Journal of Crop and Weed, 18(3): 128-135 (2022)
ISSN- O : 2349 9400 ; P : 0974 6315
http://cwssbckv.org
www.cropandweed.com

Integrated management of *Alternaria* blight caused by *Alternaria* spp. in rapeseed (*Brassica rapa* var. toria) under field conditions

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Received : 27.06.2022 ; Revised : 09.08.2022 ; Accepted : 19.08.2022

DOI : https://doi.org/10.22271/09746315.2022.v18.i3.1626

ABSTRACT

Field trial was conducted during rabi, 2017-18 and 2018-19 at Nagaon, Assam to identify effective and economic agro-technique (s) for management of Alternaria blight caused by Alternaria brassicae (Berk) Sacc. and A. brassicicola (Schw) Wiltshire in rapeseed (Brassica rapa var. toria L.). Mancozeb 75 WP @ 0.2 % spray at 45 days after sowing (DAS) followed by propiconazole 25 EC @ 0.05 % at 60 DAS with the lowest disease severity of 16.05% on leaves at 70 DAS and 7.25 % on pods at 75 DAS accrued in the highest disease reduction (56.91 % on leaf at 70 DAS and 54.11 % on pod at 75 DAS) and increase in seed yield (73.6 %) over control. This treatment accrued in a net return (NR) of Rs. 16237 ha^{-1} and benefit-cost ratio (B:C) 1.71. Seed treatment with mancozeb 75 WP @ 0.2 % in combination with foliar application of propiconazole 25 EC @ 0.05% at 45 DAS followed the former treatment with 55.97 % disease reduction on leaf, 47.47 % on pod and 69.4 % yield increase. However, this management practice recorded the highest NR (Rs 16860 ha^{-1}) and B:C (1.79). The biological management practice involving soil application of biogreen @ 2.5 kg ha^{-1}, seed treatment with biogreen @ 5 % and biogreen foliar spray @ 5 % at 45 DAS also emerged to be promising claiming the third position with 53.29 % disease reduction on leaf, 43.04 % on pod, 63.1 % yield increase and a B:C of 1.50. In comparison to the latter two treatments, the former could avoid 2.4 and 6.1 % yield loss, respectively. Under on-farm testing through KVKs in four agro-climatic zones of Assam, mancozeb 75 WP @ 0.2 % at 45 DAS + propiconazole 25 EC @ 0.05 % at 60 DAS resulted in 40.5-54.7 % disease reduction on leaves and 39-52.1 % on pods with 38.3 - 69.2 % yield increase and B:C ranging from 1.55 to1.87. Disease reduction on leaves was 25.4 - 31.1 %, on pods 22 - 36.6 %, yield increase 31.1 - 45.8 % and B:C 1.28 - 1.75 under the biological control measure was recorded using biogreen as soil treatment @ 2.5 kg ha^{-1}, seed treatment @ 5 % and foliar spray at 45 DAS @ 5%.

***Keywords*:** *Alternaria* blight, benefit-cost ratio, disease management, disease reduction, disease severity, net return, yield increase

The oilseed crops, specially *Brassica* spp. and edible oil production play a pivotal role in India's economy. India's domestic production meets only about 30 % of its requirement of edible oil, estimated at around 23 million tones. It depends on imports to meet about 70 % (Kulkarni, 2020). In Assam, total oilseeds occupy 3.10 lakh ha with a production and productivity of 1.998 lakh t and 645 kg ha^{-1}, respectively (2020-21; Department of Assam, Govt. of Assam). Out of these, rapeseed-mustard group covers 2.86 lakh ha area contributing almost 93% of total oilseed production with an average yield of 647 kg ha^{-1} (Dept.of Agriculture, Govt. of Assam, Khanapara, Guwahati). However, rapeseed (*B. rapa* var. *toria*) is the pre-dominant oilseed crop with traditional acceptability amongst the farmers of Assam. To feed the population of 3.36 crores in the state, oilseed requirement stands at around 6.11 lakh t, however, the present production level can meet only 33% of it. There are number of reasons for low productivity such as lack of irrigation facility and quality seeds, imbalanced fertilizer application, orobanche and insect-pests infestation, etc. One of the major factors responsible for low productivity is poor disease management. *Alternaria* blight caused by *A. brassicae* (Berk) Sacc. and *A. brassicicola* (Schw) Wiltshire is one of the most important limiting factors, accruing in 17 - 45 % yield loss in mustard (Kumar *et al.,* 2009). The blight also leads to reduction in seed size and impairs seed colour. The disease becomes severe at siliqua initiation stage (Rathi and Singh 2009), and it adversely affects seed germination as well as oil content both qualitatively and quantitatively (Meena *et al*., 2010). In view of the paucity of disease resistant varieties of rapeseed, search for fungicides and bioagents and their sole and integrated use to control crop diseases is the most viable proposition. Various fungicides such as blitox 50 (0.3 %), dithane M 45 (0.2 %), ridomil MZ 72, etc. had been reported to be effective against this disease (Khan *et al*., 2007). However, these fungicides have residual toxicity affecting the oil quality in

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How to cite : Chakrabarty, R., Kalita, H., Chakravarty, M., Basumutary, M., Bhattacharyya, B. and Medhi, B. 2022. Integrated management of Alternaria blight caused by Alternaria spp. in rapeseed (*Brassica rapa var. toria*) under field conditions. *J. Crop and Weed*, 18 (3): 128-135.

Brassicas (Mc Cartney *et al*., 1999). There are also reports of resistance development against fungicides (Rai *et al.*, 2014). Therefore, judicious use of chemicals and their methods and time of application are of utmost significance for sustainable oilseed production. Disease management using biocontrol agents as well as integrated approach is the need of the hour. *Trichoderma* species are omnipresent colonizers of cellulosic substances and often found wherever decaying plant waste is available. Such colonizers are also found in the rhizosphere of crop plants, where they induce systemic resistance against pathogens (Harman, 2000). Thus an experiment was undertaken to find out the efficacy of some fungicides and bio-agents and their combinations for management of *Alternaria* blight and thereby maximizing the yield of rapeseed.

MATERIALS AND METHODS

A field experiment was conducted in two consecutive years at Regional Agricultural Research Station, Nagaon, Assam during *rabi* crop season of 2017-18 and 2018-19 to test the efficacy of fungicides and bio-agents in different combinations as soil treatment, seed treatment and foliar spray against *Alternaria* blight in rapeseed. The experiment comprising nine treatments (Table 1), was laid out in a randomized block design with three replications. The soil was sandy-loam having pH 5.7, organic C 0.72%, available N 268.5 kg ha^{-1}, available P_2O_5 21.8 kg ha^{-1} and available K_2O 136.2 kg ha^{-1}. The crop (var. 'TS 46') was sown on 5th and 10th November in respective years using a seed rate of 7.5 kg ha^{-1} and fed with the recommended basal dose of fertilizers (60 kg N, 30 kg P_2O_5, 30 kg K_2O and Borax 7.5 kg ha^{-1}). The plot size was 4 m x 3 m and spacing was 30 cm x 10 cm. Crop duration ranged from 91 – 93 days. The mean maximum and minimum temperature recorded were 25.8°C and 12.5°C, respectively, mean relative humidity was 93% (morning) and 67% (evening) during the crop growth period. Rainfall received was 31.2 mm in the first year of study and 54.8 mm in the second year. The fungicides tried were mancozeb 75 WP and propiconazole 25 EC, whereas, bio-agent formulations tested were biogreen (*T. viride* based) and biofor pf (*P. fluorescens* and *T. harzianum* based). Disease severity of *Alternaria* blight was recorded on leaves at 45 and 70 DAS and on pods at 75 DAS. *Alternaria* blight was observed on leaves and pods of 10 randomly selected plants using revised rating scale of 0-9 (Conn *et al*.,1990). Per cent data were angular transformed before statistically analysis using standard procedure (Mstat software). Reduction in disease severity and increase in seed yield were computed from pooled data over that under control (no management practice adopted). However, avoidable yield loss was calculated against the highest yielding treatment. The market price of Rs. 40 kg^{-1} seed was considered for economic analysis. The agro-techniques generated and were tested through KVKs of four agro-climatic zones of Assam viz., Lower Brahmaputra Valley Zone (LBVZ), Central Brahmaputra Valley Zone (CBVZ), Upper Brahmaputra Valley Zone (UBVZ) and North Bank Plain Zone (NBPZ) during *rabi* 2019-20 for their field performance with respect to disease control, yield increase and profitability in farmers' field under KVKs of Nalbari, Morigaon, Jorhat and Darrang districts of Assam.

RESULTS AND DISCUSSION

Effect on disease severity

All the treatments controlled the *Alternaria* blight disease both on leaves at 70 DAS and pods at 75 DAS with considerable variations in effectiveness as compared to control during both the years of experimentation (Table 2). However, disease severity on leaf at 45 DAS was non-significant under all the treatments. Mancozeb 75 WP @ 0.2 % at 45 DAS and propiconazole 25 EC @ 0.05 % at 60 DAS gave the best control of *Alternaria* blight on leaves as well as on pods. Jha *et al.* (2013) and Meena *et al.* (2014) reported that mancozeb was the best among all the fungicides resulting in the lowest disease severity on leaves of mustard. Efficacy of propiconazole in reducing severity of the disease was reported by Rakesh *et al*. (2018). Pooled analysis showed the lowest disease severity on leaves (16.05%) and pods (7.25%) under this treatment which emerged to be significantly superior to all other treatments so far as disease management was concerned, except seed treatment with mancozeb @ 0.2% + foliar spray of propiconazole @ 0.05% at 45 DAS (16.40% disease severity on leaves and 8.30 % on pods) and soil treatment with biogreen (2.5 kg ha^{-1}) + seed treatment with biogreen @ 5% + foliar spray of biogreen @ 5% at 45 DAS (17.40% disease severity on leaf). These three treatments accrued in 56.91, 55.97 and 53 29% reduction in disease severity on leaves at 70 DAS (Fig. 1) and 54.11, 47.47 and 43.04% reduction on pods at 75 DAS (Fig. 2), respectively over control. Rakesh *et al.* (2018) enumerated that 0.2% mancozeb spray at 45 DAS + 0.05% propiconazole spray at 60 DAS effectively managed the disease in mustard with 62.8% reduction on leaves and 35.4% on pods over control. Rai and his co-workers in 2014 reported that seed treatment with *Trichoderma harzianum* @ 10 g kg^{-1} seed + foliar spray of *Pseudomonas fluorescens* @ 10 ml l^{-1} water at 50 DAS reduced *Alternaria* blight in mustard upto 28 % followed by seed treatment with *T. harzianum* @ 10 g kg^{-1} seed + foliar spray with *T. harzianum* @ 10 ml l^{-1}

Table 1: Treatment details

Sr. No.	Treatment detail
T_1	Soil treatment with Biogreen @ 2.5 kg ha^{-1}+ seed treatment with Biogreen @ 5%
T_2	Seed treatment with Biogreen @ 5% + foliar spray of Biogreen @ 5% at 45DAS
T_3	Soil treatment with Biogreen @ 2.5 kg ha^{-1}+ seed treatment with Biogreen @ 5% + foliar spray of Biogreen @ 5% at 45 DAS
T_4	Seed treatment with Biogreen @ 5% + mancozeb @ 0.2% at 45 DAS
T_5	Seed treatment with Biofor pf @ 100g kg^{-1} seed + mancozeb @ 0.2% at 45 DAS
T_6	Seed treatment with mancozeb @ 0.2% + foliar spray of Biogreen @ 5% at 45 DAS
T_7	Seed treatment with mancozeb @ 0.2% + propiconazole @ 0.05% at 45 DAS
T_8	Foliar spray of mancozeb @ 0.2% at 45 DAS + propiconazole @ 0.05% at 60 DAS
T_9	Control (Water spray)

Table 2: *Alternaria* leaf and pod blight disease severity as affected by different treatments

Treatments	PDI on leaves						PDI on pods		
	2017-18		2018-19		Pooled		2017-18	2018-19	Pooled
	45 DAS	70 DAS	45 DAS	70 DAS	45 DAS	70 DAS	75 DAS	75 DAS	75 DAS
T_1	7.00 (15.33)	24.50 (29.65)	7.40 (15.77)	26.00 (30.64)	7.20 (15.55)	25.25 (30.15)	12.50 (20.67)	14.10 (22.04)	13.30 (21.36)
T_2	7.60 (15.99)	22.10 (28.02)	7.50 (15.89)	22.60 (28.35)	7.55 (15.94)	22.35 (28.19)	11.50 (19.81)	13.50 (21.53)	12.50 (20.67)
T_3	6.80 (15.09)	16.80 (24.17)	7.90 (16.31)	18.00 (25.09)	7.35 (15.70)	17.40 (24.63)	8.70 (17.15)	9.30 (17.75)	9.00 (17.45)
T_4	8.00 (16.41)	19.70 (26.33)	8.30 (16.73)	20.60 (26.97)	8.15 (16.57)	20.15 (26.65)	10.90 (19.20)	12.70 (20.87)	11.80 (20.03)
T_5	7.20 (15.48)	23.70 (29.11)	7.60 (15.99)	24.50 (29.66)	7.40 (15.73)	24.10 (29.38)	12.80 (20.96)	11.80 (20.08)	12.30 (20.52)
T_6	6.90 (15.18)	17.20 (24.47)	7.20 (15.52)	18.10 (25.16)	7.05 (15.35)	17.65 (24.82)	10.30 (18.71)	10.00 (18.41)	10.15 (18.56)
T_7	7.90 (16.31)	15.90 (23.49)	8.50 (16.94)	16.90 (24.26)	8.20 (16.63)	16.4 (23.87)	7.90 (16.30)	8.70 (17.14)	8.30 (16.72)
T_8	8.10 (16.52)	15.60 (23.25)	7.80 (16.19)	16.50 (23.96)	7.95 (16.36)	16.05 (23.60)	6.80 (15.11)	7.70 (16.08)	7.25 (15.59)
T_9	7.80 (16.21)	36.70 (37.26)	8.20 (16.63)	37.80 (37.92)	8.00 (16.42)	37.25 (37.59)	15.40 (23.08)	16.20 (23.72)	15.80 (23.40)
LSD (0.05)	**NS**	**2.04**	**NS**	**1.74**	**NS**	**1.25**	**1.90**	**1.52**	**1.13**
CV (%)	**6.83**	**4.29**	**5.00**	**3.56**			**5.73**	**4.42**	

**Data within parentheses are angular transformed values*

water. Effective management of *Alternaria* blight in rapeseed-mustard using bio-agents was also reported by Meena *et al.* (2014). Reshu and Khan (2012) evaluated bio-agents against *Alternaria* blight in Indian mustard under field conditions and found that *T. viride* was most effective in reducing severity on leaf as well as on pod. Spray of *T. viride* at 45 and 75 DAS could manage *Alternaria* blight of Indian mustard as effectively as mancozeb (Meena, 2010 and 2011).

Effect on seed yield

Seed yield of rapeseed was significantly affected by different treatments (Table 3). The highest seed yield was the consequent of maximum disease reduction under foliar spray of mancozeb 75 WP @ 0.02 % at 45 DAS and propiconazole 25 EC @ 0.05 % at 60 DAS (875.33 kg ha^{-1}in 2017-18, 1084.33 kg ha^{-1}in 2018-19, which were pooled at 979.83 kg ha^{-1}) showing an yield increase of 73.6% over control. Similar findings were also

Table 3: Yield (kg ha^{-1}) as affected by different treatments

Treatments	Yield (kg ha^{-1})			Avoidable yield loss (%)
	2017-18	2018-19	Pooled	
T_1	667.13	770.00	718.57	26.7
T_2	700.33	804.20	752.27	23.2
T_3	833.07	1007.33	920.20	6.1
T_4	767.53	879.40	823.47	16.0
T_5	670.20	845.60	757.90	22.7
T_6	800.40	912.27	856.33	12.6
T_7	860.20	1052.07	956.13	2.4
T_8	875.33	1084.33	979.83	-
T_9	500.60	627.93	564.27	42.4
LSD(0.05)	**41.37**	**53.32**	**31.58**	
CV (%)	**3.20**	**3.44**		

**Data within parentheses represent angular transformed values*

Table 4: **Economics of treatments**

Treatments	CoC (Rs. ha^{-1})	GR (Rs. ha^{-1})	NR (Rs. ha^{-1})	B:C
T_1	20795	28743	7948	1.38
T_2	23545	30091	6546	1.28
T_3	24545	36808	12263	1.50
T_4	21625	32939	11314	1.52
T_5	21675	30316	8641	1.40
T_6	23529	34253	10724	1.46
T_7	21385	38245	16860	1.79
T_8	22956	39193	16237	1.71
T_9	19520	22571	3051	1.16

**CoC=Cost of Cultivation, GR=Gross Return, NR=Net Return*

Table 5: *Alternaria* blight severity and yield of rapeseed under different treatments in different locations

Treatments/Locations	PDI at 70 DAS on leaves	PDI at 75 DAS on pods	Yield (q ha^{-1})
Locations			
Nalbari (LBVZ)	21.7 (27.6)	**15.5 (23.1)**	**7.55**
Morigaon (CBVZ)	24.7 (29.6)	**14.3 (22.0)**	**7.36**
Jorhat (UBVZ)	22.7 (28.3)	**15.0 (22.5)**	**8.15**
Darrang (NBPZ)	23.2 (28.5)	**14.5 (22.3)**	**7.19**
LSD(0.05)	**1.06**	**0.56**	**0.45**
	Disease management		
Foliar spray of mancozeb @ 0.2% at 45 DAS + propiconazole @ 0.05% at 60 DAS	16.6 (24.0)	**10.7 (19.4)**	**8.80**
Soil treatment with Biogreen @ 2.5 kg ha^{-1}+ seed treatment with Biogreen @ 5% + foliar spray of Biogreen @ 5% at 45 DAS	21.9 (27.8)	**14.0 (22.1)**	**8.11**
Farmers' practice	**30.8 (33.7)**	**19.8 (25.2)**	**5.78**
LSD(0.05)	**0.92**	**0.48**	**0.39**

Data in parentheses represent angular transformed values.

Table 5a: Disease severity of *Alternaria* blight in rapeseed under different agro-climatic conditions of Assam

Treatments	Nalbari (LBVZ)		Morigaon (CBVZ)		Jorhat (UBVZ)		Darrang (NBPZ)	
	PDI at 70 DAS on leaves	PDI at 75 DAS on pods	PDI at 70 DAS on leaves	PDI at 75 DAS on pods	PDI at 70 DAS on leaves	PDI at 75 DAS on pods	PDI at 70 DAS on leaves	PDI at 75 DAS on pods
Foliar spray of mancozeb @ 0.2% at 45 DAS + propiconazole @ 0.05% at 60 DAS	16.8 (41.3)	11.5 (43.3)	17.3 (47.9)	10.1 (47.7)	17.3 (40.5)	10.2 (52.1)	14.6 (54.7)	11.1 (39.0)
Soil treatment with Biogreen @ 2.5 kg ha^{-1}+ seed treatment with Biogreen @ 5% + foliar spray of Biogreen @ 5% at 45DAS	19.7 (31.1)	14.8 (27.1)	23.1 (30.4)	13.4 (30.6)	21.7 (25.4)	13.5 (36.6)	22.9 (28.9)	14.2 (22.0)
Farmers' practice	28.6	20.3	33.2	19.3	29.1	21.3	32.2	18.2
Interaction (Location x management) **CD (5 %)**	PDI on leaves: 1.83 PDI on pods: 0.96							

**Data in parentheses represent percent disease reduction over farmers' practice*

Table 6: Seed yield of rapeseed and B:C under different treatments in varied agro-climatic conditions of Assam

Treatments	Nalbari (LBVZ)			Morigaon (CBVZ)			Jorhat (UBVZ)			Darrang (NBPZ)		
	Yield (q ha^{-1})	% yield increase	B:C	Yield (q ha^{-1})	% yield increase	B:C	Yield (q ha^{-1})	% yield increase	B:C	Yield (q ha^{-1})	% yield increase	B:C
Foliar spray mancozeb @ 0.2% at 45 DAS + propiconazole @ 0.05% at 60 DAS	8.87	54.2	1.60	8.54	53.9	1.55	9.16	38.3	1.87	8.80	69.2	1.70
Soil treatment with Biogreen @ 2.5 kg ha^{-1}+ seed treatment with Biogreen @ 5% + foliar spray of Biogreen @ 5% at 45 DAS	8.21	42.8	1.38	7.98	43.8	1.28	8.68	31.1	1.75	7.58	45.8	1.40
Farmers' practice	5.75	-	1.08	5.55	-	1.06	6.62	-	1.40	5.20	-	1.10
Interaction (Location x management) **CD (5%)**	Yield: NS											

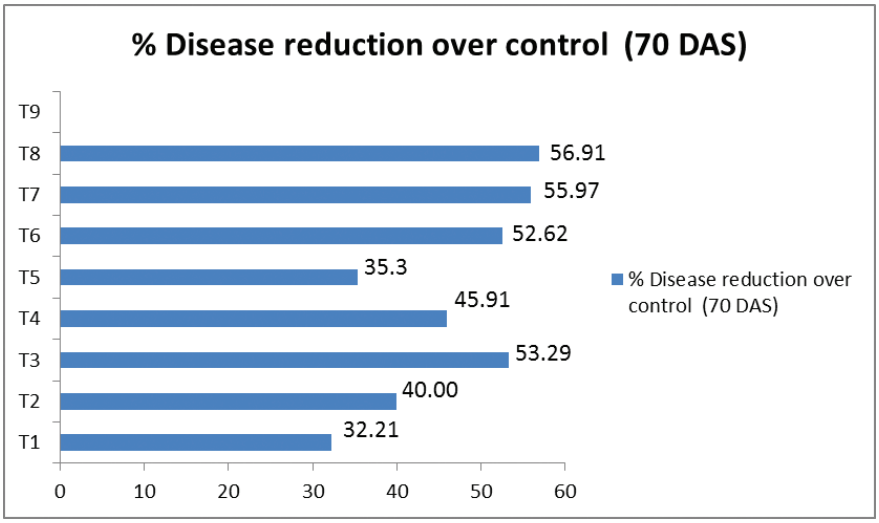

Fig. 1: Per cent disease reduction over control on leaves

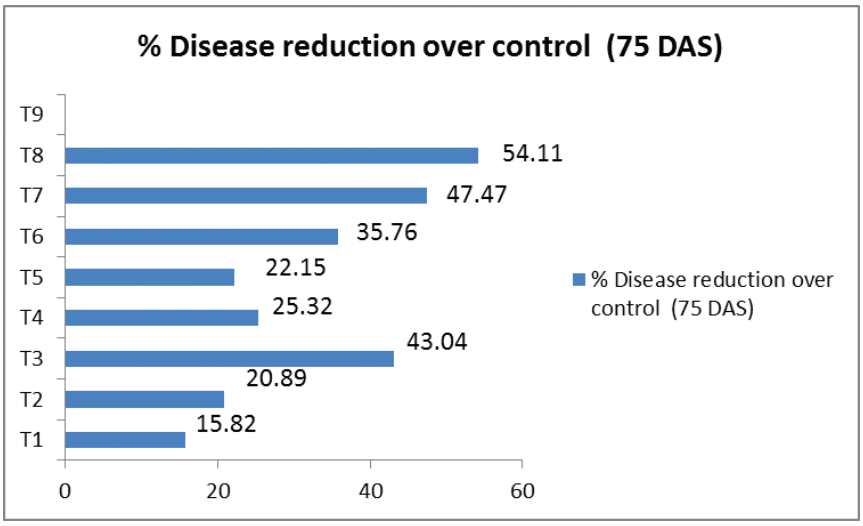

Fig. 2: Per cent disease reduction over control on pods

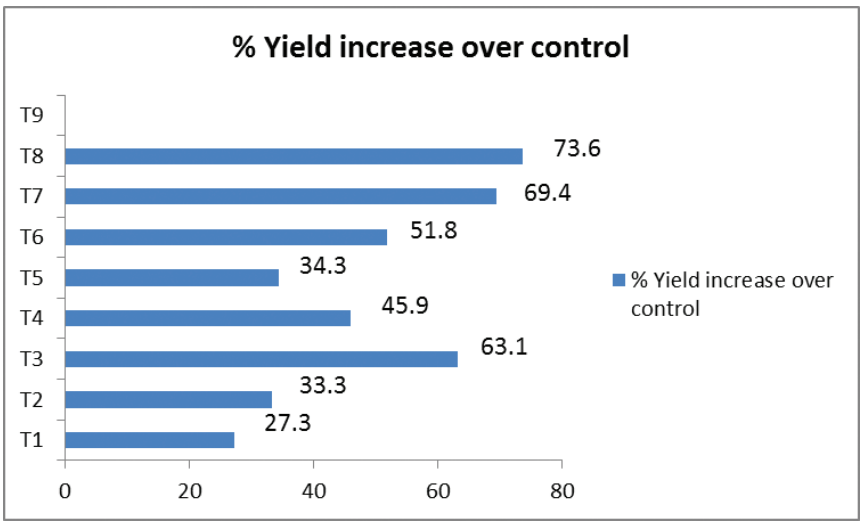

Fig. 3: Per cent yield increase over control

reported by Rakesh *et al.* (2018). This treatment was followed by seed treatment with mancozeb 75 WP @ 0.2% + foliar spray with propiconazole 25 EC @ 0.05% at 45 DAS (956.13 kg ha^{-1}). Better disease management under this treatment led to 69.4% increase in seed yield over control. Rai *et al* (2014) found that seed treatment with metalaxyl @ 6 g kg^{-1} + foliar spray of mancozeb @ 2 g l^{-1} at 50 DAS caused the highest reduction in disease severity (44%) and significantly increased seed yield to the tune of 37.6%. The biocontrol practice involving biogreen as soil treatment @ 2.5 kg ha^{-1} + seed treatment @ 5% + foliar spray @ 5% at 45 DAS also managed the disease quite effectively and hence, yielded significantly higher than the remaining treatments. The yield increase under this treatment over control was 63.1% (Fig. 3). The two-way treatment with bioagents or their integration with fungicide could not yield expected disease reduction and yield increase. Better yield performance of mustard under disease management using *T. viride* and *T. harzianum* was reported by Rai *et al*. (2014) and Reshu and Khan (2012).

Effect on economics

Mancozeb 75 WP @ 0.2 % at 45 DAS followed by spray with propiconazole 25 EC @ 0.05 % at 60 DAS though gave the highest seed yield yet emerged to be the second best with respect to economic parameters. NR and B:C under this treatment were Rs. 16237 ha^{-1} and 1.71, respectively (Table 4). These two values were the maximum under seed treatment with mancozeb @ 0.2 % + propiconazole @ 0.05 % at 45 DAS (Rs. 16860 ha^{-1} and 1.79, respectively) because of lower cost of cultivation and marginal variation in seed yield. The NR and B:C accrued by the biocontrol practice comprising three-way application of biogreen were Rs. 12263 ha^{-1} and 1.50, respectively.

On-farm testing

Based on the recommendation of the University two agro-techniques viz., mancozeb 75 WP @ 0.2 % at 45 DAS + propiconazole 25 EC @ 0.05 % at 60 DAS and soil treatment with biogreen @ 2.5 kg ha^{-1}+ seed treatment with biogreen @ 5 % + foliar spray of biogreen @ 5 % at 45 DAS were selected for On-farm testing considering the aspects of disease control and yield advantage. Besides these considerations, biological control of *Alternaria* blight for sustainable rapeseed production got emphasis for approval of the second treatment. These two treatments were tested against farmer's practice in four agro-climatic zones of Assam.

The chemical control measure reduced the *Alternaria* blight severity on leaves by 41.3, 47.9, 40.5 and 54.7 % over farmers' practice in LBVZ, CBVZ, UBVZ and NBP zones, respectively (Table 5, 5a). In respective zones, reduction in disease severity on pods was 43.3, 47.7, 52.1 and 39.0%. The corresponding per cent reduction in disease severity on leaves under the biological control measures were 31.1, 30.4, 25.4 and 28.9% and that on pods were 27.1, 30.6, 36.6 and 22.0%. Because of the effectiveness in controlling *Alternaria* blight in rapeseed, the former treatment triggered 54.2, 53.9, 38.3 and 69.2% and the latter 42.8, 43.8, 31.1 and 45.8 % yield advantage over farmers' practice in respective zones. B:C ratio under the chemical control measure ranged from 1.55 to 1.87 and under the biological control measure from 1.28 to 1.75 (Table 5, 6).

CONCLUSION

For effective management of *Alternaria* blight, the major disease of rapeseed realizing higher seed yield, chemical management practice impregnated with foliar spray of mancozeb 75 WP @ 0.2 % at 45 DAS and propiconazole 25 EC @ 0.05% at 60 DAS may be recommended in Assam. However, for sustainable oilseed production with effective *Alternaria* blight management and satisfactory seed yield, the biological management practice involving soil treatment with 2.5 kg biogreen ha^{-1}, seed treatment with biogreen @ 5 % and foliar spray of biogreen @ 5 % at 45 DAS is the better option.

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