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EFFECT OF DIFFERENT LEVELS OF SEED INFECTION WITH BLACK POINT (*Bipolaris sorokiniana*) AND POPULATION DENSITY ON THE LEAF BLIGHT SEVERITY AND YIELD ATTRIBUTES OF WHEAT

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ABSTRACT

Islam MN, Begum F, Sultana N, Aminuzzaman FM (2018) Effect of different levels of seed infection with black point (*Bipolaris sorokiniana*) and population density on the leaf blight severity and yield attributes of wheat. *Int. J. Sustain. Crop Prod.* 13(1), 10-20.

The experiment was conducted to find out the effect of seed infection levels and population density on leaf blight severity and yield of wheat. Three population density *viz*. 200 seeds/m^2, 300 seeds/m^2 and 400 seeds/m^2 and six seed infection levels *viz*. 0%, 5.1-15%, 15.1-25%, 25.1-35%, 35.1-45% and 45.1-60% were used. Maximum leaf spot severity in flag leaf stage (0.36), panicle initiation stage (0.64), flowering stage (1.57), milk stage (1.84) and hard dough stage (2.30) was found in the interaction between sowing seeds @ 400 seeds/m^2 with 45.1-60% seed infection level. In every growth stage of the plant significantly lower leaf blight severity was recorded in the interaction between 200 seeds/m^2 with sowing of 0.0% infected seeds. Similar trends in disease severity were recorded on penultimate leaf in above mentioned growth stage. Significantly higher number of grains/ear (58.00) and healthy grains/ear (55.67) was recorded in 0% seed infection with a seed rate of 200 seeds/m^2. Lower number of diseased grains/ear (2.33) were recorded in 45-60% seed contamination with 400 seeds/m^2 and 0% seed contamination with 200 seeds/m^2. Weight of diseased grains/ear ranged from 0.07 g to 0.75 g where the lowest value was recorded under 0% seed contamination X 200 seeds/m^2 treatment combination. Significantly higher (45.60) grain weight of 1000 seeds was recorded with the treatments 0% seed infection with a seed rate of 200 seeds/m^2. Straw yield under different treatment combinations ranged from 3.17-4.21 t/ha where the highest straw yield was obtained under the treatment combination of T_1 X 200 seeds/m^2. Grain yield was the highest (3.43 t/ha) when healthy seeds (0% infection) were sown @ 200 seeds/m^2.

Key words: *black point, bipolaris sorokiniana, leaf spot, plant population, wheat, management*

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the largest contributor with nearly 30% of the world grain production and 50% of the world grain trade. It is considered as the staple food crop of about two third of the world's population (Majumder 1991) in as many as 43 countries and provides about 20% of the total food calories (Anon. 1986). Use of diseased seeds are one of the major constrains for lower yield of wheat. Population density significantly influences the establishment of plant population and quality yield of wheat. For good crop and quality yield of wheat, good seed and optimum plant population are needed. The percentage of seed infection and in different plant density at all growth stages have a link to leaf blight incidence and severity caused by *Bipolaris sorokiniana*. Seed infection level had a significant effect on diseases incidence and severity at different growth stages like flag leaf stage, panicle initiation stage, flowering stage, milk stage and hard dough stage (Shah *et al*. 1995). No agricultural system seems to be complete without the optimum plant population and level of seed infection. These factors can change the morphology and physiology of the growing plant and influence the growth and yield of the plant either directly or by the leaf blight/spot development of wheat (Ansar *et al*. 1996). The present study was undertaken to determine the potential contribution of *Bipolaris sorokiniana* to initiation of leaf blight/spot development and decreasing of quality yield of wheat. The objectives of the present research work were:

i) To determine the effect of different levels of seed infection by *Bipolaris sorokiniana* on growth, leaf blight severity and yield of wheat.
ii) To study the effect of different plant population density on plant growth, leaf blight (*B. sorokiniana*) severity and yield of wheat.
iii) To determine the interaction of seed infection and population density on the plant growth, leaf blight severity and yield of wheat.

MATERIALS AND METHODS

The experiment was conducted in the Laboratory, net house and field laboratory of the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka during May 2011 to April 2012. Seeds of leaf blight susceptible wheat variety 'Sonalika' was used in this study. Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. To make different levels of seed contamination by *Bipolaris sorokiniana*, the collected seeds were mixed with black point infected wheat seeds at six different proportions to determine the development of leaf blight/spot disease. The treatments were: T_1 (0% seed contamination), T_2 (5.1-15% seed contamination), T_3 (15.1-25% seed contamination), T_4 (25.1-35% contamination), T_5 (35.1-45% seed contamination) and T_6 (45.1-60% seed contamination). Firstly, black pointed seeds were separated from healthy looking golden colored seed by manual seed sorting. Secondly, different level of seed contamination was prepared by mixing of healthy seeds and black pointed seeds and the levels of seed infection were confirmed by subsequent laboratory seed health Blotter test (ISTA 1996).

Field experiment: The experiment was laid out in split-plot design with three replications. The experimental unit was divided into three blocks. Each block was divided into three main plots in which different population density was assigned randomly. Each main plot was further divided into six sub-plots where different levels of seed infection were allotted randomly. The total number of unit plots in the entire experiment was 3×3×6 = 54. Size of each unit plot was 2 m×1.5 m. The distance between sub plots was 0.5 m and between blocks was 1 m.

The treatments were: (A) Main plots- 200 seed/m^2, 300 seed/m^2 and 400 seed/m^2; (B) Sub plots- T_1 (0% seed contamination, T_2 (5.1-15% seed contamination), T_3 (15.1-25% seed contamination), T_4 (25.1-35% seed contamination), T_5 (35.1-45% seed contamination) and T_6 (45.1-60% seed contamination).

Wheat seeds were sown in the field on 20th November, 2011. A total of 30 plants/plot were tagged for rating and mean values were determined to get rating score of each treatment. The crop was harvested at full ripening stage on 3 April, 2012.

Evaluation of leaf blight severity

Leaf blight severity of flag leaf and penultimate leaf was determined in five growth stages of plant namely- flag leaf stage, panicle initiation stage, flowering stage, milk stage and hard dough stage. The leaf blight severity was determined following 0-5 grade of Hossain and Azad (1992) (Fig. 3) where 0 = No infection (Highly resistant), 1 = Few minute lesions on leaves (Resistant), 2 = Black lesion with no distinct chlorotic halos covering ≤10% of the leaf area (Moderately resistant), 3 = Typical lesions surrounded by distinct chlorotic halos covering 10-50% of the leaf area (Moderately susceptible), 4 = Severe lesions on leaves with ample necrotic zones drying over part of the leaf, covering ≥50 % of the leaf (Susceptible) and 5 = Severe infection, drying of the leaf, spike infected to some extend (Highly susceptible).

Statistical analysis

The collected data for different parameters were compiled and tabulated in proper form. Appropriate statistical analysis was made by MSTAT Computer Package program. The treatment means were compared by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Seed infection level

Effect on the seedling emergence and infected & healthy seedling of wheat

In the tray soil, maximum (60%) seedling emergence was found under 0% contaminated seeds (T_1). With the increase in seed contamination percentage, remarkable decrease in seedling emergence was recorded and the lowest emergence (32.0%) was recorded in the seeds with maximum (45.1-60%) contamination (T_6) (Fig. 1). Hossain (2000) reported that the maximum reduction in germination was found in blotter and rolled paper towel method in 28% black point contaminated seeds. Reduction in germination of wheat seeds due to black point contamination was also recorded by other previous workers (Rana and Gupta, 1982; Sinha and Thapliyal, 1984 and Zhang *et al.* 1990).

It was revealed that different levels of seed contamination by *Bipolaris sorokiniana* had significant relationship with infected seedlings as well as healthy seedlings production. Seedling infection increased with the increased level of seed contamination in the net house tray soil (Fig. 1 and Fig. 2). The maximum number of healthy seedlings (54.0%) were counted in case of 0.0% contaminated seeds, whereas the maximum number of infected seedlings (9.0%) was recorded in case of 45.1-60% contaminated (T_6) seeds.

Effects on root length, shoot length, root weight and shoot weight of wheat

Root length, shoot length, root weight and shoot weight were also decreased with increase in the levels of seed contamination by *B. sorokiniana* (Fig. 3, Fig. 4, Fig. 5 and Fig. 6). The findings of the present study were supported by Begum (2010) and Chowdhury *et al.* 2009. Begum (2010) reported that number of infected seedlings and dead seeds was higher at maximum (45.1-60.0%) levels of seed contamination and were recorded lower at 0% level of that contamination. Chowdhury *et al.* (2009) also found a tendency of increase in seedlings infection and decrease in vigor index of wheat seedlings with the increasing levels of seed contamination by *B. sorokiniana*.

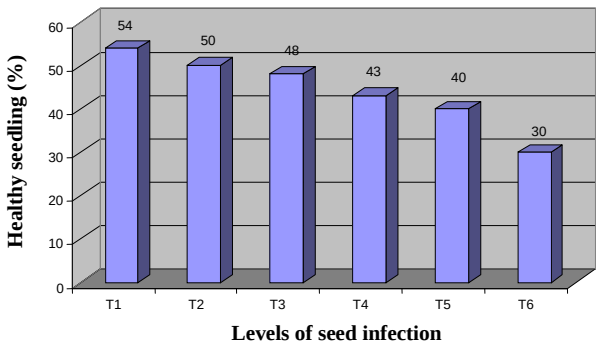

Fig. 1. Effect of different levels of seed infection by *B. sorokiniana* on healthy seedling production of wheat

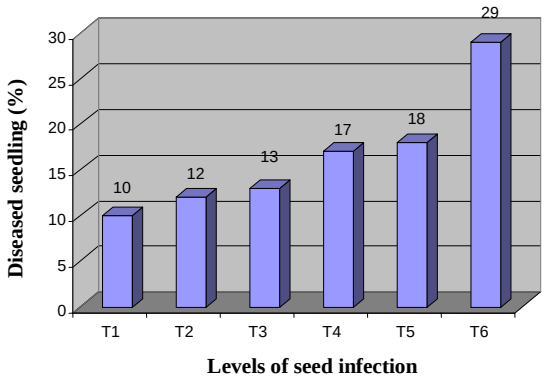

Fig. 2. Effect of different levels of seed by *B. sorokiniana* on diseased seedling production of wheat

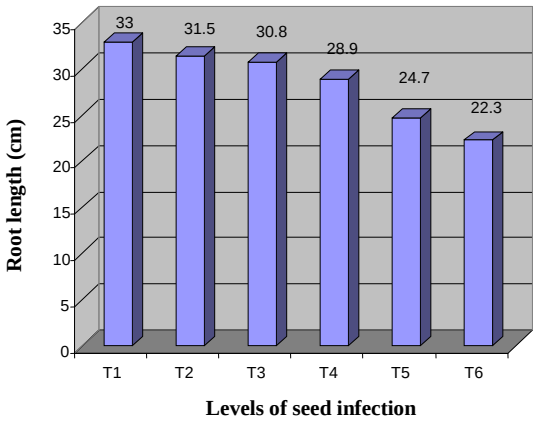

Fig. 3. Effect of different levels of seed infection by *B. sorokiniana* on root length of wheat

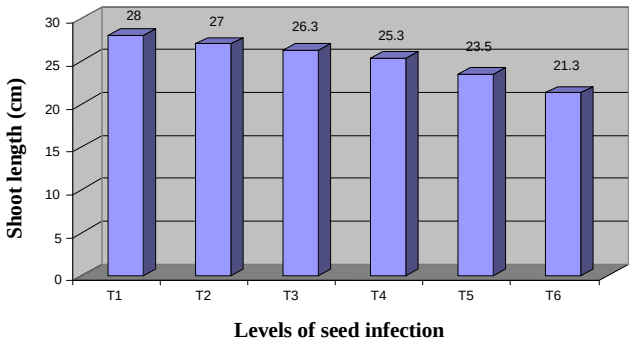

Fig. 4. Effect of different levels of seed infection by *B. sorokiniana* on shoot length of wheat seedlings

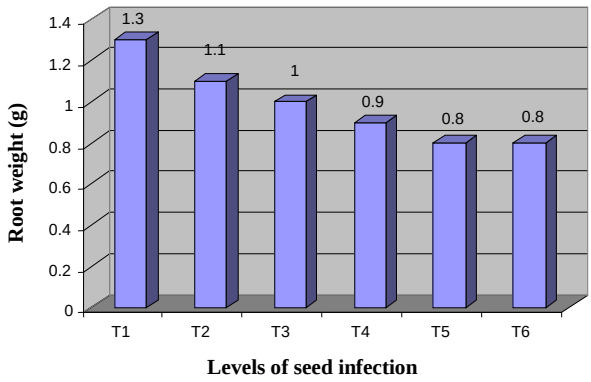

Fig. 5. Effect of different levels of seed infection by *B. sorokiniana* on root weight of wheat seedlings

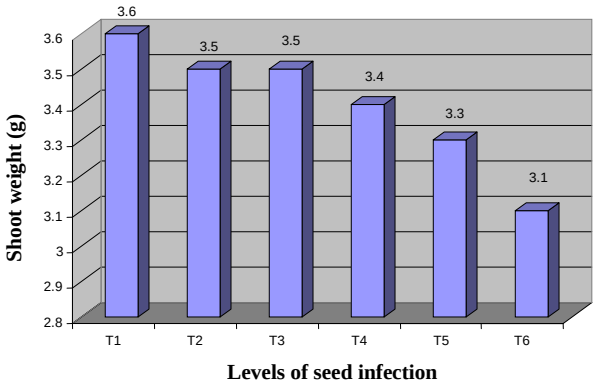

Fig. 6. Effect of different levels of seed infection by *B. sorokiniana* on root weight of wheat seedlings

Population density

Effects on the disease (*B. sorokiniana*) severity of flag leaf at different plant growth stages of wheat cv. Sonalika

Disease severity increased with higher plant population. The highest leaf spot severities of flag leaf were- 0.21 in flag leaf stage, 0.44 in panicle initiation stage, 1.43 in flowering stage, 1.62 in milk stage and 1.94 in hard dough stage when the population density was 400 seeds/m^2. Leaf blight severity was lower in all the aforementioned growth stages of the crop when seeds were sown @ 200 seeds/m^2.

On the other hand, the maximum leaf spot severity were recorded in flag leaf (0.33) stage, panicle initiation (0.60) stage, flowering (1.44) stage, milk (1.66) stage and hard dough (1.98) stage in case of 45.1-60% level of seed contamination (T_6). A significant lower level of severity was caused by 0% contaminated seed (T_1) in every growth stages of the crop (Table 1). The maximum disease severity of flag leaf was in flag leaf (0.36) stage, panicle initiation (0.64) stage, flowering (1.57) stage, milk (1.84) stage and hard dough (2.30) stage in the interaction between population density @400 seeds/m^2 and the seeds with 45.1-60% contamination. In every growth stages of the plant, significantly lower leaf blight severity was recorded in the interaction between 200 seeds/m^2 with 0.0% level of seed contamination (Table 2).

Table 1. Effect of population density and different levels of seed contamination by *B. sorokiniana* on the disease severity of flag leaf of wheat

Population density (seeds/m^2)	**Disease severity in different growth stage**				
	Flag leaf	**Panicle initiation**	**Flowering**	**Milking**	**Hard dough**
200	0.15 c	0.31 a	1.16 a	1.31 a	1.51 a
300	0.19 b	0.40 a	1.28 a	1.36 a	1.67 a
400	0.21 a	0.44 a	1.43 a	1.62 a	1.94 a
Seed infection (%)					
T_1= (0.0)	0.05 f	0.21 e	1.10 a	1.24 c	1.47 d
T_2= (5.1-15.0)	0.10 e	0.27 de	1.16 a	1.31 bc	1.57 cd
T_3= (15.1-25.0)	0.15 d	0.33 cd	1.21 a	1.39 bc	1.64 bcd
T_4= (25.1-35.0)	0.22 c	0.41 bc	1.27 a	1.46 abc	1.74 abc
T_5= (35.1-45.0)	0.27 b	0.47 b	1.56 a	1.53 ab	1.85 ab
T_6= (45.1-60.0)	0.33 a	0.60 a	1.44 a	1.66 a	1.98 a

Table 2. Interaction effect of population density and different levels of seed contamination by *B. sorokiniana* on the leaf blight severity of flag leaf of wheat

Population density (seeds/m^2)	**Levels of seed infection (%)**	**Disease severity in different growth stage**				
		Flag leaf	**Panicle initiation**	**Flowering**	**Milking**	**Hard dough**
200	T_1= (0.0)	0.02 p	0.15 j	1.00 c	1.12 i	1.29 j
	T_2= (5.1-15.0)	0.06 n	0.19 ij	1.06 c	1.18 hi	1.37 ij
	T_3= (15.1-25.0)	0.12 k	0.27 gh	1.13 bc	1.28 ghi	1.47 hij
	T_4= (25.1-35.0)	0.18 h	0.32 fg	1.18 bc	1.34 e-i	1.53 ghi
	T_5= (35.1-45.0)	0.24 f	0.37 ef	1.30 bc	1.42 d-g	1.64 d-h
	T_6= (45.1-60.0)	0.30 c	0.55 bc	1.28 bc	1.52 b-f	1.77 c-f
300	T_1= (0.0)	0.05 o	0.22 hij	1.12 bc	1.14 hi	1.46 hij
	T_2= (5.1-15.0)	0.11 l	0.27 ghi	1.18 bc	1.23 ghi	1.58 f-i
	T_3= (15.1-25.0)	0.14 i	0.33 fg	1.23 bc	1.33 f-i	1.61 e-h
	T_4= (25.1-35.0)	0.23 g	0.44 de	1.29 bc	1.36 e-h	1.71 d-g
	T_5= (35.1-45.0)	0.29 d	0.51 cd	1.38 bc	1.45 c-g	1.78 c-f
	T_6= (45.1-60.0)	0.33 b	0.60 ab	1.47 bc	1.62 bcd	1.85 cd
400	T_1= (0.0)	0.07 m	0.27 ghi	1.17 bc	1.46 c-g	1.65 d-h
	T_2= (5.1-15.0)	0.13 j	0.35 fg	1.23 bc	1.51 b-f	1.76 c-g
	T_3= (15.1-25.0)	0.18 h	0.38 ef	1.27 bc	1.56 b-e	1.83 cde
	T_4= (25.1-35.0)	0.25 e	0.48 cd	1.35 bc	1.67 abc	1.97 bc
	T_5= (35.1-45.0)	0.29 d	0.54 bc	2.00 a	1.73 ab	2.12 ab
	T_6= (45.1-60.0)	0.36 a	0.64 a	1.57 b	1.84 a	2.30 a

Effects on the disease severity (*B. sorokiniana*) of penultimate leaf at different plant growth stages of wheat

The highest leaf spot severities of penultimate leaf in flag leaf stage (0.52), panicle initiation stage (0.94), flowering stage (2.85), milk stage (2.96) and hard dough stage (3.29) were recorded when the population density was 400 seeds/m^2. Leaf blight severity was lower in all the above-mentioned growth stages when seeds were sown @ 200 seeds/m^2.

Among the different levels of seed contamination, the highest penultimate leaf spot severities were recorded in all growth stages as flag leaf (0.65) stage, panicle initiation (1.04) stage, flowering (2.94) stage, milk (2.97) stage and hard dough (3.68) stage in the treatment, T_6 (45.1-60% seed contamination). Significantly lower leaf blight severity was recorded in T_1 (0% seed infection) in every growth stage of the crop (Table 3).

Maximum leaf blight severity of the penultimate leaf in flag leaf stage (0.74), flowering stage (3.34), milk stage (3.34) and hard dough stage (3.87) was found at the interaction between the sowing @ 45.1-60% contaminated

seeds with the population density @ 400 seeds/m^2 (Table 4). Significantly lower leaf spot severity was recorded in the interaction between 200 seeds/m^2 with sowing of 0.0% (T_1) contaminated seeds (Table 4) in every growth stages of the plant. More or less similar field experiment was carried out by Begum (2010). She also found the increasing tendency of leaf blight severity of wheat with the increasing levels of seed contamination and plant population density. But she obtained two different kinds of reaction with the leaf blight susceptible Sonalika variety which was used as a test crop in the study and in all the growth stages, the disease severity was always higher in the maximum levels of seed contamination (45.1-60.0%) with the higher population density (400 seeds/m^2) and it was found maximum leaf blight severity at the flag leaf stage and panicle initiation stage when 400 seeds/m^2 were sown with the maximum levels of infection (45.1-60.0%). But in flowering, milk and hard dough stage, the leaf blight severity was higher in the plots of 300 seeds/m^2 with maximum levels of contaminated seeds.

Thus, leaf blight severity not only dependent on the interaction between population density and levels of seed contamination but some other factors like variety, position of leaf, growth stage of the crop, environmental factors and sowing time might have some impact on the leaf blight development. Hossain (2000) reported that the higher levels of seed borne fungal infection contributes to the higher level of primary inoculum resulting a higher infection in the field. He also found that the maximum infection severity was attained at hard dough stage due to the favorable temperature range 25-28°C for disease epidemic in March when the plants turn to soft dough to hard dough stage. Reza *et al.* (2006) found that the maximum seed infection level gave rise the highest disease severity in mature plants. The findings of the present study were also supported by Begum *et al.* (2017a) and (2017b).

Table 3. Effect of population density and different levels of seed contamination with the black pointed seeds on leaf blight severity of penultimate leaf of wheat

Population density (seeds/m^2)	**Disease severity in different growth stage**				
	Flag leaf	**Panicle initiation**	**Flowering**	**Milking**	**Hard dough**
200	0.35 b	0.76 a	2.31 b	2.43 b	2.94 a
300	0.43 ab	0.92 a	2.64 ab	2.45 b	3.18 a
400	0.52 a	0.94 a	2.85 a	2.96 a	3.29 a
Seed infection (%)					
T_1= (0.0)	0.22 e	0.65 b	2.25 c	2.35 c	2.65 e
T_2= (5.1-15.0)	0.32 d	0.74 ab	2.37 c	2.48 c	2.84 de
T_3= (15.1-25.0)	0.40 c	0.82 ab	2.50 bc	2.57 bc	3.05 cd
T_4= (25.1-35.0)	0.47 bc	0.91 ab	2.70 ab	2.55 bc	3.21 bc
T_5= (35.1-45.0)	0.53 b	1.08 a	2.84 a	2.78 ab	3.41 ab
T_6= (45.1-60.0)	0.65 a	1.04 a	2.94 a	2.97 a	3.68 a

Table 4. Interaction effect of the population density and different levels of seed infection by *B. sorokiniana* on leaf blight severity of penultimate leaf of wheat

Population density (seeds/m^2)	**Levels of seed infection (%)**	**Disease severity in different growth stage**				
		Flag leaf	**Panicle initiation**	**Flowering**	**Milking**	**Hard dough**
200	T_1= (0.0)	0.18 i	0.55 f	2.03 i	2.11 l	2.48 i
	T_2= (5.1-15.0)	0.24 jh	0.59 f	2.19 hi	2.30 jkl	2.75 hi
	T_3= (15.1-25.0)	0.31 f	0.70 def	2.26 gh	2.40 h-k	2.85 gh
	T_4= (25.1-35.0)	0.40 e	0.81 def	2.34 fgh	2.48 f-j	2.96 fhg
	T_5= (35.1-45.0)	0.45 de	0.92 a-e	2.45 fg	2.57 e-i	3.19 def
	T_6= (45.1-60.0)	0.52 c	0.98 a-d	2.55 ef	2.72 c-f	3.39 cd
300	T_1= (0.0)	0.21 hi	0.61 ef	2.31 gh	2.27 jkl	2.68 hi
	T_2= (5.1-15.0)	0.31 f	0.77 def	2.46 fg	2.34 ijkl	2.80 gh
	T_3= (15.1-25.0)	0.39 e	0.84 c-f	2.56 ef	2.41 g-k	3.07 efg
	T_4= (25.1-35.0)	0.45 e	0.95 a-d	2.69 de	2.20 kl	3.29 cde
	T_5= (35.1-45.0)	0.51 cd	1.13 abc	2.89 cd	2.65 d-h	3.47 cd
	T_6= (45.1-60.0)	0.69 ab	1.22 a	2.94 c	2.83 cd	3.77 ab
400	T_1= (0.0)	0.28 fg	0.78 def	2.41 fgh	2.66 d-g	2.77 h
	T_2= (5.1-15.0)	0.41 e	0.84 c-f	2.46 fg	2.78 cde	2.95 fgh
	T_3= (15.1-25.0)	0.51 cd	0.92 a-e	2.68 de	2.90 bcd	3.22 def
	T_4= (25.1-35.0)	0.56 c	0.98 a-d	3.03 bc	2.98 bc	3.36 cd
	T_5= (35.1-45.0)	0.64 b	1.18 ab	3.17 ab	3.12 ab	3.57 bc
	T_6= (45.1-60.0)	0.74 a	0.91 b-e	3.34 a	3.34 a	3.87 a

Effect of population density and different levels of seed contamination by *Bipolaris sorokiniana* and their interaction on the plant growth and spikelet formation of wheat

The individual effect of different levels of black point contamination with wheat seeds and the population density on plant growth was not significant but their interaction effect was significant regarding plant growth parameters (Table 5 and 6).The plant height was ranged from 96.76 cm -103.3 cm where the maximum height was obtained at T_1 (0% contaminated seed) and the minimum height was obtained at T_6 (45.1-60% contaminated seed) though there was no significant difference among them. Similar trends of different levels of seed contamination effects were observed on the ear length and the distance between flag leaf and base of ear. Significantly higher number of spikelets/ear (17.36) and healthy spikelets/ear (16.06) was obtained when seeds were sown @ 200 seeds/m^2. On the other hand significantly higher number of diseased spikelets/ear (3.09) was recorded under 400 seeds/m^2 (Table 5).

Table 5. Effect of population density and different levels of seed contamination by *B. sorokiniana* on plant growth and spikelet formation of wheat

Population density (seeds/m^2)	Plant height (cm)	Ear length (cm)	Distance between flag leaf and base of ear (cm)	No. of spikelets/ ear	No. of healthy spikelets/ ear	No. of diseased spikelets/ ear
200	102.2 a	17.44 a	18.74 a	17.36 a	16.06 a	1.33 b
300	101.4 a	16.53 a	17.62 a	16.61 ab	15.33 a	1.37 b
400	98.74 a	15.40 a	15.77 a	15.29 b	12.21 b	3.09 a
Seed infection (%)						
T_1= (0.0)	103.3 a	17.09 a	19.01 a	17.32 a	16.29 a	1.03 d
T_2= (5.1-15.0)	102.7 a	16.93 a	18.38 a	17.04 ab	15.61 ab	1.44 cd
T_3= (15.1-25.0)	101.8 a	16.61 a	17.91 a	16.65 abc	14.92 bc	1.76 bcd
T_4= (25.1-35.0)	101.0 a	16.22 a	15.84 a	16.17 bcd	14.21 c	1.96 bc
T_5= (35.1-45.0)	99.23 a	16.06 a	16.84 a	15.94 cd	13.77 c	2.41 ab
T_6= (45.1-60.0)	96.76 a	15.86 a	16.27 a	15.38 d	12.41 d	2.97 a

Table 6. Interaction effect of population density and different levels of seed contamination by *B. sorokiniana* on plant growth and spikelet formation of wheat

Population density (seeds/m^2)	Levels of seed infection (%)	Plant height (cm)	Ear length (cm)	Distance between flag leaf and base of ear (cm)	No. of spikelets/ ear	No. of healthy spikelets/ear	No. of diseased spikelets/ear
200	T_1= (0.0)	105.0 a	18.17	20.50 a	18.33 a	17.83 a	0.50 j
	T_2= (5.1-15.0)	104.0 b	18.00	20.00 ab	18.00 ab	17.00 a-c	1.00 h-j
	T_3= (15.1-25.0)	102.8 d	17.40	19.30 abc	17.37 b-d	16.07 c-e	1.30 g-i
	T_4= (25.1-35.0)	102.1 f	17.07	18.43 abc	16.90 c-f	15.37 e-g	1.53 f-h
	T_5= (35.1-45.0)	101.0 i	17.00	17.47 abc	17.00 c-e	15.60 d-f	1.57 f-h
	T_6= (45.1-60.0)	98.53 l	17.03	16.77 abc	16.57 d-g	14.50 gh	2.07 d-f
300	T_1= (0.0)	103.5 c	17.10	19.40 abc	17.63 a-c	17.23 ab	0.40 j
	T_2= (5.1-15.0)	103.1 d	16.90	18.07 abc	17.30 b-e	16.40 b-d	0.90 ij
	T_3= (15.1-25.0)	102.4 e	16.80	17.53 abc	16.87 c-f	15.50 d-g	1.37 g-i
	T_4= (25.1-35.0)	101.7 g	16.23	17.32 abc	16.43 e-g	15.07 e-g	1.37 g-i
	T_5= (35.1-45.0)	99.97 j	16.13	16.93 abc	16.03 f-h	14.7 f-h	1.87 e-g
	T_6= (45.1-60.0)	97.67 m	16.03	16.45 abc	15.37 hi	13.07 ij	2.30 de
400	T_1= (0.0)	101.4 h	16.00	17.13 abc	16.00 f-h	13.80 hi	2.20 de
	T_2= (5.1-15.0)	101.0 i	15.90	17.07 abc	15.83 gh	13.43 i	2.43 c-e
	T_3= (15.1-25.0)	100.0 j	15.62	16.90 abc	15.72 gh	13.18 i	2.60 cd
	T_4= (25.1-35.0)	99.17 k	15.37	11.78 d	15.17 hi	12.20 j	2.97 c
	T_5= (35.1-45.0)	96.73 n	15.03	16.13 bc	14.80 ij	11.00 k	3.80 b
	T_6= (45.1-60.0)	94.10 o	14.50	15.60 c	14.20 j	9.67 l	4.53 a

Significantly higher plant growth (105.0 cm), ear length (18.17 cm), distance between flag leaf and base of ear (20.50 cm), number of spikelets/ear (18.33) and number of healthy spikelets/ear (17.83) was recorded when healthy seeds (0% contaminated seed) were sown @ 200 seeds/m^2. On the other hand all the above mentioned parameters were lower when maximum levels of contaminated seeds (45.1-60.0%) were sown @400 seeds/m^2 except the number of diseased spikelets/ear (Table 6). However, two different findings of Chatha *et al.* (1986) and Dixit and Gupta (2004) reported that there was no significant influence among the seed rates on plant height. The maximum level of seed contamination (T_6) with the maximum population density resulted the lowest number of healthy spikelets/ear but the highest number of diseased spikelets/ear. The opposing trend was

observed in case of T_1 (0% seed contamination). Begum (2010) found similar results where the maximum seed infection resulted lowest number of spikelets/ear and healthy spikelets/ear but highest number of diseased spikelets/ear.

Effect of population density and different levels of seed contamination by *Bipolaris sorokiniana* and their interaction on grain formation and grain weight of wheat

In the present study, number of grains/ear, number of healthy grains/ear, weight of grains/ear and weight of healthy grains/ear was always higher in lower population density (200 seeds/m^2) and minimum seed contamination (0.0%) level (Table 7). In the interaction effect of the lower population density with the minimum seed contamination resulted in a higher value of the above parameters. The opposite trends were found in number and weight of diseased grains/ear (Table 8). Number of grains/ear and number of healthy grains/ear under different population density were significant and a higher number of grains/ear (53.14) and healthy grains/ear (49.33) was recorded under the population density of 200 seeds/m^2. On the other hand, significantly, lower number of grains/ear (45.75) and healthy grains/ear (40.72) was recorded under the population density of 400 seeds/m^2. Similar trends were found in case of weight of grains/ear and weight of healthy grains/ear. Although the effect of different population densities was not significant in respect of number of diseased grains/ear and weight of diseased grains/ear. On the other hand, significantly lower number of grains/ear (43.59) and healthy grains/ear (37.39) was recorded under the treatment T_6 (45.1-60% contaminated seed). Similar trends were found in the weight of grains/ear and the weight of healthy grains/ear and a higher number of diseased grains/ear (5.53) and a lower number of diseased grains/ear (2.78) were recorded under the treatments T_6 and T_1, respectively which were also significant. However, the effect of different levels of seed infections were insignificant (Table 7) considering the weight of diseased grains/ear.

Due to interaction effect, significantly higher number of grains/ear (58.00) and healthy grains/ear (55.67) was recorded under the treatment T_1 (0% contaminated seed) with a seed rate of 200 seeds/m^2. On the other hand, significantly lower number of grains/ear (41.50) and healthy grains/ear (33.10) was recorded under the treatment T_6 (45.1-60% contaminated seed) with a sowing rate of 400 seeds/m^2. Similar trends were found in the weight of grains/ear and in that of healthy grains/ear. Significantly higher number of diseased grains/ear (6.40) and lower number of diseased grains/ear (2.33) were recorded under the treatments T_6 with 400 seeds/m^2 and T_1 with 200 seeds/m^2, respectively. The weight of diseased grains/ear ranged from 0.07 g to 0.75 g whereas the highest and the lowest values were recorded under T_6 X 400 seeds/m^2 and T_1 X 200 seeds/m^2 treatment combinations, respectively (Table 8).

Dixit and Gupta (2004) observed that the population density had a significant correlation with the grain formation and, stated that the increasing sowing rate significantly reduced the number of grains/spike. Kabir (2006) also reported that seed rate had significant influence on the number of grains/spike. Hossain *et al.* (1998) observed that leaf infection at flowering stages has direct effect on the reduction of healthy grains formation with the increase in the number of black pointed as well as discolored grains. Rashid and Fakir (1998) reported that the shriveled grain and the black pointed kernel symptoms have been recorded as the effect of seed to plant to seed transmission of *Bipolaris sorokiniana*. Hossain (2000) found that the higher level of black point contamination in the seed samples incited more disease to the crop plants resulting formation of higher number of diseased seed in the field.

Table 7. Effect of population density and different levels of seed contamination by *B. sorokiniana* on grain formation and grain weight of wheat

Population density (seeds/m^2)	**No. of grains/ear**	**No. of healthy grains/ear**	**No. of diseased grains/ear**	**Weight of grains/ear (g)**	**Weight of healthy grains/ear (g)**	**Weight of diseased grains/ear (g)**
200	53.14 a	49.33 a	3.88 a	2.81 a	2.61 a	0.12 a
300	47.72 ab	44.14 b	3.58 a	2.53 ab	2.34 ab	0.11 a
400	45.75 b	40.72 b	4.69 a	2.45 b	2.16 b	0.43 a
Seed infection (%)						
T_1= (0.0)	53.33 a	50.56 a	2.78 d	2.83 a	2.89 a	0.08 a
T_2= (5.1-15.0)	51.39 ab	47.92 ab	3.47 cd	2.72 ab	2.50 ab	0.11 a
T_3= (15.1-25.0)	49.76 abc	46.01 bc	3.86 bc	2.64 abc	2.44 bc	0.23 a
T_4= (25.1-35.0)	48.63 bc	44.46 cd	4.20 bc	2.57 bc	2.36 cd	0.26 a
T_5= (35.1-45.0)	46.51 cd	42.04 d	4.47 b	2.53 c	2.23 d	0.28 a
T_6= (45.1-60.0)	43.59 d	37.39 e	5.53 a	2.31 d	2.98 e	0.36 a

Table 8. Interaction effect of population density and different levels of seed contamination by *B. sorokiniana* on grain formation and grain weight of wheat

Population density (seeds/m^2)	Levels of seed infection (%)	No. of grains/ ear	No. of healthy grains/ear	No. of diseased grains/ear	Weight of grains /ear (g)	Weight of healthy grains/ear (g)	Weight of diseased grains/ear (g)
200	T_1= (0.0)	58.00 a	55.67 a	2.33 ij	3.07 a	2.95 a	0.07 d
	T_2= (5.1-15.0)	56.33 ab	52.83 b	3.50 f-h	2.98 ab	2.80 b	0.11 b-d
	T_3= (15.1-25.0)	53.83 bc	50.17 cd	4.00 e-g	2.85 bc	2.66 cd	0.12 b-d
	T_4= (25.1-35.0)	52.67 cd	48.63 de	4.10 d-f	2.77 cd	2.58 de	0.13 b-d
	T_5= (35.1-45.0)	50.67 de	46.33 e-g	4.33 c-e	2.68 de	2.46 e-g	0.13 b-d
	T_6= (45.1-60.0)	47.33 fg	42.33 ij	5.00 bc	2.51 fg	2.24 ij	0.16 b-d
300	T_1= (0.0)	53.33 cd	51.33 bc	2.00 j	2.83 cd	2.74 bc	0.06 d
	T_2= (5.1-15.0)	50.50 de	47.67 ef	2.83 hi	2.68 de	2.52 d-f	0.09 cd
	T_3= (15.1-25.0)	48.50 ef	45.23 f-h	3.27 gh	2.57 ef	2.39 f-h	0.10 b-d
	T_4= (25.1-35.0)	46.80 fg	42.87 h-j	3.93 e-g	2.48 fg	2.27 h-j	0.10 b-d
	T_5= (35.1-45.0)	45.23 gh	41.00 jk	4.23 c-f	2.40 g	2.18 jk	0.14 b-d
	T_6= (45.1-60.0)	41.93 i	36.73 l	5.20 b	2.23 h	1.95 l	0.16 b-d
400	T_1= (0.0)	48.67 ef	44.67 g-i	4.00 e-g	2.58 ef	2.37 g-i	0.12 b-d
	T_2= (5.1-15.0)	47.33 fg	43.27 h-j	4.07 d-f	2.51 fg	2.29 h-j	0.13 b-d
	T_3= (15.1-25.0)	46.93 fg	42.63 h-j	4.30 c-f	2.48 fg	2.26 h-j	0.48 a-d
	T_4= (25.1-35.0)	46.43 f-h	41.87 j	4.57 b-e	2.46 fg	2.22 j	0.55 a-c
	T_5= (35.1-45.0)	43.63 hi	38.80 kl	4.83 b-d	2.49 fg	2.06 kl	0.57 ab
	T_6= (45.1-60.0)	41.50 i	33.10 m	6.40 a	2.18 h	2.15 m	0.75 a

Effect of population density and different levels of seed contamination by *Bipolaris sorokiniana* and their interaction on 1000 seed weight and yield of wheat

In the present study, there was no significant effect observed on the weight of thousand seeds in relation to population density and different levels of seed contamination. Grain yield as well as straw yield were found at their maximum in T_1 (0% contaminated seed) whereas, the minimum yields were obtained in T_6 which had the maximum seed contamination. Grain yields also higher (3.12 t/ha) at the minimum population density which was found to decrease with increase in population density (Table 9).

Kabir (2006) reported that the 1000 grain weight did not differ significantly due to the different seed rate of wheat. Similarly, Begum (2010) did not find any significant effect on that due to the population density although reported a significant effect on 1000 seed weight for different levels of seed contamination.

In case of interaction effect, significantly higher 1000 seed weight was obtained in the lowest population density (200 seeds/m^2) with the minimum seed containation (0.0%) which was statistically similar with the both interaction effects of lowest contaminated seed (0.0%) with the rest two population density treatments. (Table 10). The significant highest yield (3.43 t/ha) was obtained at 0.0% contaminated seeds were sown @ 200 seeds/m^2 which was statistically similar to the interaction effects of the 0.0% contaminated seeds with the rest two population densities (3.27 & 3.21 t/ha @ 300 & 400 seeds/m^2 respectively). On the other hand, significantly lower grain yield (2.58 t/ha) was recorded in higher contamination level with 400 seeds/m^2.

But in a previous study, Begum (2010) reported a tendency to increase in 1000 seed weight with the increasing population density which differed the respective findings of the present study. Chowdhury *et al.* (2010) recorded the highest grain yield of wheat in case of 0.0% contaminated seeds which was 38.69% increase over the yield of 45.1-60.0% contaminated seeds. The findings of this study differed the findings of Begum (2010) who found comparatively higher grain yield (3.28 t/ha) in case of 0.0% contaminated seeds which were sown @ 400 seeds/m^2.

Table 9. Effect of population density and different levels of seed infection by *B. sorokiniana* on 1000 seed weight and yield of wheat

Population density (seeds/m^2)	1000 seed weight (g)	Straw yield (t/ha)	Grain yield (t/ha)
200	44.38 a	3.82 a	3.12 a
300	43.43 a	3.55 a	2.90 a
400	42.40 a	3.58 a	2.92 a
Seed infection (%)			
T_1= (0.0)	44.77 a	4.05 a	3.31 a
T_2= (5.1-15.0)	44.20 a	3.92 ab	3.20 ab
T_3= (15.1-25.0)	43.83 a	3.75 abc	3.08 abc
T_4= (25.1-35.0)	43.23 a	3.59 bcd	2.94 bcd
T_5= (35.1-45.0)	42.73 a	3.39 cd	2.77 cd
T_6= (45.1-60.0)	41.67 a	3.18 d	2.60 d

Table 10. Interaction effect of population density and different levels of seed infection by *B. sorokiniana* on plant growth and spikelet formation of wheat

Population density (seeds/m^2)	Levels of seed infection (%)	1000 seed weight (g)	Straw yield (t/ha)	Grain yield (t/ha)
200	T_1= (0.0)	45.60 a	4.21 a	3.43 a
	T_2= (5.1-15.0)	45.10 ab	4.08 ab	3.35 ab
	T_3= (15.1-25.0)	44.80 ab	3.91 a-e	3.20 a-e
	T_4= (25.1-35.0)	44.20 a-c	3.75 b-f	3.08 b-f
	T_5= (35.1-45.0)	43.70 a-c	3.59 d-g	2.93 d-h
	T_6= (45.1-60.0)	42.90 a-c	3.35 g-j	2.75 g-j
300	T_1= (0.0)	44.80 ab	4.00 a-c	3.27 a-c
	T_2= (5.1-15.0)	44.20 a-c	3.87 a-e	3.15 a-f
	T_3= (15.1-25.0)	43.90 a-c	3.69 c-g	3.03 c-g
	T_4= (25.1-35.0)	43.30 a-c	3.47 f-i	2.85 f-i
	T_5= (35.1-45.0)	42.80 a-c	3.21 h-j	2.60 h-j
	T_6= (45.1-60.0)	41.60 bc	3.03 j	2.47 j
400	T_1= (0.0)	43.90 a-c	3.95 a-d	3.21 a-d
	T_2= (5.1-15.0)	43.30 a-c	3.80 b-f	3.10 b-f
	T_3= (15.1-25.0)	42.80 a-c	3.64 c-g	3.02 c-g
	T_4= (25.1-35.0)	42.20 a-c	3.55 e-h	2.89 e-h
	T_5= (35.1-45.0)	41.70 a-c	3.37 g-j	2.75 g-j
	T_6= (45.1-60.0)	40.50 c	3.17 ij	2.58 ij

CONCLUSION

Highly infected seeds along with increased seed rate cause increased leaf blight (*Bipolaris sorokiniana*) of wheat. Clean seed and optimum seed rate can reduce leaf blight problem in wheat.

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