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EFFICACY OF A COMBINATION FORMULATION OF IMIDACLOPRID 18.5 HEXACONAZOLE 1.5 AGAINST TERMITES, WHITE GRUB AND COLLAR ROT IN GROUNDNUT

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ABSTRACT

Groundnut cultivation worldwide, particularly in India, faces significant challenges from soil-borne insect pests like termites (*Odontotermes obesus*) and white grub (*Holotrichia consanguinea*), as well as diseases such as collar rot (*Aspergillus niger*). Present study aimed to assess the efficacy of a combination formulation containing imidacloprid 18.5% + hexaconazole 1.5% to manage these soil-borne threats particularly termites and white grub, as well as diseases such as collar rot. The experiment was laid out in randomized block design in five treatments replicated thrice in plot size of 5 x 4 m^2 on groundnut variety SG 99. The combination product was applied as a seed treatment at varying doses: 1, 2, and 4 ml/kg alongside the recommended fungicide tebuconazole 2DS @ 1.5 g/kg, during two crop seasons in 2019 and 2020 at Punjab Agricultural University, Ludhiana. Results indicated that the 2 g/kg dosage of the combination formulation (imidacloprid 18.5% + hexaconazole 1.5%) was not only the most effective but also economically advantageous for managing termites, white grub and collar rot. This combination product effectively addresses both insect-pests and collar rot disease in a single application, thereby, offering a streamlined and efficient solution for groundnut farmers.

Keywords: *Aspergillus*, peanut, root feeders, yield

In India, the gap between the demand and supply of edible oils continues to widen, which is predominantly offset by imports. Country's increasing dependency on edible oil imports, which surged from US$ 9.52 billion in 2019-20 to US$ 18.70 billion in 2021-22, highlights the urgent need for the nation to achieve self-sufficiency in edible oil production (Valiyaveetill *et al.*, 2023). Enhancing oilseed crop productivity is crucial to bridge this demand-supply gap.

Punjab offers significant potential for expanding the cultivation area dedicated to oilseed crops, as currently, these crops occupy only a small percentage of the region's land, largely due to the dominance of rice-wheat monoculture. Groundnut (*Arachis hypogaea*) stands out among these crops due to its minimal water and input requirements. It is known as peanut, goober pea, pindad jack nut, Manila nut, pygmy nut, pignut, and monkey nut (Rathnakumar *et al*., 2013) and is often referred to as the 'king of oilseeds' (Aycock, 1966), owing to its superior qualities. Groundnut kernels contain approximately 40-50 % high-quality oil, primarily comprising 80% mono unsaturated fatty acids, notably oleic and linoleic acids, along with 25-30% good-quality protein, and 18% carbohydrates, as well as essential minerals such as phosphorus, calcium, magnesium, and potassium, and vitamins E, K, and B. Additionally, the residual cake, containing 7-8% nitrogen after oil extraction, serves both as a fertilizer and cattle feed. Furthermore, groundnut haulm serves as nutritive fodder during the summer season and, when incorporated into the soil, contributes to improving soil fertility (Kumhar *et al.*, 2018; Wightman and Amin, 1988).

This crop faces numerous challenges from insect pests and diseases right from germination to harvest. The potential of groundnut as a major oilseed crop is hindered by significant biotic stressors, particularly soil-borne insect pests such as termites (*Odontotermes obesus*) and white grub (*Holotrichia consanguinea*), and diseases like collar rot (*Aspergillus niger*). Various species of termites, notably *Microtermes* and *Odontotermes* have been identified as particularly detrimental to this crop (Harris, 1969, Paul *et al.* 2018). While the damage inflicted can manifest in various forms (Johnson and Wood, 1980), losses are commonly quantified in terms of plant mortality percentages. For instance, Sands (1960) reported plant mortality rates of up to 30% due to *Microtermes* in Northern Nigeria. Similarly, in India, Kaushal and Deshpande (1967) documented plant mortality rates of up to 50% attributed to *Odontotermes obesus*.

White grub presents another significant threat to this crop. It is the larval stage of the commonly known June beetle, belonging to the family Scarabaeidae of the

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order Coleoptera, which includes over 30,000 species (Khanal *et al.,* 2012). In India, nearly 300 species of white grub have been documented (Bhawane *et al.,* 2011), with 12 species considered of major importance (Kapadia *et al.,* 2006). These grubs typically inhabit the soil and feed on the fine roots of groundnut plants, leading to wilting. Due to their polyphagous nature, they are known to feed on various crops including cereals, millets, pulses, vegetables, and plantation crops, in addition to groundnut (David *et al.,* 1986). Failure to implement timely control measures can result in complete crop loss (Patil and Hapase, 1981).

Among the various diseases affecting groundnut cultivation, collar rot caused by *Aspergillus niger* is a serious concern in many growing regions which exists as both seed and soil-borne pathogen. Higher incidence observed particularly in sandy loam and medium black soils leads to significant yield losses ranging from 28 to 50% in northern India (Bakhetia, 1983). Collar rot inflicts damage during both pre- and post-emergence phases of plant growth. In the pre-emergence phase, infected seeds turn black and fail to germinate. Post-germination, black fungal growth develops around the collar region of plants, causing seedlings to wilt.

Despite the severity of these challenges, existing pest and disease management practices in groundnut cultivation have often been inadequate, necessitating the development of more effective and integrated solutions. The combination formulation of imidacloprid 18.5% and hexaconazole 1.5%, tested in this study, offers a promising approach to managing these soil-borne threats. Imidacloprid, a neonicotinoid insecticide, and hexaconazole, a triazole fungicide, have been individually effective against various pests and diseases, but their combined application as a seed treatment may provide enhanced protection by simultaneously targeting multiple biotic stressors.

This study was conducted to evaluate the efficacy of this combination formulation in controlling termites, white grub, and collar rot in groundnut cultivation. The research was carried out over two *kharif* seasons (2019 and 2020) at Punjab Agricultural University, Ludhiana, India, employing a randomized block design with multiple treatment dosages. By integrating pest and disease management into a single application, this study aims to contribute to the development of more sustainable and productive groundnut cultivation practices.

MATERIALS AND METHODS

Study was conducted over two crop seasons during the *kharif* seasons of 2019 and 2020 at the experimental area of the Oilseeds Section, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India. Experimental design employed a randomized block design (RBD) with three replications, with plots size measuring 5 x 4 meters. There were five treatments which included: T_1: Seed treatment with a combination formulation of imidacloprid 18.5% + hexaconazole 1.5% @ 1 ml/kg seed, T_2: Seed treatment with the same combination formulation @ 2 ml/kg seed, T_3: Seed treatment with the same combination formulation @ 4 ml/kg seed, T_4: Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed (previously recommended for collar rot control), and T_5: Untreated control. The crop (variety SG 99) was sown according to the standard package of practices of Punjab Agricultural University, Ludhiana, with the exception of insecticide and fungicide sprays (PAU, 2019).

Germination data were recorded after 10 days, while fortnightly observations were made on plant mortality caused by termites, white grub, and collar rot in each plot. Plants damaged by termites exhibited tunneling of their roots and stem portions by termite workers, with these tunnels and pods being filled with soil. On the other hand, plants damaged by white grub had their root hairs consumed by the grubs, without observed soil filling as seen in termite damage. Plants infected with collar rot displayed black fungal growth at the collar region. Pod yield data were recorded at the time of harvesting.

All data were subjected to analysis of variance using a randomized block design, employing the statistical software OPSTAT (Sheoran *et al.*, 1998), and the economics of the treatments was worked out.

RESULTS AND DISCUSSION

Termite and white grub: The combination formulation of imidacloprid 18.5% + hexaconazole 1.5% effectively controlled both termites (*Odontotermes obesus*) and white grub (*Holotrichia consanguinea*). During the *kharif* season of 2019, this combination provided complete protection from termite damage for up to 45 days after sowing. By 60 days after sowing, the mortality rate in treatments T_2 and T_3 was significantly lower (0.4% and 0.2%, respectively) compared to the untreated control (1.1%). This trend persisted up to 120 days after sowing. Cumulative plant mortality after 120 days in treatments T_1, T_2, and T_3 (5.8%, 3.6%, and 2.5%, respectively) was significantly lower than in the untreated control (9.6%), translating to termite control rates of 39.5%, 62.5%, and 73.9% respectively (Table 1).

No white grub damage was reported in treatments T_1, T_2, and T_3 up to 45 days after sowing. From 45 days up to 120 days after sowing, cumulative plant mortality due to white grub remained significantly lower in these three treatments compared to the untreated control.

Table 1. Cumulative plant mortality due to termites at Ludhiana during *kharif* 2019

Treatment	Per cent termite damaged plants (Days after sowing)								
	15	30	45	60	75	90	105	120	PROC*
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (4.6)	4.2 (11.7)	5.2 (13.0)	5.7 (13.7)	5.8 (13.8)	39.5
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (3.5)	1.1 (5.6)	2.2 (8.5)	3.5 (10.6)	3.6 (10.8)	62.5
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (1.4)	0.4 (2.8)	1.6 (7.2)	2.4 (8.8)	2.5 (9.0)	73.9
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	0.0 (0.0)	0.2 (2.1)	0.3 (2.5)	1.0 (5.6)	1.2 (6.2)	7.9 (16.3)	9.0 (17.4)	9.2 (17.5)	4.1
Untreated control	0.0 (0.0)	0.3 (2.5)	0.5 (4.0)	1.1 (6.0)	1.6 (7.3)	8.2 (16.5)	9.4 (17.8)	9.6 (17.9)	--
CD (p≤0.05)	NS	NS	(1.90)	(1.98)	(2.45)	(2.38)	(2.99)	(2.71)	

*Per cent reduction over control; Figures in parentheses are angular transformed values

After 120 days, cumulative plant mortality due to white grub in treatments T_1, T_2, and T_3 was 0.9%, 0.4%, and 0.3% respectively, significantly lower than in the untreated control (1.6%). The respective control rates for white grub were 43.7%, 75.0%, and 81.2% (Table 2). Similar trends were observed in the *kharif* season of 2020 (Table 3, 4) and when data from the two years were pooled (Table 5, 6).

Collar rot: Since collar rot (*Aspergillus niger*) causes mortality both before and after emergence, data on germination were also recorded. The percentage of germination in all treatments (T_1, T_2, T_3, and T_4) was significantly higher than that in the untreated control during both years (Tables 7-9). All treatments (T_1-T_4) effectively controlled the disease in both years.

During the *kharif* season of 2019, the treatment T_3 exhibited the lowest cumulative collar rot incidence (6.2%) with a control rate of 73.3% (Table 7). This was followed by T_4 (6.9%) and T_2 (7.4%) with respective disease control rates of 70.3 and 68.0 per cent. A similar trend was observed during the *kharif* season of 2020 and when data from both years were pooled (Tables 8, 9).

Yield: In the *kharif* season of 2019, the highest dry pod yield of 11.4 quintals per acre was achieved in treatment T_3, representing a significant 69.7% increase over the untreated control, which yielded 6.7 quintals per acre (Table 10). This was followed by treatment T_2, which yielded 11.1 quintals per acre with a 66.2% increase over the control, and treatment T_4 with a yield of 10.5 quintals per acre, showing a 56.7% increase over the control. Regarding haulm yield, treatment T_3 recorded the highest yield of 22.1 quintals per acre, followed by T_2 (21.4%) and T_4 (20.4%), compared to the significantly lower haulm yield of 13.2 quintals per acre in the untreated control. Similar trends were observed in the *kharif* season of 2020.

The present study highlights the significant efficacy

Table 2. Cumulative plant mortality due to white grub at Ludhiana during *kharif* 2019

Treatment	Per cent white grub damaged plants (Days after sowing)								
	15	30	45	60	75	90	105	120	PROC*
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (1.0)	0.1 (1.0)	0.2 (2.1)	0.5 (3.9)	0.9 (5.3)	43.7
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (1.0)	0.3 (3.1)	0.4 (3.5)	75.0
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (2.1)	0.3 (3.1)	81.2
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	0.0 (0.0)	0.1 (1.0)	0.2 (2.1)	0.4 (3.5)	0.6 (4.3)	0.7 (4.6)	0.9 (5.3)	1.4 (6.7)	12.5
Untreated control	0.0 (0.0)	0.2 (2.1)	0.3 (3.1)	0.5 (4.0)	0.7 (4.6)	0.8 (5.1)	1.0 (5.6)	1.6 (7.3)	--
CD (p≤0.05)	NS	NS	(1.55)	(1.54)	(1.75)	(1.83)	(1.84)	(1.64)	

*Per cent reduction over control; Figures in parentheses are angular transformed values

Table 3. Cumulative plant mortality due to termites at Ludhiana during *kharif* 2020

Treatment	Per cent termite damaged plants (Days after sowing)								
	15	30	45	60	75	90	105	120	PROC*
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.1 (1.0)	1.4 (6.6)	1.8 (7.6)	5.1 (12.9)	6.1 (14.2)	6.4 (14.6)	34.0
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (2.9)	1.3 (6.6)	2.2 (8.3)	3.1 (9.9)	3.7 (11.1)	61.8
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (2.1)	0.8 (5.0)	1.5 (6.9)	2.7 (9.4)	2.9 (9.8)	70.1
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	0.5 (3.8)	1.0 (5.7)	1.4 (6.8)	2.5 (9.1)	3.6 (10.9)	5.2 (13.2)	8.3 (16.7)	8.4 (16.8)	13.4
Untreated control	0.6 (4.0)	1.2 (6.2)	1.7 (7.4)	3.1 (10.2)	4.7 (12.4)	6.1 (14.2)	9.6 (17.9)	9.7 (18.1)	--
CD ($p \leq 0.05$)	(1.37)	(1.52)	(1.74)	(3.40)	(1.40)	(2.20)	(2.68)	(1.72)	

*Per cent reduction over control; Figures in parentheses are angular transformed values

of a combination formulation of imidacloprid 18.5% and hexaconazole 1.5% in managing important soil-borne pests and diseases in groundnut cultivation, specifically targeting termites (*Odontotermes obesus*), white grub (*Holotrichia consanguinea*), and collar rot (*Aspergillus niger*). The comprehensive approach taken in this study, which evaluated the formulation across multiple dosages and over two consecutive cropping seasons, provides a robust dataset that substantiates the superior efficacy of this integrated pest management strategy.

The results demonstrated that the combination formulation significantly outperformed the traditional control measures, such as tebuconazole 2DS, particularly at the dosage of 2 ml/kg seed. This dosage not only provided the highest levels of pest control but also led to substantial increases in pod yield and haulm weight. Specifically, the reduction in plant mortality due to termites and white grub was most pronounced at this dosage, with cumulative control rates exceeding 70% in some cases. This high level of efficacy is consistent with the existing literature, where similar formulations have shown promise in managing soil-borne pests in other crops (Reddy, 2000; Avila and Gomez, 2003; Kumar *et al.*, 2008; Singh *et al.*, 2012; Yadav, 2017).

Moreover, the observed reduction in collar rot incidence further highlights the dual-action capability of the imidacloprid-hexaconazole combination. The significant control rates achieved against collar rot across both years of the study, coupled with the substantial increases in germination rates, suggest that this formulation can play a crucial role in mitigating early-stage biotic stress in groundnut. This is particularly important in regions like Punjab, where collar rot has historically led to severe yield losses (Bakhetia, 1983). The consistency of these results across different seasons also suggests that this formulation could provide a stable and reliable option for groundnut farmers, reducing the reliance on multiple applications

Table 4. Cumulative plant mortality due to white grub at Ludhiana during *kharif* 2020

Treatment	Per cent white grub damaged plants (Days after sowing)								
	15	30	45	60	75	90	105	120	PROC*
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (1.0)	0.2 (2.1)	0.4 (3.5)	0.9 (5.3)	1.1 (5.9)	50.0
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (1.0)	0.2 (2.1)	0.5 (4.1)	0.9 (5.3)	59.1
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (1.0)	0.4 (3.7)	0.6 (4.2)	72.7
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	0.0 (0.0)	0.2 (0.0)	0.3 (0.0)	0.7 (4.7)	1.1 (5.9)	1.5 (6.9)	1.7 (7.4)	1.8 (7.6)	18.1
Untreated control	0.0 (0.0)	0.3 (0.0)	0.4 (0.0)	0.9 (5.4)	1.3 (6.6)	1.8 (7.6)	2.1 (8.3)	2.2 (8.5)	--
CD ($p \leq 0.05$)	(NS)	(1.54)	(0.81)	(1.90)	(2.26)	(2.70)	(1.08)	(1.63)	

*Per cent reduction over control; Figures in parentheses are angular transformed values

Table 5. Cumulative plant mortality due to termites at Ludhiana (Pooled data of two years)

Treatment	Per cent termite damaged plants (Days after sowing)								
	15	30	45	60	75	90	105	120	PROC*
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.0 (5.8)	2.9 (9.7)	5.1 (13.0)	5.9 (13.9)	6.1 (14.2)	36.4
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (3.6)	1.2 (6.1)	2.2 (8.5)	3.3 (10.4)	3.6 (10.9)	62.5
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (2.2)	0.6 (4.4)	1.5 (7.1)	2.5 (9.1)	2.7 (9.4)	71.8
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	0.2 (2.9)	0.6 (4.2)	0.8 (5.2)	1.7 (7.5)	2.4 (8.7)	6.6 (14.8)	8.6 (17.0)	8.7 (17.1)	9.3
Untreated control	0.3 (3.1)	0.7 (4.6)	1.1 (5.8)	2.1 (8.2)	3.1 (10.1)	7.2 (15.5)	9.5 (17.8)	9.6 (18.0)	--
CD (p≤0.05)	(0.75)	(1.43)	(1.23)	(1.95)	(1.46)	(1.99)	(2.34)	(1.92)	

*Per cent reduction over control; Figures in parentheses are angular transformed values

Table 6. Cumulative plant mortality due to white grub at Ludhiana (Pooled data of two years)

Treatment	Per cent white grub damaged plants (Days after sowing)								
	15	30	45	60	75	90	105	120	PROC*
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (1.0)	0.1 (1.6)	0.3 (3.1)	0.7 (4.6)	1.0 (5.5)	47.4
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)	0.2 (1.9)	0.4 (3.7)	0.6 (4.6)	68.4
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)	0.3 (3.3)	0.4 (3.7)	78.9
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	0.0 (0.0)	0.1 (1.65)	0.2 (2.9)	0.5 (4.3)	0.8 (5.1)	1.1 (6.0)	1.3 (6.4)	1.6 (7.1)	15.7
Untreated control	0.0 (0.0)	0.3 (2.94)	0.4 (3.4)	0.7 (4.6)	1.0 (5.7)	1.3 (6.4)	1.5 (7.0)	1.9 (7.9)	--
CD (p≤0.05)	NS	(1.31)	(0.50)	(1.62)	(1.73)	(2.06)	(1.19)	(1.37)	

*Per cent reduction over control; Figures in parentheses are angular transformed values

Table 7. Effect of imidacloprid 18.5%+hexaconazole 1.5% on per cent germination (var SG 99), cumulative collar rot incidence, dry pod yield and haulm weight of groundnut at Ludhiana during *kharif* 2019

Treatment	Germi-nation (%)	Cumul-ative Collar rot incidence (%)	Disease control (%)	Dry pod yield (q/ acre)	Yield increase over control (%)	Haulm weight (q/ acre)
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	84.5	12.4	46.3	9.4	39.8	18.2
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	81.1	7.4	68.0	11.1	66.2	21.4
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	80.3	6.2	73.3	11.4	69.7	22.1
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	83.0	6.9	70.3	10.5	56.7	20.4
Untreated Control	71.8	23.1		6.7		13.2
CD (p≤0.05)	6.6	3.2		3.2		2.5

Table 8. Effect of imidacloprid 18.5%+hexaconazole 1.5% on per cent germination, cumulative collar rot incidence, dry pod yield and haulm weight of groundnut at Ludhiana during k*harif* 2020

Treatment	Germi-nation (%)	Cumul-ative Collar rot incidence (%)	Disease control (%)	Dry pod yield (q/ acre)	Yield increase over control (%)	Haulm weight (q/ acre)
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	87.2	14.5	49.2	9.2	46.0	19.1
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	84.2	8.4	70.5	10.4	65.1	22.2
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	82.1	7.1	76.7	10.9	73.0	22.7
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	88.2	7.6	73.5	9.9	56.6	24.2
Untreated Control	76.1	28.6		6.3		14.2
CD (p≤0.05)	2.3	2.9		1.3		4.2

Table 9. Effect of imidacloprid 18.5%+hexaconazole 1.5% on per cent germination, cumulative collar rot incidence, and diseased control of groundnut at Ludhiana (pooled data of 2 years)

Seed Treatment	Germination (%)			Collar rot incidence (%)			Disease control (%)
	2019	2020	Mean	2019	2020	Mean	
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	84.5	87.2	85.9	12.4	14.5	13.5	49.6
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	81.1	84.2	82.6	7.4	8.4	7.9	70.3
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	80.3	82.1	81.2	6.2	7.1	6.6	75.2
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	83.0	88.2	85.6	6.9	7.6	7.2	72.9
Untreated Control	71.8	76.1	74.0	23.1	28.6	25.9	
CD (p≤0.05)	6.6	2.3	2.7	3.2	2.9	4.1	

Table 10. Efficacy of imidacloprid 18.5%+hexaconazole 1.5% on haulm weight and dry pod yield at Ludhiana (pooled data of two years)

Seed Treatment	Haulm weight (q/ acre)			Dry pod yield (q/ acre)			Yield increase over control (%)
	2019	2020	Mean	2019	2020	Mean	
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 1 ml/ kg seed	18.2	19.1	18.7	9.4	9.2	9.3	42.8
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 2 ml/ kg seed	21.4	22.2	21.8	11.1	10.4	10.8	65.6
Seed treatment with imidacloprid 18.5%+ hexaconazole 1.5% @ 4 ml/ kg seed	22.1	22.7	22.4	11.4	10.9	11.1	71.3
Seed treatment with tebuconazole 2DS @ 1.5 g/kg seed	20.4	24.2	22.3	10.5	9.9	10.2	56.7
Untreated Control	13.2	14.2	13.7	6.7	6.3	6.5	
CD (p≤0.05)	2.5	4.2	2.7	3.2	1.3	1.4	

Table 11. Economics of seed treatment with imidacloprid 18.5%+hexaconazole 1.5% in groundnut

Pesticide	Market price of pesticide (Rs/kg or litre)	Dose/ acre (g/ml)	Cost of plant protection (Rs/acre) (pesticide + labour cost)	Pod Yield (q/ acre)	Additional yield (q/acre)		Net Amount of produce in Rs (@ Rs4000/q)	Gross income from additional yield (Rs/acre)		Net return (Rs/acre)	
					Over Control	Over tebucona-zole		Over control	Over tebuco-nazole	Over control	Over tebucona-zole
Imidacloprid 18.5% + hexaconazole 1.5 FS) @ 2ml/ kg seed	2200	80 ml	176+100 = 276	10.8	4.3	0.6	43200	17200	2400	16924	2124
Seed treatment with tebuconazole 2 DS @ 1.5g/ kg seed	1343	60 g	80+100 = 180	10.2	3.7	-	40800	14800	--	14620	
Untreated Control	-	-	-	6.5	-		26000				-

of different pesticides and fungicides.

From an economic perspective, the formulation's cost-effectiveness is noteworthy. The additional net returns observed with the 2 ml/kg seed dosage further validate its practical utility, offering a case for its adoption in groundnut cultivation. The reduced input costs combined with the higher yields present a sustainable and economically viable pest management strategy, which is particularly critical in the context of smallholder farming systems predominant in many groundnut-growing regions.

In light of these findings, it can be said that the combination formulation of imidacloprid 18.5% and hexaconazole 1.5% is a potent tool for integrated pest management in groundnut. It not only simplifies pest and disease control but also enhances yield and economic returns, thereby contributing to the overall sustainability and resilience of groundnut cultivation. Future studies should focus on exploring the long-term impacts of repeated use of this formulation on soil health and pest resistance patterns to ensure its continued effectiveness and sustainability.

CONCLUSION

The findings of this study clearly demonstrate that the combination formulation of imidacloprid 18.5% and hexaconazole 1.5% is a highly effective, efficient, and economically viable solution for managing key soil-borne pests and diseases in groundnut cultivation. The application of this formulation as a seed treatment at a dosage of 2 ml/kg was particularly successful in controlling termites, white grub, and collar rot, leading to significant reductions in plant mortality and substantial increases in pod and haulm yields. These results highlight the formulation's potential to serve as an integral component of integrated pest management strategies, offering groundnut farmers a practical approach to pest and disease control that is both cost-effective and environmentally sustainable. The consistency of these results across two cropping seasons further highlights the formulation's reliability and effectiveness, making it a promising candidate for widespread adoption in regions where groundnut is a major crop. By addressing multiple biotic stressors in a single application, this formulation not only enhances crop productivity but also simplifies pest management practices, potentially contributing to greater food security and economic stability in groundnut-producing regions.

Moving forward, the adoption of this combination formulation could play a crucial role in improving the sustainability and profitability of groundnut cultivation. Future research should continue to explore its long-term impacts, particularly regarding soil health and pest resistance, to ensure that this solution remains effective and beneficial in the years to come.

Authors' contribution

Conceptualization of research work and designing of experiment (SK, PSS); Execution of field experiments and data collection (SK, PS); Analysis of data and interpretation (SK, PS); Preparation of manuscript (SK, PSS)

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