI was worked out in each

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treatment. Soil temperature in each plot was recorded daily at three different depths viz., 5 cm, 15 cm, and 30 cm using permanently fixed soil thermometers. ~~Bacterial~~ ~~The bacterial~~ population in both the plots ~~were~~ ~~was~~ analyzed before the commencement of soil solarization, subsequently, it was recorded once ~~in~~ every 15 days. *R. solanacearum* population was estimated by using ~~the~~ serial dilution method on TZC media.

The yield observations were recorded based on the weight of rhizomes collected from ~~the~~ each ~~beds~~ ~~bed~~ were separated and the weight of the rhizomes was recorded and the average was computed and later it was converted to per hectare. The cost of cultivation was calculated based on the price of input that prevailed at the time of their use ~~and~~ was considered to work out the cost of cultivation. The cost of cultivation was worked out considering the material input cost like the rhizome, manure, fertilizer, etc. and ~~labour~~ ~~labor~~ for all the operations except the price of the treated chemicals/bio-agents. Treatment wise cost of cultivation based on the price of the treated chemicals/bio-agents was worked out and expressed as ha⁻¹. ~~→~~ The data obtained were analyzed statistically. The data on yield of rhizome in treated and control plots were also recorded and analyzed as per the statistical procedures (Sukhatme and Amble, 1985).

Results and Discussion:

As a part of experiment, the roving survey was also conducted in different Ginger growing areas of Karnataka to know the incidence and severity of bacterial rhizome rot of Ginger and collection of isolates from different geographical locations. The bacterial rhizome rot incidence was observed in all the surveyed locations of Karnataka state viz., Shivamogga, Hassan, Uttara Kannada, and Bidar districts and the disease incidence varies from 11.25 to 46.25 ~~per cent~~ ~~percent~~. In ~~the~~ evaluation of bactericides, new generation of systemic molecules were tested both in laboratory and field conditions along with recommended bactericides to know their relative efficacy against ~~pathogen~~ ~~pathogens~~. The disease could be managed effectively by incorporating fungicides, bactericides, bioagents, and organic amendments.

The results of integrated disease management of bacterial rhizome rot of Ginger were indicated in ~~table~~ ~~Table~~ ~~3,~~ ~~plate~~ ~~plates~~ 1a and 1b. The result revealed that, among the nine different integrated treatments, rhizomes of ginger treated with Streptocycline @ 0.5 g + COC @ 3.0 g/lit of water + soil application with neem cake 3q/ha followed by drenching with bleaching powder (33%) @ 2.0 g/lit + Metalaxyl MZ @ 1.0 g/lit ~~for~~ ~~for~~ three times at 20 days intervals + Ginger special spray 45 DAS (T₁) for three times at 20 days interval starting with ~~the~~ initiation of the disease recorded very less disease incidence of 14.23 ~~per cent~~ ~~percent~~ and which was found significantly superior over control (48.50 %), followed by T₇ (rhizome treatment with *Pseudomonas fluorescens* @ 8 g /Kg + Soil application of *P. fluorescens* @ 10 Kg talc powder

mixed with FYM /ha + Ginger special spray 45 DAS three time at 20 days interval starting with the disease initiation) recorded a disease incidence of 16.05 per cent. Apart from above, better drainage was maintained in the field as a good cultural practice, other cultural practices like proper land preparation, healthy planting materials, application of FYM and other nutrients have resulted in ~~the~~ good germination in treated plots.

Present findings confirm ~~with~~ the findings of earlier workers showed, rhizomes of ginger treated with streptomycin @ 0.5 g/l + COC @ 2.0 g/l + soil application of carbendazim + drenching with metalaxyl MZ @ 1.0 g/l and drenching the streptomycin at 0.5 g per lit twice at 20 days interval starting from the initiation of disease recorded very less disease incidence (Raghu *et al.*, 2013). Similar findings have also been by Anand (2014) who reported that, rhizomes treated with Streptomycin @ 0.5 g + COC @ 3.0 g/lit of water + soil application with neem cake followed by drenching with bleaching powder (33%) @ 2.0 g/lit + Metalaxyl MZ @ 1.0 g/lit for water three times at 20 days interval starting with initiation of the disease recorded less incidence of rhizome rot (15.50 %) over control (47.42 %).

Yield

The yield was significantly higher in treatments like rhizomes of ginger treated with Streptomycin @ 0.5 g + COC @ 3.0 g/lit of water + soil application with neem cake 3q/ha followed by drenching with bleaching powder (33%) @ 2.0 g/lit + Metalaxyl MZ @ 1.0 g/lit for water three time at 20 days intervals + ginger special spray 45 DAS three time at 20 days interval starting with initiation of the disease, which recorded a yield of 110.27q/ha, followed by T₇(106.05 q/ha) and T₅ (105.50 q/ha). Whereas in control plot, yielded the minimum rhizome yield of 65.51q/ha.

Benefit cost ratio

The benefit cost ratio has been worked out for different treatments and presented in table 15. The highest B: C ratio was obtained in treatment T₁ (2.53) followed by T₇ (2.28). Most of the remaining treatments, T₅ recorded 2.26 and 2.10 in T₂ respectively. Ojha *et al.* (1986) observed that, rhizome treatment with Emisan 6 + plantomycin followed by three sprayings in 30 days interval after planting gives good control of the rhizome rot disease with highest benefit cost ratio (1.980) compared to untreated control (0.78) treatment. Singh *et al.* (2000) stated that streptomycin + Streptopenicilline was effective against the *R. solanacearum* both under *in vitro* and *in vivo* conditions.



Preparation of raised beds



Rhizome treatment with streptomycin



Application of neem cake along with FYM



Planting of Rhizomes



Overall view of field

Plate 1a: IDM activities in farmers filed
Plate 19a: IDM activities in farmer's field.



Overall view of field



Control

T1 = Rhizome treatment with streptomycin @ 0.5 g + COC @ 3.0 g/l of water + soil application with neem cake 3q/ha followed by drenching with bleaching powder (33%) @ 2.0 g/l + Metalaxyl MZ @ 1.0 g/l of water three times at 20 days intervals + Ginger special spray 45 DAS.

Plate 1b: Effect of integrated approaches on *Ralstonia solanacearum* at different treatments.

Soil solarization component in the integrated disease management with special reference to *Ralstonia solanacearum*.

Integrated management of rhizome rot of ginger through soil solarization (Table 4 and Plate 2) revealed that, among the different treatments, the treatment treated with soil solarization + rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/lit of water + Soil application of *Pseudomonas fluorescens* @ 10 kg along with 25t FYM /ha recorded higher yield of 115.23 q/ha with less ~~per cent~~ disease incidence (8.20 %)

These findings are in agreement with Anith *et al.*, 2000 found that the maximum mean difference in temperature taken at 14 h. was 12.2°C in plots mulched after irrigation which ~~was~~ significantly reduced the soil microbial population, solarization and seed treatment with *P. fluorescens* strain EM 85 decreased the wilt incidence to 7.42 per cent and increased the yield to 29.42 t/ha over control. They also showed the incorporation of neem cake before solarization provides no additional advantage in controlling the disease. Interaction between solarization and bactericides leading to synergistic effect on suppression of soil-borne pathogens were demonstrated by Aharonson and Katan (1991). Hence, soil solarization concept helps the farming community to manage the disease effectively and also enhance the yield levels.

Increase in soil temperature in solarized plot was observed at 5, 15 and 30 cm depth. Soil temperature in solarized plot at 5 cm depth was increased by 10.70°C over nonsolarized plot. In deeper depth also temperature was increased by 3 to 8°C. In the month of April, highest temperature was recorded (56.60) during 2nd week of April at 5 cm depth. Similar results are obtained by Katan (1987), rise in soil temperature to the tune of 10°C in solarized field. Maximum temperature attained decrease with increasing soil depths. Balakrishnan *et al.* (1996) reported that, there was increase in temperature in solarized plot by 8°C at 5 cm depth over non-solarized plot.

Soil solarization was an effective method for managing rhizome rot has been reported by many workers (Katan *et al.*, 1976; Grinstein *et al.*, 1979, Stapleton and DeVay, 1984). The temperature range of 37-52°C is sufficient to kill or inhibit most of the major pathogens provided sufficiently long exposure time for sunlight is allowed (Katan, 1981). Significant reduction of *R. solanacearum* population could be noticed in solarized plots. *R. solanacearum* populations were almost same before solarization and non-solarized control plots.



Soil solarization plots



T3 = Soil solarization + Rhizome treatment with streptomycin @ 0.5 g + COC @ 3.0 g/l of water + soil application of *Pseudomonas fluorescens* @ 10 kg along with 25t FYM/ha

Control

Plate 2: Integration of soil solarization for the management of rhizome rot of ginger

Conclusion:

Bacterial rhizome rot is the major constraint of Ginger production throughout the world. Since the pathogen is soil and seed born once it enters the soil, it can multiply and transmit in a short period of time, which leads to difficulty ~~to manage~~ ~~in managing~~. As of now, a single control measure ~~is~~ ~~has~~ not found effective against the pathogen. However, some ~~level~~ ~~levels~~ of bacterial rot diseases can be managed through the possible use of a combination of diverse methods, like disease resistance, quarantine methods, agronomic practices, biological control, and chemical control with integrated disease management approaches. Even though these different approaches have been developed to control this disease, we still lack an efficient and environmentally friendly control measure for most of the host crops, especially for Ginger. Special focus should be given to this pathogen in the future to avoid crop loss.

References:

- Aharonson, K. and Katan, J.,(1991), Integration of soil solarization with chemical, biological and cultural control for the management of soil borne diseases of vegetables. *Plant and Soil*,**253**(2):493-506
- Anand, (2014), Investigations on bacterial wilt of ginger caused by *Ralstonia solanacearum* (E. F. Smith) Yabucchi *et al.* *M.Sc Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).
- Anith, K.N. Manomohandas, T.P., Jayarajan, M., Vasanthakumar. and Aipe, K.C. (2000), Integration of soil solarization and biological control with a fluorescent *Pseudomonas* sp. for controlling bacterial wilt *Ralstonia solanacearum* (E. F. Smith) Yabuuchi *et al.* of ginger. *J. Biol. Control*, **14**(1): 25-29.
- Balakrishnan, P., Usman, N.M. and Sarma, Y.R., (1996), Management of rhizome rot disease of ginger (*Zingiber officinale* Rosc.) by soil solarization. *Journal of Plantation Crops*, **24** (Supplement): 192-199.
- Bhai, R.S., Kishore, V.K., Kumar, A., Anandaraj, M.,Espin, S.J. (2005). Screening of rhizobacterial isolates against soft rot disease of ginger (*Zingiberofficinale* Rosc.). *Journal of Spices and AromaticCrops*,**14**(2):130-136.
- Dake, G.N., Edison, S. (1989). Association of pathogens with rhizome rot of ginger inKerala. *Indian Phytopathology*,**42**(1):116-119.

- Denny, T.P.(2006), Plant Pathogenic *Ralstonia* species. p. In: Gnanamanickam SS (Ed.). Plant Associated Bacteria, Springer, And The Netherlands. Pp. 573-644.
- Grinstein, A., Orion, D., Greenberger, A. and Katan, J., (1979), Solar heating of the soil for the control of *Verticillium dahliae* and *Pratylenchus thornei* in potatoes. In *Soil Borne Plant Pathogens* (ed. Schippers B. and Gams, W.). Academic Press. London: 431-438.
- Hayward, AC., Moffett, ML. and Pegg, K. G., (1967), Bacterial wilt of ginger in Queensland. *Queensland J. Agric. Anim. Sci.*, **24**: 1-5.
- Ishii, M. and Aragaki, M., (1963), Ginger wilt caused by *Pseudomonas solanacearum* (E. F. Smith). *Plant Dis. Rep.*, **47**: 711-713.
- Jamil, M., (1964), In : *Annu. Rep.* of the Department of Agriculture, Federation of Malaya, 1961. 85.
- Katan J.,(1981), Solar heating of soil for control soil borne pest. *Annual Review of Phytopathology*, **19**: 211-236.
- Katan, J. (1987), Soil solarization, In *Innovative approaches to plant disease management*, (ed. I. Chet). John Wiley and Sons Inc., New York: 77-105.
- Katan, J., Greenberger, A., Aton, H. and Grinstein, A., (1976), Solar heating by polythene mulching for the control of diseases caused by soil borne pathogens. *Phytopathology*, **66**:683-688.
- Kavyashree, R. (2009). An efficient *in vitro* protocol for clonal multiplication of Ginger- var. Varada. *Indian Journal of Biotechnology*, **8**: 328-331.
- Meng F., (2013). *Ralstonia solanacearum* Species Complex and Bacterial Wilt Disease. *J Bacteriol Parasitol* **4**: e119.
- Ojala, T., Remes, S., Haansuu, P., Vuorela, H., Hiltunen., Haahtela, K., Vuorela, P. (2000). Antimicrobial activity of some coumarin containing herbal plants growing in Finland. *Journal of Ethnopharmacology* **73**: 299-305.
- Orlan, G., (1953), *Botanical Division Rep.*, Department of Agriculture, Mauritius 1952:37 40.
- Paret, M.L., Cabos, R., Kratky, B.A., Alvarez, A.M. (2010). Effect of plant essential oils on *Ralstonia solanacearum* Race 4 and bacterial wilt of edible ginger. *Plant Disease* **94**(5): 521-527.
- Raghu, S., Ravikumar, R.M., Santosheddy, R.M., Benagi, V.I. and Nargund, V. B., (2013), Integrated management of Rhizome rot of ginger with special reference to *Ralstonia solanacearum* (E. F. Smith) Yabuuchi *et al.*, *J. Mycopathol. Res.*, **51**(2): 285-288.
- Senapati, A.K., Ghose, S. (2005). Screening of ginger varieties against rhizome rot disease complex in eastern ghat high land zone of Orissa. *Indian Phytopathology* **58**(4): 437-439.

- Sharma, B.R., Dutta, S., Roy, S., Debnath, A., Roy, M.D.(2010). The effect of soil physico-chemical properties on rhizome rots and wilt disease complex incidence of ginger under hill agro-climatic region of West Bengal. *Plant Pathology Journal* **26**(2): 198-202.
- Singh, D.K., Sinha, S.K., Singh, V.N. and Singh, D.N., (2000), Control of bacterial wilt of ginger (*Zingiber officinale*) with antibiotics. *J. Res.*, **12**: 41-43.
- Smith, J.J., Offord, L.C., Holderness, M. and Saddler, G.S., (1995), Genetic diversity of *Burkholderia solanacearum* (synonym *Pseudomonas solanacearum*) race 3 in Kenya. *Applied and Environmental Microbiology*, **61** (12), pp. 4263-4268.
- Stapleton, J.J. and De Vay, J.E. (1984). Thermal components of soil solarization as related to changes in soil and root microflora and increased plant growth response. *Phytopathology*, **74**: 255-259.
- Sukhatme, P.V. and Amble, V.N., (1985), *Statistical Methods of Agricultural Workers*, Publication and Information Division, New Delhi, p. 553.
- Supriadi, (2000), Bacterial wilt disease of medicinal plants caused by *R. solanacearum* and strategy to control the disease. *J. Penelitian and Pengembangan Pertanian*, **19**: 17-26.

Table 1: Treatment details of the integrated disease management of Rhizome rot of Ginger caused by *R. solanacearum*

Plot size : 8m x 8m

Design : RCBD

Treatments : 7

Replications : 4

Variety : Himachal

Location : Bikonahalli village, Shivamogga.

Treatment No.	Treatment details
T ₁	Rhizome treatment with Streptocycline @ 0.5 g + COC @ 3.0 g/l of water + soil application with neem cake 3q/ha followed by drenching with bleaching powder (33%) @ 2.0 g/l + Metalaxyl MZ @ 1.0 g/l for water three time at 20 days intervals + Ginger special spray 45 DAS.
T ₂	Rhizome treatment with Kasugamycin @ 0.5 g + COC @ 3.0 g/l of water + soil application with neem cake 3q/ha followed by drenching with bleaching powder (33%) @ 2.0 g/lit + Metalaxyl MZ @ 1.0 g/l for water three time at 20 days intervals + Ginger special spray 45 DAS.
T ₃	Rhizome treatment with Streptocycline @ 0.5 g + COC @ 3.0 g/l of water + soil application with neem cake 3q/ha followed by drenching with Copper oxychloride @ 3.0 g/l + Metalaxyl MZ @ 1.0 g/l for water three time at 20 days intervals + Ginger special spray 45 DAS.
T ₄	Rhizome treatment with Kasugamycin @ 0.5 g + COC @ 3.0 g/lit of water + soil application with neem cake 3q/ha followed by drenching with Copper oxychloride @ 3.0 g/l + Metalaxyl MZ @ 1.0 g/l of water three time at 20 days intervals + Ginger special spray 45 DAS.
T ₅	Rhizome treatment with <i>Trichoderma harzianum</i> @ 8 g/Kg + Soil application of <i>Trichoderma harzianum</i> @ 10 Kg talc powder mixed with 25t FYM /ha + Ginger special spray 45 DAS.
T ₆	Neem cake 3q/ha + Metalaxyl MZ @ 1.0 g/lit. of water three time at 20 days intervals + Ginger special spray 45 DAS.
T ₇	Rhizome treatment with <i>Pseudomonas fluorescens</i> @ 8 g /Kg + Soil application of

	<i>P. fluorescens</i> @ 10 Kg talc powder mixed with FYM /ha + Ginger special spray 45 DAS.
T ₈	Ginger special spray 45 DAS
T ₉	Untreated (Control)

Table 2: Treatment details of soil solarization treatments as a component of integrated disease management.

Plot size : 8m x 8m

Design : RCBD

Treatments : 7

Replications : 4

Variety : Himachal

Location : Bikonahalli village, Shivamogga.

Sl. No.	Treatment details
T ₁	soil solarization alone
T ₁	T ₁ + Rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/l of water + soil application of 25t FYM /ha
T ₂	T ₁ + Rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/l of water + Soil application of <i>Trichoderma harzianum</i> @ 10 kg along with 25t FYM /ha
T ₃	T ₁ + Rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/l of water + Soil application of <i>Pseudomonas fluorescens</i> @ 10 kg along with 25t FYM /ha
T ₄	T ₁ + Rhizome treatment with <i>P. fluorescens</i> @ 10 g /kg rhizomes
T ₅	T ₁ + Rhizome treatment with Streptocycline @ 0.5 g + COC @ 3.0 g/l of water + Soil application of <i>P. fluorescens</i> @ 10 kg along with 25t FYM /ha + Metalaxyl MZ @ 1.0 g/l drenching (45 DAP immediately after the onset of the diseases)

T ₇	Control (Without soil solarization)
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Table 3: Integrated Management of Rhizome rot of ginger caused by *Ralstonia solanacearum* under field condition

	Treatment details	Per cent disease incidence	Yield (Q/ha)	Benefit cost ratio
T ₁	Rhizome treatment with Streptocycline @ 0.5 g + COC @ 3.0 g/l of water + soil application soil application with neem cake 3q/ha followed by drenching with bleaching powder (33%) @ 2.0 g/l + Metalaxyl MZ @ 1.0 g/lit for water three time at 20 days intervals + Ginger special spray 45 DAS.	14.23 (22.16)*	110.27	2.53
T ₂	Rhizome treatment with Kasugamycin @ 0.5 g + COC @ 3.0 g/l of water + soil application soil application with neem cake 3q/ha followed by drenching with bleaching powder (33%) @ 2.0 g/l + Metalaxyl MZ @ 1.0 g/lit for water three time at 20 days intervals + Ginger special spray 45 DAS.	17.15 (24.46)	98.38	2.10
T ₃	Rhizome treatment with Streptocycline @ 0.5 g + COC @ 3.0 g/lit of water + soil application with neem cake 3q/ha followed by drenching with Copper oxychloride @ 3.0 g/lit + Metalaxyl MZ @ 1.0 g/lit for water three time at 20 days intervals + Ginger special spray 45 DAS.	17.80 (24.95)	95.63	1.96
T ₄	Rhizome treatment with Kasugamycin @ 0.5 g + COC @ 3.0 g/lit of water + soil application with neem cake 3q/ha followed by drenching with Copper oxychloride @ 3.0 g/lit + Metalaxyl MZ @ 1.0 g/lit of water three time at 20 days intervals + Ginger special spray 45 DAS.	18.20 (25.25)	90.20	1.61
T ₅	Rhizome treatment with <i>Trichoderma harzianum</i> @ 8 g/Kg + Soil application of <i>T. harzianum</i> @ 10 Kg talc powder mixed with 25t FYM /ha + Ginger special spray 45 DAS.	16.75 (24.16)	105.50	2.26
T ₆	Neem cake 3q/ha + Metalaxyl MZ @ 1.0 g/lit. of water three time at 20 days intervals + Ginger special spray 45 DAS.	30.45 (33.49)	80.08	1.31
T ₇	Rhizome treatment with <i>Pseudomonas fluorescens</i> @ 8 g /Kg + Soil application of <i>P. fluorescens</i> @ 10 Kg talc powder mixed with FYM /ha + Ginger special spray 45 DAS.	16..05 (23.62)	106.05	2.28
T ₈	Ginger special spray 45 DAS	37.33 (37.66)	73.24	0.97
T ₉	Control	48.50 (44.14)	65.51	0.78
	S.Em ±	0.58	0.624	
	CD at 5 %	1.84	4.02	

* Figures in the parenthesis are corresponding arcsine transformed values.

Table 4: Effect of soil solarization and rhizome treatment and drenching of bactericides/ biocontrol agents/ organic manure on *Ralstonia solanacearum* under field condition

Treatment details		Per cent disease incidence	Yield (Q/ha)	Benefit cost ratio
T ₁	Soil solarization alone	10.60 (19.00) *	112.43	2.30
T ₂	T ₁ + Rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/l of water + soil application of 25t FYM /ha	15.30(23.03)	98.18	2.15
T ₃	T ₁ + Rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/l of water + Soil application of <i>Trichoderma harzianum</i> @ 10 kg along with 25t FYM /ha	8.20 (16.64)	115.23	3.80
T ₄	T ₁ + Rhizome treatment with Streptocycline @ 0.5 g + Copper Oxy Chloride @ 3.0 g/l of water + Soil application of <i>Pseudomonas fluorescens</i> @ 10 kg along with 25t FYM /ha	13.15(21.26)	108.48	2.78
T ₅	T ₁ + Rhizome treatment with <i>P. fluorescens</i> @ 10 g /kg rhizomes	17.33(24.60)	91.68	1.80
T ₆	T ₁ + Rhizome treatment with Streptocycline @ 0.5 g + COC @ 3.0 g/l of water + Soil application of <i>P. fluorescens</i> @ 10 kg along with 25t FYM /ha + Metalaxyl MZ @ 1.0 g/l drenching (45 DAP immediately after the onset of the diseases)	20.65(27.03)	86.63	1.20
T ₇	Control (Without soil solarization)	48.20(43.97)	70.38	0.97
S.Em ±		0.970	1.452	
CD at 5 %		2.97	4.361	

* - Figures in the parenthesis are corresponding arcsine transformed values.