

POTENTIAL APPLICATION OF HEMP IN CONTROLLING THE RICE INSECT PEST *Nilaparvata lugens* (Stål, 1854) IN PADDY FIELDS

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ABSTRACT

The potential of *Cannabis sativa* L. subsp. *sativa* (hemp) in controlling the rice pest *Nilaparvata lugens* (Stål) (brown planthopper) was investigated through direct spraying touch testing in paddy field testing plots. Treatments included hemp leaf extract, hemp seed oil, hop-headed barleria (*Barleria lupulina* Lindl.) extract, and hemp leaf extract with petroleum oil (SK EnSpray99), with water as the negative control. Randomised Complete Block Design (RCBD) with eight treatments in three replications each was conducted during September to December 2021. The plant extracts were obtained using 95% methanol as the solvent in a rotary evaporator. The efficacy of the plant extracts in controlling brown planthoppers (*Nilaparvata lugens* Stål) in rice fields was evaluated using a contact-killing spray method every 7 days. The numbers of brown planthoppers and green mirids (*Cyrtorhinus lividipennis* Reuter) were randomly sampled after spraying the plant extracts. The process of spraying each solution type onto rice plants in each subplot uses 2 litres of solution per subplot. The equipment used is a low-pressure spray tank and a spot-spray head to prevent the solution from spreading. The results of random counting of 24 plots of brown planthoppers in paddy fields after spraying revealed that their populations were statistically significantly different from those in the control. Using 5% hemp leaf extract with petroleum oil on 80-day-old rice plants yielded the most significant decrease in brown planthopper population, with an average of 2.75 insects/clump counted after treatment. This was significantly different to the counts obtained following the 10% hemp leaf extract (3.50 insects/clump) and 5% hemp leaf extract (3.85 insects/clump) treatments. Moreover, the efficacies of the latter treatments were significantly higher than those of the 10% hop-headed barleria extract (6.25 insects/clump), 5% hop-headed barleria extract (6.50 insects/clump), 5% hemp seed oil (7.25 insects/clump), 10% hemp seed oil (7.00 insects/clump), and control (9.50 insects/clump), respectively. All treatments were statistically significantly different at a $p < 0.05$ level of confidence.

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Introduction

Thailand is an agricultural country that produces food with the target of developing the country into the world's kitchen. The largest rice-growing areas in the central region are Pathum Thani, Suphan Buri, Nakhon Pathom, Sing Buri, Ang Thong, Ayutthaya, Chai Nat, and Nakhon

Nayok. Farmers have encountered severe pest problems during the dry season, namely brown planthoppers in rice fields, which negatively impact rice yields. Farmers have used high levels of synthetic chemicals, which have also destroyed natural predators such as green mirids

that suck the eggs of brown planthoppers, houseflies, dragonflies, and other ladybugs. This has led to a decrease in insect diversity in the ecosystem and pesticide residues in the environment, so the biopesticides derived from plants, on the other hand, contain a combination of active ingredients and often have multiple modes of action, making it difficult for insects to develop resistance (Phimsamhan & Sangwan, 2001; Aekamnuay, 2009; Arunmit *et al.*, 2023).

In Thailand, farmers, especially the Hmong hill-tribe people who live in the north, grow and use hemp (Thiprat *et al.*, 2008). For example, there is a culture of using hemp fibres to make clothing. Hemp is grown once a year, harvested using only the fibres from the stems, not the leaves, and the seeds are stored for planting in the next season. Therefore, there is interest in developing innovations for underutilised leaves and hemp seeds, promoting hemp as a future economic crop, and thus creating opportunities for economic competition (Nathagangijgul *et al.*, 2009). Some Thai government agencies have funded research into the levels of essential substances in hemp, as well as the factors affecting those levels.

In addition, the Office of the National Economic and Social Development Commission supported hemp-planting research and development projects during 2007 until 2010. This involved the creation of a database for essential substances such as tetrahydrocannabinol (THC) and cannabidiol (CBD). The THC content in hemp ranges from 0.682 to 0.833 d.w., while its CBD content ranges from 0.446 to 0.580 d.w. (Thiprat & Thitajaree, 2008), which differs from the contents of these chemicals in cannabis by less than 1%. To distinguish between hemp and cannabis in the laws stipulated in the ministerial regulation granting permission to produce, sell, or possess narcotics in category 5 (comprising only hemp), B.E. 2016, Section 3 of the regulation states that “hemp” denotes the plant with the scientific name *Cannabis sativa* L. subsp. *sativa*, which is a subspecies of the cannabis plant (*Cannabis sativa* L.).

Moreover, this plant must contain no more than 1.0% THC on a dry-weight basis, as analysed in accordance with the criteria and methods announced by the committee (Thiprat *et al.*, 2009). Citizens can request permission to plant, harvest, or process hemp in accordance with the announcement. Currently, there are agencies requesting permission to grow hemp to further develop the use of hemp fibre in the north of Thailand, namely the Highland Research and Development Institute (HRDI) (Public Organisation) and the Royal Project Foundation, Chiang Mai Province. Therefore, the present study is of great use in elucidating basic information on the use of hemp plants in other areas, especially on oil extracted from hemp seeds and cassava leaf extracts for protection against important rice insect pests (Srirattanasak *et al.*, 2007), namely the brown planthopper *Nilaparvata lugens* (Stål), as an innovative natural pesticide (Charoenkrung *et al.*, 2014). Such innovations will also create more jobs and careers for hill tribe people in processing hemp products, as well as opportunities for future use of hemp as an economic crop.

Moreover, this research is on the development of innovative hemp-based pest control for rice provides crucial foundational information for farmers, the government, the private sector, and civil society. To be consistent with the context of the area, the research results obtained here can be transferred in the form of academic services to the community and society based on the sustainable use of natural resources in a circular manner as per the Bio-Circular Green Economy policy (Penpo *et al.*, 2019; Sangpakdee *et al.*, 2024). However, this study specifically aimed to research the uses of the hemp plant in preventing and eliminating the brown planthopper rice pest and the relationships between natural enemy insects, green mirid (*Cyrtorhinus lividipennis* Reuter) (Plant Protection Promotion and Soil-Fertiliser Management Division, 2024). This involved testing hemp seed oil extract, hemp leaf extract combined with petroleum oil, and hop-headed barleria (*Barleria lupulina* Lindl.) extract at

different concentrations, against water (the control). The work serves as a guide for further research into the commercial use of hemp extracts.

Materials and Methods

The Study Sites

The sample collection area was located in northern Thailand. This study focused on an individual region within this area where different agricultural activities were conducted: Case crop production, hemp production, and hemp planting on farm plots in Pa Kha Mai Village, Khiri Rat Subdistrict, Phop Phra District, Tak Province (Figure 1).

Sample Preparation and Element Analysis

Hemp leaf samples and hemp seeds were obtained from farm plots in Phop Phra District, Tak Province, collected in plastic bags containing 5 kg per sample, and placed in a refrigerated box for transportation to the laboratory. For hemp leaf samples, 500 g of the leaves were dried at 40°C in a hot-air oven for 36 hours, and the dried hemp leaves, fresh hemp leaves, and hemp seeds were stored in a refrigerator at 4°C (Kroeksakul et al., 2023).

Analysis of Important Substances through HPLC

High-performance liquid chromatography (HPLC) was used to determine the key compounds in 1-g samples of dried hemp leaves, fresh hemp leaves, and hemp seeds using the TSKgel new_V column.lcm HPLC column and Shimadzu Corporation series RF-20Axs fluorescence detector (Japan). The following ShimadZu LC solution calibration curves (Japan) were obtained for important substances: CBDV: $f(x)=12924.5*x+3798.85$ $Rr1=0.9997821$ $Rr2=0.9995642$, CBDA: $f(x)=19187.3*x-19410.3$ $Rr1=0.9980465$ $Rr2=0.9960967$, CBGA: $f(x)=15068.6*x+6406.45$ $Rr1=0.9984615$ $Rr2=0.9969254$, CBG: $f(x)=12777.1*x+12344$ $Rr1=0.9996604$ $Rr2=0.9993209$, CBD: $f(x)=12635.3*x+13300.7$ $Rr1=0.9995430$ $Rr2=0.9990862$, THCV: $f(x)=12912.1*x+5075.66$ $Rr1=0.9993282$ $Rr2=0.9986568$, CBN: $f(x)=20798.1*x+2365.3$ $Rr1=0.9997569$ $Rr2=0.9995139$, d9-THC: $f(x)=11536.7*x+28925.8$ $Rr1=0.9997830$ $Rr2=0.9995661$, CBC: $f(x)=11832.7*x+3751.75$ $Rr1=0.9994813$ $Rr2=0.9989628$, and THCA-A: $f(x)=12125.6*x-10398.7$ $Rr1=0.9974343$ $Rr2=0.9948752$.



Figure 1: Study site and field plots where samples were collected

Sample Preparation of Plant Extracts

The samples for plant extract analysis included dried hemp leaves, hemp seeds, and hop-headed barleria collected from the study sites (the barleria was sourced from the herb garden plots of community farmers in Khlong 15). These samples were dried at room temperature until reaching < 10% moisture content. Afterwards, using 95% methanol as a solvent in the extraction process, rotary evaporators and an IKA RV 10 D S99 vacuum pump (Germany) were used to obtain extractions from plants at 40°C for 10 hours. After that, the obtained plant extracts were prepared into solutions of different concentrations, including 5% and 10% dried hemp leaf extract, 5% and 10% hemp seed oil, 5% and 10% hop-headed barleria extract, as well as 5% hemp leaf extract with petroleum oil (trade name SK EnSpray99), were compared with plain water (control) in an experiment testing their effectiveness in preventing and eliminating the brown planthopper (Department of Agricultural Extension, 2018). This trial was conducted in farm fields in Ongkharak District, Nakhon Nayok Province, during September until December 2021.

Experimental Design

The plant extracts were obtained using 95% methanol as the solvent in a rotary evaporator. The efficacy of the plant extracts in controlling brown planthoppers (*Nilaparvata lugens* Stål) in rice fields was evaluated using a contact-

killing spray method every 7 days. The numbers of brown planthoppers and green mirids (*Cyrtorhinus lividipennis* Reuter) were randomly sampled after spraying the plant extracts. The process of spraying each solution type onto rice plants in each subplot uses 2 litres of solution per subplot. The equipment used is a low-pressure spray tank and a spot spray head to prevent the solution from spreading.

The plant extracts prepared in solutions of different concentrations as described above, including 5% and 10% dried hemp leaf extract, 5% and 10% hemp seed oil, 5% and 10% hop-headed barleria extract, as well as 5% hemp leaf extract with petroleum oil (trade name SK EnSpray99), were compared with plain water (control) in an experiment testing their effectiveness in preventing and eliminating the brown planthopper (Department of Agricultural Extension, 2018). This trial was conducted in farm fields in Ongkharak District, Nakhon Nayok Province, during September until December 2021.

The experiment was planned using Randomised Completely Block Design (RCBD)



Figure 2: Crude extraction process

with 3 repetitions each of 8 methods included 24 plots, a plot size of 3 × 5 m, and statistical data collected after receiving the material, divided into six time periods: 45 days, 52 days, 59 days, 66 days, 73 days, and 80 days (Sangpakdee et al., 2014). The location of this study site is presented in Figure 3.

After spraying the solution, a random count of brown planthoppers was conducted using a 1-square-metre wooden frame placed over the rice plants in each treatment to count the insects at the base of the rice stalks and record the data for statistical analysis. Meanwhile, the random inspection of natural enemies is the green mirid using a swooping swing that must walk in a diagonal line in the shape of an X in each subplot. Then transfer the insects from the swing into a clear plastic bag lined with a hard plastic sheet to count the green mirids and record the data for statistical analysis. The experimental methods in rice fields presented in Figure 4.

Data Analysis

Data were analysed using one-way Analysis of Variance (ANOVA) for variance, and differences were deemed significant at the $p < 0.05$ confidence level. All analyses were conducted using Statistical Package for the Social Sciences (SPSS) version 22.

Results and Discussions

The Context of the Study Sites

Hemp leaf samples and seeds were collected during a survey of hemp planting plots in Phop Phra District, Tak Province, northern Thailand, for further research under laboratory conditions. In addition, basic information on hemp cultivation by Hmong hill tribe farmers in the Ban Pa Kha Mai area, Khiri Rat Subdistrict, Phop Phra District, Tak Province was obtained. Through these surveys, it was found that the Hmong hill tribe people have a culture of using hemp to produce fabric pipe fibres for garments worn in everyday life. This fibre production is also an important tradition in the annual Hmong New Year Festival. The Hmong people use only fibres from the stem, whereas the leaves, which are not used are picked and discarded in the plot. The hemp seeds, on the other hand, are kept for planting the next season, and some stems with the fibres removed are kept for a folk decoction used to treat vaginal discharge. The remaining part of the stem is used to make firewood, after which the ashes are mixed with the seeds to prevent insects from destroying the seeds. The ashes are also scattered over the hemp plantations the following year. From a survey of the hemp-growing plot area managed by each household, it was found that each household

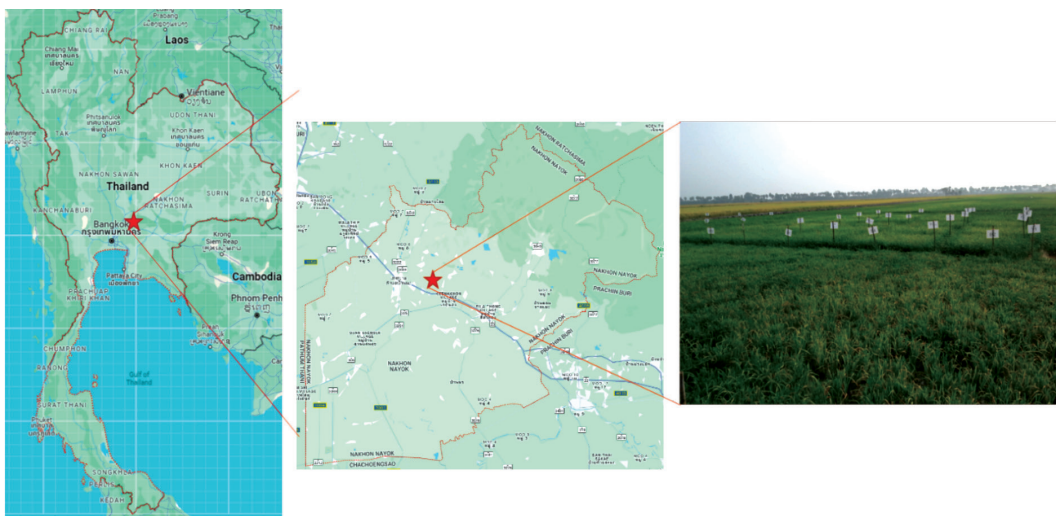


Figure 3: Study site and experimental plots in farm fields, Ongkharak District, Nakhon Nayok Province

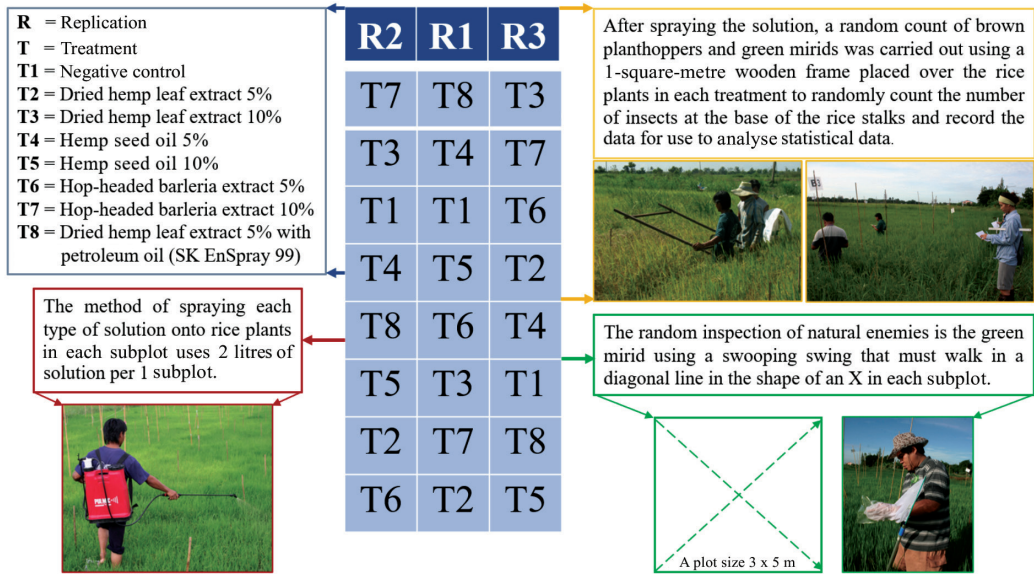


Figure 4: The experimental methods in rice fields

grows hemp on an area not exceeding 400 m². The total area of hemp planting from the survey of 10 households was 6,628 m², used solely to produce clothing fibres for family members each year, sufficient for the household’s number of members. As for the hemp variety, it is the original native “Phop Phra” variety. This variety has tough fibres suitable for producing woven-clothing products, skirts, and bags.

Analysis of Important Substances in the Leaves and Hemp Seeds

The results of the HPLC analysis of the amounts of important substances in the dried hemp leaves showed that they contained several important substances, including cannabidiol (CBDV, 0.020% W/W), cannabidiolic acid (CBDA, 0.017% W/W), cannabigerolic acid (CBGA,

Table 1: Analysis of important substances in dried hemp leaves

PDA			Quantitative Results			
ID	Substances	Ret. Time	Area	Height	Conc.	Units
1	CBDV	4.302	83548	15637	0.020	% W/W
2	CBDA	5.241	103163	14904	0.017	% W/W
3	CBGA	5.437	357511	48754	0.074	% W/W
4	CBG	0.000	0	0	0.000	% W/W
5	CBD	5.966	293183	38195	0.069	% W/W
6	THCV	6.464	419160	52491	0.098	% W/W
7	CBN	8.297	521556	49664	0.077	% W/W
8	d9-THC	10.129	613786	55573	0.158	% W/W
9	CBC	12.520	289872	22543	0.074	% W/W
10	THCA-A	13.179	109884	7855	0.029	% W/W

Note: CBDV = Cannabidiol; CBDA = Cannabidiolic acid; CBGA = Cannabigerolic acid; CBG = Cannabigerol; CBD = Cannabidiol; THCV = Tetrahydrocannabivarin; CBN = Cannabinol; d9-THC = Delta-9-tetrahydrocannabinol; CBC = Cannabichromene; THCA-A = Tetrahydrocannabinol acid.

0.074% W/W), cannabigerol (CBG, 0.000% W/W), cannabidiol (CBD, 0.069% W/W), tetrahydrocannabivarin (THCV, 0.098% W/W), cannabiniol (CBN, 0.077% W/W), delta-9-tetrahydrocannabinol (d9-THC, 0.158% W/W), cannabichromene (CBC, 0.074% W/W), and tetrahydrocannabinol acid (THCA-A, 0.029% W/W), as presented in Table 1.

The important substances detected in fresh hemp leaves, on the other hand, included CBDV (0.002% W/W), CBDA (0.007% W/W), CBGA (0.020% W/W), CBG (0.001% W/W), CBD (0.001% W/W), THCV (0.000% W/W), CBN (0.005% W/W), d9-THC (0.010% W/W), CBC (0.002% W/W), and THCA-A (0.820% W/W), as presented in Table 2.

Finally, the important substances detected in hemp seeds included CBDV (0.0000% W/W), CBDA (0.0004% W/W), CBGA (0.0004% W/W), CBG (0.0003% W/W), CBD (0.0003% W/W), THCV (0.0021% W/W), CBN (0.0016% W/W), d9-THC (0.0030% W/W), CBC (0.0035% W/W), and THCA-A (0.0035% W/W), as presented in Table 3.

The results of the analysis of the important substance contents in hemp leaves and seeds are consistent with the study of Fetterman *et al.* (1971), in which classification of cannabis

(drug phenotype) and hemp (fibre phenotype) is conducted using the ratio (THC + CBN)/CBD. If the ratio is greater than 1, the plant is classified as cannabis. If it is less than 1, it is classified as hemp. On the other hand, small and beckstead classified the plant into three phenotypes: The drug phenotype has more than 0.3% of THC and less than 0.5% CBD for both males and females, the intermediate phenotype is a female plant with more than 0.3% of THC and more than 0.5% of CBD, and the non-drug phenotype is a female plant with less than 0.3% of THC but more than 0.5% of CBD.

While Meijer *et al.* (2003) also classified cannabis plants into three phenotypes based on their cannabinoid profiles, they classified cannabis plants with more than 0.5% THC, less than 0.5% CBD, and THC/CBD above 1 as the drug type and those with a quantity of THC and CBD greater than or equal to 0.5% as one of nine intermediate types. In Meijer *et al.* (2009), cannabis plants with a quantity of THC less than 0.5%, CBD greater than or equal to 0.5%, and THC/CBD below 1 were classified as a non-drug type.

The hemp plant contains various types of cannabinoids, including delta-9-tetrahydrocannabinol (d9-THC). This substance has the effect of causing a euphoric and happy

Table 2: Analysis of important substances in fresh hemp leaves

PDA		Quantitative Results				
ID	Substances	Ret. Time	Area	Height	Conc.	Units
1	CBDV	4.449	5975	1129	0.002	% W/W
2	CBDA	5.313	38658	4709	0.007	% W/W
3	CBGA	5.501	90765	11569	0.020	% W/W
4	CBG	5.776	5148	596	0.001	% W/W
5	CBD	6.041	2025	318	0.001	% W/W
6	THCV	6.841	300	40	0.000	% W/W
7	CBN	8.205	30033	2783	0.005	% W/W
8	d9-THC	10.244	34774	3202	0.010	% W/W
9	CBC	12.733	5534	389	0.002	% W/W
10	THCA-A	13.363	2891162	210807	0.820	% W/W

Note: CBDV = Cannabidivarin; CBDA = Cannabidiolic acid; CBGA = Cannabigerolic acid; CBG = Cannabigerol; CBD = Cannabidiol; THCV = Tetrahydrocannabivarin; CBN = Cannabiniol; d9-THC = Delta-9-tetrahydrocannabinol; CBC = Cannabichromene; THCA-A = Tetrahydrocannabinol acid.

Table 3: Analysis of important substances in hemp seeds

PDA		Quantitative Results				
ID	Substances	Ret. Time	Area	Height	Conc.	Units
1	CBDV	4.445	140	36	0.0000	% W/W
2	CBDA	5.262	2144	343	0.0004	% W/W
3	CBGA	5.473	2000	266	0.0004	% W/W
4	CBG	5.798	1424	222	0.0003	% W/W
5	CBD	6.011	1081	142	0.0003	% W/W
6	THCV	6.504	8960	1070	0.0021	% W/W
7	CBN	8.181	10399	1063	0.0016	% W/W
8	d9-THC	10.241	11442	1093	0.0030	% W/W
9	CBC	13.081	13618	931	0.0035	% W/W
10	THCA-A	13.343	13166	946	0.0035	% W/W

Note: CBDV = Cannabidiol; CBDA = Cannabidiolic acid; CBGA = Cannabigerolic acid; CBG = Cannabigerol; CBD = Cannabidiol; THCV = Tetrahydrocannabivarin; CBN = Cannabinol; d9-THC = Delta-9-tetrahydrocannabinol; CBC = Cannabichromene; THCA-A = Tetrahydrocannabinol acid.

mood in humans, which is more intense if consumed by smoking than by eating. Currently, US's scientists have extracted THC from cannabis to use in the production of a drug called dronabinol, trade name Marinol®, which has been approved for use by the US Food and Drug Administration (FDA) to prevent nausea and vomiting in cancer patients who must receive chemotherapy, administered before undergoing treatment. Marinol® is also used as an appetite stimulant in patients with Acquired Immunodeficiency Syndrome (AIDS). In addition, cannabichromene (CBC) has been shown to have anti-inflammatory effects, reduce pain, and exhibit antimicrobial and antifungal properties.

The Potential of Plant Extracts for Controlling Insect Pests in Paddy Fields

Images of the hemp plant extract and natural product experiment, involving random counting of the brown planthopper populations (Aekamnuay, 2009; Garrood *et al.*, 2016) of the number of brown planthoppers after spraying the substances in farm fields up to the harvest (Zhang *et al.*, 2016; Arunmit *et al.*, 2023), are presented in Figure 5.

Effects of Plant Extracts on Brown Planthopper Pest [*Nilaparvata lugens* (Stål, 1854)]

The treatment using 5% dried hemp leaf extract with petroleum oil (SK EnSpray 99) (80 cc per 20 L of water) reduced the brown planthopper populations to the most significant degree, with 2.75 insects per clump detected at the 80-day-old rice stage. This was significantly different to the 10% dried hemp leaf extract treatment (3.50 insects/clump) and 5% dried hemp leaf extract treatment (3.85 insects/clump), and showed significantly higher efficiency compared to the 10% hop-headed barleria extract treatment (6.25 insects/clump), 5% hop-headed barleria extract treatment (6.50 insects/clump), 5% hemp seed oil treatment (7.25 insects/clump), 10% hemp seed oil treatment (7.00 insects/clump), and the water control (9.50 insects/clump). Every treatment showed a statistically significant difference at the $p < 0.05$ confidence level, as presented in Table 4.

The findings of this study are consistent with those reported by Rismayani *et al.* (2023). Their research was conducted in the laboratory and the field. Screen house research was conducted at the Indonesian Spices and Medicinal Crops Research Institute by testing the botanical



Figure 5: The plant-extract spraying experiment in rice fields, up to the harvest stage

insecticide formulation at five concentrations (0, 0.5, 2.5, 4.5, and 6.5 cc/L) and repeated five times. The results showed that at a concentration of 4.5 cc/L, the insecticide caused 97% mortality in the insects. This concentration was then used for spray application in the screen house, which showed a greater number of productive tillers, grain per bunch, and 1,000-grain weight than the control treatment, and about 25% higher plant production. The field study conducted in Indramayu District showed that the botanical insecticide suppressed *N. lugens* populations without harming natural enemies. The production of plants sprayed with botanical insecticides was 16.39% higher than the control treatment. This indicated that the botanical insecticide tested can suppress *N. lugens* populations, is safe against natural enemies, and increases rice production.

A comparative analysis of research findings on rice yield in paddy fields was reported by Balasubramaniam and Kumar (2019), who investigated the use of neem formulations, the treatment with multineem 1.0% EC@2,500 mL/ha recorded lower yellow stem borer damage (7.89% to 6.73%/hill) and (6.96% to 5.46%/hill) with a percent reduction of 36.77% to 48.62%

and 41.90% to 65.75% as compared to the untreated check. The highest yield was observed in the treatment with dinotefuran 20 SG@200 g/ha (4.31 and 5.77 t/ha) and among the neem formulations, multineem 1% EC@2,500 mL/ha recorded the highest yield (3.90 and 5.40 t/ha) as compared to the untreated check (2.85 and 3.40 t/ha). Therefore, this study demonstrates that the use of botanical extracts can significantly reduce the population of *N. lugens*, in rice fields. This reduction is statistically significant and correlates with an increase in the green mirid population, a natural enemy of the brown planthopper. As a result, rice plants can grow more effectively and achieve higher yields.

Effects of Plant Extracts on Green Mirid (Cyrtorhinus lividipennis Reuter)

The assessment of green mirid (*Cyrtorhinus lividipennis* Reuter) (Wangsilabat et al., 2002) populations following the application of plant extracts (Sornnuwat, 1997; Phimsamhan & Sangwan, 2001) at different concentrations revealed statistically significant differences in their abundance. At 120 days, the control treatment had the highest number of green

Table 4: The number of brown planthoppers after rice field spraying (June–July, 2021)

Treatment	Population of <i>Nilaparvata lugens</i> (Stål) Per Rice Clump					
	45 days	52 days	59 days	66 days	73 days	80 days
Control	1.60	2.50 ^a	5.00 ^a	7.50 ^a	8.75 ^a	9.50 ^a
Dried hemp leaf extract 5%	1.50	1.50 ^b	2.85 ^c	2.75 ^d	3.75 ^d	3.85 ^d
Dried hemp leaf extract 10%	1.30	1.75 ^b	2.20 ^c	2.50 ^d	3.00 ^d	3.50 ^d
Hemp seed oil 5%	1.50	2.20 ^{ab}	4.85 ^{ab}	5.25 ^b	6.50 ^b	7.25 ^b
Hemp seed oil 10%	1.50	2.00 ^{ab}	4.10 ^b	4.40 ^c	6.75 ^b	7.00 ^b
Hop-headed barleria extract 5%	1.50	2.25 ^{ab}	4.50 ^{ab}	5.75 ^b	6.25 ^b	6.50 ^c
Hop-headed barleria extract 10%	1.40	1.75 ^b	4.30 ^{ab}	4.70 ^c	5.25 ^c	6.25 ^c
Dried hemp leaf extract 5% with petroleum oil (SK EnSpray 99)	1.40	1.20 ^b	1.50 ^d	2.00 ^e	2.50 ^e	2.75 ^e
F-test	ns	*	*	*	*	*
CV (%)	10.82	23.32	22.96	18.24	17.52	16.62

Note: *Significant ($p < 0.05$); ns = Nonsignificant ($p > 0.05$); and, vertical letters (a, b, c, and d) indicate significant statistical differences in confidence (95%).

mirids (4.25 insects/clump), followed by the 5% dried hemp leaf extract and 5% hemp seed oil treatment (3.50 insects/clump), 10% hemp seed oil treatment (3.00 insects/clump), 10% dried hemp leaf extract treatment (2.750 insects/clump), 5% and 10% hop-headed barleria extract treatments (1.25 insects/clump), and 5% hemp

leaf extract with petroleum oil (80 cc per 20 L of water) (1.25 insects/clump). All treatments showed statistically significant differences at the $p < 0.05$ level, as shown in Table 5.

This is consistent with the research of Songyot and Thanomchit (2000), who studied the effects of BPH pesticide on the survival of

Table 5: The population of green mirids following the application of plant extracts at different concentrations (June–July, 2021)

Treatment	Number of Green Mirids Per Rice Clump							
	15 days	30 days	45 days	60 days	75 days	90 days	105 days	120 days
Control	0.00	1.00	5.52 ^a	5.25 ^a	6.50 ^a	6.50 ^a	5.50 ^a	4.25 ^a
Dried hemp leaf extract 5%	0.00	0.00	4.00 ^b	3.75 ^b	4.00 ^b	5.25 ^{ab}	3.50 ^{bc}	3.50 ^b
Dried hemp leaf extract 10%	0.00	0.00	1.75 ^c	2.25 ^c	2.50 ^c	3.00 ^b	2.25 ^c	2.75 ^{bc}
Hemp seed oil 5%	0.00	1.00	4.25 ^b	4.50 ^{ab}	4.25 ^b	5.50 ^{ab}	4.50 ^b	3.50 ^b
Hemp seed oil 10%	0.00	0.00	4.10 ^b	4.25 ^{ab}	4.00 ^b	5.50 ^{ab}	3.75 ^{bc}	3.00 ^b
Hop-headed barleria extract 5%	0.00	0.00	2.75 ^{bc}	2.50 ^c	2.75 ^c	2.25 ^c	1.75 ^{cd}	1.25 ^c
Hop-headed barleria extract 10%	0.00	0.00	2.50 ^{bc}	2.25 ^c	2.75 ^c	2.00 ^c	1.25 ^{cd}	1.25 ^c
Dried hemp leaf extract 5% with petroleum oil (SK EnSpray 99)	0.00	0.00	0.50 ^d	0.25 ^d	1.50 ^d	1.00 ^d	0.50 ^d	0.25 ^d
F-test	ns	ns	*	*	*	*	*	*
CV (%)	40.10	36.50	21.62	24.24	28.62	26.42	25.40	27.61

Note: *Significant ($p < 0.05$); ns = Nonsignificant ($p > 0.05$); and, vertical letters (a, b, c, and d) indicate significant statistical differences in confidence (95%).

the egg-predatory bug, *Tytthus chinensis* Stål. From a study on the effectiveness of 20 plant extracts against the brown planthopper, garlic, papaya, kaffir lime, and custard apple extracts had the best control, with 0% to 33.30% survival. Basil, *Jatropha* sp., and mint had moderate control over brown planthopper, with 46.67% to 53.33% survival. Although the use of 5% hemp leaf extract with petroleum oil (SK EnSpray 99) (80 cc per 20 L of water) in the present study was more effective in reducing brown planthopper populations than other plant extract treatments (Phimsamhan, 1997; Tomizawa & Casida, 1999), it also had a detrimental impact on the green mirid population, which plays a crucial role in controlling brown planthoppers (Leucha, 2010). This is because green mirids prey directly on brown planthopper eggs, helping to reduce their population in rice fields (Simmons & Jackson, 2000), as presented in Figure 6.

Conclusions

The researchers conducted brown planthopper control experiments using a lethal contact method of spraying plant extracts and a petroleum oil product (SK EnSpray 99) in rice

fields. Random counts of brown planthoppers after spraying revealed that their populations differed significantly across treatments. At the 80-day-old rice stage, the treatment with 5% dried hemp leaf extract and petroleum oil (SK EnSpray 99) reduced the density of the brown planthopper population to the greatest extent, with 2.75 insects per clump detected. Finally, plant extracts have demonstrated effectiveness in controlling brown planthoppers and are not toxic to a green mirid, so they are a natural enemy.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

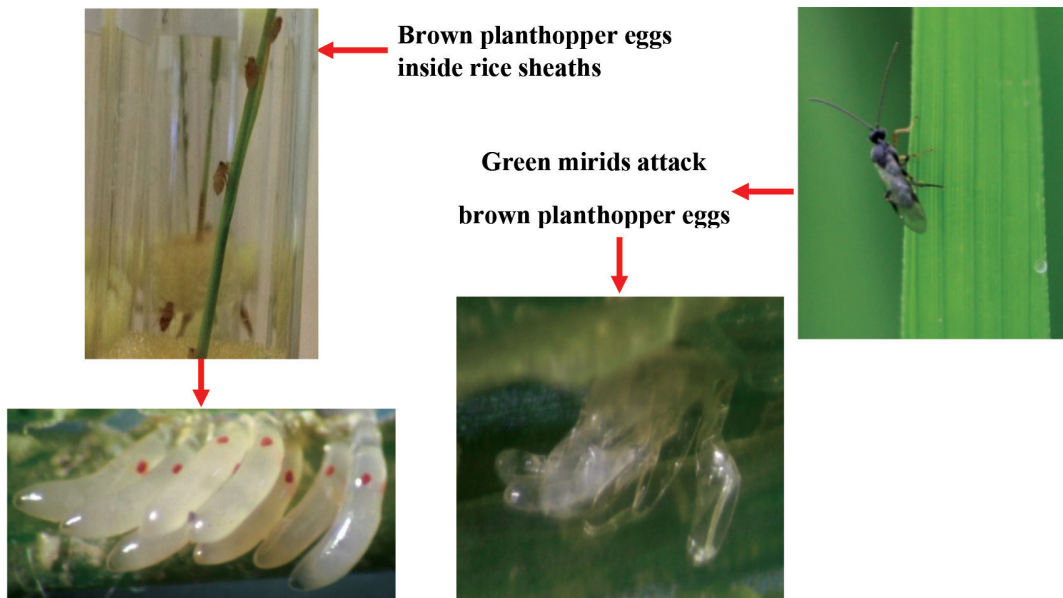


Figure 6: Appearance of brown planthopper eggs inside rice sheaths, as observed in rice fields

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