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RESEARCH

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Field evaluation of horticultural mineral oils and botanicals against bean thrips, *Megalurothrips distalis* (Karny) (Thysanoptera: Thripidae), in summer mung bean

Harkamalpreet Singh[1], Harpreet Kaur Cheema[2*] and Ravinder Singh[2]

Abstract

Background: Bean thrips, *Megalurothrips distalis* (Karny), are a serious insect pest of mung bean grown in summer season as a catch crop in wheat–rice cropping system in North West India. Severe incidence leads to flower shedding and fewer pods leading to loss in grain yield. Field studies were conducted to evaluate the efficacy of horticultural mineral oils, neem-based botanicals, and pongamia soap in the form of spray in comparison to the insecticide dimethoate in 2018 and 2019.

Main body: Randomized complete block design (RCBD) was used with 11 treatments including untreated control in 3 replications. Neem seed kernel extract (NSKE) at 5% gave the highest mean percent reduction in the number of thrips (90.44 and 79.59%), followed by 10 ml l^{-1} of Neem Kavach 1500 ppm (85.55 and 78.97%) and the insecticide dimethoate 30% EC at 250 ml ha^{-1} (84.92 and 78.22%) 1 and 3 days after treatment. Neem Baan 1500 ppm, Indo-Neem 1500 ppm, and Nimbecidine 300 ppm each at 10 ml l^{-1} also provided 75.29–82.42% and 61.18–75.82% reduction 1 and 3 days after treatment. Horticultural mineral oils also reduced the insect population by about 64%, while pongamia soap was least effective (31.58%) among botanicals. Dimethoate 30% EC at 250 ml ha^{-1} recorded the highest grain yield and net returns, followed by NSKE, Nimbecidine, and Neem Kavach that were on par with it. Homemade neem extracts evaluated in 2019 caused 62.7–77.3% reduction in thrips population up to 3 days after treatment with yields comparable to 10 ml l^{-1} of Indo-Neem spray.

Conclusion: The study indicated that neem extract was capable to manage the bean thrips in flowers of summer mung bean and obtained a high grain yield.

Keywords: Botanicals, Neem, Mineral oils, Bean thrips, *Megalurothrips distalis*, Mung bean

Background

Mung bean, *Vigna radiata* (L.) Wilczek, is also known as a warm season grain legume crop. It has great importance in the vegetarian diet and is used as cereal supplement for human diets due to its high lysine content. Mung bean seeds are rich source of minerals and protein (Dahiya et al. 2013). Its immature grains are used as a vegetable and are the source of plant protein, fiber, antioxidants, and phytonutrients which provide numerous health benefits. Mung bean is an economically important crop of Asia, especially in the Indian sub-continent grown globally on an area of 5.5 M ha (Weinberger 2003). India is the primary producer as well as consumer

* Correspondence: hkcheema@pau.edu
[2]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab 141004, India
Full list of author information is available at the end of the article

of mung bean, contributing 65% of global crop production (Vijayalakshmi et al. 2003).

Mung bean yield is affected by several biotic and abiotic factors, of which insect pests are of much importance. Among its various insect pests, whitefly *Bemisia tabaci* (Gennadius), jassid, *Empoasca* spp., and bean thrips, *Megalurothrips distalis* (Karny), are the major sucking pests (Kooner et al. 2006). Whitefly and jassid cause damage mainly in the *kharif* or the rainy season crop. Verma et al. (1980) reported 3 species of thrips on summer mung bean in India, viz., *Frankliniella schultzei* (Trybom), *Thrips flavus* Schrank, and *Megalurothrips distalis* (Karny). Among these species, *M. distalis* is the most important thrips found in flowers of summer mung bean crop. Both nymphs and adults suck the oozing plant cell sap causing flower shedding before opening resulting in elongation of terminal shoot. Under severe incidence, the plants become bushy, dark green with few pods leading to loss in grain yield (Kooner et al. 1983). It is imperative to control *M. distalis* damages to minimize attributed yield losses. Chhabra and Kooner (1985a) reported the cumulative damage caused by insect pest complex (*Melanagromyza phaseoli*, *Acherontia styx*, and *M. distalis*) as up to 54.3% in mung bean.

Some bio-rational management strategies such as botanical-based insecticides or biopesticides that are economically and environmentally safe to non-target organisms and humans are desirable for managing insect pests (Begum et al. 2013). Botanicals such as neem (*Azadirachta indica* Juss.) and Karanj (*Pongamia glabra*) can be effectively used in managing pests in field crops and stored grains (Regnault-Roger and Philogène 2008). *A. indica* is a well-known plant species that has insecticidal activities against more than 250 species of agricultural pests (Morgan 2009). Seeds of neem comprise 40% oil with azadirachtin as the major active ingredient having insecticidal property (Isman et al. 1991). Petroleum spray oils and mineral oils have been used also for controlling insect pests in many crops around the world (Mensah et al. 2005a, 2005b; Najar-Rodriguez et al. 2007). To overcome any negative effects resulting from use of synthetic insecticides, the study was conducted to test the efficacy of alternate strategies such as botanicals and horticultural mineral oils (HMOs) against bean thrips in mung bean.

Materials and methods

Neem seed kernel extraction

Dried neem seed kernels were procured from the local market of Ludhiana and powdered in electric grinder. The powdered kernels were soaked overnight in water and filtered next day for spraying as a 5% neem seed kernel extract (NSKE). Commercial formulations of neem (Neem Baan 1500 ppm, Indo-Neem 1500 ppm, Nimbecidine 300 ppm, Neem Kavach 1500 ppm) and the insecticide Rogor 30% EC (dimethoate 30% EC) were procured from the local market. The 4 commercial formulations of neem were applied at the rate of 10 ml l^{-1}, using 200 L of water per ha. Pongamia soap (*Pongamia pinnata*) was procured from the Indian Institute of Horticultural Research, Bangalore, and was applied at 10 g l^{-1}. MAK All Season HMO was procured from Bharat Petroleum Corporation Ltd. Mumbai, while Arbofine HMO was obtained from Total Oil India Pvt. Ltd., Mumbai. Homemade neem extracts were evaluated only in 2019. These were prepared by boiling for half an hour or simply by overnight soaking of 1 kg of Neem leaves and fruits in 2 L of water. The contents were filtered and used at the rate of 10 ml l^{-1} of water. Rogor 30% EC (dimethoate 30% EC) was applied at the rate of 250 ml ha^{-1} (75 g a.i. per ha using 200 L of water) as a standard recommended insecticide against thrips in summer mung bean (Anonymous 2017). Water spray at 200 L per ha was also evaluated, while untreated plots served as control.

Phytotoxicity of horticultural mineral oil

Phytotoxicity of HMOs (Arbofine HMO and MAK All Season HMO) was assessed at concentrations ranging from 0.10 to 0.75% by spraying on 20 days old summer mung bean crop. Both the HMOs exhibited yellowing of leaf lamina at concentrations higher than 0.3%, whereas treatment at 0.3% concentration was non-phytotoxic and suitable for the crop.

Experimental design

Experiments were carried out to determine the efficacy of field applications of horticultural mineral oils and botanicals for the management of *M. distalis* in summer mung bean at Ludhiana (30.9010° N, 75.8573° E). An early maturing variety of summer mung bean (TMB 37) was sown as per recommended agronomic practices at Pulses Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, in plots measuring 10.5 m^2 (9 rows of 5 m row length with 22.5 cm spacing) in 3 replications, using the randomized complete block design (RCBD). The crop was monitored regularly for natural appearance of thrips. Except bean thrips, no other insect pests were observed on the crop. Foliar sprays of HMOs, neem-based commercial formulations, NSKE, homemade neem extract, pongamia, and dimethoate 30% EC were sprayed, using backpack sprayer in the plots upon appearance of bean thrips at flowering initiation stage of the crop. Numbers of thrips (nymphs and adults) were recorded from 10 randomly selected flowers from each plot before treatment and 1, 3, 7, and 10 days after treatment (DAT). The effect of treatments on mung bean grain yield was recorded, and economic returns were estimated.

Statistical analysis

Data obtained were transformed to square root values and then subjected to analysis of variance (ANOVA) using a randomized complete block design (RCBD). The means were separated using least significant difference (LSD) at 5% level of significance (Gomez and Gomez 1984). The reduction percentage was calculated according to Henderson and Tilton (1955) with the following equation:

$$100\mathrm{x}1 - \left(\frac{\text{Number of insects in control before spray} \times \text{Number of insects in treatment after spray}}{\text{Number of insects in control after spray} \times \text{Number of insects in treatment before spray}}\right)$$

The cost of treatment was estimated based on retail price of insecticides. Net profit was estimated based on the income of grain yield (Indian Rupees INR 70 per kg) and the cost per hectare from treatments.

Results and discussion

Average numbers of *M. distalis* after treatment

In 2018, the numbers of thrips per 10 flowers did not differ significantly and ranged from 5.67–10.00 before treatment (Table 1). Following application of 5% NSKE, 250 ml ha^{-1} of dimethoate 30% EC, 10 ml l^{-1} of Indo-Neem 1500 ppm, 10 ml l^{-1} of Nimbecidine 300 ppm, 10 ml l^{-1} of Neem Kavach 1500 ppm, 0.3% Arbofine HMO, 10 ml l^{-1} of Neem Baan 1500 ppm, 10 g l^{-1} of Pongamia soap, and 0.3% MAK All Season HMO, the thrips count was lowered to 0.67, 1.33, 1.33, 2.00, 2.33, 2.33,3.00, 3.33, and 4.00 thrips per 10 flowers, respectively 1 day after treatment (DAT). However, in case of water spray (control), thrips incidence reduced from 6.67 to 3.33, one DAT, and then increased soon after (3 DAT) to 8.67 and to 14.00 thrips per 10 flowers up to 10 DAT, while in untreated control, there was a continuous increase in incidence on all the days of observation. One day after spray, 5% NSKE was found to be the most effective against bean thrips (0.67 thrips per 10 flowers) and treatments with dimethoate, Indo-Neem, Nimbecidine, Neem Kavach, and Arbofine HMO were on par with it ($P = 0.05$).

Similar trend was observed in 2019, where the thrips count per 10 flowers ranged from 10.33–15.33 in various plots before treatment; the differences were non-significant (Table 2). One DAT, the thrips counts per 10 flowers were reduced in all the treatments, except the water spray and untreated control. Least numbers of thrips (1.33 thrips per 10 flowers) were observed in the treatments 5% NSKE and 10 ml l^{-1} of Neem Kavach 1500 ppm, followed by insecticide dimethoate and Arbofine HMO (2.00 thrips/10 flowers). Three DAT, Neem Kavach had the least insect incidence, followed by 250 ml ha^{-1} dimethoate 30% EC, 5% NSKE, Indo-Neem, Neem Baan, and Arbofine HMO, which were statistically on par with it and significantly better than remaining treatments. Incidence of thrips in homemade neem extracts ranged from 3.33–5.33 and 5.33–6.66 thrips per 10 flowers one and 3 DAT, respectively as compared to 15.33 and 19.33 ones in untreated control in 2019 (Table 2).

Pooled data, reflected lower incidence of thrips, was observed 1 DAT at the treatments 5% NSKE (1.00 thrips/10 flowers), followed by dimethoate 30% EC, Neem Kavach, Indo-Neem, Arbofine HMO, and Nimbecidine, which were on par with it (Table 3). The least effective treatments were MAK All season HMO (5.50) and pongamia

Table 1 Efficacy of mineral oils and botanicals on the incidence of *Megalurothrips distalis* in summer mung bean in 2018

Treatment	No. of thrips per 10 flowers				
	Pre treatment	1DAT	3DAT	7DAT	10DAT
MAK All Season HMO 0.3%	10.00	4.00^{c} (2.22)	5.00^{cd} (2.44)	7.33^{de} (2.89)	10.33^{a} (3.36)
Arbofine HMO 0.3%	7.00	2.33^{abc} (1.80)	4.67^{cd} (2.38)	5.00^{abc} (2.44)	9.00^{a} (3.16)
NSKE 5%	5.67	0.67^{a} (1.27)	2.00^{a} (1.72)	4.67^{ab} (2.38)	7.67^{a} (2.94)
Neem Baan 1500 ppm 10 ml l^{-1}	9.00	3.00^{bc} (1.96)	4.33^{cd} (2.31)	6.33^{bcde} (2.71)	9.00^{a} (3.15)
Indo-Neem 1500 ppm 10 ml l^{-1}	8.00	1.33^{ab} (1.52)	4.67^{cd} (2.38)	6.00^{abcd} (2.63)	8.67^{a} (3.11)
Nimbecidine 300 ppm 10 ml l^{-1}	9.00	2.00^{abc} (1.72)	4.33^{cd} (2.29)	6.67^{cde} (2.76)	9.00^{a} (3.14)
Neem Kavach 1500 ppm 10 ml l^{-1}	9.00	2.33^{abc} (1.80)	4.00^{bc} (2.23)	7.00^{de} (2.82)	8.67^{a} (3.09)
Pongamia soap 10 g l^{-1}	6.00	3.33 (2.07^{c})	5.67 (2.57^{d})	8.00 (3.00^{ef})	10.67 (3.40^{ab})
Rogor 30% EC (dimethoate 30% EC) 250 ml ha^{-1}	8.00	1.33^{ab} (1.47)	2.67^{ab} (1.90)	4.33^{a} (2.31)	8.67^{a} (3.10)
Water	6.67	3.33^{c} (2.07)	8.67^{e} (3.10)	10.00^{f} (3.31)	14.00^{bc} (3.87)
Untreated control	9.00	10.00^{d} (3.31)	12.33^{f} (3.65)	14.67^{g} (3.95)	17.33^{c} (4.27)
CD ($P = 0.05$)	NS	(0.53)	(0.34)	(0.34)	(0.50)
F value; df = 10	1.77	9.23	21.73	16.93	5.46

Means followed by the same letter in each column with treatments did not differ significantly at the 5% level by LSD test. Figures in parentheses are $\sqrt{n+1}$ transformed values
DAT days after treatment

Table 2 Efficacy of mineral oils and botanicals on the incidence of *Megalurothrips distalis* in summer mung bean in 2019

Treatment	No. of thrips per 10 flowers				
	Pre treatment	1 DAT	3 DAT	7 DAT	10 DAT
MAK All Season HMO	14.67	7.00^{c} (2.82)	7.00^{b} (2.82)	12.00^{d} (3.60)	13.33^{abcd} (3.78)
Arbofine HMO	10.67	2.00^{ab} (1.72)	4.00^{a} (2.20)	10.67^{bcd} (3.41)	14.00^{bcde} (3.87)
NSKE	13.33	1.33^{a} (1.47)	3.33^{a} (2.07)	8.67^{ab} (3.11)	10.00^{a} (3.30)
Neem Baan	14.00	3.33^{b} (2.07)	3.33^{a} (2.07)	10.00^{bcd} (3.31)	12.00^{abc} (3.60)
Indo-Neem	12.67	2.67^{ab} (1.90)	3.33^{a} (2.07)	10.00^{bcd} (3.31)	12.00^{abc} (3.60)
Nimbecidine	10.33	2.67^{ab} (1.90)	6.00^{b} (2.65)	11.33^{cd} (3.51)	12.67^{f} (3.67)
Neem Kavach	14.00	1.33^{a} (1.47)	2.67^{a} (1.90)	7.33^{a} (2.88)	10.87^{ab} (3.41)
Pongamia soap	11.33	7.33 (2.88^{c})	10.67 (3.41^{c})	16.00 (4.12^{e})	14.67^{cde} (3.96)
Dimethoate 30% EC	12.00	2.00^{ab} (1.72)	3.33^{a} (2.07)	9.00^{abc} (3.16)	13.33^{abcd} (3.78)
Homemade neem extract (boiled)	13.33	3.33^{b} (2.08)	5.33^{b} (2.51)	11.33^{cd} (3.51)	13.33^{abcd} (3.78)
Homemade neem extract (overnight soaking)	12.66	5.33^{bc} (2.51)	6.66^{b} (2.76)	12.00^{d} (3.58)	14.66^{cde} (3.95)
Water	15.33	12.00^{d} (3.60)	14.67^{d} (3.95)	16.67^{e} (4.19)	18.00^{e} (4.35)
Untreated control	14.00	15.33^{d} (4.03)	19.33^{e} (4.51)	20.00^{f} (4.58)	17.33^{de} (4.28)
CD (P = 0.05)	NS	(0.57)	(0.39)	(0.38)	(0.50)
F value; df = 12	0.87	17.42	36.74	14.52	3.09

Means followed by the same letter in each column with treatments did not differ significantly at the 5% level by LSD test. Figures in parentheses are √n + 1 transformed values
DAT days after treatment

Table 3 Incidence of bean thrips, *Megalurothrips distalis*, and reduction percent after application of treatments in summer mung bean (pooled data of 2018 and 2019)

Treatment	Pre treatment	1 DAT		3 DAT		7 DAT		10 DAT	
	No. of thrips/ 10 flowers	No. of thrips/ 10 flowers	Reduction %	No. of thrips /10 flowers	Reduction %	No. of thrips/ 10 flowers	Reduction %	No. of thrips/ 10 flowers	Reduction %
MAK All Season HMO	12.33	5.50^{c} (2.52)	59.47	6.00^{de} (2.63)	64.67	9.67^{c} (3.24)	47.95	11.83^{bc} (3.57)	36.34
Arbofine HMO	8.83	2.16^{ab} (1.77)	77.78	4.33^{bcd} (2.30)	64.39	7.83^{ab} (2.93)	41.16	11.50^{bc} (3.51)	13.58
NSKE	9.50	1.00^{a} (1.38)	90.44	2.67^{a} (1.89)	79.59	6.67^{a} (2.74)	53.41	8.83^{a} (3.13)	38.33
Neem Baan	11.50	3.16^{bc} (2.02)	75.29	3.83^{abc} (2.19)	75.82	8.17^{abc} (3.00)	52.86	10.50^{abc} (3.38)	39.42
Indo-Neem	10.33	2.00^{ab} (1.70)	82.42	4.00^{abc} (2.22)	71.88	8.00^{abc} (2.97)	48.62	10.33^{ab} (3.35)	33.65
Nimbecidine	9.67	2.33^{ab} (1.81)	78.12	5.17^{cd} (2.47)	61.18	9.00^{bc} (3.13)	38.25	10.83^{abc} (3.41)	25.69
Neem Kavach	11.50	1.83^{ab} (1.63)	85.55	3.33^{ab} (2.06)	78.97	7.17^{a} (2.85)	58.63	9.67^{ab} (3.25)	44.21
Pongamia soap	8.67	5.33^{cd} (2.48)	44.18	8.17^{e} (2.99)	31.58	12.00^{d} (3.56)	8.16	12.67^{c} (3.68)	3.04
Dimethoate 30% EC	10.00	1.66^{ab} (1.60)	84.92	3.00^{ab} (1.98)	78.22	6.67^{a} (2.73)	55.74	11.00^{abc} (3.44)	27.02
Water	11.00	7.66^{d} (2.83)	36.77	11.67^{f} (3.53)	22.98	13.33^{d} (3.76)	19.59	16.00^{d} (4.11)	3.49
Control	11.50	12.66^{e} (3.68)	-	15.83^{g} (4.07)	-	17.33^{e} (4.27)	-	17.33^{d} (4.27)	-
CD (P = 0.05)	NS	(0.46)		(0.37)		(0.28)		(0.33)	
F value; df = 12	0.79	17.46		28.41		23.94		9.13	

Means followed by the same letter in each column with treatments did not differ significantly at the 5% level by LSD test. Figures in parentheses are √n + 1 transformed values
DAT days after treatment

soap (5.33 thrips per 10 flowers). Both 3 and 7 DAT, NSKE 5% was found to be as effective as dimethoate 30% EC, followed by Neem Kavach.

Reduction percentage

One day after treatment, NSKE 5% gave the highest mean percent reduction in the number of thrips (90.44%), followed by Neem Kavach (85.55%), dimethoate 30% EC (84.92%), Indo-Neem (82.42%), Nimbecidine (78.12%), and Neem Baan (75.29%) (Table 3). Arbofine HMO provided 77.78% reduction, while pongamia provided the least reduction of 44.18%. In a similar trend, 3 DAT, NSKE 5% gave the highest mean percent reduction in the number of thrips (79.59%), followed by Neem Kavach (78.97%), dimethoate 30% EC (78.22%), Neem Baan (75.82%), Indo-Neem (71.88%), and Nimbecidine (61.18%). Horticultural mineral oils also reduced the insect population with about 64%, while pongamia soap was the least effective (31.58%). Maximum efficacy of all 5 neem-based treatments was obtained 1 DAT (75.29–90.44% reduction in thrips population) that became 61.18–79.59% 3 DAT. The efficacy subsequently decreased to reach 38.25–58.63 and 25.69–44.21% reduction after 7 and 10 days of spray, respectively. Although the efficacy of all treatments lessened over a period of 7–10 days, second spray was not considered as the crop has a short duration. In this hot dry summer season, the crop matures in 60 days and is a catch crop that fits well in the wheat–rice cropping system.

Neem extracts usually act as antifeedant, repellent, and oviposition deterrent on a wide spectrum of insect pests (Regnault-Roger and Philogène 2008). Neem seed kernel extract of 5% was found to be effective against flower bud thrips, *Megalurothrips sjostedti* Trybom, in cowpea in Nigeria (Egho and Emosairue 2010a). Irulandi and Balasubramanian (2000) reported that 5% NSKE and 2% neem oil were effective against *M. distalis* in mung bean in South India. Application of local neem oil proved most effective in reducing *M. sjostedti* population to a level similar to insecticides when applied at early stage (budding) than late stage (25% flowering) in cowpea (Traore et al. 2019). This is in agreement with the present study, where neem-based treatments were effective against *M. distalis* when applied at flowering initiation stage. NSKE 5% and neem oil has been reported to be highly effective against onion thrips (Singh et al. 2009) and cotton thrips (Asif et al. 2018). Kordy and Barakat (2014) reported that applications of Nimbecidine® (azadirachtin), followed by Tracer® (spinosad), gave effective reduction in incidence of onion thrips after 7 days (94.64 and 93.65%). In the present study, Nimbecidine reduced thrips to 61.18%, 3 DAT. The soaked and boiled homemade neem extracts evaluated in 2019 recorded thrips reductions of 61.69 and 77.27%, respectively, 1DAT; 62.00 and 71.05%, respectively, 3DAT; 33.64 and 40.50%, respectively, 7DAT; and only 6.55 and 19.30%, respectively, 10 DAT as can be derived from Table 2 according to Henderson and Tilton (1955). Overall, dimethoate was still the most effective treatment providing 55.74 to 84.92% reduction up to 7 DAT but with decreasing efficacy over the days as was the case for all the treatments. Earlier, Chhabra and Kooner (1985b) reported that dimethoate gave a high control of thrips in mung bean in Punjab. HMOs also reduced the insect population with 41.16–77.78%, while pongamia soap was the least effective (8.16–44.18%) among all botanicals although it was significantly better than water spray alone and untreated control.

Yield and percent increase in yield over untreated control

In 2018, yield of mung bean ranged from 968 to 1430 kg ha^{-1} in various treatments, as compared to 963 and 914 kg ha^{-1} in water spray and untreated control, respectively (Table 4). Among all treatments, significantly higher yield was recorded at dimethoate 30% EC (1430 kg ha^{-1}), and nimbecidine was on par with it. Among the botanicals and HMOs, Nimbecidine gave the highest grain yield (1389 kg ha^{-1}), followed by Neem Kavach, NSKE, and Indo-Neem which were on par with it. In 2019, grain yield was the highest at NSKE (1302 kg ha^{-1}), and the treatments dimethoate (1245 kg ha^{-1}) and Neem Kavach (1236 kg ha^{-1}) were on par with it.

Table 4 Yield of summer mung bean as influenced by various treatments for management of *Megalurothrips distalis*

Treatment	Yield (kg ha^{-1})			Percent increase in yield over control
	2018	2019	Mean	
MAK All Season HMO	1110^{d}	865de	987^{e}	14.50
Arbofine HMO	1130^{d}	1013^{c}	1071^{d}	24.25
NSKE	1345^{b}	1302^{a}	1324^{a}	53.59
Neem Baan	1245^{c}	1223^{b}	1234^{c}	43.16
Indo-Neem	1343^{b}	1189^{b}	1266^{bc}	46.86
Nimbecidine	1389^{ab}	1230^{b}	1309^{ab}	51.86
Neem Kavach	1362^{b}	1236^{ab}	1299^{ab}	50.69
Pongamia soap	968^{e}	930^{d}	949^{e}	10.09
Dimethoate 30% EC	1430^{a}	1245^{ab}	1337^{a}	55.10
Water	963^{e}	810^{e}	887^{f}	2.90
Control	914^{e}	810^{e}	862^{f}	-
CD (P = 0.05)	54.46	70.97	57.79	
F value; df = 12	106.4	64.66	86.17	

Means followed by the same letter in each column with treatments did not differ significantly at the 5% level by LSD test. Yields obtained in 2019 in additional treatment homemade neem (boiled) = 1210 kg ha^{-1} and overnight soaked = 1102 kg ha^{-1}

Table 5 Economics of various treatments over untreated control for the management of *Megalurothrips distalis* in summer mung bean

Treatments	*Cost of insecticide (INR ha^{-1})	*Total cost (insecticide + labor) (INR ha^{-1})	Additional yield over control (kg ha^{-1})	Income from additional yield (INR ha^{-1})	Net return over control (INR ha^{-1})
MAK All Season HMO	750	1450	126	8820	7370
Arbofine HMO	750	1450	209	14,630	13,180
NSKE	1250	2300	462	32,340	27,290
Neem Baan	1438	2137.5	372	26,040	23,902.5
Indo-Neem	1189	1887.5	404	28,280	26,392.5
Nimbecidine	1125	1825	447	31,290	29,465
Neem Kavach	1125	1825	437	30,590	28,765
Pongamia soap	525	1225	87	6090	4865
Dimethoate 30% EC	119	818.5	475	33,250	32,431.5

*For one spray, number of persons required to spray 1 ha = 2; daily wages = INR 350; market price of mung bean = INR 70 per kg; Nimbecidine 300 ppm = INR 450 per liter; Rogor 30% EC (dimethoate) = INR 475 per liter; Neem Kavach 1500 ppm = INR 450 per liter; NSKP = INR 100 per kg; Neem Baan 1500 ppm = INR 575 per liter; Indo-Neem = INR 475 per liter; Arbofine HMO = INR 100 per liter; MAK All Season HMO = INR 100 per liter; pongamia soap = INR 210 per kg

Mean yields in treatments dimethoate 30% EC (1337 kg ha^{-1}) and NSKE (1324 kg ha^{-1}) were significantly higher than other treatments, while the lowest mean grain yields were recorded in water spray and untreated control (887 and 862 kg ha^{-1}, respectively), followed by pongamia soap (949 kg ha^{-1}) and Arbofine HMO (987 kg ha^{-1}). The percent increase in yield over untreated control was 55.10, 53.59, 51.86, and 50.69%, following application of dimethoate 30% EC, NSKE, Nimbecidine, and Neem Kavach, respectively. In 2019, treatment with homemade neem extracts (boiled and overnight soaking) resulted in a yield of 1210 and 1102 Kg ha^{-1}, respectively, to get 40.37 and 27.9% increase in yield over untreated control. Chhabra and Kooner (1985b) reported that dimethoate gave a high control of thrips in mung bean at Ludhiana and increased the yield with up to 89%. Horticultural mineral oils MAK All Season and Arbofine were less effective than botanicals as they led to only 14.50 and 24.25% increase in yield over untreated control, respectively (Table 4). The oils were moderately effective in reducing thrips population in the mung bean flowers at 0.3% without any phytotoxicity. In a similar study, Egho and Emosairue (2010b) reported effective control of *M. sjostedti* on cowpea in Nigeria, using mineral oils. Dhaliwal (2018) evaluated the efficacy of several horticultural mineral oils against the thrips and mites on kinnow at Ludhiana, Punjab, and all the HMOs reduced the thrips population marginally providing about 40% control of thrips up to 7DAT. Phytotoxicity at concentrations more than 2%, even though at higher concentrations, were more effective. Similarly, HMO at 1.5% reduced citrus fruit blemishes caused by mites and thrips in Pakistan (Khalid et al. 2012). In the present study, concentrations greater than 0.3% resulted in phytotoxicity on leaves. Phytotoxicity at such low concentrations could also be related to the hot and dry weather conditions prevailing in the cropping season at the time.

Comparative economics of different treatments evaluated against bean thrips over untreated control is presented in Table 5. The total cost for various treatments ranged from INR 1225 to INR 2300 per ha, while in insecticidal treatment, it was 818.50 INR per ha. The net returns over untreated control of different treatments ranged from INR 4865 to INR 32431.5 (69 to 460 USD) per ha. Maximum returns were obtained using dimethoate due to the highest efficacy and the lowest cost. Among the botanicals and HMOs evaluated, treatment with 10 ml l^{-1} of Nimbecidine 300 ppm gave the highest net returns over untreated control, followed by 10 ml $l^{-1}$of Neem Kavach 1500 ppm and NSKE at 5%. If the farmers can collect and process the neem seed kernels themselves, it may further reduce the cost of treatment to get high returns.

Conclusions

For managing bean thrips in mung bean, dimethoate 30% EC was found to be the most effective providing the maximum grain yield and the highest net returns over untreated control. Among all botanicals evaluated, 5% spray of NSKE showed promising results.

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Author details
[1]Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab 141004, India. [2]Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, Punjab 141004, India.

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