Seed Priming and Trichoderma Application: A Method for Improving Seedling Establishment and Yield of Dry Direct Seeded Boro (Winter) Rice in Bangladesh

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Abstract Seedling mortality is the major barrier to optimum stand establishment in dry direct seeded boro (winter) rice. Two experiments were carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh during January to June 2012 and 2013 to study the effect of seed priming, Trichoderma and fungicide application on seedling establishment and yield performance of dry direct seeded Boro rice. First experiment comprised three seed priming treatments, osmopriming with 3% ZnSO₄ solution, hydropriming and no priming. There were five treatment combinations of Trichoderma and fungicides. These were seed treatment with Trichoderma (T₁), spraying of rice seedling with sulphur fungicide (Thiovit) (T₂); propiconazole fungicide (Potent) (T₃), and combination of Thiovit and Potent (T₄) and a control treatment (T₅) where no fungicide or Trichoderma was applied. The treatment was applied at 20 days after sowing (DAS). In year 2013, the experiment comprised ten treatment combinations of Trichoderma and fungicides viz.seed treatment with Trichoderma (T₁), seed treatment with Trichoderma + spraying of Thiovit (T₂), seed treatment with Trichoderma + spraying of Potent (T₃), seed treatment with Thiovit and Potent (T₄), spraying of Thiovit (T₅), spraying of Potent (T₆), seed treatment with Thiovit + spraying of Potent (T₇), seed treatment with Potent + spraying of Thiovit (T₈), spraying of mixture of Thiovit and Potent (T₉), and control (no fungicide or Trichoderma) (T₁₀). Both the experiments used Randomized Complete Block Design (RCBD) with three replications. Results showed that osmopriming gave higher number of seedling, length and dry matter of shoot and root and yield than hydropriming. All these attributes were highest with seed treatment by Trichoderma. Experiment 2 revealed that seed treatment with Trichoderma harzianum followed by spraying of Thiovit gave the highest yield of rice. The study concludes that sowing of seed after osmopriming with 3% ZnSO₄ and biopriming with Trichoderma and then application of sulphur fungicide at 20 days after sowing could be practiced for ensuring high seedling establishment and yield of rice under dry direct seeded system in boro season.

Keywords Rice, Boro Season, Dry Direct Seeding, Priming, Fungicide Application

1. Introduction

Rice (Oryza sativa L.) is the staple food for nearly half of the world’s population. The global rice requirement has been increased by more than two folds (e.g. 150 million tones in 1961 and 350 million tones in 2011) during the last five decades [23]. In 2011-12, 33.541 million tons of rice is produced from 11.527 million hectares of land in Bangladesh [5]. Among the three rice seasons viz. Aus, Aman and Boro, rice yield is the highest in Boro season. Boro rice contributes about 56% of the total rice production in Bangladesh. Therefore, Boro rice is the main contributor to the food production and security in the country.

Rainfall is practically nil during Boro season (December – March) and therefore, rice production in this season is fully dependant on irrigation. Rice is mainly cultivated in puddle transplanted flood irrigation (PTR-CI) system requiring 3000-5000 litres of water to produce one kilogram of rice. Very recently, scarcity of irrigation water is evident in many parts of the country that threatens the sustainability of boro rice production. Under this water scarce situation, farmers may be forced to shift their rice land to other crops which would cause severe food shortage in the country.

Rice production could be sustained in water shortage areas by adopting technologies that ensures rice production with less water. Recent research shows that boro rice could be produced using 50-70% less water by adopting the dry direct seeded rice production technology [28, 32]. In this system rice seed is directly sown on dry cultivated land during December to January. This sowing period coincides with very low temperature which causes poor seedling establishment owing to seedling mortality. The poor seedling establishment due seedling mortality poses a serious hindrance to the rice production in this new system.

Application of chemical fungicides (e.g. sulphur or
propiconazole) helps improve field emergence and percent survival of seedlings and thus contributes to stand establishment [33]. Research reports reveal that seed priming helps improve germination rate, reduces the germination time, improves synchronized germination and increases establishment in rice [3, 13]. Other reports indicate that *Trichoderma harzanium*, a plant growth promoting fungi (PGPF) can be used for improving germination and seedling establishment [10, 20]. The present study sought to investigate the effect of seed priming, *Trichoderma* and fungicide application on seedling establishment and yield performance of dry direct seeded *Boro* rice.

2. Materials and Methods

2.1. Study Site

Field experiments were conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh during *Boro* season (January to June) 2012 and 2013. The experimental site is a medium high land belonging to the Sonatala series of Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9) having non-calcareous dark grey floodplain soils. The site is located at 24°75’ N latitude and 90°50’ E longitude having an altitude of 18 m. The soil was silt loam with pH 6.5. Soil contained 1.78% organic matter, 0.14% total N, 1.98 μg g⁻¹ available P, 0.10 meq 100g⁻¹ exchangeable K and 4.56 μg g⁻¹ available S. The crop experienced very low rainfall (0-15 mm) during January – March which coincided with the vegetative stage. However, high rainfall was experienced in the later phase of plant growth. The average minimum temperatures of the area are below 15 °C during mid December and mid February and rises to more than 20 °C in last week of February.

2.2. Treatments and Experimental Design

In 2012, the experiment comprised three seed priming treatments viz. osmo-priming, hydro-priming and no priming and five *Trichoderma* and chemical fungicide treatment combinations viz. *Trichoderma harzanium* (T₁), sulphur fungicide (T₂), propiconazole fungicide (T₃), sulphur fungicide + propiconazole fungicide (T₄), and control (no fungicide or *Trichoderma*) (T₅) treatment. In 2013, the experiment comprised ten treatment combinations viz. seed treatment with *Trichoderma* (T₁), seed treatment with *Trichoderma* + spraying of sulphur fungicide (T₂), seed treatment with *Trichoderma* + spraying of propiconazole fungicide (T₃), seed treatment with *Trichoderma* + spraying of sulphur fungicide and propiconazole fungicide (T₄), spraying of sulphur fungicide (T₅), spraying of propiconazole fungicide (T₆), seed treatment with sulphur fungicide + spraying of propiconazole fungicide (T₇), seed treatment with propiconazole fungicide + spraying of sulphur fungicide (T₈), spraying of mixture of sulphur fungicide and propiconazole fungicide (T₉) and control (no fungicide or *Trichoderma*) treatment (T₁₀). Both the experiments used Randomized Complete Block Design (RCBD) and three replications. The plot size was 4.0 m × 2.5 m with 1 meter drain in between two plots to manage the irrigation easily.

2.3. Husbandry

BRRI dhan28 was used as test crop and seed was sown at 25 cm × 15 cm spacing allocating 4 seeds hill⁻¹. The sowing was done on 5 and 16 January 2012 and 2013, respectively. Hydro-priming and osmo-priming were done by soaking seeds in tap water and in 3% ZnSO₄ solution, respectively for 24 hours followed by incubation at 35 °C for 30 hours. *T.harzianum* inoculum was mixed with seed at the rate of 4% of seed weight before 4 hours of sowing. Sulphur fungicide and propiconazole fungicide were mixed with seed at 3% of seed weight. The land was fertilized with N, P, K, S and Zn @ 120, 14, 58, 8 and 1 kg ha⁻¹ as urea, triple supper phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate, respectively. All the fertilizers were applied at final land preparation while urea was top dressed in three equal splits at 30, 45, and 65 days after sowing (DAS). Sulphur and propiconazole fungicide were applied at 20 DAS @ 2.5 kg ha⁻¹ and 0.5 litre per hectare, respectively. A pre-emergence herbicide Panida (Pendimethalin) was applied at 2 DAS @ 2 litre ha⁻¹. In addition, four hand weedings were done at 30, 45, 60 and 75 DAS. Land preparation was done with residual moisture and therefore, no irrigation was required during land preparation. Then five irrigations were done at 40, 55, 70, 85 and 90 DAS. Standing water of 3-4 cm was maintained during irrigation at 85 and 90 DAS. Crop management was done following standard agronomic practices when necessary. The crop was harvested on 19 and 31 May, respectively in 2012 and 2013 crop seasons.

2.4. Recording of Data

Number of seedlings were counted at 7, 15 and 30 DAS from the central 1.5 m² (1.5 m length of four central rows) of each plot. Randomly selected ten seedlings were uprooted from each plot at 30 DAS to measure shoot and root length and their dry matter. Dry matter was recorded after oven drying of the plants at 70 °C for 72 hours in force draft oven and was expressed in g plant⁻¹. The crop was harvested at maturity (when 80% grains become golden yellow in colour) from the central 3.6 m² area of each plot. The number of tillers and panicle m⁻² were counted from the harvest area. The plant height was recorded from randomly selected five hills. The number of grains and unfilled spikelets panicle⁻¹ were counted from the randomly selected 10 panicles of the harvested crops. Grain and straw yields were recorded after sun drying. Grain yield was adjusted to 14% moisture content. Harvest index was calculated as percentage of grain yield to total above ground biomass. The weight of 1000 grain was also recorded from the collected grains of each plot.
2.5. Statistical Analysis

All data were subjected to statistical analysis following analysis of variance (ANOVA) technique with the help of computer package programme MSTAT-C and Duncan's Multiple Range Test (DMRT) was used for mean comparison [15].

3. Results

The number of seedling at 7, 15 and 30 days after sowing (DAS), seedling shoot and root length, shoot and root dry matter at 30 DAS, plant height, number of tillers and panicle m\(^2\) at harvest, panicle length, number of filled grains panicle\(^{-1}\), 1000-grain weight, grain yield, straw yield and harvest index were affected significantly by seed priming. *Trichoderma* and fungicide application treatments but not by their interactions (experiment 1). In 2013, the effects of *Trichoderma* and fungicide application treatments showed significant effects on these characters (experiment 2). The results obtained for these experiments are presented here.

3.1. Seed priming

The highest numbers of seedling m\(^2\) at 7, 15 and 30 DAS were found in osmopriming treated plots and the values were 58, 112 and 110, respectively while the values for hydropreaming treatments were 53, 104 and 101, respectively. The corresponding values for crops with no priming treatment were only 7, 88 and 84, respectively (Table 1). The number of seedlings at 7 days after sowing did not significantly differ for osmopriming and hydropreaming but this became significant at later stages at 15 and 30 DAS. Osmopriming produced the highest shoot and root lengths and shoot and root dry matters of seedlings at 30 DAS than the hydropreaming plots. The shoot and root lengths for osmopriming were 20.06 and 7.38 cm while those for hydropreaming were 18.10 and 6.66 cm respectively. The shoot and root dry matter for osmopriming were 2.149 and 0.862 g plant\(^{-1}\) while those for hydropreaming were 1.970 and 0.753 g plant\(^{-1}\) (Table 3). The yield obtained from hydropreaming treatment was statistically lower than the osmopriming treatment. Seed priming had significant effect on plant height, number of panicle m\(^2\), panicle length, numbers of grains panicle\(^{-1}\), 1000-grain weight, grain and straw yield (Table 5 and 6). For all these parameters, the highest values were found with osmopriming which was significantly higher than those of hydropreaming treated crops. The lowest values for all these characters were found with no priming control treatment.

3.2. *Trichoderma* and fungicide treatment

*Trichoderma* and fungicide treatment had significant effects on seedling establishment in both the years. In 2012, the number of seedlings at 7, 15 and 30 DAS were 65.56, 113.40 and 112.00 for *Trichoderma* treatment while the corresponding values for control plots were 36.56, 97.11 and 84.33, respectively (Table 2). The highest number of tillers (339 tillers m\(^2\)) was obtained for *Trichoderma* treatment. This value was statistically similar to those obtained for other fungicide treatments but significantly higher than control plots (Table 2). The lengths of root and shoot as well as the dry matter of root and shoot were significantly affected by *Trichoderma* and fungicide treatments. The highest values were found with *Trichoderma* treatment for all these parameters (Table 4). In 2013, the numbers of seedling at 10, 18 and 30 DAS as well as number of tiller m-2 at harvest were affected significantly by *Trichoderma* and fungicide treatment. The highest number of seedling (86.66, 113.00) were found with M1 treatment but 10 and 18 DAS which were statistically similar to M2, M3, M4, M7 and M8 treatments. At 30 DAS the highest number of seedlings (112.33) was found with M2 treatment which was statistically similar to M1, M3, M4, M7 and M8 treatment. The lowest number of seedling (45.00, 71.66 and 65.00) was found with M9 treatment at 10, 18 and 30 DAS which was statistically similar to M8, M9 and M10 treatment (Table 9). The highest shoot and root length (20.19 cm and 8.25 cm) were recorded from M1 treatment at 30 DAS, which was statistically similar to M2 and M4 treatments whereas the lowest shoot and root length (16.10 cm and 5.82 cm) were recorded from M10 treatment. The highest shoot dry matter was found with M2 treatment which was statistically similar to M1, M3 and M4 treatments (Table 10). The highest root dry matter was found with M1 treatment which was statistically similar to M2, M3 and M4 treatment. The lowest shoot and root dry matter were found with M10 treatment at 30 DAS (Table 10).

Number of panicle m\(^2\), filled grains panicle\(^{-1}\), grain yield and straw yields were affected significantly by *Trichoderma* and fungicide treatments but plant height, 1000-grain weight and harvest index remained unaffected. The highest number of panicle m\(^2\) (380.33 m\(^2\)), filled grain panicle\(^{-1}\) (98), grain yield (6.28 t ha\(^{-1}\)) and straw yield (7.45 t ha\(^{-1}\)) were found with the plot sown with *Trichoderma* treated seeds followed by spraying of sulphur fungicide at 20 DAS. The highest number of tiller and panicle (426.00 and 380.33) were observed with M2 treatment which was statistically similar to M1, M3 and M4 treatments (Table 9). The highest shoot and root length (20.19 cm and 8.25 cm) were recorded from M10 treatment. The lowest number of tiller and panicle (287.33 and 237.66) were observed with M9 and M10 treatment, respectively. No. of filled grains panicle\(^{-1}\) (98.00) was found significantly highest with M2 treatment and the lowest no. of filled grains panicle\(^{-1}\) (75.66) was found with M10 treatment (Table 11). The highest grain yield (6.28 t ha\(^{-1}\)) was recorded from M2 treatment and the highest straw yield (7.54 t ha\(^{-1}\)) was recorded from M1 treatment which was statistically similar to M1 and M2 treatments, respectively whereas the lowest grain (3.41 t ha\(^{-1}\)) and straw yield (4.12 t ha\(^{-1}\)) were recorded from M10 treatment. Plant height and 1000-grain weight were not affected significantly by any of the *Trichoderma* and fungicide treatment (Table 12).
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### Table 1. Effect of seed priming on number of seedlings and tillers of dry direct seeded Boro rice in 2012

| Seed priming | No. of seedling m$^{-2}$ | No. of tiller m$^{-2}$ at harvest |
|--------------|--------------------------|----------------------------------|
|              | 7 DAS                    | 15 DAS                           | 30 DAS                           |
| P$_1$        | 58.33a                   | 111.6a                           | 109.7 a                          | 339a                                |
| P$_2$        | 52.53a                   | 103.6b                           | 100.8b                           | 328b                                |
| P$_3$        | 16.66b                   | 88.13c                           | 83.47c                           | 320b                                |
| S$\bar{x}$   |                          | 2.017                            | 2.083                            | 2.114                               | 3.407                              |
| CV (%)       |                          | 18.52                            | 7.93                             | 8.38                                | 4.01                               |
| Level of significance | ** | ** | ** | ** |

In a column, figures having common letter(s) do not differ significantly whereas mean values with dissimilar letter(s) differ significantly as per DMRT.

LS= Level of Significance, CV= Coefficient of Variance, **= Significant at 1% level P$_1$= Osmo-priming, P$_2$= Hydro-priming, P$_3$= No priming, T$_1$= Trichoderma, T$_2$= Sulfur Fungicide, T$_3$= Propiconazole fungicide, T$_4$= Sulfur fungicide+ propiconazole fungicide, T$_5$ = Control

### Table 2. Effect of Trichoderma and fungicide on number of seedlings and tillers of dry direct seeded Boro rice in 2012

| Trichoderma and fungicide | No. of seedling m$^{-2}$ | No. of tiller m$^{-2}$ at harvest |
|---------------------------|--------------------------|----------------------------------|
|                           | 7 DAS                    | 15 DAS                           | 30 DAS                           |
| T$_1$                     | 65.56a                   | 113.4a                           | 112.00a                          | 339a                                |
| T$_2$                     | 35.89b                   | 95.44b                           | 94.11b                           | 333a                                |
| T$_3$                     | 37.56b                   | 99.66b                           | 98.88b                           | 333a                                |
| T$_4$                     | 37.00b                   | 99.88b                           | 99.66b                           | 330a                                |
| T$_5$                     | 36.56b                   | 97.11b                           | 84.33c                           | 310b                                |
| S$\bar{x}$               |                          | 2.604                            | 2.689                            | 2.729                               | 4.398                              |
| CV (%)                   |                          | 18.37                            | 7.98                             | 8.37                                | 4.01                               |
| Level of significance | ** | ** | ** | ** |

### Table 3. Effect of seed priming on shoot and root length and dry matter of dry direct seeded Boro rice in 2012

| Seed priming | At 30 DAS |
|--------------|-----------|
|              | Shoot length (cm) | Root length (cm) | Shoot dry matter (g plant$^{-1}$) | Root dry matter (g plant$^{-1}$) |
| P$_1$        | 20.06a     | 7.38a          | 2.149a                             | 0.862a                             |
| P$_2$        | 18.10b     | 6.66b          | 1.970b                             | 0.753b                             |
| P$_3$        | 15.71c     | 5.99c          | 1.790c                             | 0.659c                             |
| S$\bar{x}$  | 0.4443     | 0.1590         | 0.3782                             | 0.2422                             |
| CV (%)       | 9.58       | 9.21           | 7.44                               | 12.38                              |
| Level of significance | ** | ** | ** | ** |

### Table 4. Effect of Trichoderma and fungicide on shoot and root length and dry matter of dry direct seeded Boro rice in 2012

| Trichoderma & fungicide | At 30 DAS |
|-------------------------|-----------|
|                         | Shoot length (cm) | Root length (cm) | Shoot dry matter (g plant$^{-1}$) | Root dry matter (g plant$^{-1}$) |
| T$_1$                  | 19.7a      | 7.61a          | 2.191a                             | 0.888a                             |
| T$_2$                  | 18.70ab    | 6.76bc         | 1.993b                             | 0.762bc                             |
| T$_3$                  | 17.72b     | 6.27c          | 1.997b                             | 0.695cd                             |
| T$_4$                  | 19.07ab    | 7.18ab         | 2.137ab                            | 0.836ab                             |
| T$_5$                  | 14.57c     | 5.57d          | 1.531c                             | 0.610d                              |
| S$\bar{x}$  | 0.5736     | 0.2052         | 0.4883                             | 0.3127                              |
| CV (%)       | 9.58       | 9.21           | 7.44                               | 12.38                              |
| Level of significance | ** | ** | ** | ** |
Table 5. Effect of seed priming on the yield components and yield of dry direct seeded *Boro* rice in 2012

| Seed priming | Plant height (cm) | No. of panicle m\(^{-2}\) | Panicle length (cm) | No. of filled grain panicle\(^{-1}\) |
|--------------|------------------|--------------------------|-------------------|-------------------------------|
| P\(_1\)      | 102.72a          | 310a                     | 23.35a            | 98.40a                        |
| P\(_2\)      | 99.39b           | 305ab                    | 22.98a            | 93.67a                        |
| P\(_3\)      | 98.27b           | 299b                     | 22.07b            | 86.20b                        |
| S\(_X\)     |                  |                          |                   |                               |
| CV (%)       | 0.7504           | 3.407                    | 0.2798            | 1.728                         |
| Level of significance | **   | *                        | **                | **                            |

In a column, figures having common letters do not differ significantly whereas mean values with dissimilar letters differ significantly as per DMRT. 

LS= Level of Significance, CV= Coefficient of Variance, **= Significant at 5% level, ***= Significant at 1% level, P\(_1\)= Osmo-priming, P\(_2\)= Hydro-priming, P\(_3\)= No priming, T\(_1\)= Trichoderma, T\(_2\)= Sulfur fungicide, T\(_3\)= Propiconazole fungicide, T\(_4\)= Sulfur fungicide + Propiconazole fungicide, T\(_5\)= Control.

Table 6. Effect of seed priming on the yield components and yield of dry direct seeded *Boro* rice in 2012

| Seed priming | 1000 - grain weight (g) | Grain yield (t ha\(^{-1}\)) | Straw yield (t ha\(^{-1}\)) | Harvest index (%) |
|--------------|--------------------------|----------------------------|-----------------------------|-------------------|
| P\(_1\)      | 22.43a                   | 6.75a                      | 7.87a                       | 46.16a            |
| P\(_2\)      | 22.12ab                  | 6.27b                      | 7.47b                       | 45.59a            |
| P\(_3\)      | 21.88b                   | 5.61c                      | 6.92c                       | 44.78b            |
| S\(_X\)     |                          | 0.1225                    | 0.0509                      | 0.0627            | 0.2249            |
| CV (%)       | 2.14                     | 3.16                       | 3.28                        | 1.91              |
| Level of significance | **   | **                        | **                           | **                |

Table 7. Effect of *Trichoderma* and fungicide on the yield and yield components of drydirect seeded *Boro* rice in 2012

| Trichoderma and fungicide | Plant height (cm) | No. of panicle m\(^{-2}\) | Panicle length (cm) | No. of filled grain panicle\(^{-1}\) |
|---------------------------|------------------|--------------------------|-------------------|-------------------------------|
| T\(_1\)                   | 101.73           | 318a                     | 23.76a            | 99.22a                        |
| T\(_2\)                   | 100.7            | 301b                     | 22.03b            | 96.56a                        |
| T\(_3\)                   | 98.31            | 306ab                    | 23.30a            | 95.11a                        |
| T\(_4\)                   | 100.16           | 314ab                    | 23.63a            | 92.67a                        |
| T\(_5\)                   | 99.74            | 285c                     | 21.29b            | 80.22b                        |
| S\(_X\)                  |                  |                          |                   |                               |
| CV (%)                   | 0.9687           | 4.398                    | 0.3612            | 2.231                         |
| Level of significance    | NS               | **                       | **               | **                            |

Table 8. Effect of *Trichoderma* and fungicide on the yield and yield components of dry direct seeded *Boro* rice in 2012

| Trichoderma and fungicide | 1000 grain weight (g) | Grain yield (t ha\(^{-1}\)) | Straw yield (t ha\(^{-1}\)) | Harvest index (%) |
|---------------------------|-----------------------|-----------------------------|-----------------------------|-------------------|
| T\(_1\)                   | 22.26                 | 6.64a                       | 7.80a                       | 45.95ab           |
| T\(_2\)                   | 22.04                 | 6.36b                       | 7.72a                       | 45.12bc           |
| T\(_3\)                   | 22.30                 | 6.38b                       | 7.47b                       | 46.05a            |
| T\(_4\)                   | 22.21                 | 6.35b                       | 7.58ab                      | 45.53ab           |
| T\(_5\)                   | 21.92                 | 5.32c                       | 6.45c                       | 44.89c            |
| S\(_X\)                  |                       |                            |                             |                   |
| CV (%)                   | 0.1581                | 0.0658                     | 0.0809                      | 0.2904            |
| Level of significance    | NS                    | **                         | **                          | *                 |

In a column, figures having common letter(s) do not differ significantly whereas mean values with dissimilar letter(s) differ significantly as per DMRT. 

LS= Level of Significance, CV= Coefficient of Variance, **= Significant at 1% level, P\(_1\)= Osmo-priming, P\(_2\)= Hydro-priming, P\(_3\)= No priming, T\(_1\)= Trichoderma, T\(_2\)= Sulfur Fungicide, T\(_3\)= Fungicide, T\(_4\)= Sulfur fungicide + Fungicide, T\(_5\)= Control.
Table 9. Effect of *Trichoderma* and fungicide on number of seedlings of dry direct seeded *boro* rice in 2013

| Treatment | 10 DAS | 18 DAS | 30 DAS | No. of tillers m$^{-2}$ at harvest |
|-----------|--------|--------|--------|----------------------------------|
| M1        | 86.66a | 113.00a| 111.66a| 411.33a                          |
| M2        | 85.33a | 112.66a| 112.33a| 426.00a                          |
| M3        | 83.33a | 111.33a| 109.66a| 320.66be                         |
| M4        | 85.00a | 109.66a| 107.66a| 319.33be                         |
| M5        | 51.33b | 79.33b | 73.33b | 340.33b                          |
| M6        | 52.00b | 78.00b | 69.66b | 337.66bc                         |
| M7        | 83.00a | 107.66a| 106.00a| 324.00bc                         |
| M8        | 77.00a | 106.33a| 105.00a| 326.00bc                         |
| M9        | 45.00a | 71.66a | 65.00b | 287.33d                          |
| M10       | 48.66b | 74.00b | 65.00b | 302.66cd                         |
| $\bar{x}$| 3.476  | 3.540  | 3.235  | 10.62                            |
| CV (%)    | 8.63   | 6.36   | 6.06   | 5.42                             |

Level of significance: ** ** ** **

In a column, figures having common letter(s) do not differ significantly whereas mean values with dissimilar letter(s) differ significantly as per DMRT.

M1 = seed treatment with Trichoderma
M2 = seed treatment with Trichoderma + spraying of sulphur fungicide at 20 (DAS)
M3 = seed treatment with Trichoderma + spraying of propiconazole fungicide at 20 DAS
M4 = seed treatment with Trichoderma + spraying of sulphur and propiconazole fungicide at 20 DAS
M5 = spraying of sulphur fungicide at 20 DAS
M6 = spraying of propiconazole fungicide at 20 DAS
M7 = seed treatment with sulphur fungicide + spraying of propiconazole fungicide at 20 DAS
M8 = seed treatment with propiconazole fungicide + spraying of sulphur fungicide at 20 DAS
M9 = spraying of mixture of sulphur fungicide and propiconazole fungicide at 20 DAS and
M10 = control treatment

Table 10. Effect of *Trichoderma* and fungicide on shoot and root of dry direct seeded *boro* rice in 2013

| Treatment | Shoot length (cm) | Root length (cm) | Shoot dry matter (g plant$^{-1}$) | Root dry matter (g plant$^{-1}$) |
|-----------|------------------|------------------|----------------------------------|----------------------------------|
| M1        | 20.19a           | 8.25a            | 2.198ab                          | 0.995a                           |
| M2        | 19.12ab          | 7.15ab           | 2.242a                           | 0.875ab                          |
| M3        | 19.73ab          | 6.32bc           | 2.259a                           | 0.830ab                          |
| M4        | 18.38ab          | 7.32ab           | 2.131ab                          | 0.782b                           |
| M5        | 17.71bc          | 6.26bc           | 1.894c                           | 0.700b                           |
| M6        | 17.60bc          | 6.11bc           | 1.870c                           | 0.754b                           |
| M7        | 18.73ab          | 6.83bc           | 2.095ab                          | 0.813b                           |
| M8        | 18.41ab          | 6.73bc           | 1.977ab                          | 0.875ab                          |
| M9        | 16.78cd          | 6.03cd           | 1.924bc                          | 0.702b                           |
| M10       | 16.10d           | 5.82d            | 1.854c                           | 0.698b                           |
| $\bar{x}$| 0.7125           | 0.3737           | 0.856                            | 0.5486                           |
| CV (%)    | 6.75             | 9.68             | 7.25                             | 11.84                            |

Level of significance: * ** ** * *

In a column, figures having common letter(s) do not differ significantly whereas mean values with dissimilar letter(s) differ significantly as per DMRT.

M1 = seed treatment with Trichoderma
M2 = seed treatment with Trichoderma + spraying of sulphur fungicide at 20 (DAS)
M3 = seed treatment with Trichoderma + spraying of propiconazole fungicide at 20 DAS
M4 = seed treatment with Trichoderma + spraying of sulphur and propiconazole fungicide at 20 DAS
M5 = spraying of sulphur fungicide at 20 DAS
M6 = spraying of propiconazole fungicide at 20 DAS
M7 = seed treatment with sulphur fungicide + spraying of propiconazole fungicide at 20 DAS
M8 = seed treatment with propiconazole fungicide + spraying of sulphur fungicide at 20 DAS
M9 = spraying of mixture of sulphur fungicide and propiconazole fungicide at 20 DAS and
M10 = control treatment
### Table 11. Effect of *Trichoderma* and fungicide on yield contributing characters of dry direct seeded boro rice in 2013

| Treatment | Plant height (cm) | No. of panicle m⁻² | No. of filled grain pan⁻¹ |
|-----------|-------------------|---------------------|--------------------------|
| M1        | 98.06             | 364.00a             | 92.66c                   |
| M2        | 100.00            | 380.33a             | 98.00a                   |
| M3        | 97.93             | 300.33b             | 93.00c                   |
| M4        | 98.73             | 276.66b             | 90.00d                   |
| M5        | 96.80             | 288.33b             | 87.33f                   |
| M6        | 96.66             | 270.00bc            | 88.66e                   |
| M7        | 99.00             | 276.33bc            | 96.00b                   |
| M8        | 97.13             | 251.00cd            | 83.33g                   |
| M9        | 97.00             | 237.66d             | 75.66i                   |
| xS        | 1.381             | 10.42               | 0.164                    |
| CV (%)    | 2.44              | 6.20                | 8.23                     |
| Level of significance | NS | ** | * |

### Table 12. Effect of *Trichoderma* and fungicide on yield contributing characters and yield of dry direct seeded boro rice in 2013

| Treatment | 1000 grain wt. (g) | Grain yield (t ha⁻¹) | Straw yield (t ha⁻¹) | Harvest index (%) |
|-----------|---------------------|-----------------------|----------------------|-------------------|
| M1        | 22.09               | 6.08ab                | 7.54a                | 44.64             |
| M2        | 21.72               | 6.28a                 | 7.45a                | 45.72             |
| M3        | 21.68               | 5.65bc                | 6.75b                | 45.55             |
| M4        | 22.31               | 5.29c                 | 6.38b                | 45.32             |
| M5        | 22.04               | 4.42d                 | 5.47c                | 44.68             |
| M6        | 22.13               | 4.69d                 | 5.53c                | 45.83             |
| M7        | 22.10               | 5.36c                 | 6.62b                | 44.80             |
| M8        | 22.02               | 5.30c                 | 6.33b                | 45.54             |
| M9        | 21.89               | 4.63d                 | 5.68c                | 44.93             |
| M10       | 21.74               | 3.41e                 | 4.12d                | 45.28             |
| xS        | 0.248               | 0.164                 | 0.173                | 0.459             |
| CV (%)    | 1.95                | 5.57                  | 4.85                 | 1.76              |
| Level of significance | NS | ** | ** | NS |

In a column, figures having common letters do not differ significantly whereas mean values with dissimilar letters differ significantly as per DMRT.

M1 = seed treatment with *Trichoderma*
M2 = seed treatment with *Trichoderma* + spraying of sulphur fungicide at 20 (DAS)
M3 = seed treatment with *Trichoderma* + spraying of propiconazole fungicide at 20 DAS
M4 = seed treatment with *Trichoderma* + spraying of sulphur and propiconazole fungicide at 20 DAS
M5 = spraying of sulphur fungicide at 20 DAS
M6 = spraying of propiconazole fungicide at 20 DAS
M7 = seed treatment with sulphur fungicide + spraying of propiconazole fungicide at 20 DAS
M8 = seed treatment with propiconazole fungicide + spraying of sulphur fungicide at 20 DAS
M9 = spraying of mixture of sulphur fungicide and propiconazole fungicide at 20 DAS and
M10 = control treatment

### 4. Discussion

Establishment of optimal number of seedling in dry direct seeded rice in boro (winter) season is very difficult mainly because of seedling mortality due to cold injury. The seed sowing is done during early January when the minimum temperature generally goes below (15 °C) that delayed seedling emergence, reduced seedling early growth and causes seedling mortality.

Seed priming allows the early DNA transcription and RNA and protein synthesis which repair the damaged parts of the seed and reduce metabolic exudation and ultimately improve seed germination characteristics and the seedling emergence [14, 22]. In the present study it was found that seedling emergence and seedling growth was higher in osmoprimed seed than the hydroprimed seed. Osmopriming helped not only improving seedling establishment but also helped increase yield of dry direct seeded rice by improving the yield attributes such as number of panicle m⁻² and grains panicle⁻¹. Similar result was reported by Islam *et al.* [25] and Takhti and Shekafandeh [37] who reported that osmo-priming increased the shoot length, root length, shoot
dry matter and root dry matter. Farooq et al. [12, 13] reported that the seedling establishment, grain and straw yield were improved by priming. The osmopriming with 3% ZnSO₄ solution in this study significantly improved number of seedling, early growth and yield significantly over hydropriming. This was probably because of the supply of Zn in the seed which is an essential component for the plant growth required for chlorophyll synthesis, pollination, fertilization and germination [7, 19]. Khan and Sinha [27] reported that seed priming improved the physiological responses under the environmental stress conditions and increased seeds tolerance to the environmental stress.

In the present study Trichoderma harzianum seed treatment significantly contributed to the improvement in establishment of plant stand and yield of dry direct seeded boro rice. The yield increase by T. harzianum application was probably related to increased plant stand establishment and crop growth [9, 21]. Entesari et al. [11] reported that Trichoderma harzianum application induced profound changes in plant characteristics and encouraged more uniform seed germination and plant growth in soybean. Trichoderma harzianum has the ability to solubilize P, Mn and Zn and extract insoluble nutrients from soil which contributed to the growth promoting effects on crops [39]. Altomare et al. [2] reported that T. harzianum stimulated root growth [18, 38], enhances biomass production [35], increases rates of germination of seeds [6, 8], increases disease tolerance in the seedlings [17, 26, 29, 36]. Trichoderma inoculation increased levels of SOD, increasing ROS scavenging abilities peroxidase, glutathione reductase, glutathione-s-transferas (GST) and other detoxifying enzyme in leaves [1, 30, 34].

Trichoderma seed treatment followed by application of sulphur fungicide significantly improved seedling population, root and shoot growth and yield in the present study. Similar improvement was reported by Hamed et al. [16], Azarmi et al. [4] and Nzanza et al. [31]. So, seed treatment with Trichoderma and seed treatment with Trichoderma + spraying of sulphur fungicide at 20 DAS treatments can be used to improve seedling establishment and increase yield of dry direct seeded Boro rice.

5. Conclusions

Osmopriming with 3% ZnSO₄ followed by Trichoderma seed treatment (biopriming) improved seedling establishment and yield in dry direct seeded rice in boro season. Trichoderma application alone or application of Trichoderma followed by spraying of sulphur fungicide at 20 DAS gave similar yield in dry direct seeded boro rice. Therefore, osmopriming of seed with 3% Zn SO₄ solution followed by seed treatment with Trichoderma inoculum could be used for improving seedling establishment and increase grain yield of dry direct seeded boro rice.

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