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Integrated disease management strategy of common rust of maize incited by *Puccinia sorghi* Schw.

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Common rust incited by *Puccinia sorghi* Schw. is the most destructive fungal foliar disease of maize worldwide. It is reported that common rust diseases can greatly reduce grain yield of maize in susceptible genotypes by 40% on an average. Foliar disease management in maize often involves indiscriminate use of chemicals or total reliance on host plant resistance (HPR). Integrated disease management (IDM) have clearly demonstrated that when moderate levels of HPR are combined with field treatment and affordable levels of chemical control, expected yields and economic returns are higher than obtained with chemical control of susceptible genotypes. Local agronomic practices were followed during the same period of investigation. Foliar application of Tebuconazole @ 0.1% at 35 and 50 DAS, that is, T_1 was significantly superior and highly effective in reducing the disease severity (19.74%) and gave maximum grain yield (66.87 q/ha). The next best treatment was foliar application of Hexaconazole @ 0.1% at 35 and 50 DAS (28.23%) followed by foliar application of Tebuconazole @ 0.1% at 35 DAS and Neemazole F 5% at 50 DAS. The study suggests that any technology developed for maize should offer a clear yield and foliar disease resistance advantage over farmers' current practices.

Key words: Botanicals, common rust, field evaluation, fungicides, integrated disease management, *Puccinia sorghi*, *Zea mays.*

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in terms of total production in the world. Among the cereals, maize is the most wide spread crop next only to wheat and rice in the world and ranks fourth after rice, wheat and sorghum (Adegbite, 2011). It is the single largest source of calories and protein for the poor in about 20 countries and a primary weaning food for the babies. During the last few years, there has been a progressive escalation in demand for maize grain for the value added products like glucose, sorbitol and dextrose, besides livestock, poultry and animal feeds, manufacture of starch and starch based products.

With the introduction of high yielding hybrids, both indigenous and exotic and use of fertilizers, there has been a phenomenal increase in the area and production, but at the same time, it is prone to several foliar and stalk rot diseases (Payak and Sharma, 1980). Among the foliar diseases affecting maize, the common rust caused by

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Table 1. Some important diseases of maize crop along with their losses and causal agent.

S/N	Disease	Causal agent	Losses (%)	Reference
1	Northern corn leaf blight	*Setosphaeria turcica*	0–66	Pataky et al., 1998
2	Southern corn leaf blight	*Cochliobolus heterotropus*	15–46	Zwonitzer et al., 2009
3	Gray leaf spot	*Cercospora zeae*	5–30	Ward et al., 1999
4	Curvularia leaf spot	*Cochliobolus lunatus*	10–60	Akinbode, 2010
5	Brown spot	*Physoderma maydis*	6–20	Lal and Chakarvati, 1976
6	Southern corn rust	*Puccinia polysora*	0–50	Castellanos et al. 1998
7	Common corn rust	*Puccinia sorghi*	12 - 61	Dey et al., 2012
8	Eye spot	*Aureobasidium zeae*	14–44	Chang and Hudon, 1990
9	Head smut	*Sporisorium reilianum*	Up to 30	Njuguna, 2001
10	Common smut	*Ustilago zeae*	40–100	Pope and McCarter, 1992
11	Ear rot	*Fusarium verticillioides*	5–15	Ako et al., 2003
12	Banded leaf and sheath blight	*Rhizoctonia cerealis*	0–60	Tang et al., 2004
13	Root rot	*Fusarium graminearum*	25–30	Hebbar et al., 1992
14	Maize dwarf mosaic	*Maize dwarf mosaic virus*	0–90	Goldberg and Brakke, 1987
15	Maize rough dwarf	*Maize rough dwarf virus*	10–70	Dovas et al., 2004
16	Bacterial stalk rot	*Pseudomonas zeae*	85	Thinda and Payakab, 1985

Puccinia sorghi is of worldwide importance (Carmona et al., 2009). Maize is affected by an average of almost 100 pathogens but only a fraction of diseases are present in a given location depending upon various factors and rarely do the number of these diseases become severe. The major diseases of maize along with their causal organism and economic yield losses are listed in Table 1.

Common rust reduces yield of sweet corn upto about 0.6% for each 1% leaf area infected (rust severity). Host resistance is the most effective and efficient method to control rust; however when resistance is not adequate, severe infection can be prevented by applying fungicides.

When hybrids with moderate to susceptible reactions to rust were grown in wet, cool environments that favored disease development, EBDC fungicides or Propiconazole (Tilt) sometimes were applied to prevent severe infection. Action thresholds for initial applications of these fungicides are relatively low (for example, 6-pustules per leaf) because these compounds are not curative. Applications of Tilt or EBDCs are of little benefit if infection is severe. These fungicides are applied initially when plants are young because juvenile tissue is more susceptible than adult-plant tissues, and moisture that accumulates in leaf whorls of seedlings creates excellent conditions for urediniospores to germinate and infect. Early application of fungicides also prevents the production of large amounts of secondary inoculation. One or two well-timed applications before rust infection is severe providing better control than multiple applications after rust infection is severe. Action thresholds for these fungicides increased slightly with each level of general resistance (for example, Susceptible, Highly Susceptible, Resistant, Moderately Resistant and Highly Resistant) and with each subsequent growth stage as plants mature.

Scouting fields for rust provides information that will assist in determining whether or not to apply fungicides. Early-planted sweet corn can be scouted as an indicator of increasing rust populations. If significant amounts of rust are observed at harvest of early-planted crops, later-planted crops may be at risk. Alternatively, later-planted fields can be scouted directly for thresholds and protected with fungicides when weather is favorable for rust development.

Corn grain development is very sensitive to stress timing. Corn is extremely susceptible to different kinds of environmental stress, including water deficit (Grant et al., 1989), light deficit and defoliation (Shapiro et al. 1986) from silking to approximately 2 weeks after silking. These stresses reduce grain yield by limiting photosynthesis. During pollination, corn grain development is extremely dependent upon current photosynthate production, even when accumulated carbohydrates are plentiful (Schussler and Westgate, 1991). The sink capacity of the ear is limited, compared with stalks, during this transition from vegetative to reproductive growth (Setter and Meller, 1984). Generally, common rust is a leaf disease of maize that generally appears from mid to late December where the characteristic reddish-brown pustules can be found on the leaf surface. Heavily infected leaves may become chlorotic and die.

The objective of this study was to investigate the efficacy of fungicides or botanicals or in combination to determine the one that effectively reduces the severity of common rust in maize.

MATERIALS AND METHODS

A field experiment was laid out with various treatments during *kharif* (monsoon) 2010 at Main Agricultural Research Station, Dharwad,

Plate 1. Typical symptoms of common rust disease of maize.

Karnataka, India. The most effective fungicide and botanical products were applied as foliar spray at 35 and 50 days after sowing. Different treatments, *viz*., foliar spray alone and in combination with each other were evaluated to observe their individual as well as combined effects on common rust of maize. Field experiments were laid out in randomized block design using hybrid DMH-2 during *kharif* (monsoon) 2010. Plot size was 5 x 5 m with a spacing of 60 x 30 cm and replicated four times. All agronomic practices were followed according to package of practices of University of Agricultural Sciences, Dharwad (Anonymous, 2003). Eight treatments were imposed in integrated disease management trial *viz*., T_1 (foliar application of Tebuconazole @ 0.1% at 35 and 50 DAS), T_2 (foliar application of Hexaconazole @ 0.1% at 35 and 50 DAS), T_3 (foliar application of Mancozeb @ 0.25% at 35 and 50 DAS), T_4 (foliar application of Tebuconazole @ 0.1% at 35 and Neemazole F 5% at 50 DAS), T_5 (foliar application of Hexaconazole @ 0.1% at 35 and Neemazole F 5% at 50 DAS), T_6 (foliar application of Mancozeb @ 0.25% at 35 and Neemazole F 5% at 50 DAS), T_7 (foliar application of Neemazole F 5% at 35 and 50 DAS), T_8 (untreated control).

The data on disease severity was recorded on ten randomly selected plants using a 1-5 scale at silk drying stage and later percent disease index was worked out according to Singh (1988). The per cent disease control was calculated by the following formula:

$$\frac{\text{PDI in untreated check} - \text{PDI in treated}}{\text{PDI in untreated check}} \times 100$$

Also, the percent increase in yield by various treatments was calculated by using the formula:

$$\frac{\text{Yield in treated plot} - \text{Yield in check plot}}{\text{Yield in check plot}} \times 100$$

RESULTS AND DISCUSSION

The typical developed rust symptoms on leaves show circular to elongate (0.2 to 2 mm long) with dark brown pustule (uredinia) scattered over both leaf surfaces giving the leaf a rusty appearance. Pustules emerge in circular bands due to infection that occurred in the whorl. Pustules break through the leaf epidermis and release powdery reddish-brown spores (urediospores). As pustules mature, they release brownish-black spores (teliospores) which are the overwintering spores. Under severe disease pressure, leaves turn chlorotic and dry prematurely (Plate 1).

During the course of investigation, the effect of different disease managing technologies on common rust of maize was assessed *in vitro* and then most effective ones were tested in the field to develop integrated disease management (IDM). Field experiment was conducted during *kharif* (monsoon) 2010 to assess the possibility of managing the disease by combining different management measures. The data on integrated disease management is presented in Table 2. Results (Plate 2) indicated signify-cant differences among treatments for percent disease

Table 2. Integrated management of common rust of maize caused by *Puccinia sorghi.*

Treatment no.	Treatment	Rust index (%)	Percent disease control over untreated	Grain yield (q/ha)	Percent increase in yield over untreated
T_1	Foliar application of Tebuconazole @ 0.1 % at 35 and 50 DAS	26.37* (19.74)**	64.37	66.87**	28.94
T_2	Foliar application of Hexaconazole @ 0.1 % at 35 and 50 DAS	32.08 (28.23)	49.05	64.94	25.22
T_3	Foliar application of Mancozeb @ 0.25 % at 35 and 50 DAS	39.41 (40.34)	27.19	56.28	8.52
T_4	Foliar application of Tebuconazole @ 0.1 % at 35 and Neemazole F 5 % at 50 DAS	35.29 (33.42)	39.68	59.25	14.25
T_5	Foliar application of Hexaconazole @ 0.1 % at 35 and Neemazole F 5 % at 50 DAS	38.13 (38.14)	31.16	57.25	10.39
T_6	Foliar application of Mancozeb @ 0.25 % at 35 and Neemazole F 5 % at 50 DAS	42.91 (46.39)	16.27	54.79	5.64
T_7	Foliar application of Neemazole F 5 % at 35 and 50 DAS	44.36 (48.92)	11.71	53.81	3.76
T_8	Untreated control	48.09 (55.41)	_	51.86	_
	SEm±	0.45		0.52	
	CD at 5%	1.36	_	1.57	_
	CV (%)	2.02		1.54	

*Arcsine transformed values; **data in parenthesis are original values.

index (PDI) and grain yield. Integration of effective foliar spray with fungicide or fungicide and botanicals were found more effective in the management of common rust and also increased the grain yield. The treatments, *viz*., T_1, T_2 and T_4 (Table 2 and Figure 1) were significantly most effective in managing the common rust (19.74, 28.23 and 33.42% PDI, respectively), as compared to 55.41% PDI in control. Significantly minimum PDI (19.74%) and maximum grain yield (66.87 q/ha) was recorded in treatment T_1, that is, foliar application of Tebuconazole @ 0.1% at 35 and 50 DAS followed by foliar application of Hexaconazole @ 0.1% at 35 and 50 DAS. The treatment T_4, that is, foliar application of Tebuconazole @ 0.1% at 35 and Neemazole F 5% at 50 DAS (33.42% PDI and 59.25 q/ha yield) was the next best as compared to the control PDI (55.41%) and the lowest grain yield (51.86 q/ha). Either Neemazole or Mancozeb alone were not that much effective, but when Neemazole was combined with Tebuconazole or Hexaconazole, their efficacy increased leading to lower PDI and higher yields.

Foliar spray with Mancozeb alone (T_3) and Mancozeb-Neemazole (T_6) were different significantly with respect to PDI and grain yield. However, foliar application of Hexaconazole @ 0.1% at 35 DAS and Neemazole 5% at 50 DAS (T_5) followed by foliar application of Mancozeb @ 0.25% at 35 and 50 DAS (T_3) were statistically at par with each other.

Foliar application of Tebuconazole @ 0.1% at 35 and 50 DAS, that is, T_1 was significantly superior and highly effective in reducing the disease severity (19.74%) and gave maximum grain yield (66.87 q/ha), the next best treatment were foliar application of Hexaconazole @ 0.1% at 35 and 50 DAS (28.23%) followed by foliar application of Tebuconazole @ 0.1% at 35 DAS and Neemazole F 5% at 50 DAS. Sharma et al. (2004) studied integrated management of chilli dieback and anthracnose disease and stated that the disease was effectively controlled by integration of four sprays of the NSKE (4%) and neem oil (0.5%) sprayed at 14, 64 and 104 days after transplanting (DAT) followed by one spray of Triazophos (1 g/L) and Bavistin (0.2%) given at 44 and 99 DAT, respectively, and recorded increased yield over control. The chemical basis of this antifungal activity has been attributed to the presence of oil in the plants parts of *Azadirachta indica* (Singh and Dwivedi, 1990). The systemic triazole fungicide, Tebuconazole 250 EC @0.1% applied at 35 and 50 DAS resulted in minimum

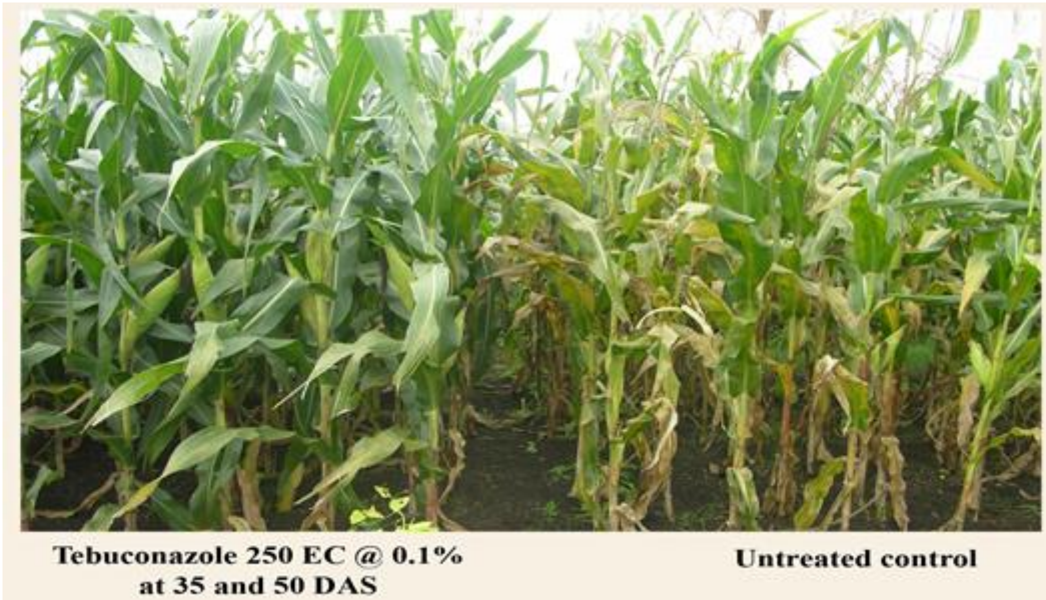

Plate 2. Management of common rust of maize.

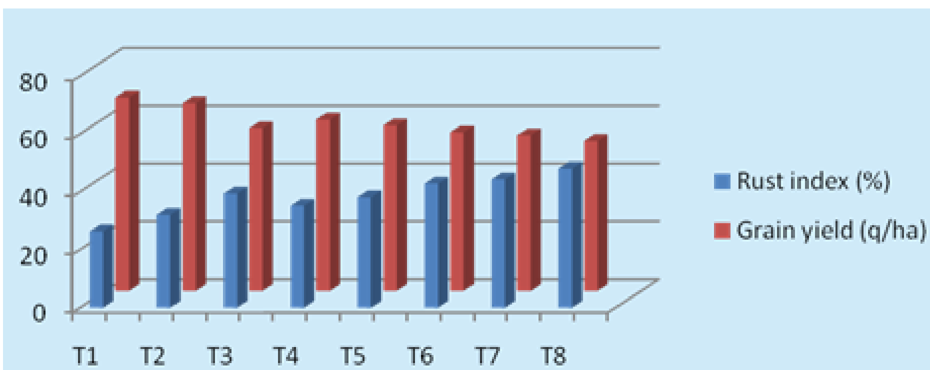

Figure 1. Integrated management of common rust of maize.

disease severity and enhanced yield. This treatment recorded 64.37% disease control efficacy and 28.94% increased yield over untreated check. Neemazole F 5% can also be used as an alternate spray to avoid pathogen resistance development and reduce pesticide load.

The timing of common rust infection in relation to corn growth stage can critically influence the amount of potential grain yield reduction and fungicidal effectiveness. Common rust development on corn was reduced by fungicide application before tasseling. Fungicidal control of common rust increased yield of a susceptible hybrid grown in a high-yielding environment, compared with an untreated control. This improved grain yield is especially significant since the high-yielding environment is also conducive to common rust development. Corn grown in a lower-yield potential (dry land) environment may be less likely to produce a yield response.

Yield response was attributed to depletion of photo-synthate during pollination. Corn grain development is extremely dependent upon current photosythate production during and shortly after pollination. This dependence decreases as grain approaches maturity.

This research supports the use of a fungicide when an action threshold of 1 to 2% disease severity (about six uredinia per leaf) is reached on susceptible field corn hybrids before tasseling, as proposed on sweet corn by Pataky and Headrick (1988) and Dillard and Seem (1990). This action threshold should be relevant for the ear leaf and higher leaves (upper six to eight leaves), since they produce the majority of photosynthetic energy required for grain development.

Yield reduction resulting from common rust infection after pollination is less likely for several reasons. Corn grain yield is less sensitive to stress as kernel development approaches maturity. Pre-tassel treatment differences in disease severity were no longer evident after tassel emergence at two of three sites. This finding could have resulted from hybrids becoming more resistant after tassel emergence, as reported by Headrick and Pataky (1987), or from hot weather arresting the disease development. Temperatures normally exceed the upper developmental threshold for common rust during late June to early July. Thus, fungicide applications after anthesis will likely not be warranted except for susceptible hybrids heavily exposed to common rust in an environment highly conducive for disease development.

It is a broad spectrum systemic triazole fungicide with a protective curative and eradicant activity, and the primary mode of action is the inhibition of ergosterol biosynthesis in fungi (Hewitt, 1998). Even though different triazole fungicides have a similar mechanism of action, they may show marked differences in their activity against different fungal pathogens (Buchenauer, 1987; Scheinpflug and Kuck, 1987). Many light and electron microscope studies have been carried out on the effects of ergosterol biosynthesis-inhibiting (EBI) fungicides on plant pathogenic fungi. EBI fungicides usually cause marked morphological malformations, irregular cell wall thickening and excessive branching in fungi (Hippe, 1984; Smolka and Wolf, 1986; Heller et al., 1990; Maffi et al., 1995, 1998; Kang et al., 1993, 1996, 2001).

Han et al. (2006) showed that inhibition of development of *Puccinia striiformis* in wheat leaf tissues treated with the fungicide was accompanied by severe morphological and structural changes in the hyphal and haustorial development. These changes included increased vacuolation, irregular cell wall thickening and necrosis or degeneration of cytoplasm. These alterations are very similar to those reported for other plant pathogenic fungi treated with ergosterol biosynthesis-inhibiting (EBI) fungicides (Coutinho et al., 1995; Leinhos et al., 1997). Morphological alterations of hyphal structures and haustoria of the stripe rust fungus in tebuconazole treated wheat plants may be triggered by the primary mode of action of triazole fungicides. Interference in sterol biosynthesis by inhibition of 14a-demethylase results in insufficient availability of ergosterol and accumulation of 14a-methyl sterols. Ergosterol, an essential membrane constituent, may be responsible for maintaining membrane integrity and activity. Insufficiency of ergosterol in fungal membranes severely disturbs membrane functions. Deficiency of ergosterol in the plasmalemma markedly alters activity of membrane-bound enzymes; for instance chitin synthase is activated leading to irregular thickenings and accumulation of chitin-like material in cell walls and proper synthesis of new hyphal cell walls is severely disturbed.

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