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Non-chemical agents provide tenable, eco-friendly alternatives for the management of the major diseases devastating Indian mustard (*Brassica juncea*) in India

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A B S T R A C T

India is a leading producer of oilseed Brassicas, contributing approximately 23 percent of the country's total oilseed production. In India, the Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] crop is ravaged by various diseases, including Alternaria blight, white rust, downy mildew, Sclerotinia rot and powdery mildew, which can contribute to fluctuations in crop yields. A field experiment examining an integrated disease management system for Indian mustard (*B. juncea*) was conducted under the All India Coordinated Research Project on Rapeseed-Mustard (Indian Council of Agricultural Research or ICAR) during three crop seasons (2006–09) at 11 locations to assess treatments suitable for the management of crop disease. The data from the different locations and years regarding disease severity and incidence were pooled and analyzed. Seed treatments with freshly prepared *Allium sativum* bulb aqueous extract (1 percent w/v) resulted in significantly higher initial plant stands, across locations and years. Seed treatment with *A. sativum* bulb extract, followed by its use as a foliar spray, resulted in significantly reduced Alternaria leaf and pod blight severity, reduced white rust severity, fewer stag heads per plot, reduced downy mildew and Sclerotinia rot incidence, and reduced powdery mildew severity, across locations and years. The combination also provided significantly higher seed yields compared with the control across locations and years and was at par with treatment by chemical fungicides. The combination used in the present study was as effective as the combination of seed treatment with *Trichoderma harzianum* and foliar spraying with *Pseudomonas fluorescens* and *T. harzianum*. Economic returns were higher when using biorational treatments (*A. sativum* bulb extract, *T. harzianum*, *P. fluorescens*) compared with chemical fungicides. The combination of seed treatments with *T. harzianum* followed by its use as a foliar spray (17.22), and the similar combination of seed treatments and foliar spraying with the *A. sativum* bulb extract (17.18), resulted in a higher benefit to cost ratio. This eco-friendly technology can help oilseed *Brassica* growers in India safeguard the crops from major diseases and increase the stability and productivity of the Indian mustard crop.

1. Introduction

The rapeseed-mustard production trends in India fluctuate from season to season, with an all-time production high of 8.1 mt from

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7.3 mha of land during the 2005–06 season (GoI, 2007). The oilseed *Brassica* plays a significant role in the Indian oil economy by contributing to approximately 23 percent of the total oilseed production. India produced 6.4 mt of rapeseed-mustard from 5.5 mha of land during the 2009–10 season, with the variable yield levels ranging from 854 (2002–03) to 1142 kg/ha (2009–10) over the past eight years; globally, India's production accounts for 17.5 and 10.8 percent of the total acreage and production, respectively (GoI, 2010; FAO, 2012). This high level of production indicates a need to focus efforts on attaining a high and stable level of productivity per unit area per unit time. Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] is mainly cultivated in India and contributes to approximately 85 percent of the total rapeseed-mustard crop area because it is more adaptable and has higher comparative tolerances to biotic and abiotic stresses than other cultivated oilseed *Brassica* species (AICRP-RM, 2000–09).

The crop can be ravaged by several diseases, including Alternaria blight [*Alternaria brassicae* (Berk.) Sacc.], white rust [*Albugo candida* (Pers. Ex Lev.) Kuntze], downy mildew [*Hyaloperonospora parasitica* (Pers.) Constant], Sclerotinia rot [*Sclerotinia sclerotiorum* (Lib.) de Bary] and powdery mildew (*Erysiphe cruciferarum* Opiz ex L. Junell), which remain a major cause behind the fluctuation in yields, apart from the wide gap that exists between the potential yield and the realized yield. Among the biotic stresses, Alternaria blight disease, which has been reported on all continents, is responsible for 10–70 percent of oilseed losses (Ram and Chauhan, 1998), depending upon the prevailing weather and disease situations (Meena et al., 2004; Chattopadhyay et al., 2005), with no proven source of resistance. White rust and downy mildew diseases are capable of causing yield losses of up to 47 percent (Chattopadhyay, 2008), while powdery mildew is also known to inflict Indian mustard yield losses of up to 19 percent (Dange et al., 2002). Sclerotinia rot disease is reported to cause yield losses of up to 39.9 percent for Indian mustard in India (Chattopadhyay et al., 2003). Notably, among the diseases indicated, the pathogens that cause Sclerotinia rot, white rust and downy mildew are soilborne in India (Chattopadhyay, 2008). The continuous use of specific fungicides runs the risk of the development of fungicide resistance in the fungal pathogens. The foliar application of fungicides at critical plant growth stages was reported to reduce losses in seed yield due to Alternaria blight (Meena et al., 2004), white rust and powdery mildew (Meena et al., 2003). Sclerotinia rot has been reported to be manageable by both seed treatments and foliar spraying with fungicides (Chattopadhyay et al., 2004, 2007).

Non-chemical, eco-friendly fungicides could help to optimize the economic yields and enable farmers to grow healthy Indian mustard crops by overcoming biotic stress(es). Because very little information is available on the integrated management of diseases in this crop, particularly by use of non-chemical interventions, the present study has been performed over multiple locations to obtain suitable information regarding disease management and more precise estimates for seed yields and the economics of different treatments in Indian mustard. This paper reports the effect of plant extracts, bioagents and chemical fungicides, both individually and in combination, on the integrated management of Alternaria blight, white rust, powdery mildew, downy mildew and Sclerotinia rot in Indian mustard.

2. Materials and methods

2.1. Locations and design of trial

A field trial was performed over three crop seasons (2006–09) at 11 locations across India: Sriganganagar (29°92′N, 73°88′E), Faizabad (25°51′N, 82°72′E), Morena (26°47′N, 77°99′E), Pantnagar (29°N; 79°3′E), Ludhiana (30°90′N, 75°80′E), Navgaon (27°02′N, 74°22′E), Kanpur (25°51′N, 80°31′E), Jagdalpur (19°08′N, 82°02′E), Hisar (29°15′N, 75°70′E), Dholi (25°59′N; 85°75′E) and SK Nagar (24°12′N, 72°12′E). The chemical fungicides and bioagents used for seed treatments and foliar sprays and the seeds used in this experiment were provided by the Directorate of Rapeseed-Mustard Research (Indian Council of Agricultural Research or ICAR), Bharatpur. The trial was set up as a randomized block design during the fourth week of October using cv. Varuna, with each treatment being replicated three times, in 5 m × 3 m plots and maintaining spacing at 30 cm × 10 cm, adjusted at 28 days after sowing. All experiments received the recommended (NRCRM, 1999) dose of N (80 kg/ha) and P (40 kg/ha). No K fertilizer was applied. Insect-pest protection was comprised of seed treatments with Imidacloprid (7 g/kg) and spraying with oxydemeton methyl (0.025 percent a.i.) at 15-day intervals. No protections were taken against any diseases.

2.2. Chemical and non-chemical treatments

The treatments were selected based on their previously reported success (Chattopadhyay, 2008). Seeds (500 approx. per plot) were immersed in a freshly prepared, aqueous bulb extract (1 percent w/v) of garlic (*Allium sativum*) for 15 min. The seeds were drained of water and then air-dried before sowing. An extract of the same concentration was used as a foliar spray. Dry seed treatments with Carbendazim at 1 g a.i., Apron 35 SD (Metalaxyl of Syngenta India Ltd., Mumbai, India) at 6 g/kg or their combination were applied before sowing, while Ridomil MZ 72 WP (metalaxyl + mancozeb; Syngenta India Ltd., Mumbai, India) was used as a foliar spray at 2 g/l. Dry seed treatments with a one-month old talc-based formulation (26×10^7 cfu/g) of *Trichoderma harzianum* was applied prior to sowing at 10 g/kg seed. A foliar spray of a three-month old oil-based formulation of *Pseudomonas fluorescens* (isolate: PBA 2; source: Biocontrol Laboratory, Dept. Plant Pathology, GBPUAT, Pantnagar 263145, India; 9×10^8 cfu/ml) or *T. harzianum* (isolate: PBA 1; source: Biocontrol Laboratory, Dept. Plant Pathology, GBPUAT, Pantnagar 263145, India; 2×10^9 cfu/ml) was applied at 10 ml/l water. Foliar sprays were applied uniformly at all locations at 50 days after sowing. The number of plants counted post-germination at 25 days after sowing (Table 1) received each foliar spray per plot. A suitable untreated control was also maintained.

2.3. Observations and data analysis

The trial relied entirely on the natural occurrence of the diseases. The percentages of disease severity for Alternaria blight, white rust, and powdery mildew were recorded at all locations and experimental plots by examining the leaves and pods using the standard pictorial rating scale developed by Conn et al. (1990). The incidences of downy mildew and Sclerotinia rot were recorded as the percentages of affected plants in respective plots. The dry seed yield was recorded at harvest time for each treatment at all of the locations. The data collected as percentages were processed by an angular transformation, and all data were statistically analyzed using an analysis of variance (ANOVA) to determine the least significant difference ($P < 0.05$). The data collected at each location in different years were analyzed statistically year wise for each location to derive means for the particular location and year for the specific parameter. Then the means for different locations were considered for the specific parameter and year for analysis to derive means for the particular year, which are presented in the tables. They were further considered together for analysis to derive pooled mean.

The economics of each treatment were determined by using the laborer wage rate of 140 Indian Rupees (INR) per day, the minimum