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COMPARATIVE EFFICACY OF INSECTICIDES AGAINST TERMITES IN WHEAT CULTIVATION IN THE TRANSITION PLAIN OF LUNI BASIN

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SUMMARY

Termites, among the most polyphagous pests, are particularly destructive to wheat crops worldwide. They thrive in loamy or light soils and dry areas lacking adequate irrigation. Research on termite control in wheat under field conditions, focusing on seed treatment and management of standing crops through popular insecticides, is crucial. We examined the effects of insecticidal treatments on termite damage in wheat during two consecutive *rabi* seasons (2020-21 and 2021-22). The efficacy of the insecticides was evaluated based on plant damage, yield parameters, and cost-benefit analysis. The findings showed that the T_4 treatment (seed treatment and soil application of imidacloprid 17.8 SL after 60 DAS) resulted in the minimum plant damage (0.91%), highest grain yield (29.33 q/ha), highest straw yield (40.76 q/ha), and maximum benefit-cost ratio (2.28). This was followed by the T_6 treatment (seed treatment and soil application of fipronil 5 SC after 60 DAS) and the T_2 treatment (seed treatment and soil application of chlorpyriphos 20 EC after 60 DAS), all of which proved superior to other treatments. The T_7 treatment (soil application of fipronil 0.3 G) was moderately effective, while the T_1 treatment (seed treatment with chlorpyriphos 20 EC) was less effective.

Keywords: Wheat, termite, seed treatment, efficacy and management

Wheat (*Triticum aestivum* L.) is a crucial cereal crop, providing sustenance to over a third of the global population. It is a rich source of protein, minerals, vitamins, and dietary fiber, essential for many people's diets. Wheat flour is commonly used in various foods such as chapatti, puri, bread, cakes, sweets, and halwa. Additionally, wheat straw is utilized in the paper industry and for constructing temporary huts and roofs. The bran, husk, and other parts of the wheat grain and straw are valuable resources for livestock feed and bedding materials. Numerous biotic constraints, particularly insect pest infestations, pose significant challenges to wheat production from germination to crop maturity.

The wheat crop is attacked by 24 species of insect pests (Singh, 1998) with termites being the most significant pest not only in India but also across South Asia (Geddes and Iles, 1991). Termites are polyphagous and are among the most destructive pests affecting agricultural, horticultural, agroforestry, and plantation crops (Rashmi and Sundararaj, 2013; Kashyap *et al.*, 1984; Paul *et al.*, 2018). About 16 species of termites have been reported to cause damage to wheat crops in India, of these *Odontotermes obesus* (Rambur) and *Microtermes obesi* (Holm) were found predominant, which caused 80 percent loss in south Asia (Roonwal, 1979; Sattar and Salihah, 2001; Chhillar *et al.*, 2006; Dhadwal *et al.*, 2014). Severe damage to wheat crops caused by termites was also documented in parts of Madhya Pradesh, Uttar Pradesh, Gujarat, and Rajasthan (Kumar and Pardeshi, 2011). Termite damage in wheat crops in India varies significantly, ranging from 13 to 100 percent (Parween *et al* 2016; Roonwal, 1979). Among Indian states, Rajasthan and parts of Madhya Pradesh experience particularly severe damage from termites (Sharma *et al.*, 2004). Termite damage tends to be lower in clay and black soils, higher in sandy loam soils, and most severe in red soils (Hakeem *et al.*, 2016). In rainfed crops, termite infestation ranges from 20 to 25 percent, while in irrigated crops, it is around 10 percent (Sharma *et al.*, 2009). Specifically, in western Rajasthan, the infestation is more severe in light, rainfed soils compared to heavier, irrigated soils. Termite damage begins at the sowing stage and can continue until harvest (Jain and Bhargava, 2007). Termites destroy the root system, causing leaves to yellow and plants to weaken and wither. Affected plants can be easily uprooted with minimal pressure. During strong winds, the weakened plants bend, causing the earheads to fall, which can lead to plant death before maturity. At the earhead stage, termite damage results in chaffy earheads with little or no grain formation (Kumawat, 2001; Mahapatro and Sreedevi, 2014; Paul *et al.*, 2018; Chhotani, 1980). Considering the destructive nature and significance of termite damage, the present studies were conducted.

MATERIALS AND METHODS

Field experiments were conducted at the Agricultural Research Station, Keshwana (Jalore) during the *rabi* season of 2020-2021 and at the College of Agriculture, Sumerpur (Agriculture University, Jodhpur) during the *rabi* season of 2021-2022. The experiments followed a simple randomized block design with eight treatments, including an untreated control, each replicated three times. Wheat variety Raj-3077 was sown in the second week of November during both years, in plots measuring 3.5 x 2.5 meters with 20 cm row spacing. Half of the recommended nitrogen fertilizer and the full doses of phosphate and potash fertilizers were applied during the final ploughing. The remaining nitrogen was applied in two splits through top dressing during the first and second irrigations. Weeds were managed manually through weeding and hoeing, and the crop was cultivated using standard agronomic practices for the zone. Wheat seeds were treated with respective insecticides using 50 ml of water before sowing. For soil application, the required amount of insecticide was mixed with sand and broadcasted before irrigation, 60 days after sowing. The details of the treatments are as follows:

Observations on termite damage were recorded weekly by counting healthy and damaged tillers from three-meter row length (each of one meter) of each plot, starting one week after germination until harvest, following the technique described by Kumar *et al.*, 2020. Grain and straw yields were recorded from each plot after harvesting and separating the grain. Percent infestation data were statistically analyzed after transforming to arcsine values, and percent termite damage was analyzed using angular transformation values (Bliss, 1937). Avoidable loss and yield increase over the untreated control were calculated using following formulas:

$$\text{Avoidable loss (\%)} = \frac{\text{Highest yield in treated plot} - \text{Yield in treatment}}{\text{Highest yield in treated plot}} \times 100$$

$$\text{Increase in yield (\%)} = \frac{\text{Yield in the treatment} - \text{Yield in untreated check}}{\text{Yield in untreated check}} \times 100$$

Although these formulas do not provide exact loss or yield increase figures due to residual damage even in the best treatments, they are considered the most feasible method for determining percent loss due to insect pests in any treatment (Pradhan, 1964). To identify the most effective and economical treatment, the net profit and benefit-cost ratio were calculated by considering the expenditure on individual insecticidal treatments and the corresponding yield.

RESULTS AND DISCUSION

To evaluate the effectiveness of various insecticides in managing termite infestations in wheat crops, several criteria were employed. This investigation considers the impact of insecticide application on the percentage of plant damage, seed yield, straw yield, and the economic viability of treatments.

Effect of insecticides application on plant damage

Observations from the *rabi* seasons of 2020-

Detail of treatments	Dose
T_1–Seed treatment with Chlorpyriphos 20 EC	4.0 ml/ kg seed
T_2–T1 + soil application of Chlorpyriphos 20 EC 60 DAS	4.0 liter/ha
T_3–Seed treatment with imidacloprid 17.8 SL	2.0 ml/ kg seed
T_4–T3 + soil application of imidacloprid 17.8 SL 60 DAS	500 ml / ha
T_5–Seed treatment with fipronil 5 SC	6.0 ml /kg seed
T_6–T5 + soil application of fipronil 5 SC 60 DAS	2.5 liter / ha
T_7–Soil application of fipronil 0.3 G	25.0 kg /ha
T_8–Control/ Untreated check	-

21 and 2021-22 indicated that termite attacks on wheat crops began four weeks after germination and continued until harvest. All insecticidal treatments significantly reduced termite damage up to 16 weeks after sowing. Among the seed treatments, seed treatment with imidacloprid 17.8 SL proved superior, followed by fipronil 5 SC. The least termite damage was recorded in treatment T4 (seed treatment and soil application of imidacloprid 17.8 SL after 60 DAS), followed by T6 (seed treatment and soil application of fipronil 5 SC after 60 DAS) throughout the cropping season.

The data presented in Table 1 and Fig. 1 revealed that during *Rabi* 2020-21, the treatment T4 (seed treatment and soil application of imidacloprid 17.8 SL after 60 DAS) resulted in the minimum termite damage (0.98%). This was followed by T6 (seed treatment and soil application of fipronil 5 SC after 60 DAS) with 1.09 per cent damage, and T2 (seed treatment and soil application of chlorpyriphos 20 EC after 60 DAS) with 1.35% per cent damage. These treatments did not differ significantly from each other but were significantly superior to the other treatments. The maximum termite damage (3.83%) was recorded in the treatment T1 (seed treatment with chlorpyriphos 20 EC), followed by T5 (seed treatment with fipronil 5 SC) at 3.38 per cent, and T7 (soil application of fipronil 0.3 G) at 3.21 per cent. These treatments did not differ significantly from each other but were inferior to the rest of the treatments. Treatment T3 (seed treatment with imidacloprid 17.8 SL) exhibited a middle level of efficacy with 3.0 per cent plant damage, comparable to T7 (soil application of fipronil 0.3 G) and T5 (seed treatment with fipronil 5 SC).

During the second year, i.e., *Rabi* 2021-22 (Table 2 and Fig. 2), all pesticidal treatments proved superior compared to the untreated check. The minimum termite damage (0.84%) was observed in treatment T4 (seed treatment and soil application of imidacloprid 17.8 SL after 60 DAS), followed by 0.95 per cent in T6 (seed treatment and soil application of fipronil 5 SC after 60 DAS). These treatments were highly effective and showed no significant difference. Moderately effective treatments included T2 (seed treatment and soil application of chlorpyriphos 20 EC after 60 DAS), T7 (soil application of fipronil 0.3 G), and T3 (seed treatment with imidacloprid 17.8 SL). However, there was no significant difference between T2 and T6, nor among T7, T3, and T5. The maximum termite damage (3.59%) was recorded in T1 (seed treatment with chlorpyriphos 20 EC), followed by 3.10 per cent in T5 (seed treatment with fipronil 5 SC). These treatments were the least effective and did not differ statistically.

The pooled analysis of data indicated that all insecticidal treatments significantly minimized termite damage compared to the untreated check (Table 3 and Fig. 3). The minimum termite damage (0.91%) was recorded in treatment T4 (seed treatment and soil application of imidacloprid 17.8 SL after 60 DAS), followed by 1.02 per cent in T6 (seed treatment and soil application of fipronil 5 SC after 60 DAS). These treatments were statistically similar and proved superior to the rest. The next moderately effective treatment was T2 (seed treatment and soil application of chlorpyriphos 20 EC after 60 DAS) with 1.27 per cent termite damage, which did not differ significantly from T6. The maximum termite damage (3.71%) was

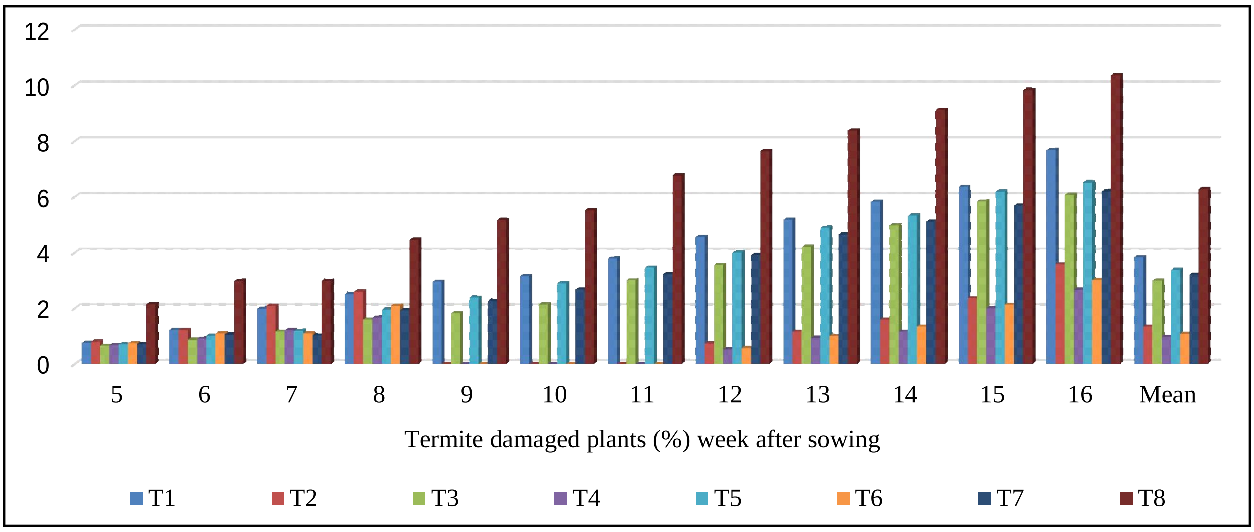

Fig. 1. Effect of insecticides application on plant damage during *rabi* 2020-21.

TABLE 1

Effect of insecticides application on plant damage during *rabi* 2020-21

Detail of treatments	Termite damaged plants (%) week after sowing												Mean
	5	6	7	8	9	10	11	12	13	14	15	16	
T1–Seed treatment with	0.77	1.22	1.99	2.52	2.96	3.16	3.79	4.56	5.18	5.83	6.36	7.67	3.83
Chlorpyriphos 20 EC	(5.00)	(6.32)	(8.09)	(9.11)	(9.91)	(10.23)	(11.21)	(12.31)	(13.16)	(13.96)	(14.59)	(16.08)	(11.29)
T2–T1 + soil application of	0.80	1.22	2.09	2.60	0.00	0.00	0.00	0.74	1.16	1.60	2.36	3.58	1.35
Chlorpyriphos 20 EC 60 DAS	(5.11)	(6.34)	(8.31)	(9.28)	(0.00)	(0.00)	(0.00)	(4.92)	(6.17)	(7.24)	(8.77)	(10.80)	(6.66)
T3–Seed treatment with	0.66	0.87	1.17	1.60	1.83	2.14	3.01	3.56	4.21	4.98	5.84	6.07	3.00
imidacloprid 17.8 SL	(4.67)	(5.34)	(6.20)	(7.26)	(7.78)	(8.40)	(9.98)	(10.81)	(11.85)	(12.89)	(13.97)	(14.26)	(9.97)
T4–T3 + soil application of	0.68	0.91	1.22	1.67	0.00	0.00	0.00	0.53	0.94	1.16	2.00	2.67	0.98
imidacloprid 17.8 SL 60 DAS	(4.73)	(5.42)	(6.35)	(7.42)	(0.00)	(0.00)	(0.00)	(3.42)	(5.56)	(6.14)	(8.12)	(9.36)	(5.68)
T5–Seed treatment with fipronil	0.71	1.02	1.19	1.95	2.39	2.90	3.46	4.00	4.89	5.33	6.19	6.52	3.38
5 SC	(4.82)	(5.79)	(6.23)	(8.00)	(8.87)	(9.78)	(10.70)	(11.51)	(12.73)	(13.29)	(14.36)	(14.74)	(10.57)
T6–T5 + soil application of	0.75	1.10	1.10	2.09	0.00	0.00	0.00	0.57	1.01	1.35	2.13	3.02	1.09
fipronil 5 SC 60 DAS	(4.96)	(6.01)	(5.99)	(8.30)	(0.00)	(0.00)	(0.00)	(4.26)	(5.76)	(6.66)	(8.39)	(9.99)	(6.00)
T7–Soil application of fipronil	0.72	1.06	1.03	1.94	2.27	2.68	3.23	3.91	4.65	5.11	5.69	6.20	3.21
0.3 G	(4.85)	(5.79)	(5.71)	(7.97)	(8.63)	(9.42)	(10.53)	(11.39)	(12.43)	(13.06)	(13.78)	(14.41)	(10.32)
T8–Control/ Untreated check	2.15	2.99	2.99	4.47	5.17	5.52	6.77	7.64	8.38	9.12	9.83	10.36	6.28
	(8.41)	(9.94)	(9.94)	(12.14)	(13.05)	(13.48)	(14.98)	(15.97)	(16.76)	(17.53)	(18.23)	(18.76)	(14.47)
S.Em.±	0.28	0.42	0.44	0.51	0.46	0.49	0.48	0.66	0.51	0.56	0.87	0.6	0.36
C.D. at 5%	0.86	1.27	1.33	1.54	1.39	1.49	1.44	2.00	1.53	1.69	2.03	1.99	1.10
C.V. %	9.28	11.40	10.66	10.10	13.16	13.29	11.51	12.26	8.30	8.49	9.27	8.38	6.71

Figures in parentheses are arcsine value.

TABLE 2
Effect of insecticides application on plant damage during *rabi* 2021-22

Detail of treatments	Termite damaged plants (%) week after sowing												Mean
	5	6	7	8	9	10	11	12	13	14	15	16	
T1–Seed treatment with	0.65	1.12	1.85	2.31	2.71	2.91	3.80	3.95	4.93	5.34	6.07	7.46	3.59
Chlorpyriphos 20 EC	(4.57)	(6.06)	(7.81)	(8.71)	(9.48)	(9.75)	(11.24)	(11.45)	(12.82)	(13.34)	(14.21)	(15.84)	(10.92)
T2–T1 + soil application of	0.73	1.08	1.71	2.26	0.00	0.00	0.00	0.51	1.08	1.46	2.09	3.19	1.18
Chlorpyriphos 20 EC 60 DAS	(4.91)	(5.96)	(7.46)	(8.61)	(0.00)	(0.00)	(0.00)	(4.03)	(5.96)	(6.92)	(8.28)	(10.25)	(6.22)
T3–Seed treatment with	0.57	0.89	1.03	1.45	1.69	2.06	3.01	3.38	4.06	4.59	5.58	5.91	2.85
imidacloprid 17.8 SL	(4.27)	(5.40)	(5.72)	(6.90)	(7.46)	(8.24)	(9.99)	(10.58)	(11.60)	(12.32)	(13.64)	(14.07)	(9.72)
T4–T3 + soil application of	0.54	0.78	0.97	1.54	0.00	0.00	0.00	0.38	0.80	1.18	1.70	2.22	0.84
imidacloprid 17.8 SL 60 DAS	(4.19)	(5.06)	(5.62)	(7.11)	(0.00)	(0.00)	(0.00)	(2.90)	(5.04)	(6.19)	(7.49)	(8.56)	(5.27)
T5–Seed treatment with fipronil	0.59	0.79	1.10	1.65	1.92	2.42	3.38	3.69	4.51	5.01	5.92	6.25	3.10
5 SC	(4.35)	(5.07)	(6.00)	(7.37)	(7.94)	(8.91)	(10.58)	(11.05)	(12.23)	(12.88)	(14.07)	(14.41)	(10.14)
T6–T5 + soil application of	0.61	0.85	1.05	1.58	0.00	0.00	0.00	0.50	0.92	1.29	1.94	2.62	0.95
fipronil 5 SC 60 DAS	(4.43)	(5.28)	(5.87)	(7.21)	(0.00)	(0.00)	(0.00)	(4.01)	(5.43)	(6.51)	(8.00)	(9.23)	(5.58)
T7–Soil application of fipronil	0.58	0.80	0.99	1.45	1.62	1.93	3.00	3.35	3.97	4.56	5.55	5.73	2.79
0.3 G	(4.32)	(5.11)	(5.66)	(6.85)	(7.28)	(7.97)	(9.93)	(10.54)	(11.47)	(12.33)	(13.60)	(13.84)	(9.62)
T8–Control/ Untreated check	1.97	2.58	3.01	4.11	4.86	5.35	6.75	7.22	8.00	8.82	9.80	10.11	6.05
	(8.07)	(9.22)	(9.98)	(11.70)	(12.62)	(13.35)	(14.98)	(15.51)	(16.41)	(17.28)	(18.22)	(18.52)	(14.22)
S.Em.±	0.33	0.34	0.41	0.43	0.43	0.45	0.47	0.65	0.46	0.52	0.59	0.63	0.22
C.D. at 5%	1.02	1.04	1.23	1.29	1.29	1.37	1.44	1.96	1.39	1.57	1.80	1.91	0.67
C.V. %	11.87	10.08	10.42	9.17	13.17	12.95	11.60	12.77	7.84	8.18	8.41	8.33	4.30

Figures in parentheses are arcsine value.

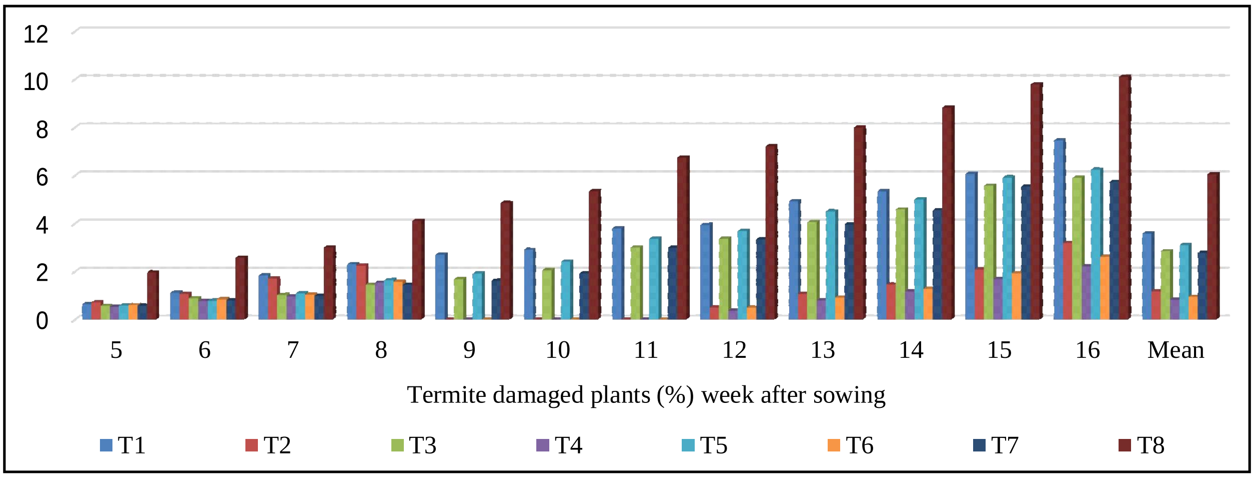

Fig. 2. Effect of insecticides application on plant damage during *rabi* 2021-22.

recorded in T1 (seed treatment with chlorpyriphos 20 EC), followed by 3.24 per cent in T5 (seed treatment with fipronil 5 SC). These treatments were statistically comparable to each other. The moderately effective treatments were T3 (seed treatment with imidacloprid 17.8 SL), T7 (soil application of fipronil 0.3 G), and T5 (seed treatment with fipronil 5 SC), with termite damage rates (2.93%, 3.00%, and 3.24%), respectively. These treatments did not differ statistically from each other.

Effect of insecticides on the seed yield of wheat

The data presented in Table 3 and Fig. 3 revealed that insecticidal treatments significantly increased wheat seed yield compared to the untreated control in both years. During the first year, *rabi* 2020-21, the highest seed yield (21.71 q/ha) was obtained from plots treated with T4 (seed treatment and soil application of Imidacloprid 17.8 SL after 60 DAS), followed by 20.95 q/ha in T6 (seed treatment and soil application of Fipronil 5 SC after 60 DAS), and 19.43 q/ha in T2 (seed treatment and soil application of Chlorpyriphos 20 EC after 60 DAS). These treatments were significantly superior to the rest, with T4 statistically on par with T6, and T6 with T2. A yield of 16.75 q/ha was obtained from the moderately effective treatment T7 (soil application of Fipronil 0.3 G). The lowest seed yield (10.29 q/ha) was recorded in plots treated with T1 (seed treatment with Chlorpyriphos 20 EC), followed by 12.57 q/ha in T5 (seed treatment with Fipronil 5 SC), and 13.71 q/ha in T3 (seed treatment with Imidacloprid 17.8 SL), with no significant difference between T5 and T3.

A similar trend was observed in the second year, *rabi* 2021-22. The maximum seed yield (36.95 q/ha) was obtained from plots treated with T4, followed by 34.29 q/ha in T6. The minimum seed yield (28.57 q/ha) was recorded in plots treated with T1.

The pooled data indicated that all insecticidal treatments significantly increased seed yield compared to the untreated control (15.81 q/ha). The highest seed yield (29.33 q/ha) was recorded in T4 (seed treatment and soil application of Imidacloprid 17.8 SL after 60 DAS), followed by 27.62 q/ha in T6 (seed treatment and soil application of Fipronil 5 SC after 60 DAS), and 26.29 q/ha in T2 (seed treatment and soil application of Chlorpyriphos 20 EC after 60 DAS). These treatments were significantly superior to the rest, with T4 statistically on par with T6, and T6 with T2. The moderately effective treatment T7 (soil application of Fipronil 0.3 G) yielded 24.19 q/ha. There was no significant difference between T2 and T7, and between T7 and T3. The lowest seed yield (19.43 q/ha) was recorded in plots treated with T1 (seed treatment with Chlorpyriphos 20 EC), followed by 20.76 q/ha in T5 (seed treatment with Fipronil 5 SC), and 21.71 q/ha in T3 (seed treatment with Imidacloprid 17.8 SL), with no significant difference among the least effective treatments.

Effect of insecticides on the straw yield of wheat

The data presented in Table 3 and Fig. 3 reveals that insecticidal treatments significantly increased the straw yield of wheat compared to the untreated control in both years. During the first year (*rabi* 2020-21), the highest straw yield (39.62 q/ha) was obtained from plots treated with T4 (seed treatment and soil application of Imidacloprid 17.8 SL after 60 DAS), followed by 38.48 q/ha in T6 (seed treatment and soil application of Fipronil 5 SC after

TABLE 3

Effect of insecticides application on plant damage and yield during *rabi* 2020-21 and 2021-22

Detail of treatments	Mean Termite damaged plants (%)			Yield (q/ha)					
				Grain			Straw		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T1–Seed treatment with Chlorpyriphos 20 EC	3.83 (11.29)	3.59 (10.92)	3.71 (11.11)	10.29	28.57	19.43	32.00	34.29	33.15
T2–T1 + soil application of Chlorpyriphos 20 EC 60 DAS	1.35 (6.66)	1.18 (6.22)	1.27 (6.44)	19.43	33.14	26.29	37.33	39.62	38.48
T3–Seed treatment with imidacloprid 17.8 SL	3.00 (9.97)	2.85 (9.72)	2.93 (9.85)	13.71	29.71	21.71	33.90	36.19	35.05
T4–T3 + soil application of imidacloprid 17.8 SL 60 DAS	0.98 (5.68)	0.84 (5.27)	0.91 (5.48)	21.71	36.95	29.33	39.62	41.90	40.76
T5–Seed treatment with fipronil 5 SC	3.38 (10.57)	3.10 (10.14)	3.24 (10.36)	12.57	28.95	20.76	32.38	34.67	33.53
T6–T5 + soil application of fipronil 5 SC 60 DAS	1.09 (6.00)	0.95 (5.58)	1.02 (5.79)	20.95	34.29	27.62	38.48	40.76	39.62
T7–Soil application of fipronil 0.3 G	3.21 (10.32)	2.79 (9.62)	3.00 (9.97)	16.76	31.62	24.19	35.05	37.33	36.19
T8–Control/ Untreated check	6.28 (14.47)	6.05 (14.22)	6.17 (14.35)	7.24	24.38	15.81	22.86	30.10	26.48
S.Em.±	0.36	0.22	0.29	0.73	1.25	0.99	1.62	1.61	1.62
C.D. at 5%	1.10	0.67	0.89	2.20	3.80	3.00	4.91	4.89	4.90
C.V. %	6.71	4.30	5.37	8.19	7.02	7.00	8.27	7.57	7.02

Figures in parentheses are arcsine value.

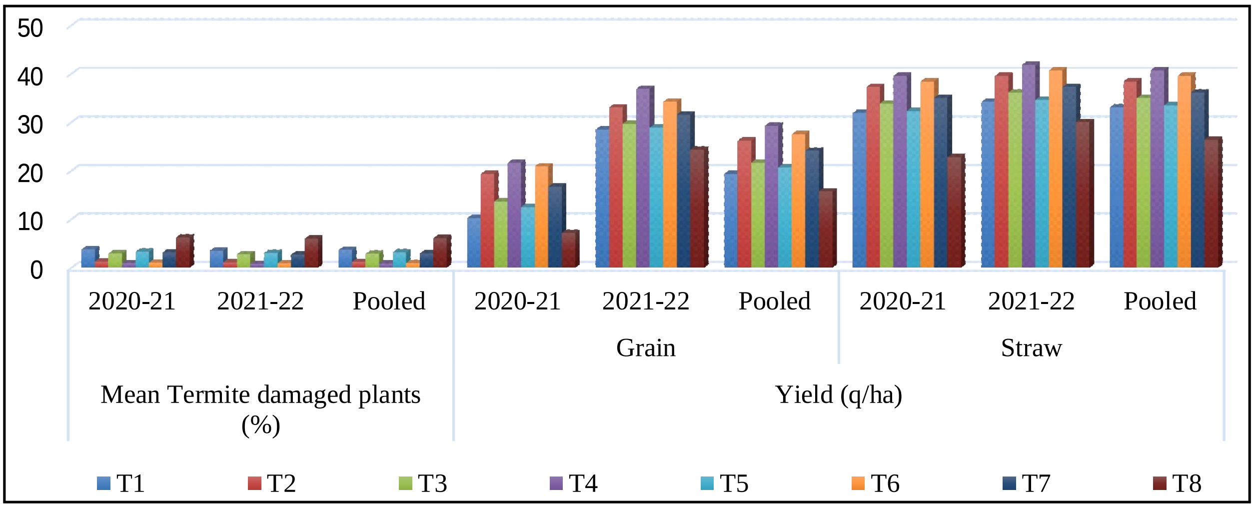

Fig. 3. Effect of insecticides application on plant damage and yield during *rabi* 2020-21 and 2021-22.

60 DAS) and 37.33 q/ha in T2 (seed treatment and soil application of Chlorpyriphos 20 EC after 60 DAS). These treatments were significantly superior to the rest and remained statistically at par with each other. A straw yield of 35.05 q/ha was obtained from the moderately effective treatment T7 (soil application of Fipronil 0.3 G). The lowest straw yield (32.0 q/ha) was recorded in plots treated with T1 (seed treatment with Chlorpyriphos 20 EC), followed by 32.38 q/ha in T5 (seed treatment with Fipronil 5 SC) and 33.90 q/ha in T3 (seed treatment with Imidacloprid 17.8 SL), with no significant difference among these treatments.

In the second year (*rabi* 2021-22), a similar trend was observed. The highest straw yield (41.90 q/ha) was obtained from plots treated with T4, followed by 40.76 q/ha in T6. The lowest straw yield (34.29 q/ha) was recorded in plots treated with T1.

The pooled data indicates that all insecticidal treatments significantly increased straw yield compared to the untreated control (26.48 q/ha). The highest straw yield (40.76 q/ha) was recorded in T4 (seed treatment and soil application of Imidacloprid 17.8 SL after 60 DAS), followed by 39.62 q/ha in T6 (seed treatment and soil application of Fipronil 5 SC after 60 DAS) and 38.48 q/ha in T2 (seed treatment and soil application of Chlorpyriphos 20 EC after 60 DAS). These treatments were significantly superior to the rest with no significant difference among them. The moderately effective treatment T7 (soil application of Fipronil 0.3 G) yielded 36.19 q/ha. The lowest straw yield (33.15 q/ha) was recorded in plots treated with T1 (seed treatment with Chlorpyriphos 20 EC), followed by 33.53 q/ha in T5 (seed treatment with Fipronil 5 SC) and 35.05 q/ha in T3 (seed treatment with Imidacloprid 17.8 SL), with no significant difference among these least effective treatments.

Assessment the economic impact of insecticidal treatments on wheat yield

When assessing the utility of insecticides in pest management, it is crucial to consider not only their potency against target pests and the duration of crop protection but also the economics of the treatments. Hence, the benefit-cost ratio was also calculated in this study.

The pooled results indicated that the treatment T4 (seed treatment and soil application of imidacloprid 17.8 SL after 60 DAS) resulted in zero percent avoidable losses in grain and straw yields compared to the untreated control (Table 4). This was followed by T6 (seed treatment and soil application of fipronil 5 SC after 60 DAS) and T2 (seed treatment and soil application of chlorpyriphos 20 EC after 60 DAS), with avoidable losses of 5.83% & 2.80% and 10.36% & 5.59%, respectively. Treatments T7 (soil application of fipronil 0.3 G) and T3 (seed treatment with imidacloprid 17.8 SL) resulted in avoidable losses of 17.52% & 11.21% and 25.98% & 14.01%, respectively. The highest avoidable losses in grain and straw yields (46.10% & 35.03%) were recorded in the untreated control, followed by T1 (seed treatment with chlorpyriphos 20 EC) and T5 (seed treatment with fipronil 5 SC), with corresponding figures of 33.75% & 18.67% and 29.22% & 17.74%, respectively.

The maximum increase in grain and straw yields over the untreated control (46.10% & 35.03%) was recorded in the plots treated with T4. This was followed by T6 and T2, with increases of 42.76% & 33.17% and 39.86% & 31.19%, respectively. The minimum increases in grain and straw yields over the untreated control (18.63% & 20.12%) were recorded in T1, followed by T5 with figures of 23.84% & 21.03%. Treatments T7 and T3 recorded increases in grain and straw yields of 34.64% & 26.83% and 27.18% & 24.45%, respectively.

The data also revealed that the maximum net profit (Rs. 40,424.00) was recorded in the T4 treatment, followed by T6 (Rs. 33,301.00) and T2 (Rs. 32,150.00). Other treatments, such as T7, T3, and T1, recorded net profits of Rs. 27,714.00, Rs. 24,295.00, and Rs. 19,240.00, respectively.

An analysis of the pooled data showed the maximum benefit-cost ratio (2.28) for the T4 treatment, followed by T2 (1.97), T6 (1.95), and T7 (1.85). The minimum benefit-cost ratio (1.63) was recorded in T1, followed by T5 (1.68) and T3 (1.79).

Comparative discussion with earlier findings

The current research evaluated the efficacy of popular pesticides against termite damage in wheat. The findings indicated that all pesticidal treatments were effective in managing termites through both seed treatment and standing crop treatment. Among all treatments, the T4 treatment (seed treatment and soil application of imidacloprid 17.8 SL after 60 DAS) resulted in the least plant damage, highest grain yield, highest straw yield, and maximum benefit-cost ratio. This was followed by the T6 treatment (seed treatment and soil application of fipronil 5 SC after 60 DAS) and the T2 treatment (seed treatment and soil application of chlorpyriphos 20 EC after 60 DAS), which also proved superior to other treatments. The T7 treatment (soil application of fipronil 0.3 G) was moderately effective, while the T1 treatment (seed treatment with chlorpyriphos 20 EC) was less effective.

Kumar *et al.* (2020) evaluated different pesticides as seed treatment against termite in wheat at Bikaner and found Imidacloprid 600 FS @ 3 ml/kg seed was found to be the most effective. The treatments of Chlorpyriphos 20 EC @ 4.5 ml/kg, Fipronil 5 SC @ 5 ml/kg and Imidacloprid 17.8 SL @ 3 ml/kg seed were found moderately effective against termites and significantly superior over rest of the treatments. Similarly, Kumar et al. (2018) conducted a field demonstration on seed treatment with Fipronil 5 SC @ 6 ml/kg seed before sowing and soil treatment with Fipronil 5 SC @ 1.6 l/ha at farmers' fields in the adopted village of KVK, Patan (Gujarat). They observed a 53.46 per cent reduction in termite infestation, resulting in an 18.92 per cent increase in wheat crop productivity.

TABLE 4

Assessment of losses caused by termite and comparative economics of treatments in wheat during *rabi*, 2020-21 and 2021-22 (Pooled)

Detail of treatments	Yield (q/ha)		Per cent increase in yield over untreated check		Per cent avoidable losses		Total cost of expenditure (Rs/ha)*	Total gross income (Rs/ha)**	Net profit (Rs/ha)	B : C ratio
	Grain	Straw	Grain	Straw	Grain	Straw				
T1–Seed treatment with Chlorpyriphos 20 EC	19.43	33.15	18.63	20.12	33.75	18.67	30665	49905	19240	1.63
T2–T1 + soil application of Chlorpyriphos 20 EC 60 DAS	26.29	38.48	39.86	31.19	10.36	5.59	33065	65215	32150	1.97
T3–Seed treatment with imidacloprid 17.8 SL	21.71	35.05	27.18	24.45	25.98	14.01	30745	55040	24295	1.79
T4–T3 + soil application of imidacloprid 17.8 SL 60 DAS	29.33	40.76	46.10	35.03	0.00	0.00	31545	71969	40424	2.28
T5–Seed treatment with fipronil 5 SC	20.76	33.53	23.84	21.03	29.22	17.74	31295	52637	21342	1.68
T6–T5 + soil application of fipronil 5 SC 60 DAS	27.62	39.62	42.76	33.17	5.83	2.80	34920	68221	33301	1.95
T7–Soil application of fipronil 0.3 G	24.19	36.19	34.64	26.83	17.52	11.21	32575	60289	27714	1.85
T8–Control/ Untreated check	15.81	26.48	0.00	0.00	46.10	35.03	30425	40429	10004	1.33

* It includes cost of cultivation, cost of insecticides and labour charges.

** Market price of wheat was Rs. 1950 per q. and market price of straw was Rs. 362.5 per q.

Kambrekar *et al.* (2016), conducted an experiment to evaluate the efficacy of different dosages of Fipronil 0.3 GR against termites in wheat and observed that Fipronil 0.3 GR @ 20 kg/ha recorded maximum reduction in tiller damage and higher grain yield of wheat. Singh et al. (2004) also reported that Imidacloprid 600 FS @ 10 ml/kg seed treatment was the most effective, resulting in the least plant damage and the highest pearl millet grain yield. Seed treatment with Chlorpyriphos 20 EC was found effective and economical for managing termites in wheat. Mishra *et al.* (2007) evaluated various insecticides (Endosulfan, Monocrotophos, Chlorpyriphos, Imidacloprid, Carbaryl, Quinalphos, and Methyl-parathion) as seed treatments at different dosages (2.5, 2.5, 5.0, 2.0, 4.0, 2.5, and 2.5 ml/kg seeds, respectively) for controlling *O. obesus* and *M. obesi* infesting wheat in Uttar Pradesh. The highest plant stands, minimum infested tillers due to termites, and maximum grain yield were obtained with Imidacloprid @ 2.0 ml/kg, followed by Chlorpyriphos @ 5 ml/kg seed, whereas Carbaryl was least effective. Similarly, Sundriya and Acharya (2012) studied the eco-friendly management of termites in wheat and found that Imidacloprid 70 WS @ 10 g/kg seeds as seed treatment provided effective control.

CONCLUSION

Based on the results summarized above, it can be concluded that among the different treatments, the seed treatment with imidacloprid 17.8 SL was found to be the most effective, followed closely by fipronil 5 SC. The T4 treatment, which involved seed treatment and soil application of imidacloprid 17.8 SL after 60 days after sowing (DAS), exhibited the minimum termite damage throughout the cropping season. This treatment not only minimized plant damage but also resulted in the highest grain yield, highest straw yield, and the maximum benefit-cost ratio. Following T4, the T6 treatment (seed treatment and soil application of fipronil 5 SC after 60 DAS) also demonstrated significant efficacy in reducing termite damage and enhancing crop yield. These results suggest that the combined approach of seed treatment and soil application, particularly with imidacloprid 17.8 SL and fipronil 5 SC, provides a robust strategy for managing termite infestations in wheat crops. Furthermore, other treatments such as T2 (seed treatment and soil application of chlorpyriphos 20 EC after 60 DAS) also showed effectiveness but were less impactful compared to T4 and T6. The T7 treatment (soil application of fipronil 0.3 G) was moderately effective, indicating that while it can manage termite damage to some extent, it is not as efficient as the aforementioned treatments. Lastly, the T1 treatment (seed treatment with chlorpyriphos 20 EC) was found to be the least effective among the evaluated methods. In conclusion, integrating seed treatment with soil application of imidacloprid 17.8 SL or fipronil 5 SC after 60 DAS stands out as the most effective strategy for controlling termite damage in wheat crops, ensuring higher yields and better economic returns.

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