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Identification of Effective Seed Dressing Synthetic Fungicide against Covered Smut of Barley

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Barley is an important field crop. The present study was designed to identify the efficient seed dressing synthetic fungicide against *Ustilago hordei* causing covered smut of barley. The treatments included three seed dressing fungicides (Bayton 10 DS, Topsin-M, Dividend-Star 36 F.S) and 4th treatment was set as control to compare their efficacy against the disease. The findings of the treatment indicated that crop stand, seedling mortality, smut infected grains and yield characters of barley were found significantly ($P<0.05$) controlled with treatment of seed inoculation/ seed dressing with treated fungicides. Fungicide Topsin-M ranked first and sowing of barley with Topsin inoculated seed resulted in 198.67 seed germination m-2, 0.70% seedling mortality, 1.34 grains infected by covered smut, 2.08 percent infected grain, 413.33 spikes m-2, 38.16 grains spike^{-1}, 10.75cm spike length and 3220.70kg ha^{-1} grain yield. The fungicide Bayton 10 DS ranked second and sowing of barley with Bayton inoculated seed resulted in 182.67 seed germination m-2, 1.11% seedling mortality, 2.14 grains infected by covered smut, 3.05 percent infected grain, 395.67 spikes m-2, 36.50 grains spike^{-1}, 10.43cm spike length and 3037.70kg ha^{-1} grain yield. The seed dressing fungicide Dividend-Star 36 FS ranked third and sowing of barley with Dividend inoculated seed resulted in 171.67 seed germination m-2, 1.69% seedling mortality, 2.51 grains infected by covered smut, 4.85 percent infected grain, 380.67 spikes m-2, 34.61 grains spike^{-1}, 10.30cm spike length and 2980.70kg ha^{-1} grain yield. The control plots, where the barley was sown without seed inoculation ranked least (4th) and resulted in 159 seed germination m-2, 3.68% seedling mortality, 3.81 grains infected by covered smut, 10.63 percent infected grain, 333.33 spikes m-2, 34.67 grains spike^{-1}, 10.03cm spike length and 2591kg ha^{-1} yield of the grain. Concluded findings showed that all the treatments showed effective results as compare to control and minimized the covered smut disease in barley crop; however, among all treated seed dressing fungicides, Topsin-M fungicide was identified with better findings to minimize the disease as compared other above captioned fungicides.

Keywords: Covered Smut of Barley, seed dressing fungicides, Barley, Covered smut, Seed dressing fungicides, Ustilago hordei, Crop protection.

INTRODUCTION

Hordeum vulgare L. locally known as barley is an important cereal grain cop. It is being used in daily used products of human food like in various quality bread components and also being used by mixing with wheat and rye, as well as in beverages i.e. soups and in other foods for human uses as it contains gluten quality and other major healthy foods nutrients. It is also being used for animal fodder, it is among the hard crops so can bear the adverse environmental conditions also. Being grown in all hard conditions also like drought and in desert areas a Food as well as animal fodder (Mishra and Shivakumar, 2000). Yield of barley crop is high in western regions and being cultivated on a large area out of which 20% is being grown in spain and in west Europe until the south America's humid regions per ha cultivation is about

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12 million (Lovarelli *et al.,* 2020). Previously barley was ranked 4th among all the cereals of the crops in year 2007 being grown in the world in term of area under cultivation and in term of yield figures may be explained as 566,000 km² cultivated area with yield of 136 million tons production (FAOSTAT, 2009). 0.9t/ ha is known as the average barley yield at Pakistan which is vary less as compare to the world as in the world average yield of barley is equivalent to 3t/ha. Such 3 times less yield resulting barley imports; on which in 2020 thousand dollars invested which is equivalent to 50/33% of annual average yield (Abid, 2020). Among the Major production of cereal crops in the world after Rice, wheat and Maiz on 4th rank *Hordeum vulgare* which is known as Barley is standing (Houshyar, 2017). And even barley is being produced in various areas of the world where important cereals like rice and main are not being grown (Zhou, 2009). Barley is known as the plant susceptible to a variety of diseases. Damaging pathogens of barley crop includes *Blumeria graminis hordei*, *Rhynchosporium secalis*, *Puccinia hordei*, *Ustilago nuda* and importantly *Ustilago hordei* are causing various diseases which includes powdery mildew, leaf scald, Barley rust, Loose smut and importantly covered smut of barley respectively (Bogdan, 2001; Mathre, 1997*;* Martens *et al.*, 1984). The destructive damage of barley crop is being triggered by different factors; disease causing pathogen is highly dependable upon the various conditions which may include the susceptible variety, availability of inoculum in growing area and one of the important factor is environment either favoring the development or not (Mathre, 1997). Teliospores overwintering is a common strategy of fungal disease known as covered smut, this overwintering will be on seed surface/seed hull of the seeds which will be seen as healthy as the pathogen is seed born after barley germination promycelium of the pathogen will also germinate. 4 basidiospores are produced by the meiosis process and mating separates in 1:1 ratio with type (MAT^{-1} & MAT-2). Pathogen produces the dikaryotic mycelium, which is infectious and it was formed after conjugation reproduction method by opposite mating of sporidia. Covered smut of barley pathogen causing infection to the crop during the process of germination of spores of pathogen (Hu *et al*., 2002).

Ustilago hordei spore will germinate at various range of temperature between 14 to 25°C in the barley crop and will emerge as infectious spore to cause harm to the plant if coleoptile amount increases the infection level will increase in the plant and effect the number of tillers per plant ultimately effects the yield of the plant it depends upon the penetration of coleoptile with in the main growing tissues of host plant and it will invade even in the flower primordia to form its teliospores; which may be thick walled and multiply and produces spores in high quantity from each infected heads up-to millions in number, which not only effects the yield of the crop but also effects the next season crop if same infected seeds will be used because the kernel tissues are mostly being replaced by these harmful spores and hulls are associated with such dormant mycelium, Spore of the pathogen may also remain in the soil specially in dried area and such inoculum also effects the barley production and causes heavy losses (Grewal *et al.* 2008). At the flowering stage kernel tissues are mostly being replaced by these harmful spores and hulls are associated with such dormant mycelium which may be observed as black mass it mean that the head are highly infected with mature teliospores and it may spread on plant leaves of infected barley of the plant also *(*Mathre, 1997*)* So study was carried out to find out the efficient fungicide to overcome the effect of covered smut of barely through synthetic fungicide.

MATERIALS AND METHODS

The present study was designed to identify the efficient seed dressing synthetic fungicide against *Ustilago hordei* causing covered smut of barley. The experiment was conducted at the experimental fields of Department of Plant Pathology, Sindh Agriculture University Tandojam. Experiment was laid out in Randomized Complete Block design with three replications having plot size of 5x3m. The Seeds of barley purchased from market were treated with the following synthetic fungicides treatments Viz., T1 = Bayton 10 DS 2gm / kg seed, T2 = Topsin M 2gm / kg seed, T3 = Dividend star 036 F.S 2g / kg seed, T4 = Control.

The fungicide solution was prepared by mixing the powder of each fungicide at the rate given on the label of each fungicide. The Barley seeds inoculation procedure was carried out by inoculating with pathogen *Ustilago hordei* before sowing by 'go-go' modified method (Joshi *et al*., 1988). Then the seeds were dipped into fungicide solution for 10-20 minutes. The entire experiment was done in Plant Pathology Laboratory of Sindh Agriculture University Tandojam before sowing of the crop. The preparation of the seed beds were made by the dry ploughing one time and followed by clod crushing method and leveled to attain a good seed bed so that distribution of the irrigation water needs to be done uniformly. Width of ridges were 90 cm and length was 10 cm. Before sowing irrigation was applied as soaking dose. Three seeds of barley were dibbled on both sides of the ridges after every 20cm. After sowing two irrigations were applied in the field at an interval of 2 days and later on irrigation were applied as per requirement of crop with an interval of about $10^{-1}2$. Soil aeration was applied and weeds eradicated. Urea having nitrogen fertilizer @ 168 kg ha^{-1} & DAP having phosphorus @ 82kg ha^{-1} were applied. All P was applied with sowing and N was applied in 3 split 1st at the time of sowing, than with 1st irrigation and with 2nd irrigation. Random selection was performed by selecting 4 plants in each treated plot and labeling was done for agronomical traits observations on growth parameters and when crop reached its physiological maturity, the labeled plants were harvested manually and knotted in minor bundles, and was lifted towards threshing area. Threshing process was carried out manually; the grains were collected with care for computation and recorded. The all agronomical practices were performed in all treatments.

Parameters studied

1. Seed germination m^{-2}
2. Seedling mortality (%)
3. Number of seeds $spike^{-1}$ infected by covered smut
4. Percentage of covered smut infected grains $spike^{-1}$
5. Number of grains spikes m^{-2}
6. Number of tillers m^{-2}
7. Spike length (cm)
8. Grain yield (kg ha^{-1})

Statistical analysis**:** The data was recorded by randomly selected plants in all treatments. And findings of the treatments were obtainable as the means of all given replicates i.e. Mean ± S.D. (M ± standard deviation). Outcomes and recorded data were discriminated by (Snedecor, 1980). The result for were analyzed in "Statistix 8.1" software to find out the significance of effective fungicide.

RESULTS AND DISCUSSION

The experimental results of the treatments included seed dressing fungicides Viz., Bayton 10 DS (@ 2gm/kg seed), Topsin M (@ 2gm/kg seed), Dividend Star 36 F.S (@ 2g/kg seed) and control analyzed for various pathological and agronomic parameters are as under.

Seed germination m**$^{-2}$:** The efficacy of various seed dressing fungicides against *Ustilago hordei* causing covered smut of barley was examined and the subsequent effect on seed germination m-2 was explored. The data ($Table^{-1}$) showed that seed inoculation with Topsin M (@ 2g kg^{-1} seed) resulted in maximum seed germination of 198.67m-2, while Bayton ranked second with 182.67m-2 and Dividend Star 36 FS (@ 2g/kg seed) ranked third with seed germination of 171.67m-2. However, the seed germination was lowest (159m-2) in plots where the barley was sown without seed dressing treatment (control). Statistically, the effect of seed dressing fungicides on seed germination was linearly significant (P<0.05). The results suggest that Topsin M was maximally effective to show positive effect on seed germinability in barley.

Table1. Effect of seed dressing fungicides on the seed germination (m-2) of barley.

Fungicides	Mean
Bayton 10 DS	182.67 b
Topsin-M	198.67 a
Dividend Star 36 FS	171.67 c
Untreated (control)	159.00 d

S.E.± 1.4142; LSD 0.05 3.4605; LSD 0.01 5.2431

Seedling mortality (%)**:** The seedling mortality in barley due to *Ustilago hordei (Pers) Lagerh* causing covered smut of barley and the effect of seed inoculation by fungicidal treatments was explored; the results are presented in Table-2. It was observed that the seedling mortality in barley was lowest (0.79%) in plots where before sowing, the barley seed was inoculated with Topsin M (@ 2g/kg seed), while the seedling mortality was 1.11 percent in plots where seed was inoculated by Bayton and seed inoculation with Dividend Star 36 FS (@ 2g/kg seed) resulted seedling mortality of 1.69 percent. The seedling mortality in barley was markedly higher (3.68%) in crop where the seed was sown without inoculation (control). This indicates all the fungicides were effective to reduce seedling mortality when compared with control. However, among fungicides, Topsin showed excellent efficacy against the covered smut and due to seed inoculation before sowing the smut infection controlled fundamentally and in result the seedling mortality was minimized.

Table 2. Effect of seed dressing fungicides on the seedling mortality (%) of barley

Fungicides	Mean
Bayton 10 DS	1.11 c
Topsin-M	0.79 d
Dividend Star 36 FS	1.69 b
Untreated (control)	3.68 a

S.E.± 0.1271; LSD 0.05 0.3111; LSD 0.01 0.4713

Covered smut infected grains spike**$^{-1}$:** The data in regards to the number of grains $spike^{-1}$ infected by covered smut in barley as affected by seed treatment with different fungicides are shown in Table-3. Seed dressing treatments on the covered smut infected grains $spike^{-1}$ was significant (P<0.05). The lowest number of covered smut infected grains (1.34) $spike^{-1}$ was noted in plots sown with Topsin-M inoculated seed, while the smut infected grains $spike^{-1}$ was relatively higher i.e. 2.24 and 2.51 $spike^{-1}$ in plots sown with Bayton 10 DS and Dividend Star 36 FS inoculated barley seed. However, the covered smut infected grains $spike^{-1}$ was highest (3.81) in control plots where the seed was sown without fungicidal treatment. The results clearly suggested that Topsin-M proved its superiority by minimizing the number of infected grains $spike^{-1}$ over Bayton and Dividend.

Table 3. Effect of seed dressing fungicides on the number of covered smut infected grains spike^{-1} of barley.

Fungicides	Mean
Bayton 10 DS	2.24 b
Topsin-M	1.34 c
Dividend Star 36 FS	2.51 b
Untreated (control)	3.81 a

S.E.± 0.3952; LSD 0.05 0.9670; LSD 0.01 1.4651

Percentage of covered smut infected grains spike^{-1}**:** The percentage of covered smut infected grains was worked out on the basis of total grains spike^{-1}. The results related to percentage of grains infected by covered smut as affected by seed inoculation by fungicides are given in Table-4. The minimum percentage of covered smut infected grains (2.08%) was observed in plots sown with Topsin-M inoculated seed, while the percentage of smut infected grains was relatively higher i.e. 3.05% and 4.85% in plots sown with Bayton 10 DS and Dividend Star 36 FS inoculated seed. However, the highest percentage of smut infected grains (10.63%) was found in control plots where the seed was sown without fungicidal treatment. The LSD test indicated that differences in the percentage of infected grains were non-significant (P>0.05) when Bayton and Dividend fungicides were compared; and significant (P<0.05) when these fungcides were compared with Topsin-M and control. All the fungicides were effective to minimize the percentage of smut infected grains over control and Topsin-M was identified as most efficient.

Table 4. Effect of seed dressing fungicides on percentage of covered smut infected grains spike^{-1}.

Fungicides	Mean
Bayton 10 DS	3.05 b
Topsin-M	2.08 c
Dividend Star 36 FS	4.85 b
Untreated (control)	10.63 a

S.E.± 0.3952; LSD 0.05 0.9670; LSD 0.01 1.4651

Number of grains spike^{-1}**:** The effect of seed inoculation before sowing with various fungicides on the number of grains spike^{-1} of barley was explored and the results are presented in Table-5. The highest number of grains (38.16) spike^{-1} was achieved from the plots sown with Topsin-M inoculated seed, and the grains spike^{-1} reduced to 36.50 and 34.61 spike^{-1} in plots sown with Bayton 10 DS and Dividend Star 36 FS inoculated seed. However, the grains spike^{-1} was minimum (34.67) in control plots where the seed was sown without inoculation. Although, all the fungicides were effective to improve the number of grains spike^{-1} over control, but Topsin-M was more effective to check the development of covered smut and in result the number of grains spike^{-1} was higher than the plots treated with Bayton and Dividend. The LSD test suggested that differences in number of grains spike^{-1} were non-significant (P>0.05) when Dividend fungicide was compared with control; and significant (P<0.05) when Dividend and control were compared with Bayton and Topsin-M.

Table 5. Effect of seed dressing fungicides on the number of grains spike^{-1} of barley.

Fungicides	Mean
Bayton 10 DS	36.50 b
Topsin-M	38.16 a
Dividend Star 36 FS	34.61 c
Untreated (control)	34.67 c

S.E.± 0.3952; LSD 0.05 0.9670; LSD 0.01 1.4651

Number of tillers m^{-2}**:** The number of tillers m-2 in barley as affected by seed inoculation with various fungicides (against covered smut caused by *Ustilago hordei*) was recorded and the data are shown in Table-6. The effect of seed dressing treatments with various fungicides on the number of tillers m-2 was statistically significant (P<0.05). The seed inoculation with Topsin M resulted in maximum number of tillers (413.33m-2), while Bayton ranked second with 395.67 tillers m-2 and Dividend Star 36 FS ranked third with 380.67 tillers m-2. However, the lowest number of tillers (333.33m-2) was obtained in plots where the barley was sown without seed treatment (control). Statistically, the effect of seed dressing fungicides on tillers was linearly significant (P<0.05), either comparison was made amongst fungicides for this trait or with control. It is obvious from the results that Topsin-M recorded more positive impact to result higher number of tillers m-2 as compared to the plots sown with Bayton and Dividend inoculated seed.

Table 6. Effect of seed dressing fungicides on the number of tillers m^{-2} of barley.

Fungicides	Mean
Bayton 10 DS	395.67 b
Topsin-M	413.33 a
Dividend Star 36 FS	380.67 c
Untreated (control)	333.33 d

S.E.± 3.6388; LSD 0.05 8.9038; LSD 0.01 13.491

Spike length (cm)**:** The data in relation to spike length of barley as affected by seed inoculation against covered smut caused by *Ustilago hordei* with various fungicides are given in Table-7. The spike length was significantly (P<0.05) affected by seed dressing treatments with different fungicides. The spike length was maximum (10.75cm) in plots sown with Topsin-M inoculated seed, and the spike length considerably reduced to 10.43 cm and 10.30 cm in plots sown with Bayton 10 DS and Dividend Star 36 FS inoculated barley seed. However, the spike length was minimum (10.03cm) in control plots where the seed was sown without treatment. The results suggested that all the fungicides were effective to have positive impact on spike length over control, but among fungicides, Topsin-M was superior to have positive impacts on spike length as compared to Bayton and Dividend.

Table 7. Effect of seed dressing fungicides on spike length (cm) of barley.

Fungicides	Mean
Bayton 10 DS	10.43 b
Topsin-M	10.75 a
Dividend Star 36 FS	10.30 c

Untreated (control)	10.03 d

S.E.± 0.0298; LSD 0.05 0.0730; LSD 0.01 0.1106

***Grain yield (kg ha^{-1})*:** The results in regards to grain yield ha^{-1} of barley as affected by seed inoculation against covered smut caused by *Ustilago hordei* with various fungicides are presented in Table-8. showed that the grain yield was significantly (P<0.05) influenced by seed dressing treatments with different fungicides. The grain yield was highest (3220.30 kg ha^{-1}) in plots sown with Topsin-M inoculated seed, and the grain yield reduced to 3037.70 kg ha^{-1} and 2980.70 kg ha^{-1} in plots sown with Bayton 10 DS and Dividend Star 36 FS inoculated seed. However, the grain yield was lowest (2591 kg ha^{-1}) in control plots where the seed was sown without inoculation. The results indicated that all the fungicides were effective to influence the grain yield positively over control; however, among fungicides, Topsin-M was more effective as compared to Bayton and Dividend. The LSD test indicated that differences in grain yield either between fungicides or when compared with control were linearly significant (P<0.05).

Table 8. Effect of seed dressing fungicides on grain yield (kg ha^{-1}) of barley.

Fungicides	Mean
Bayton 10 DS	3037.70 b
Topsin-M	3220.30 a
Dividend Star 36 FS	2980.70 c
Untreated (control)	2591.00 d

S.E.± 21.926; LSD 0.05 5.652; LSD 0.01 8.290

***Conclusion*:** It was concluded from the present study that all the treated fungicides showed the effective control against the covered smut in barley as compare to the control; however, among all treated fungicides, Topsin-M seed dressing fungicide was identified as more effective as compared to Bayton and Dividend fungicides in controlling the covered smut disease.

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***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere.

***Consent to participate*:** Nawab Ali Ghouri and Muhammad Waris conceived the idea and prepared manuscript.

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