Management of Stalk Rot of Maize Caused by *Fusarium moniliforme* (Sheldon)

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**A B S T R A C T**

Stalk rot in maize caused by *Fusarium moniliforme* has been a concern in majority of maize growing areas. There are no hybrids resistant to this disease. A study was conducted to identify the suitable strategies for effective mitigation of stalk rot. Biocontrol agents were tested by seed treatment and soil application in comparison with chemical seed treatment usually followed for soil borne diseases. Among the different treatments, seed treatment with *T. viride* and *P. fluorescens* at 2.5g each/kg of seed and soil application of 1.25kg/ha each fortified with 250kg of FYM had lowest stalk rot of 6.07 per cent during 2014 and 8.13 per cent during 2015. The pooled disease incidence was 7.10 per cent. The treatment was statistically significant over other treatments which also recorded highest grain yield of 6044kg/h during 2014, 6067kg/h during 2015. The pooled yield was 6056kg/ha with a cost benefit ratio of 2.09. In untreated control stalk rot was 31.33 per cent during 2014, 42.10 per cent during 2015 and grain of 3378kg/h and 3444kg/h respectively during 2014 and 2015 with a pooled yield of 3411kg/h and cost benefit ratio of 0.78, the lowest among all. Seed treatment with Mancozeb 50% + Carbendazim 25% WS (sprint) 1g/kg & 2g/kg and Thiram 75WP (1g/kg) had more disease compared to biocontrol treated plots. The results once again reconfirm the beneficial characters of *T. viride* and *P. fluorescens* against the pathogenic microbes in soil. Their ability to parasitize the pathogens by starvation, encourage growth of the plants by acting as defense agents and adoptability to different kinds of climatic fluctuations makes them more suitable for engaging against the stalk rot of maize. These will be free from residue effects and low cost in adoption.

**Keywords**

Stalk rot, Maize, *Fusarium moniliforme*, Management.

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**Introduction**

Maize (*Zea mays* L) is popularly known as queen of cereals, cultivated throughout the world and has the highest production among all the cereals. Maize is also recognized by different synonyms such as zea, corn, silk corn etc. In Hindi it is called Makka and Barajovar. Maize is mother grain of Americans and is considered as the earliest cultivar of the new world. It is most widely distributed world’s plant (Dilip Kumar and Aditya Narayan Jhariya, 2013). The worldwide production of maize was more than 960 million MT in 2013-14. In India during 2014-15 it stood at 24.17 million tone from an area of 9.23million hectare and productivity of 2.56 t/ha (Vinay Mahajan, 2016). It is an important staple food in many countries and is also used in animal feed and industrial applications. The crop has tremendous genetic variability, which enables...
Maize production in India is dominated by Andhra Pradesh and Karnataka, majority of the area is covered by hybrid maize, production is supported by technologies for crop husbandry, crop protection and crop improvement. However, severe constraints in crop protection are faced since three years due to stalk rot caused by *Fusarium verticilloides* (Saccardo) Nirenberg (*Fusarium moniliforme* (Sheldon)).

The disease was first reported from United States of America by Pammel (1914) as a serious root and stalk diseases. Later Valleau (1920) indicated that *Fusarium moniliforme* was a primary cause of root rot and stalk rot of maize. In India *Fusarium* stalk rot was first reported from Mount Abu, Rajasthan (Arya and Jain, 1964).

It has been infecting maize in north and central Karnataka causing economic losses up to 85 per cent. As per earlier records the disease incidence ranged from 10 to 42% in Karnataka (Harlapur et al., 2002). Hooker and Britton (1962) estimated the reduction in grain weight by 5-20%, whereas the estimated loss due to *Fusarium* stalk rot has been reported as 38% in total yield (AICRP, 2014). Growers are not only worried of income but shortage of fodder which is starving the animals. Some are switching to alternate crops. Irrespective public and private bred hybrids all are succumbing to severe stalk rot. *Fusarium* stalk rot was observed in the plant age group of 55 to 65 days which coincides with tasselling and silking and immediately followed grain formation stage. At these stages the stem reserves are depleted and most of the carbohydrates are translocated to developing sinks and stalks are predisposed to the fungi (Desai et al., 1992). The soil borne pathogen led to breakage of stalk, rotting, lodging and premature death of the infested plants. The plants expressed symptoms of drying from margin of leaves extending towards mid rib covering entire leaf lamina. Subsequent death of all leaves leads to drying of whole plant before seed set.

In other parts of world, it is a major disease of maize causing severe damage to the standing crop and may infect all types of corn (Renfro and Ullastrup, 1976). According to Sharma et al. (1993), maize production in India is severely limited due to the incidence of a soil borne disease commonly called Post-flowering stalk rot (PFSR) or stalk rot. Being a soil borne in nature, it has remained undeterred for many years. There are no resistant or tolerant hybrids against this disease. In order to overcome the losses due to stalk rot, the current experiment was conducted to develop an integrated disease management strategy suitable for adoption at low cost.
Materials and Methods

Stalk rot in maize caused by *Fusarium* is a soil borne pathogen and no chemical application or drenching are feasible. It is economically non viable for site application of chemicals which otherwise also harm the beneficial soil microflora. The present experiment was undertaken to explore the potential of biocontrol agents widely used against many soil borne diseases. *Trichoderma viride* a fungal bioagent and *Pseudomonas fluorescens* a potential bacterial bioagent also a plant growth promoting rhizobacteria were employed in different mode of delivery. Among the chemicals only seed treatment by Mancozeb 50% + Carbendazim 25% WS (Sprint) 1g/kg & 2g/kg and Thiram 75WP (1g/kg) could able to reduce the seedling infection since earlier also seed treatment with Carbendazim or Captan gave effective control of late wilt of maize in India (Satyanarayana and Begum, 1996), but failed to prevent further infection at vegetative growth. Seed treatment with *T. viride* and *P. fluorescens* at 2.5g each/kg of seed and soil application of 1.25kg/h each fortified with 250kg of FYM had lowest stalk rot of 6.07 per cent during 2014 and 8.13 per cent during 2015 (Table 1). The pooled disease incidence was 7.10 per cent. The treatment was statistically significant over other treatments which also recorded highest grain yield of 6044kg/h during 2014, 6067kg/h during 2015. The pooled yield was 6056kg/ha with a cost benefit ratio of 2.09 (Table 2). The control treatment had stalk rot of 31.33 per cent during 2014, 42.10 per cent during 2015 and grain of 3378kg/h and 3444kg/h respectively during 2014 and 2015 with a pooled yield of 3411kg/h and cost benefit ratio of 0.78, the lowest among all.

The seed treatment of either chemical or biocontrol agent would certainly act against the seedling infection but more impact would be visible after their spread and multiplication in rhizosphere and acting against pathogens. In addition biocontrol agents are a good alternative for sustainable agriculture to overcome the problems of public concern associated with pesticides and pathogens resistance to chemical pesticides and to become eco-friendly (Akhtar and Siddiqui, 2008). The biological control activities are exerted either directly through antagonism of soil-borne pathogens or indirectly by eliciting a plant-mediated resistance response.

Results and Discussion

Stalk rot in maize is usually noticed at the time of tassel emergence. The infection of plants begins from seed germination to tassel emergence, but symptoms will be visible later. The current experiment conducted was aimed to prevent early infection of plants after seed emergence by seed treatment and avoid proliferation of the pathogen by soil application of bioagents. Seed treatment with Mancozeb 50% + Carbendazim 25% WS (sprint) 1g/kg & 2g/kg and Thiram 75WP (1g/kg) could able to reduce the seedling infection since earlier also seed treatment with Carbendazim or Captan gave effective control of late wilt of maize in India (Satyanarayana and Begum, 1996), but failed to prevent further infection at vegetative growth. Seed treatment with *T. viride* and *P. fluorescens* at 2.5g each/kg of seed and soil application of 1.25kg/h each fortified with 250kg of FYM had lowest stalk rot of 6.07 per cent during 2014 and 8.13 per cent during 2015 (Table 1). The pooled disease incidence was 7.10 per cent. The treatment was statistically significant over other treatments which also recorded highest grain yield of 6044kg/h during 2014, 6067kg/h during 2015. The pooled yield was 6056kg/ha with a cost benefit ratio of 2.09 (Table 2). The control treatment had stalk rot of 31.33 per cent during 2014, 42.10 per cent during 2015 and grain of 3378kg/h and 3444kg/h respectively during 2014 and 2015 with a pooled yield of 3411kg/h and cost benefit ratio of 0.78, the lowest among all.

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Table 1 Effect of different treatments on incidence of stalk rot of maize and its yield

| Sl. No. | Treatments                                                                 | Stalk rot incidence (%) | Yield (kg/plot) | Yield (kg/h) |
|---------|-----------------------------------------------------------------------------|-------------------------|----------------|--------------|
|         | Year : 2015, 2016, Pooled                                                  | 2015, 2016, Pooled      | 2015, 2016, Pooled | 2015, 2016, Pooled |
| 1       | T1. Seed treatment with *Trichoderma* 5g/kg                                | 20.57 (26.92)           | 5.83 (13.95)    | 5.58 (27.59)  |
|         |                                                                             | 22.43 (28.22)           | 5.33 (13.33)    | 3556         |
| 2       | T2. T1 + soil application at 2.5kg/ha fortified with 250kg FYM             | 11.23 (19.46)           | 8.17 (16.58)    | 8.17 (19.34)  |
|         |                                                                             | 10.77 (19.11)           | 8.17 (16.58)    | 5444         |
| 3       | T3. Seed treatment with *Trichoderma* + *Pseudomonas fleurosense* 5g/kg    | 17.40 (24.57)           | 6.03 (14.21)    | 6.05 (26.15)  |
|         |                                                                             | 21.53 (27.60)           | 6.07 (14.24)    | 4044         |
| 4       | T4. T3 + soil application at 2.5kg/ha fortified with 250kg FYM             | 6.07 (14.15)            | 7.10 (17.52)    | 9.08 (15.43)  |
|         |                                                                             | 8.13 (16.50)            | 7.10 (17.54)    | 6044         |
| 5       | T5. Seed treatment with Mancozeb 50% + Carbendazim 25% WS (Sprint) 1gm/kg  | 14.93 (22.67)           | 7.13 (15.41)    | 7.08 (24.08)  |
|         |                                                                             | 18.43 (25.30)           | 7.03 (15.31)    | 4689         |
| 6       | T6. Seed treatment with Mancozeb 50% + Carbendazim 25% WS (Sprint) 2gm/kg  | 11.40 (19.62)           | 7.32 (22.05)    | 4778         |
|         |                                                                             | 16.87 (24.18)           | 7.32 (22.05)    | 4978         |
| 7       | T7. Seed treatment with Thiram 75WP 2gm/kg                                  | 16.23 (23.70)           | 6.87 (15.16)    | 6.62 (25.31)  |
|         |                                                                             | 20.37 (26.77)           | 6.37 (14.59)    | 4244         |
| 8       | T8. Control                                                                 | 31.13 (33.88)           | 5.17 (13.11)    | 5.12 (37.20)  |
|         |                                                                             | 42.10 (40.43)           | 5.07 (12.99)    | 3378         |
|         | CD 5%                                                                       | 36.62 (13.05)           | 5.17 (13.11)    | 3444         |
|         | SE (m)                                                                       | 5.17 (13.11)            | 5.12 (37.20)    | 3411         |
|         |                                                                             | 1.42 (1.26)             | 1.35 (1.99)     | 2.63         |
**Table.2** Cost benefit analysis of management of stalk rot of maize by different treatments

| Sl. No. | Treatments                                                                 | Yield kg/ha | Gross returns (Rs.) | Net returns (Rs.) | Cost benefit ratio |
|--------|----------------------------------------------------------------------------|-------------|---------------------|-------------------|-------------------|
| 1      | T1. Seed treatment with *Trichoderma* 5gm/kg                                | 3722        | 50994               | 24734             | 0.94              |
| 2      | T2. T1 + soil application at 2.5kg/ha fortified with 250kg FYM              | 5444        | 74589               | 47754             | 1.78              |
| 3      | T3. Seed treatment with *Trichoderma + Pseudomonas fluorescens* 5gm/kg      | 4033        | 55257               | 28997             | 1.10              |
| 4      | T4. T3 + soil application at 2.5kg/ha fortified with 250kg FYM              | 6056        | 82961               | 56126             | 2.09              |
| 5      | T5. Seed treatment with Mancozeb 50% + Carbendazim 25% WS (Sprint) 1gm/kg   | 4722        | 64694               | 38429             | 1.46              |
| 6      | T6. Seed treatment with Mancozeb 50% + Carbendazim 25% WS (Sprint) 2gm/kg   | 4878        | 66826               | 40546             | 1.54              |
| 7      | T7. Seed treatment with Thiram 75WP 2gm/kg                                  | 4411        | 60432               | 34172             | 1.30              |
| 8      | T8. Control                                                                | 3411        | 46732               | 20482             | 0.78              |
The mechanisms involve antibiosis, parasitism, competition for nutrients and space, cell wall degradation by lytic enzymes and induced disease resistance (Singh, 2014). Thus both the biocontrol agents were competitive enough to fight against the pathogens than chemicals used for seed treatment. The soil application of these biocontrol agents would add to their population.

Often soil amendment with chemical application are not suitable, they are costly, hazardous and threaten the microflora, under such circumstances naturally available biocontrol agents are most promising. *Trichoderma* a widely used biocontrol agent is well known magical weapon against soil borne pathogens (Srivastava et al., 2015) and also known for its mycoparasitic and antagonistic mechanism for the control of fungal disease (Gomathinayagam et al., 2010) which was evident in the present study. Majority of *Fusarium* wilts and rots are being controlled using *Trichoderma* spp. In the current study also the disease caused by *F. moniliforme* was found suppressed due to the application of *Trichoderma* along with *P. fluorescens*. In a similar study on management of tomato wilt caused by *F. oxysporum* f. sp. *lycopersici*, *Trichoderma* spp. was found highly effective against the pathogen and reduced the disease significantly (Sundaramoorthy and Balabaskar, 2013). The beneficial use of *P. fluorescens* found in the present study was also reported against the growth of *Sclerotina sclerotiorum* (Vishal Kumar Deshwal, 2011). It was effective against the bacterial wilts such as *Ralstonia solanacearum* in brinjal (Gargi Chakravarty and Kalita, 2012). The bacterial biocontrol also induces plant growth and disease suppression in sustainable agriculture production systems which might have helped in boosting the grain yield in our experiment. Effectiveness of this novel bioagent were also recorded against six fungi viz. *Pyricularia oryzae* *Fusarium oxysporum*, *Aspergillus niger*, *Aspergillus flavus*, *Alternaria alternata* and *Erysiphe cruciferarum* (Shanker Kumer Pandey and Shyam Chandra Roy Chandel, 2014). Both the biocontrol in the study showed consistence performance over the years and could be used against the stalk rot of maize without any concern of residual issues. Even these biocontrol agents were proved superior against the foliar diseases also. In a study conducted on use of *T. viride* and *P. fluorescens* against *Phytophthora infestans* showed reduction of the disease compared to the untreated check (Zegeye, 2011). The experiment gave a sound strategy for management of stalk rot in maize without harming the environment and adding much to the cost of cultivation.

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