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Use of nitrogen and PGPRs for management of spot blotch in barley (*Hordeum vulgare*)

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Barley (*Hordeum vulgare* L.) is a widely grown crop in India and ranks 4th among cereal grains globally after wheat, rice and maize. However, its productivity in India is still below the world average. Spot blotch caused by the *Bipolaris sorokiniana* is one of the most important fungal diseases of barley, which causes economic injury levels with a great magnitude (Arabi *et al.* 2011, Al-Sadi 2016). It becomes most serious under hot and humid areas where wheat and barley are grown (Gupta *et al*. 2018). The seeds produced under such conditions are the main source of inoculum that exhibits poor seed germination and gives rise to diseased and frail seedlings (Neupane *et al*. 2010, Harding 2011). The proliferation of this disease can cut the yield as high as 30% (Singh *et al*. 2009, Kumar *et al.* 2020). Use of fungicides can have adverse effects on the environment and on consumers of crop products (Bacmaga *et al*. 2016). Therefore, present study was conducted to minimize the incidence of spot blotch in barley using different nitrogen levels and plant growth-promoting rhizobacteria (PGPRs).

An experiment was conducted at Research Station Masodha, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh on barley during winter (*rabi)* season of 2016–17 with three nitrogen levels (N_1, 50%; N_2, 75% and; N_3, 100% and 5 PGPRs (B_1, *Azotobacter*; B_2, Phosphate solubilizing bacteria (PSB); B_3, *Azotobacter* + PSB; B_4, Biomix and; B_5, Control) as seed treatment and replicated thrice under split plot design. Disease was allowed to develop from natural inoculums and disease rating was done by taking the per cent blighted area on flag leaf (F) and flag 1 (F-1) leaf using the rating scale as: 0, No infection; 1, up to 10%; 2, 11–20%; 3, 21–30%; 4, 31–40%; 5, 41–50%; 6, 51–60%; 7, 61–70%; 8, 71–80% and; 9, >80% leaf area blighted (Singh and Kumar 2005). The disease scores were recorded by following Kumar *et al*. (1998) using double digit scale (Table 1).

Disease severity was assessed by determining the number of lesions per cm^2. First and second value, respectively represents per cent blighted area on the top (flag) and second top leaf. Value 1, 2, 3, 4, 5, 6, 7, 8, and 9, respectively correspond to 10, 20, 30, 40, 50, 60, 70, 80, and 9: > 80% blighted area. The per cent disease intensity (PDI) and plant disease control (PDC) were calculated using equation I and II while Abdul Baki and Anderson (1973) were followed for seedling vigour index-I (SVI-I).

$$PDI = \frac{\text{Sum of all numerical ratings}}{\text{Total number of observations taken} \times \text{highest disease score}} \times 100 \quad \text{(I)}$$

$$PDC = \frac{\text{PDI in control plants} - \text{PDI in treated plants}}{\text{PDI in control plants}} \times 100 \quad \text{(II)}$$

Table 1 Disease scores recorded using double digit scale based on per cent blighted area on the flag leaf and one leaf (Kumar *et al*. 1998)

Severity		Rating	
Top (flag) leaf	Second top leaf	Disease response	Range
0	0–1	Immune (I)	00–01
1–2	2–4	Resistant (R)	12–24
3–4	4–6	Moderately resistant (MR)	34–46
5–6	6–8	Moderately susceptible (MS)	56–68
7–8	8–9	Susceptible (S)	78–89
9	9	Highly susceptible (HS)	99

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The minimum disease severity (28.1%) with reduction of 29.5% was recorded in N_1 against the maximum disease severity (30.3%) with 24.2% reduction in N_3 (Table 2). This might be due to the negative effects of nitrogen on physical defence and the development of anti-microbial phytoalexins (Sharma 2020). Among PGPRs, the minimum disease severity (19.5%) with 51.2% reduction was recorded with B_3. This supports the findings of Biswas *et al.* (2015). The interactions of N and PGPRs showed that $N_1 \times B_3$ showed minimum disease severity (18.7%) with 53.2% reduction compared to control ($N_3 \times B_5$) and conforms the findings of Biswas *et al.* (2015).

The per cent seed infection under all the N levels varied significantly (Table 2) where minimum and maximum infection (17.7 and 21.9%) was recorded with N_1 and N_3, respectively. Among PGPRs the minimum (7.2%) and maximum (34.3%) seed infection was recorded in B_3 and B_5, respectively. Reduced diseases severity due to seed treatment with *Azotobacter* has also been reported by Biswas *et al.* (2015). The interaction of N and PGPRs revealed that $N_1 \times B_3$ recorded the minimum seed infection (6.5%) compared to maximum infection (36.3%) in $N_3 \times B_5$. The result corroborates the findings of Biswas *et al*. (2015)

Table 2 Effect of nitrogen level and seed treatment with PGPRs on disease intensity and seed yield attributes of barley infected with spot botch

Treatment	PDI (%)	PDC (%)	Seed infection (%)	1000-seed weight (g)	Yield kg/ plot	Yield loss (%)
Nitrogen level						
N_1	28.1 (31.8)	29.5 (31.6)	17.7 (24.0)	40.2	2.5	28.7 (31.2)
N_2	28.7 (32.2)	28.1 (30.6)	19.9 (25.7)	39.5	2.4	24.8 (28.3)
N_3	30.3 (33.2)	24.2 (25.9)	21.9 (27.1)	38.7	1.9	21.8 (24.5)
SEm±	0.08 (0.06)	0.21 (0.14)	0.20 (0.16)	0.12	0.01	0.67 (0.5)
CD (P=0.05)	0.33 (0.22)	0.84 (0.55)	0.57 (0.45)	0.33	0.04	2.70 (2.04)
Seed treatment with PGPRs						
B_1	22.1 (28.0)	44.7 (42.0)	11.1 (19.4)	41.4	2.2	32.9 (35.9)
B_2	35.5 (36.5)	11.2 (19.4)	28.2 (32.0)	37.6	1.8	07.9 (20.1)
B_3	19.5 (26.2)	51.2 (45.7)	7.2 (15.5)	43.5	2.3	42.1 (43.5)
B_4	30.0 (33.2)	24.9 (29.9)	18.4 (25.3)	39.7	2.0	20.7 (29.8)
B_5	38.2 (38.1)	4.4 (9.8)	34.3 (35.8)	35.2	1.6	3.5 (8.7)
SEm±	0.16 (0.11)	0.41 (0.33)	0.25 (0.20)	0.15	0.01	0.57 (0.45)
CD (P=0.05)	0.48 (0.32)	1.20 (0.96)	0.74 (0.58)	0.43	0.03	1.68 (1.33)
Interaction effect						
$N_1 \times B_1$	21.7 (27.8)	45.6 (42.4)	10.0 (18.4)	42.4	2.3	43.1 (41.0
$N_1 \times B_2$	34.6 (36.0)	13.3 (21.4)	24.8 (29.8)	38.8	1.8	13.2 (21.8)
$N_1 \times B_3$	18.7 (25.6)	53.2 (46.8)	6.5 (14.8)	44.4	2.4	49.4 (44.2)
$N_1 \times B_4$	28.5 (32.3)	28.6 (32.3)	14.3 (22.2)	39.9	2.1	32.0 (34.4)
$N_1 \times B_5$	37.1 (37.5)	7.0 (15.2)	32.8 (34.9)	35.6	1.7	6.6 (14.9)
$N_2 \times B_1$	21.8 (27.8)	45.4 (42.4)	11.3 (19.6)	41.3	2.2	35.9 (36.8)
$N_2 \times B_2$	35.4 (36.5)	11.4 (19.8)	28.8 (32.4)	37.6	1.8	12.4 (20.6)
$N_3 \times B_3$	19.3 (26.0)	51.7 (46.0)	7.0 (15.3)	43.3	2.3	47.5 (43.3)
$N_4 \times B_4$	29.6 (33.0)	25.8 (30.5)	18.8 (25.6)	39.7	2.0	24.7 (29.8)
$N_5 \times B_5$	37.5 (37.7)	6.1 (14.2)	33.8 (35.5)	35.6	1.7	4.0 (11.1)
$N_3 \times B_1$	22.7 (28.4)	43.2 (41.1)	12.0 (20.3)	40.4	2.1	34.3 (35.8)
$N_3 \times B_2$	36.4 (28.4)	8.8 (17.2)	31.0 (33.8)	36.4	1.8	10.2 (18.5)
$N_3 \times B_3$	20.5 (26.9)	48.6 (44.2)	8.0 (16.4)	42.6	2.3	46.8 (42.8)
$N_3 \times B_4$	31.8 (34.3)	20.4 (26.8)	22.3 (28.1)	39.4	1.9	18.3 (25.3)
$N_3 \times B_5$	39.9 (39.2)	0.00	36.3 (37.0)	34.5	1.6	0.000
SEm±	0.13 (0.09)	0.33 (0.25)	0.45 (0.35)	0.26	0.01	0.62 (0.48)
CD (P=0.05)	0.41 (0.27)	1.04 (0.78)	1.27 (1.00)	0.74	0.04	2.25 (1.73)

Refer fo the Methodology for treatment details. Data given in parenthesis are angular transformed values.

The highest 1000-seed weight (40.2 g) and yield (2.5 kg/plot) with 28.2% increase was recorded in N_1 compared to a lower 1000-seed weight (39.5 g) and yield (2.4 kg/plot) with 24.8% increase in N_2. A higher 1000-seed weight under lower dose of N may be attributed to declined disease infection under lower N dose in the present study. Among PGPRs the maximum 1000-seed weight (43.5 g) and yield (2.3 kg/plot) with 42.1% increase was recorded in B_3 followed by B_1 (41.4 g 1000-seed weight and 2.28 kg/plot yield with 32.9% yield increase) against the minimum 1000-seed weight (35.2 g) and yield (1.6 kg/plot) with control (B_5) (Table 2). Among different interactions, the maximum 1000-seed weight (44.4 g) and yield (2.4 kg/plot) with 49.4% increase was recorded with $N_1 \times B_3$ over control.

Table 3 clarified that the highest seed viability (70.0%), germination (67.0%), seedling length (23.7 cm) and SVI-I (1663.0) was recorded in N_1 compared to minimum seed vigour (62.0%), germination (57.0%), seedling length (21.8 cm) and SVI-I (1329.8) in N_3. Regarding PGPRs, the maximum seed viability (93.0%), germination (90.0%), seedling length (27.2 cm) and SVI-I (2459.7) was evident in B_3. However, the interaction of N and PGPRs showed significant effect only with seedling length and the maximum seedling length (28.4 cm) being in $N_1 \times B_3$ followed by 27.2 cm in $N_2 \times B_3$ over the control (16.2 cm). The present findings are in accordance with the findings of Singh and Kumar (2008).

Table 3 Effect of nitrogen level and seed treatment with PGPRS on seed quality of barley infected with spot botch

Treatment	Viability (%)	Germination (%)	Seedling length (cm)	SVI-I
Nitrogen level				
N_1	70.0 (59.0)	67.0 (56.0)	23.7	1663.0
N_2	67.0 (56.0)	62.0 (53.0)	22.9	1491.2
N_3	62.0 (53.0)	57.0 (50.0)	21.8	1329.8
SEm±	0.53 (0.36)	0.67 (0.45)	0.14	18.32
CD (P=0.05)	1.046	1.30	0.41	53.15
Seed treatment with PGPRs				
B_1	82.0 (65.0)	79.0 (63.0)	25.1	1978.8
B_2	51.0 (45.0)	46.0 (43.0)	20.6	962.1
B_3	93.0 (75.0)	90.0 (02.0)	27.2	2459.7
B_4	68.0 (56.0)	64.0 (53.0)	23.8	1531.4
B_5	37.0 (37.0)	31.0 (34.0)	17.2	541.4
SEm±	0.69 (0.47)	0.87 (0.58)	0.18	23.6
CD (P=0.05)	1.35	1.67	0.52	68.6
Interaction effect				
$N_1 \times B_1$	85.0 (68.0)	84.0 (66.0)	25.5	2,119.2
$N_1 \times B_2$	55.0 (48.0)	52.0 (46.0)	22.1	1168.5
$N_1 \times B_3$	96.0 (78)	92.0 (73.0)	28.4	2616.3
$N_1 \times B_4$	74.0 (59.0)	71.0 (58.0)	24.4	1735.5
$N_1 \times B_5$	42.0 (40.0)	38.0 (38.0)	17.8	675.6
$N_2 \times B_1$	82.0 (65.0)	79.0 (63.0)	25.3	2001.6
$N_2 \times B_2$	53.0 (47.0)	45.0 (42.0)	21.0	944.4
$N_3 \times B_3$	93.0 (75.0)	91.0 (72.0)	27.2	2472.4
$N_4 \times B_4$	68.0 (56.0)	64.0 (53.0)	23.4	1495.9
$N_5 \times B_5$	37.0 (38.0)	31.0 (34.0)	17.4	541.6
$N_3 \times B_1$	78.0 (62.0)	74.0 (60.0)	24.5	1815.6
$N_3 \times B_2$	45.0 (42.0)	41.0 (40.0)	18.8	773.4
$N_3 \times B_3$	91.0 (72.0)	88.0 (70.0)	26.0	2290.3
$N_3 \times B_4$	63.0 (53.0)	58.0 (50.0)	23.5	1362.8
$N_3 \times B_5$	32.0 (34.0)	25.0 (30.0)	16.2	407.1
SEm±	01.19 (0.81)	1.45 (0.66)	0.31	40.95
CD (P=0.05)	(NS)	NS	0.91	NS

Refer to the Methodology for treatment details. NS, Non-significant. Data given in parenthesis are in angular transformation.

SUMMARY

Spot blotch disease of barley caused by *Bipolaris sorokiniana* is prevalent everywhere but causes significant yield losses under warm and humid climates. Use of fungicides is a common practice to control the spot blotch but at the same time it can pose a risk to environment as well as humans consuming such products. A field experiment was conducted to minimize the incidence of spot blotch in barley using different nitrogen levels and PGPRs as seed treatment. Application of lower nitrogen dose (50% of RDF – N_1) and seed treatment with *Azotobacter* + PSB – B_3) either individually or in combination significantly reduced the severity of spot blotch and increased the yield of barley. As such it may be concluded that spot blotch disease of barley can be managed by use of lower dose of nitrogen along with seed treatment with *Azotobacter* + PSB and use of fungicide may be avoided.

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