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Ajay Kumar
Department of Agriculture, Faculty of Science, Jagannath University, Jaipur, Rajasthan, India

Dr. Veer Singh
Department of Entomology, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan, India

Dr. Hem Singh
Department of Entomology, College of Agriculture, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India

Corresponding Author:
Ajay Kumar
Department of Agriculture, Faculty of Science, Jagannath University, Jaipur, Rajasthan, India

Efficacy of different insecticidal seed treatments against termite in wheat (*Triticum aestivum* L.) in arid eco-system of Rajasthan

Ajay Kumar, Dr. Veer Singh and Dr. Hem Singh

Abstract
The research experiment was conducted at Research Farm of College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner (Rajasthan) during *rabi* 2013-14. The efficacy of nine insecticide *viz.* Bifenthrin 10 EC, Chlorpyriphos 20 EC, Clothianidin 50 WDG, Cypermethrin 25 EC, Fipronil 5 SC, Imidacloprid 600 FS, Imidacloprid 17.8 SL, Quinalphos 25 EC and Thiamethoxam 35 FS were evaluated as seed treatment against termite in wheat. Out of these insecticides Imidacloprid 600 FS @ 3 ml/kg seed was found to be the most effective followed by Bifenthrin 10 EC @ 2 ml/kg and Clothianidin 50 WDG @ 2 gm/kg seed. The treatments of Thiamethoxam 35 FS @ 3 ml/kg, 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. The treatments of Quinalphos 25 EC @ 5 ml/kg and Cypermethrin 25 EC @ 2ml/kg seed were found to be the least effective against termite management in wheat crop.

Keywords: Insecticides, efficacy, wheat, termite, seed treatment

Introduction
Wheat [*Triticum aestivum* (Linnaeus) Em. Thell] belongs to family Gramineae, believed to have originated from South West Asia. It is most important cereal cultivated crop in temperate area of the world. Wheat is second important staple food crop after rice. Its value in human diet, both as a source of carbohydrates and protein and its baking qualities make it relatively more important crop than other cereal grains. Wheat flour is used in the form of *chapatti*, *puri*, *bread*, *cake*, *sweetmeats*, *halwa*, etc. It provides characteristic substance "Gluten" which is very essential for bakers. Wheat straw is also used in paper industries and for making temporary huts and roof. The bran, husk and other portion of grain and straw are valuable feed for livestock as well as good source of bedding material for livestock. The ripe unthreshing ear heads are used to decorate items. It provides 20 percent of total calories for human. Wheat grain contains 12.2 percent protein, which is more than other cereals. Wheat is one of the leading cereal crops which have provided daily sustenance for a large proportion of the world's population for millennia.

There are many biotic constraints that hamper wheat production of which infestation of insect pests is major one. Wheat crop is attacked by 24 species of insect pests (Singh, 1998) [11]. Major insect pests of wheat are termite, *Odontotermes obesus* (Rambur), gujhia weevil, *Tanymecus indicus* (Faust), cutworm, *Agrotis ipsylon* (Hufnagel), brown wheat mite, *Petrobia lateens* (Muller), armyworm, *Mythimna separate* (Walker), thrips, *Anapothrips flavicinctus* (Karny), aphids, *Macrosiphum granarium*(Kirby), shoot fly, *Anthericona soccata* (Rondani), stem borer, *Sesamia inferens* (Walker), surface grasshopper, *Atractomorpha crenulata* (Fabrikins), desert locust, *Schistocerca gregaria*(Forkall), stink bug, *Aelia eostrata* (Boheman), cereal leaf beetle, *Oulema melanopa*(Linnaeus), hessian fly, *Mayetiola destructor* (Say), wheat stem maggot, *Meromyze americana* (Fitch), sawfly, *Cephus cinctus* (Nort), white grub, *Holotrichia consanguinea* (Blanch), wireworm, *Agroites mancus* (Say), cricket, *Gryllodes sigillatus*, (Linnaeus) and stalk borer, *Chilo auricilius* (Dudgeon). It is calculated the loss due to termite up to 230 million rupees for all the agricultural crops (Mehta and Verma, 1968) [13]. Out of these pests, termite ranks first as a pest of wheat not only in India but South Asia too as per the pest ranking system developed by Natural Resource Institute, UK (Geddes and Iles, 1991) [4].

Tanymecus indicus and *Microtermes obesi* were the main insect pest of wheat, damaging 14 and 20 percent of the plants, respectively in Uttar Pradesh (Kishen *et al*., 1972) [7]. *Microtermes obesi* caused a significant reduction of 1.67 percent in grain yield. About 16 species of termite were found to damage the wheat crop in India, of these two species, *Odontotermes obesus* (Rambur) and *Microtermes obesi* (Holm) are found dominant, which caused 80 percent loss in south Asia (Chhillar *et al.*, 2006) [2].

Materials and Methods

The field experiment was conducted at Research farm, Collage of Agriculture, Swami Keshwanad Rajasthan Agricultural University, Bikaner (Rajasthan) during *rabi* season 2013-14. The climate of this zone is typically arid, characterized with low rain and wide range of temperature in summer and winter. The experimental land was ploughed and levelled with heavy plank 15 days before sowing the crop. Farm Yard Manure (FYM) 300 q ha^{-1} and chemical fertilizers were applied as per recommended package of practices of the zone (120 kg N, 60 kg P, 40 kg K). The seed rate used was 120 kg ha^{-1} and sowing was done in furrows, opened with manually operated hand driven plough at row to row spacing of 20 cm at 5 cm depth. Irrigation was applied at an interval of 15 days by the sprinkler system. First irrigation was applied after 20 days of sowing.

An experiment on evaluation of nine different insecticides against termites as seed treatment was conducted in a simple randomized block design. There were 10 treatments (Bifenthrin 10 EC, Chlorpyriphos 20 EC, Clothianidin 50 WDG, Cypermethrin 25 EC, Fipronil 5 SC, Imidacloprid 600 FS, Imidacloprid 17.8 SL, Quinalphos 25 EC and Thiamethoxam 35 FS) including untreated control and each treatment was replicated three times. Wheat variety Raj-3077 was sown during 25th November 2013 in the plot size of 3.0 x 2.0 m keeping 20 cm row to row spacing. The crop was raised successfully by adopting standard recommended agronomical practices. The wheat seeds were treated with respective insecticides by using 50 ml of water before 12 hours of sowing. Germination counts were recorded from 2 m length area of each plot after 10 days of sowing to know the effect of insecticides on seeds. The tillers were recorded from 10 randomly selected plants from each plot after 28 days of germination. For recording observations on termite incidence, infested and healthy plants were counted at weekly interval from 3 m length (each of 1 m) of each plot starting from one week of germination till the harvest of the crop. The Eucalyptus sticks were installed at a depth of 15 cm in each plot and termite counts were recorded from the sticks at weekly interval and again reinstalled the sticks. The tillers of different cultivars were also recorded from randomly selected 10 plants from each plot at 28 days after germination. The grain and straw yield of each variety was recorded from each plot after harvesting and separating the grain. All the experimental plots were kept free from any pesticidal application. The grain and straw yield of each treatment was recorded from each plot after harvesting and separating the grain.

The periodical data on population of termites were subjected to analysis of variance (ANOVA) after transforming them to square root value. The data on percent infestation were analyzed statistically after transforming them to arcsine value. The data were analyzed periodically.

Results and Discussion

Effect of various insecticides as seed treatment against termite in wheat

Termite damage

Nine different insecticides presented in Table 1 were evaluated for their efficacy as a seed treatment against termite in wheat. All the insecticidal treatments were found significantly superior to control till 15th week after sowing. There was no pest incidence up to 4th week of crop age. After 5th week after sowing, the lowest (0.57%) termite damage was noted in plots treated with Imidacloprid 600 FS and it was statistically at par with Bifenthrin 10 EC (0.84%), Clothianidin 50 WDG (0.92%) and Thiamethoxam (1.01%). Imidacloprid 17.8 SL (1.19%) was found equally effective as Thiamethoxam but also at par with Chlorpyriphos 20 EC (1.40%) and fipronil 5 SC (1.45%). The highest (2.16%) damaged plants observed in seed treated with Cypermethrin 25 EC and it was at par with Quinalphos 25 EC (2.03%).

Seed treatment of Imidacloprid 600 FS (0.92%) was found significantly superior in controlling the termite in wheat among all the evaluated insecticidal seed treatments except Bifenthrin 10 EC (1.09%) and Clothianidin 50 WDG (1.36%) after 6th week after sowing. Thiamethoxam 35 FS and Imidacloprid 17.8 SL registered 1.62 and 2.21 percent damage of termite in wheat, respectively and were found superior than rest of the insecticides. Fipronil (2.02%) and Chlorpyriphos 20 EC (2.16%) were equally effective against the pest and superior to Quinalphos and Cypermethrin. Among the evaluated insecticides as seed treatment, the highest (3.16%) damage was observed in the plots treated with Cypermethrin and it was at par with Quinalphos (3.10%).

After 7th week after sowing, the lowest (1.19%) termite damage was noted in plots treated with Imidacloprid 600 FS and it was at par with Bifenthrin 10EC (1.25%) and Clothianidin 50 WDG (1.82%). The treatment of Thiamethoxam 35 FS (2.04%) was statistically equally effective as Clothianidin 50 WDG (1.82%) and it was at par with Chlorpyriphos (2.40%). Imidacloprid 17.8 SL (3.20%) and Fipronil 5 SC (3.07) were equally effective as Chlorpyriphos against the pest (Table 1). The highest (4.36%) termite damage was noticed in plots treated with Cypermethrin 25 EC and it was at par with Quinalphos (4.32%).

After 8th to 11th week after sowing more or less similar trend of effectiveness was observed in suppression of termites in wheat crop. In which, the lowest (1.40-2.86%) damage was registered in Imidacloprid 600 FS and it was statistically at par with Bifenthrin 10 EC (1.56-3.17%) and Clothianidin 50 WDG (2.36-4.86%). These three treatments were found significantly superior than all the evaluated insecticides. Thiamethoxam 35 FS were found at par with above tested insecticides in controlling the termite in wheat in 8th and 9th week after sowing. Imidacloprid 17.8 SL, Chlorpyriphos 20 EC and Fipronil 5 SC were at par with each other and found more effective than remaining two insecticides (Quinalphos and Cypermethrin). Among the tested insecticidal seed treatments, the highest (5.52-13.09%) damage was noticed in the treatment of Cypermethrin and it was at par with and Quinalphos 25 EC.

Seed treated with Imidacloprid 600 FS (3.77%) was found superior in controlling the termite in wheat than all the evaluated insecticidal seed treatments except Bifenthrin 10 EC (4.12%) after twelve week after sowing. The treatment of

Clothianidin 50 WDG and Thiamethoxam 35 FS registered 6.55 and 7.47 percent plant damage in wheat, respectively and found statistically at par to each other but significantly differ with the treatment of Imidacloprid 600 FS. Chlorpyriphos (9.71%), Fipronil (10.09%) and Imidacloprid 17.8 SL were found at par with each other against the pest and superior to remaining two insecticides (Quinalphos and Cypermethrin). Out of the tested insecticides as seed treatment, the highest (18.30%) damage was observed in the treatment of Cypermethrin 10 EC and it was at par with Quinalphos (16.26%). All the insecticidal treatments were found statistically superior to control.

Minimum (4.63%) damage of pest was found after thirteen week after sowing in the treatment of Imidacloprid 600 FS and it was significantly at par with Bifenthrin 10 EC (4.85%) and Clothianidin 50 WDG (7.62%) and these treatments were found superior to rest of the treatments (Table 4.6). Thiamethoxam 35 FS (11.17%), Chlorpyriphos 20 EC (11.66%), Fipronil 5 SC (11.74%) and Imidacloprid 17.8 SL (13.08%) were equally effective in managing the termite in wheat and more effective than remaining insecticidal treatments. Among the tested insecticides as seed treatment, the highest (23.11%) damage was observed in the treatment of Cypermethrin followed by Quinalphos (21.55%) but found significantly superior over control.

After fourteen and fifteen week after sowing, more or less similar trend of effectiveness was observed against termite damage in wheat crop (Table 1). The lowest plant damage 5.39 - 6.22 percent was found in Imidacloprid 600 FS and it was at par Bifenthrin 10 EC in which damage was 5.89 - 6.68 percent and Clothianidin 50 WDG in which the percent plant was damage 9.08 - 10.27 in the subsequent weeks. These insecticidal treatments were found significantly superior to rest of the insecticides. Thiamethoxam 600 FS, Chlorpyriphos 20 EC, Fipronil 5 SC and Imidacloprid 17.8 SL were equally effective in checking the termite incidence and they were significantly superior to the remaining two insecticides (Quinalphos and Cypermethrin). The highest damage was noticed in Cypermethrin treated plots and it was at par with Quinalphos.

Table 1: Effect of seed treatment against termite damage in wheat

Treatments	Termite damaged plants (%) week after sowing											Pooled
	5	6	7	8	9	10	11	12	13	14	15	
Bifenthrin 10 EC (2 ml/kg)	0.84 (5.26)	1.09 (5.98)	1.25 (6.43)	1.56 (7.18)	1.83 (7.77)	2.21 (8.54)	3.17 (10.25)	4.12 (11.71)	4.85 (12.72)	5.84 (13.98)	6.68 (14.98)	3.04 (10.04)
Chlorpyriphos 20 EC (4.5 ml/kg)	1.40 (6.78)	2.16 (8.45)	2.40 (8.91)	3.58 (10.90)	4.26 (11.91)	5.26 (13.26)	7.52 (15.91)	9.71 (18.15)	11.66 (19.96)	13.76 (21.77)	15.54 (23.22)	7.02 (15.36)
Clothianidin 50 WDG (2 gm/kg)	0.92 (5.51)	1.36 (6.69)	1.82 (7.76)	2.36 (8.84)	2.87 (9.75)	3.51 (10.80)	4.86 (12.73)	6.55 (14.83)	7.62 (16.02)	9.08 (17.54)	10.27 (18.69)	4.66 (12.47)
Cypermethrin 25 EC (2 ml/kg)	2.16 (8.45)	3.16 (10.23)	4.36 (11.91)	5.52 (13.58)	6.50 (14.77)	8.51 (16.96)	13.09 (21.21)	18.30 (25.33)	23.11 (28.74)	27.66 (31.73)	31.61 (34.21)	13.08 (21.21)
Fipronil 5 SC (5 ml/kg)	1.45 (6.92)	2.02 (8.17)	3.07 (10.10)	3.79 (11.22)	4.77 (12.62)	5.83 (13.98)	8.10 (16.53)	10.09 (18.52)	11.74 (19.94)	14.30 (22.22)	16.52 (23.98)	7.42 (15.80)
Imidacloprid 600 FS (3 ml/kg)	0.57 (4.32)	0.92 (5.49)	1.19 (6.27)	1.40 (6.79)	1.73 (7.56)	2.07 (8.28)	2.86 (9.74)	3.77 (11.20)	4.63 (12.42)	5.39 (13.42)	6.22 (14.44)	2.79 (9.62)
Imidacloprid 17.8 SL (3 ml/kg)	1.19 (6.26)	1.87 (7.86)	2.76 (9.56)	3.56 (10.88)	5.04 (12.97)	5.96 (14.13)	8.52 (16.97)	10.13 (18.55)	13.08 (21.21)	22.48 (28.30)	25.61 (30.40)	9.11 (17.56)
Quinalphos 25 EC (5 ml/kg)	2.03 (8.19)	3.10 (10.15)	4.32 (12.00)	5.42 (13.46)	6.30 (14.53)	8.16 (16.60)	12.77 (20.93)	16.26 (23.78)	21.55 (27.66)	27.24 (31.46)	31.19 (33.95)	12.58 (20.77)
Thiamethoxam 35 FS (3 ml/kg)	1.01 (5.76)	1.62 (7.31)	2.03 (8.19)	2.74 (9.52)	3.15 (10.22)	4.52 (12.28)	5.64 (13.73)	7.47 (15.87)	11.17 (19.53)	14.48 (22.37)	16.91 (24.28)	6.43 (14.69)
Control	3.01 (9.98)	3.98 (11.51)	5.22 (13.21)	7.01 (15.35)	8.32 (16.76)	10.20 (18.63)	15.14 (22.90)	24.44 (29.63)	28.70 (32.39)	35.03 (36.29)	38.53 (38.37)	16.33 (23.84)
S. Em. ±	0.44	0.41	0.50	0.54	0.59	0.63	0.74	0.80	1.13	1.30	1.45	0.52
C. D. at 5%	(1.32)	(1.23)	(1.50)	(1.61)	(1.77)	(1.87)	(2.22)	(2.38)	(3.45)	(3.80)	(4.22)	(1.89)
C. V. %	11.45	8.79	9.29	8.75	8.70	8.20	8.05	7.40	8.90	9.25	9.66	5.58

Figures in parentheses are arcsine value.

Pooled over period results in Table 1 revealed that the seed treatment with Imidacloprid 600 FS (2.79%) stood first in controlling the termite in wheat and it was at par with Bifenthrin 10 EC (3.04%) and Clothianidin 50 WDG (4.66%). These three treatments were found statistically superior to rest of the insecticides. Thiamethoxam 35 FS (6.43%), Chlorpyriphos 20 EC (7.02%), Fipronil 5 SC (7.42%) and Imidacloprid 17.8 SL (9.11%) were found equally effective in controlling the pest and at par with each other. Among the evaluated insecticides as seed treatments, the highest (13.08%) plant damage was noted in the treatment o Cypermethrin and it was equally effective as Quinalphos in which the plant damage was 12.58 percent.

From the above results, it can be concluded that the insecticidal seed treatment of Imidacloprid 600 FS @ 3 ml/kg, Bifenthrin 10 EC @ 2 ml/kg and Clothianidin 50 WDG @ 2 gm/kg seed were found highly effective against termite in wheat crop.

Singh *et al.* (2004) [10] also reported that Imidachloprid 600 FS @ 10 ml/kg seed found the most effective with the minimum plant damage (4.18%) and highest pearl millet grain yield (13.45 q ha^{-1}). Seed treatment with Bifenthrin 10% EC @ 2 ml/kg seeds was found effective and economical followed by Endosulfan 35 EC @ 7 ml and Chlorpyriphos 20 EC @ 1.5 ml for the management of termites in wheat also supported the present findings.

The above results are also agreement with findings of Mishra *et al.*, (2007) [14] who evaluated the effect of insecticides (Endosulfan, Monocrotophos, Chlorpyriphos, Imidacloprid, Carbaryl, Quinalphos and Methyl-parathion) as seed treatments @ 2.5, 2.5, 5.0, 2.0, 4.0, 2.5 and 2.5 ml/kg seeds, respectively, for the control of *O. obesus* and *M. obesi* infesting wheat in Uttar Pradesh. The maximum plant stand (77.7 plants/m^2) and minimum infested tillers (5 tillers/plot)

due to termites and maximum grain yield (42.2 q/ha) was obtained in Imidacloprid @ 2.0 ml/kg followed by Chlorpyriphos @ 5 ml/kg seed, whereas carbaryl found least effective. Apart from wheat, it also causes damage to maize, bajra, rice, barley and sorghum. Loss of 15–25 per cent of maize yield and about 1478 million rupees was estimated in India (Joshi *et al.*, 2005) [5]. In wheat, yield losses of 80% (Roonwal, 1979) [8], 43% (Sattar and Salihah, 2001) [9] and 60% (Kakde *et al*., 2006) [6] was reported due to termite infestation.

Similarly Sundriya and Acharya (2012) [12] studied the eco-friendly management of termites in wheat and found that Imidacloprid 70 WS @ 10 g/kg seeds as seed treatment gave effective control.

Table 2: Effect of seed treatments on population of termites in wheat

Treatments	No. of termites/stick week after sowing														Pooled
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Bifenthrin 10 EC (2 ml/kg)	0.0 (0.71)	0.0 (0.71)	3.99 (2.12)	5.80 (2.51)	8.14 (2.94)	7.79 (2.88)	10.30 (3.08)	8.14 (2.94)	7.23 (2.78)	5.12 (2.37)	7.34 (2.80)	11.33 (3.44)	12.46 (3.60)	15.26 (3.97)	7.49 (2.83)
Chlorpyriphos 20 EC (4.5 ml/kg)	0.40 (0.95)	1.46 (1.40)	3.65 (2.04)	5.80 (2.51)	10.20 (3.27)	14.93 (3.93)	14.40 (3.86)	15.48 (3.98)	16.30 (4.10)	15.94 (4.05)	14.70 (3.90)	16.90 (4.17)	24.88 (5.04)	36.95 (5.61)	13.28 (3.71)
Clothianidin 50 WDG (2 gm/kg)	0.31 (0.90)	0.24 (0.86)	2.30 (1.67)	4.95 (2.33)	9.71 (3.71)	12.64 (3.62)	10.32 (3.29)	12.63 (3.62)	10.98 (3.39)	13.12 (3.69)	11.13 (3.41)	14.58 (3.88)	14.31 (3.85)	20.61 (4.59)	9.91 (3.23)
Cypermethrin 25 EC (2 ml/kg)	1.42 (1.38)	2.03 (1.59)	4.49 (2.33)	10.45 (3.31)	15.88 (4.05)	20.86 (4.62)	21.34 (4.67)	22.09 (4.75)	25.86 (5.13)	26.36 (5.18)	28.09 (5.35)	30.47 (5.56)	35.14 (5.97)	40.48 (6.40)	20.35 (4.56)
Fipronil 5 SC (5 ml/kg)	1.81 (1.52)	2.63 (1.77)	3.85 (2.08)	5.80 (5.51)	10.51 (3.32)	12.84 (3.65)	14.93 (3.93)	16.07 (4.07)	18.75 (4.39)	17.81 (4.28)	15.74 (4.03)	20.91 (4.63)	25.52 (5.00)	32.58 (5.75)	14.27 (3.84)
Imidacloprid 600 FS (3 ml/kg)	0.0 (0.71)	0.46 (0.98)	2.34 (1.68)	2.31 (1.68)	3.72 (2.05)	4.48 (2.23)	5.05 (2.35)	5.41 (2.43)	4.80 (2.30)	4.45 (2.22)	3.10 (1.90)	5.38 (2.42)	6.69 (2.68)	7.42 (2.81)	3.97 (1.99)
Imidacloprid 17.8 SL (3 ml/kg)	1.81 (1.52)	3.63 (2.03)	4.85 (2.31)	6.80 (2.70)	11.51 (3.46)	13.84 (3.78)	15.93 (4.05)	16.07 (4.07)	19.75 (4.50)	18.81 (4.39)	15.74 (4.03)	20.91 (4.62)	25.52 (5.10)	32.58 (5.75)	14.83 (3.91)
Quinalphos 25 EC (5 ml/kg)	1.12 (1.27)	2.81 (1.82)	3.97 (2.11)	6.30 (2.60)	9.35 (3.14)	10.64 (3.33)	12.97 (3.67)	16.02 (4.06)	18.02 (4.30)	23.68 (4.91)	25.12 (5.06)	28.19 (5.36)	29.10 (5.44)	35.46 (6.00)	15.91 (4.05)
Thiamethoxam 35 FS (3 ml/kg)	0.40 (0.95)	1.46 (1.40)	2.65 (1.77)	3.80 (2.07)	5.20 (2.39)	8.93 (3.07)	10.40 (3.30)	14.40 (3.86)	15.30 (3.97)	16.94 (4.17)	18.70 (4.38)	20.90 (4.63)	25.88 (5.14)	28.95 (5.43)	12.85 (3.65)
Control	4.65 (2.27)	5.02 (2.35)	15.18 (3.96)	50.77 (7.16)	45.47 (6.78)	43.32 (6.62)	40.08 (6.37)	52.35 (7.27)	54.70 (7.43)	45.47 (6.78)	42.01 (6.52)	53.38 (7.34)	66.41 (8.18)	90.89 (9.56)	43.55 (6.60)
S. Em. ±	0.15	0.17	0.18	0.33	0.35	0.31	0.28	0.27	0.30	0.30	0.32	0.27	0.34	0.37	0.21
C. D. at 5%	(0.43)	(0.47)	(0.38)	(0.90)	(0.97)	(0.86)	(0.84)	(0.79)	(0.90)	(0.89)	(0.96)	(0.81)	(0.99)	(1.15)	(0.95)
C. V. %	15.95	16.82	8.35	10.53	11.92	11.10	11.07	9.68	10.38	10.98	12.51	9.32	9.85	10.35	8.35

Figures in parentheses are $\sqrt{X + 0.5}$ transformed value.

Termite populations

Termite population on eucalyptus stick was also recorded throughout the cropping season. All the insecticidal seed treatments were found significantly superior to control till 14 week after sowing. Pooled over data presented in Table 2 revealed that the lowest termite incidence (3.97/stick) was observed in Imidacloprid 600 FS which statistically differ from all the treatments including control. Bifenthrin 10 EC and Clothianidin 50 WDG resulted in 7.49 and 9.91 termites/stick, respectively and were significantly superior to rest of the insecticides. The plots treated with Thiamethoxam (12.85/stick), Chlorpyriphos (13.28/stick), Fipronil (14.27/stick) and Imidacloprid 17.8 SL (14.83/stick) were at par with each other in harbouring the termite population. Among the tested insecticides, the highest (20.35/stick) termites were noticed in treatment of Cypermethrin followed by and Quinalphos (15.91/stick).

From the above results, it can be concluded that the insecticidal treatment of Imidacloprid 600 FS @ 3 ml/kg, Bifenthrin 10 EC @ 2 ml/kg and Clothianidin 50 WDG @ 2 gm/kg seed were found highly effective in suppression of the termite population. Thiamethoxam 35 FS @ 3 ml/kg, Chlorpyriphos 20 EC @ 4.5 ml/kg, Fipronil 5 SC @ 5ml/kg and Imidacloprid 17.8 SL @ 3 ml/kg seed were moderately effective against termite. Treatments of Quinalphos 25 EC @ 5 ml/kg, and Cypermethrin 25 EC @ 2 ml/kg seed were found less effective in managing the termite in wheat.

Bali *et al.* (2010) [1] studied the efficacy of various pesticides for the control of termites in wheat crop and reported that the lowest mean per cent damage of tillers per meter row was with fipronil followed by gradual increase with endosulfan 35 EC, imidacloprid 200 SL, thiamethoxam 70 WS and bifenthrin 10 WP as compared to control.

Gadhiya and Board (2012) [3] also evaluated nine insecticides as seed treatment of Fipronil 5 SC @ 5 ml/kg, Imidacloprid 600 FS @ 3 ml/kg and Bifenthrin 10 EC @ 2 ml/kg seed were found highly effective in suppression of the termite population among all the tested insecticides against termites.

Grain and straw yield, Increase in yield, Avoidable losses and Economics

The basic principal of the pest management is to suppress the target pests by using different components and its ultimate effect on yield, economics and environment. Therefore, to determine the effects of various insecticides on produce, the yield data were recorded. On the basis of grain and straw yield, increase in yield over control and avoidable losses were calculated, whereas by using costs of treatments, Incremental Cost Benefit Ratio (ICBR) was calculated. The results in this regard are presented in Table 3 and 4.

Grain yield

The data presented in Table 3 showed that the treated plots produced significantly higher yield than control during *rabi* 2013-14. The highest (4083 kg ha^{-1}) grain yield was obtained from the plot treated with imidacloprid 600 FS and it was closely at par with bifenthrin 10 EC (3852 kg ha^{-1}) and clothianidin 50 WDG (3728 Kg ha^{-1}). The treatment with

chlorpyriphos 20 EC, thiamethoxam 35 FS and imidacloprid 17.8 SL yielded 3544, 3525, and 3439 kg ha^{-1} grain, respectively and were at par with each other and higher than rest of the three insecticides (quinalphos, cypermethrin and fipronil). Among the evaluated insecticidal seed treatments, the lowest (3244 kg ha^{-1}) yield was recorded in cypermethrin 25 EC and it was at par with fipronil 5 SC (3311 kg ha^{-1}) and quinalphos (3306 kg ha^{-1}) and found superior to control.

Increase in yield

The percent increase in yield over control in wheat grain presented in Table 3 revealed that maximum (30.41%) yield was increased in the plots treated with imidacloprid 600 FS. In rest of the treatments it remained between 17.39 to 26.24 percent in imidacloprid 17.8 SL, thiamethoxam, chlorpyriphos, clothianidin and bifenthrin. The increase in yield over control was 12.42 to 14.19 percent in plots treated with cypermethrin, quinalphos and fipronil.

Avoidable losses

The avoidable losses in grain yield of wheat varied from 5.65 to 30.42 percent in different treatments, considering the maximum (4083 kg ha-1) yield of imidacloprid 600 FS taken as base (Table 3). The avoidable loss was lowest (5.65%) in the treatment of bifenthrin followed by clothianidin (8.69%). It varied between 13.20 to 20.54 percent in chlorpyriphos, thiamethoxam, imidacloprid 17.8 SL, fipronil, quinalphos and cypermethrin. The least effective insecticide cypermethrin recorded 20.54 percent loss in grain yield of wheat.

Straw yield

The insecticidal treated seed plots produced higher straw yield (Table 3) than the control during *rabi* 2013.14. The significantly highest (4922 kg ha^{-1}) straw yield was obtained from insecticidal seed treatment of imidacloprid 600 FS and statistically at par with bifenthrin 10 EC (4689 kg ha^{-1}), clothianidin 50 WDG (4689 kg ha^{-1}) and chlorpyriphos 20 EC (4261 kg ha^{-1}) than all the evaluated insecticidal seed treatments. Thiamethoxam, fipronil and imidacloprid 17.8 SL gave straw yield 4144 kg ha^{-1}, 4133 kg ha^{-1} and 4083 kg ha^{-1} and was at par with each other. Among the evaluated insecticidal seed treatments, the lower (3872 kg ha^{-1}) straw yield (Fig. 4.3) was noticed in cypermethrin and it was at par with quinalphos (4011 kg ha^{-1}).

Increase in yield

The percent increase in straw yield of wheat over control was also worked out and presented in Table 3. The maximum (26.98%) yield was increased in the plots treated with imidacloprid 600 FS. The yield ranged from 23.35 to 13.04 percent in the treatment of bifenthrin, clothianidin, chlorpyriphos, thiamethoxam and fipronil. The increase in yield over control was 7.17, 10.39 and 11.97 percent in plots treated with cypermethrin, quinalphos and imidacloprid 17.8 SL.

Avoidable losses

The avoidable losses in Table 3 showed that the in straw yield of wheat varied from 5.65 to 30.42 percent in different treatments, considering the maximum (4083 kg ha^{-1}) yield of imidacloprid 600 FS taken as base. The avoidable loss was the lowest (5.65%) in the treatment of bifenthrin followed by clothianidin (8.69%). It was between 13.00 and 16.00 percent in thiomethoxam, chlorpyriphos, and fipronil. Highest (20.54%) avoidable loss in straw yield of wheat was noticed in the plots treated with cypermethrin followed by quinalphos (19.03%) and imidacloprid 17.8 SL (15.77%).

Table 3: Effect of seed treatments on germination and yield of grain and straw due to termite in wheat

Treatments	Germination (%)	No. of tillers/m row length	Yield (kg/ha)		Increased in yield over control (%)		Avoidable loss (%)	
			Grain	Straw	Grain	Straw	Grain	Straw
Bifenthrin 10 EC (2 ml/kg)	88.00	100.53	3852	4689	26.24	23.35	05.65	04.73
Chlorpyriphos 20 EC (4.5 ml/kg)	88.67	95.50	3544	4261	19.83	15.65	13.20	13.42
Clothianidin 50 WDG (2 gm/kg)	86.67	98.86	3728	4594	23.79	21.77	08.69	06.66
Cypermethrin 25 EC (2 ml/kg)	86.67	96.33	3244	3872	12.42	07.17	20.54	21.33
Fipronil 5 SC (5 ml/kg)	85.33	97.80	3311	4133	14.19	13.04	18.91	16.03
Imidacloprid 600 FS (3 ml/kg)	89.33	95.66	4083	4922	30.41	26.98	-	-
Imidacloprid 17.8 SL (3 ml/kg)	86.67	98.36	3439	4083	17.39	11.97	15.77	17.04
Quinalphos 25 EC (5 ml/kg)	85.33	96.33	3306	4011	14.06	10.39	19.03	18.50
Thiamethoxam 35 FS (3 ml/kg)	88.30	97.16	3525	4144	19.40	13.27	13.66	15.80
Control	88.30	96.16	2841	3594	-	-	30.42	26.98
S. Em. ±	5.10	1.03	187.0	225.0	-	-	-	-
C. D. at 5%	(NS)	(NS)	(555.5)	(668.5)	-	-	-	-
C. V. %	9.98	1.82	9.29	9.21	-	-	-	-

Economics

Economics of various insecticidal treatments as seed treatment against termite infesting wheat are presented in Table 4 which showed the maximum (23235 Rs. ha^{-1}) net realization from the treatment of imidacloprid 600 FS. It was 18955.5 and 16748.5 Rs. ha^{-1} in bifenthrin and clothianidin treatments, respectively. The plots treated with thiomethoxam, chlorpyriphos and imidacloprid 17.8 SL exhibited net realization between 12252 and 10736 Rsha^{-1}, whereas, the remaining insecticides of quinalphos, cypermethrin and fipronil registered 8458.5 to 8902 Rsha^{-1}. On the basis of ICBR, the highest (64.81) return was obtained with the treatment of bifenthrin. The ICBR of clothianidin, chlorpyriphos and cypermethrin treated seed gave 4.36, 40.39 and 24.90, respectively. However, chlorpyriphos was found mediocre, whereas cypermethrin was poorest against termite in wheat crop. Imidacloprid 600 FS, fipronil, imidacloprid 17.8 SL, thiamethoxam and quinalphos gave 20.31, 8.53, 12.64, 3.84 and 22.49 ICBR, respectively. Out of these seed treatments, imidacloprid 600 FS and bifenthrin were found highly effective against termite in wheat.

Table 4: Economics of seed treatments used for the control of termite in wheat

Treatments	Dose (ml/ kg of seed)	Quantity of insecticides (ml/ha)	Total cost of plant protection (Rs/ha)	Yield (kg/ha)		Gross realization (Rs/ha)	Net realization over control (Rs/ha)	Net profit (Rs/ha)	ICBR
				Grain	Straw				
Bifenthrin 10 EC	2	240	288.0	3852	4689	73773.0	18955.5	18667.5	64.81
Chlorpyriphos 20 EC	4.5	540	312.30	3544	4261	67715.0	12897.5	12585.2	40.29
Clothianidin 50 WDG	2	240	3120.00	3728	4594	71566.0	16748.5	13628.5	04.36
Cypermethrin 25 EC	2	240	273.28	3244	3872	61898.0	7080.5	6807.2	24.90
Fipronil 5 SC	5	600	934.00	3311	4133	63719.5	8902.0	7968.0	08.53
Imidacloprid 600 FS	3	360	1090.00	4083	4922	78052.5	23235.0	22145.0	20.31
Imidacloprid 17.8 SL	3	360	787.00	3439	4083	65553.5	10736.0	9949.0	12.64
Quinalphos 25 EC	5	600	360.00	3306	4011	63276.0	8458.5	8098.5	22.49
Thiamethoxam 35 FS	3	360	3000.00	3525	4144	67069.5	12252.0	9252.0	03.84
Control	-	-	-	2841	3594	54817.5	-	-	-

Market price of wheat grain Rs. 1550/quintal and straw Rs. 300/quintal

Conclusion

In the light of result summarized above, among nine insecticides used as seed treatment, it can be concluded that the insecticidal treatment of imidacloprid 600 FS @ 3 ml/kg, bifenthrin 10 EC @ 2 ml/kg and clothianidin 50 WDG @ 2 gm/kg seed were found highly effective in suppression of the termite population. Thiamethoxam 35 FS @ 3 ml/kg, chlorpyriphos 20 EC @ 4.5 ml/kg, fipronil 5 SC @ 5ml/kg and imidacloprid 17.8 SL @ 3 ml/kg seed were moderately effective against termite while the treatments of quinalphos 25 EC @ 5 ml/kg, and cypermethrin 25 EC @ 2 ml/kg seed were found to be the less effective in managing the termite in wheat.

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