



Assessment of avoidable yield losses due to insect pests and diseases in wheat (*Triticum aestivum*)

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ABSTRACT

Biotic stress, including insect pests and diseases, poses a significant constraint to the cultivation of food grain crops including wheat (*Triticum aestivum* L.) which is affected by several pests. Therefore, the present study was carried out during winter (*rabi*) seasons of 2020–21 and 2021–22 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to assess the yield loss due to multiple pests in a holistic manner with wheat variety HD 3086 (Pusa Gautami). Estimated avoidable yield loss due to higher aphid infestation and minimum disease incidences of Karnal bunt and black point disease during both the seasons (2020–21 and 2021–22) was 7.79% and 6.10%, respectively. Meanwhile, in treatment with a lower aphid infestation and minimum disease incidence of Karnal bunt and black point diseases, yield losses were 4.80% and 6.90% in 2020–21 and 2021–22, respectively. Incidences of the diseases were found to be minimal in both the seasons, thus the estimated avoidable losses attributed to aphids to a large extent.

Keywords: Black point disease, Imidacloprid, Karnal Bunt, Potato aphid

Cereals play a key role in meeting the food and nutrition needs of the growing global population. Being known as the king of cereals, wheat (*Triticum aestivum* L.) occupies 217.19 million hectares globally, holding the first rank in terms of acreage with an annual production of around 762 million metric tonnes (USDA 2019). Actual losses in wheat crop are estimated at 7.7%, 7.9% and 12.6% due to weeds, animal pests and diseases, respectively, amounting to a 28.2% yield loss in worldwide wheat production (Orke 2006). Biotic stress is a major constraint in crop production, causing an overall 33% yield loss in India. Among the major pests, weeds cause 12.5% loss, whereas insects in the field inflict 9.5% loss, diseases 6.5% and other pests 4.5% loss (DWR 2015). Wheat is ravaged by a number of insect pests amongst them aphid complex is predominant sap sucking pests. There are six species of aphids infesting wheat crop, viz. *Rhopalosiphum padi*, *Schizaphis graminum*, *R. maidis*, *Metopolophium dirhodum*, *Sitobion avenae* and *Diuraphis noxia* (Farook *et al.* 2019). Apart from these insect pests, wheat crop is also a host to a range of pathogens such as fungi, bacteria and viruses which cause variable degrees of yield losses in wheat production around the globe. However, yield loss estimates are available for individual pests and

diseases separately. Hence, it is essential to have holistic estimates of yield loss due to various pests in any region. It has been estimated that global yield losses due to insect pests in the pre-green revolution era were about 5.1%, however, the losses increased to 9.3% in the post-green revolution in 1990s indicating dynamic and highly adaptable nature of insects (Dhaliwal *et al.* 2010). Keeping this in view, the present study aimed to assess crop losses due to important insect pests and diseases on wheat.

MATERIALS AND METHODS

The field experiment was conducted during winter (*rabi*) seasons of 2020–21 and 2021–22 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi in a randomized block design (RBD) with 4 treatments (including control) and 5 replications of each in a 3.0 m × 3.0 m plot size, viz. T₁, Seed treatment with carbendazim 50% WP (Bavistin®) @2 g/kg of seeds + *Trichoderma harzianum* 6 g/kg of seed and single foliar spray of *T. harzianum* @10 g/l of water; T₂, Foliar spray of Azadirachtin 5% Neem Baan® 200 ml/ha of water, foliar spray of imidacloprid 17.80% SL (Confidor®) @250 ml/ha; T₃: Seed treatment carbendazim 50% WP 2 g/kg of seeds, foliar spray of propiconazole 25% EC (Tilt®) @450 ml/ha, two foliar spray imidacloprid 17.80% SL @250 ml/ha and Control: Unprotected plots without any application. Wheat variety HD-3086 (Pusa Gautami) was sown at a seed rate of 100 kg/ha with row-to-row spacing of 20 cm and plant-to-plant distance of 5.0 cm on 1.12.2020 and 3.12.2021,

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respectively. The recommended package of practice was followed except for the plant protection measures (Singh *et al.* 2014). The control plots (unprotected) had natural infestations of insect pests, viz. aphids, *Rhopalosiphum padi* and *Macrosiphum euphorbiae* and fungal infections of Black point disease (*Bipolaris sorokiniana* and *Alternaria alternata*) and Karnal bunt (*Tilletia indica* Mitra (syn. *Neovossia indica* (Mitra) Mundkur), which were kept untreated. In the T₁ plot, seed treatment with carbendazim 50% WP + *Trichoderma harzianum*) and foliar sprays of *T. harzianum* were given in both the seasons. In T₂ plots, a single foliar spray of Neem Baan® and 2 foliar sprays of imidacloprid 17.80% SL were applied based on economic threshold level (ETL) on the 63rd, 75th, and 83rd DAS in 2020–21, whereas foliar sprays of each Neem Baan® and imidacloprid 17.80% SL were applied in T₂ on the 63rd and 76th DAS, respectively, based on ETL during 2021–22. In T₃ plots, protection against insects and diseases was provided by seed treatment with carbendazim 50% WP, two foliar sprays of propiconazole 25% EC, and two foliar sprays of imidacloprid 17.80% SL. Ten plants from each replication were randomly sampled for aphids during crop growth. The mean values of the aphid complex were subjected to a square-root transformation. At harvest, 2000 grains from each replication were observed for diseases. The observed percent disease incidence was subjected to arc-sine transformation before statistical analysis. Grain yield per plot was recorded separately for each plot and converted to yield per ha. The yield increase in protected over unprotected plots and avoidable yield loss was worked out according to Pradhan (1969). Yield loss was converted to monetary value at the market price of grain in the respective years. All the data were subjected to analysis of variance (ANOVA), after transformations wherever necessary, in a randomized block design (RBD), and the mean was separated using Tukey's

test. Tests were carried out at a 5% level of significance using SPSS (version 16.0) software.

RESULTS AND DISCUSSION

In T₁ plots (protected against diseases), the mean number of aphid populations (*R. padi* and *M. euphorbiae*) reached ETL on the 63rd DAS during both seasons (Table 1 and 2). The mean population observed in T₂ (protected against aphids) in the week of peak aphid infestations was 19.77 as compared with 52.51 in the unprotected plot (T₁) and 55.70 in the control plots during 2020–21 (Table 1). In the case of T₃ plots, which were protected against both insect pests and diseases, the mean aphid populations in the period of highest infestation, i.e. on the 77th DAS (2020–21) were 6.28, being the least among all treatments. The mean population observed in T₂ (protected against aphids) in the week of peak aphid infestations was 4.72 as compared with 34.36 in the unprotected plot (T₁) and 34.00 in the control plots during 2021–22 (Table 2). In the case of T₃ plots, which were protected against both insect pests and diseases, the mean aphid populations in the period of highest infestation, i.e., on the 69th DAS (during 2021–22), was 1.40, being the least among all treatments. To summarize, the pooled mean populations of aphids for T₂ plots (protected against aphids) during 2020–21 and 2021–22 were 10.70 and 10.48, respectively, the least among all treatments. The control plot indicated the highest pooled mean population (29.05 and 20.12) for the crop growing season during 2020–21 and 2021–22, respectively (Tables 1 and 2).

Data on the disease infection during both the seasons revealed no significant difference between protected and unprotected plots. In T₁ plots (protected against diseases), the mean incidence of Karnal bunt (0.11%) and black point disease (0.91%) were noticed during 2020–21. On the other hand, unprotected plots T₂ had disease incidences of Karnal

Table 1 Mean aphid population (*Rhopalosiphum padi* and *Macrosiphum euphorbiae*) on wheat crop during rabi season of 2020–21

Treatment	Mean aphid population per plant days after sowing (DAS)								Pooled Mean	Yield /Plot (9 m ²)
	63	69	77	83	89	97	104	111		
T ₁	20.96 (4.684 ^b)	34.40 (5.949 ^a)	52.51 (7.315 ^a)	29.74 (7.585 ^a)	36.40 (6.113 ^a)	19.50 (4.525 ^a)	20.92 (4.674 ^a)	19.68 (4.526 ^a)	27.50 (5.29)	3.589 (2.142 ^a)
T ₂	20.88 (4.675 ^b)	4.72 (2.385 ^b)	19.77 (4.555 ^b)	13.87 (4.670 ^b)	1.52 (1.561 ^b)	14.96 (3.971 ^b)	19.48 (4.522 ^a)	13.72 (3.813 ^b)	12.94 (3.67)	3.705 (2.169 ^a)
T ₃	22.52 (4.848 ^b)	1.40 (1.527 ^c)	6.28 (2.693 ^c)	10.25 (2.518 ^c)	0.44 (1.178 ^c)	18.52 (4.416 ^{ab})	20.36 (4.616 ^a)	18.04 (4.34 ^{ab})	10.70 (3.35)	3.892 (2.212 ^a)
Control	27.2 (5.306 ^a)	36.2 (6.097 ^a)	55.7 (7.526 ^a)	57.8 (7.667 ^a)	38.34 (6.271 ^a)	19 (4.469 ^a)	21.4 (4.731 ^a)	20.2 (4.602 ^a)	29.05 (5.44)	3.476 (2.116 ^a)
P value	S	S	S	S	S	S	NS	S	-	S
CD	0.288	0.319	0.28	0.393	0.281	0.356	-	0.458	-	0.018
SE(m)	0.093	0.102	0.09	0.126	0.09	0.114	0.106	0.147	-	0.006
SE(d)	0.131	0.145	0.127	0.178	0.128	0.162	0.15	0.208	-	0.008
CV	4.24	5.741	3.633	5.025	5.343	5.887	5.108	7.614	-	0.597

S, Significant; NS, Non-Significant. Figures in parentheses are square root transformed values. Letters in superscript indicate the statistical difference between treatments. Treatment details are given under Materials and Methods.

Table 2 Mean aphid population (*Rhopalosiphum padi* and *Macrosiphum euphorbiae*) on wheat crop during *rabi* season of 2021–22

Treatment	Mean aphid population per plant days after sowing (DAS)							Pooled Mean	Yield/Plot (9 m ²)
	63	69	75	77	84	91	97*		
T ₁	20.08 (4.586 ^a)	34.36 (5.945 ^a)	26.80 (5.26 ^a)	16 (4.193 ^a)	3.80 (2.168 ^a)	0.12 (1.057 ^a)	-	20.48 (4.580)	3.509 (2.123 ^b)
T ₂	20.88 (4.675 ^a)	4.72 (2.385 ^b)	19.44 (4.521 ^b)	16 (4.299 ^a)	2.88 (1.708 ^a)	0.12 (1.058 ^a)	-	13.13 (3.691)	3.479 (2.116 ^b)
T ₃	21.76 (4.768 ^a)	1.40 (1.527 ^c)	19.64 (4.54 ^b)	6.20 (2.518 ^b)	0.36 (0.640 ^b)	0.10 (1.048 ^a)	-	10.48 (3.313)	3.737 (2.176 ^a)
Control	20.20 (4.597 ^a)	34 (5.915 ^a)	25.80 (5.171 ^a)	16.20 (4.146 ^a)	3 (1.870 ^a)	0.14 (1.065 ^a)	-	20.12 (4.540)	3.286 (2.07 ^b)
P value	NS	S	S	S	S	NS	-	-	S
CD	-	0.30	0.28	0.24	0.30	-	-	-	0.046
SE(m)	0.10	0.09	0.09	0.07	0.09	0.016	-	-	0.015
SE(d)	0.14	0.13	0.13	0.10	0.14	0.022	-	-	0.021
CV	4.88	5.46	4.26	4.55	12.15	3.356	-	-	1.561

S, Significant; NS, Non-Significant. Figures in parentheses are square root transformed values. Letters in superscript indicate the statistical difference between treatments. *No aphids were observed in all treatment plots. Treatment details are given under Materials and Methods.

bunt (0.12%) and black point diseases (1.06%) during 2020–21. Compared to these two plots, T₃ plots (protected against aphids and diseases) showed less disease incidences of Karnal bunt (0.11%) and black point disease (0.97%) during 2020–21. In control plots, the mean incidences of Karnal bunt (0.18%) and black point disease (1.11%) were observed which were higher than that of T₁, T₂ and T₃ plots during 2020–21 (Supplementary Table 1). In T₁ plots (protected against diseases), the mean incidence of Karnal bunt 0.10% and black point disease (0.87%) were noticed during the 2021–22. On the other hand, unprotected plots in T₂ had disease incidences of Karnal bunt (0.11%) and black point diseases (1%) during 2021–22. Compared to these two plots, T₃ plots (protected against aphids and diseases) showed less disease incidences of Karnal bunt (0.09%) and black point disease (0.93%) during 2021–22. In control plots,

mean disease incidences of Karnal bunt (0.16%) and black point diseases (1.03%) were observed, which were higher than other protected plots but not significantly different (Supplementary Table 1).

After harvest, T₃ plots (protected against both diseases and aphids) produced the highest mean yield, amounting to 4324.44 and 4152.22 kg/ha whereas control plots reaped the lowest mean yield of 3862.22 and 3651.11 kg/ha during 2020–21 and 2021–22 (Table 3).

Result showed that yield loss in T₁ plots (protected against diseases) was 7.79% (336.67 kg/ha) *vis-a-vis* T₃ (protected against aphids and diseases) in 2020–21. Yield loss in T₁ plots was accounted for aphids with the highest pooled mean population 27.50 and disease incidences of Karnal bunt (0.12%) and black point diseases (1.11%) for crop seasons of 2020–21. In the case of T₂ plots (protected

Table 3 Yield loss assessment of wheat crop during *rabi* seasons of 2020–21 and 2021–2022

Treatment	Season	Yield kg/plot (9 m ²)	Yield (kg/ha)	Yield loss (kg/ha)	Per cent avoidable yield loss	Monetary loss in ₹	Gain over control (kg)	Per cent gain over control
T ₁	2020–21	3.589	3987.77	336.67	7.79	6480.83	125.56	3.25
	2021–22	3.509	3898.88	253.33	6.10	5003.33	247.78	6.79
T ₂	2020–21	3.705	4116.66	207.78	4.80	3999.72	254.44	6.59
	2021–22	3.479	3865.55	286.67	6.90	5661.67	214.44	5.87
T ₃	2020–21	3.892	4324.44	-	-	-	462.22	11.97
	2021–22	3.737	4152.22	-	-	-	501.11	13.72
Control	2020–21	3.476	3862.22	462.22	10.69	8897.78	-	-
	2021–22	3.286	3651.11	501.11	12.07	9896.94	-	-

Treatment details are given under Materials and Methods.

against aphids) 4.80% (207.78 kg/ha) yield losses were estimated during 2020–21. During 2020–21, the estimated yield loss of 4.80% in T₂ plots (protected against aphids) was lowest amongst all treatments (Table 3). Result showed that yield loss in T₁ plots (protected against diseases) was 6.10% (253.33 kg/ha) *vis-a-vis* T₃ (protected against aphids and diseases) in 2021–22. Yield loss in T₁ plots was accounted for aphids with the highest pooled mean population of 20.48 and disease incidences of Karnal bunt (0.10%) and black point diseases (0.87%) during 2021–22 (Table 3). During 2021–22, an estimated yield loss (6.90%) in T₂ plots (protected against aphids) was higher than in T₁ plots (protected against diseases). It indicates varying degree of losses caused in two seasons with same treatment. Comparing with control plots, T₃ plots (protected for aphids, Karnal Bunt and black point diseases) showed the highest yield gains of 11.97% (462.22 kg/ha) and 13.72% (501.11 kg/ha) over the control plots during 2020–21 and 2021–22, respectively (Table 3).

In a nutshell, lower infestation of aphids (pooled mean population 12.94) and minimum incidence of Karnal bunt (0.12%) and black point diseases (1.06%) caused 4.80% avoidable yield loss during 2020–21. During 2021–22, minimum incidence of Karnal bunt (0.11%) and Black point diseases (1%) and lower infestation of aphids (pooled mean population 13.12) caused 6.90% avoidable yield loss. Yield losses due to aphids and diseases in unprotected plots amounted to 10.69% during 2020–21 and 12.07% during 2021–22 in comparison to the protected plots. Protection against both aphids and diseases resulted in 462.22 kg/ha and 501.11 kg/ha of extra yield compared to the control indicating effectiveness of protection measures during 2020–21 and 2021–22, respectively (Table 3).

The wheat crop is attacked by several insect pests, viz. complex species of aphids such as *R. maidis*, *R. padi*, *S. avenae*, and *S. miscanthi* (Srivastava *et al.* 2016). In the present study, two aphid species, the bird cherry aphid *R. padi* and the potato aphid, *M. euphorbiae*, were observed to infest wheat crops. Out of these species, *M. euphorbiae* was recorded for the first time on wheat as a host crop (Venkatesh *et al.* 2023). However, Alawi *et al.* (2021) had reported wheat aphids, *R. padi* and *S. avenae* infesting wheat on the same field. In the present study, findings reveal that unprotected crops were infested with aphids, with the highest mean population of 52.51 per plant on the 77th DAS and 34.36 per plant on the 69th DAS in crop seasons 2020–21, and 2021–22, respectively. The pooled mean value of aphid populations for unprotected plots was 20.48 and 27.50 for seasons 2020–21 and 2021–22, respectively. On the other hand, the mean population for wheat aphids was 7.88 per plant on 75 DAS (Alawi *et al.* 2021). Variation in population indicates the results of complex factors such as predators, mean temperature, crop variety, nutritional factors, fecundity, and so on.

Similarly, in another study, authors reported that the highest aphid population was 51.55 aphids/plant (Khan *et al.* 2012). It was observed that the number of aphids increased

during the earing and flowering of wheat, with the highest population density recorded during grain development and the initiation of wax ripening (Kostyukovskii *et al.* 1990). The decline in the aphid population could also be the result of crop maturity (Ridell 1990). The present findings are in conformity with those of Xiong (1990) and Nawaz (2000), who observed that the population of aphids in the field increased with the development of the wheat and peaked at the heading stage.

In present study, two diseases, viz. Karnal bunt and black point disease were observed in traces. Similarly, extensive post-harvest surveys indicated the presence of Karnal bunt in the northwest regions of India, such as Haryana, Punjab, Rajasthan, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, and Karnataka (ICAR-IIWBR, Annual Report 2018–2019). In this study, mean incidences of Karnal bunt (0.12 and 0.11%) were recorded during 2020–21 and 2021–22, respectively. Results in the present study are in line with previous studies which found that Karnal bunt infection ranged between 0.27–51.57% and resulted in a significant reduction in the weight of infected grains (Rai and Singh 1985). However, there was no statistically significant difference observed between treatments for diseases incidence. Seed treatment with Bavistin did not show any significant result in present study. Similarly, seed treatment with either Vitavax-200 or Homai-80 WP was found ineffective in reducing black point incidence (Malaker and Mian 2009). On the other hand, foliar sprays with Tilt® 25 EC under all the spray schedules except spraying at 70 and 90 DAS significantly minimized the disease severity over unsprayed control (Malaker and Mian 2009). Kumar *et al.* (2017) suggested comparatively higher disease control with Tilt®, but in present investigation results did not show any significant difference between sprayed and unsprayed plots. Seed treatment with *Tricoderma harzianum* recorded Karnal bunt incidence of 0.95% (Srivastava 2014). Present investigation did not show any significant results with *T. harzianum* in controlling Karnal bunt. Various workers have recommended a single spray of Propiconazole @0.1% for Karnal Bunt and black point disease-free quality seed production having export quality (Malaker and Mian 2009, Shukla *et al.* 2018). However, there was no significant difference found between treated and untreated plots for the incidence of these two diseases in the present study.

In present investigation, the avoidable yield losses due to the aphids were 7.79 and 6.10% in 2020–21 and 2021–22, respectively. These losses are valued at 6481 and 5003 rupees (₹) for the respective years. Higher losses in the first season (2020–21) were due to a more extended period of aphid feeding days (Voss *et al.* 1997). In another experiment, a reduction of 4.57% in yield was recorded due to aphid infestation (Khan *et al.* 2012). In previous studies related to losses in wheat due to aphids, indicated a reduction in yield of 12%, which was more than that of present study (Gair *et al.* 1987, Oakley *et al.* 1993). Several others have found significantly higher yields of various crops under chemical

protection than under control (Patil *et al.* 2009, Sagar *et al.* 2018). These experimental studies shows that higher yields in protected crops against aphids resulted from Imidacloprid (Confidor®) spray. In consonance with the results of this study, the efficacy of Confidor® 17.8 SL against wheat aphids and the highest yield against control was reported by other researchers (Patil *et al.* 2009, Matharu and Tanwar 2009). Results in the present study corroborate the findings of Elbert *et al.* (1991), who reported that Confidor® 17.8 SL has outstanding insecticidal activity against sucking pests with longer persistent toxicity.

The present study finds that losses due to aphids and diseases together in unprotected plots amount to 10.69 and 12.07%. On the other hand, protection against both offers an appreciably higher yield, than that of unprotected control plots. In general, farmers tend to underestimate damage caused by sucking pests, viz. cereal aphids. However, aphids cause damage to the growing crop leading to economic losses to the farmers. In addition, insect pests and diseases can cause varying degree of losses, depending on favourable conditions and the lack of intervention. Therefore, timely interventions should be directed towards both pests based on threshold levels to prevent economic losses.

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