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Some Insecticidal Plant Extracts for Controlling Maize Weevil, *Sitophilus zeamais* Motschulsky (Coleoptera : Curculionidae)

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ABSTRACT

The toxicity of crude extracts from three selected plants namely Waan-nam (*Acorus calamus* L.), Noi-naa (*Annona squamosa* L.) and Lian (*Melia azedarach* L.) was investigated under laboratory conditions of 27±3°C and 80±20% RH. By the use of dry film method, for the toxicity test, the result revealed that crude extract from Waan-nam was more toxic to maize weevil than crude extract from Noi-naa seed. Due to low toxicity of Lian to maize weevil, thus, it was dropped out from further investigation. The efficacy and long-term residual effect of crude extracts from Waan-nam root and Noi-naa seed were also studied. Crude extracts of both plants were treated to maize seeds and the number of dead and alive maize weevils were counted. The results indicated that crude extract from Waan-nam root at the concentration of 10% (w/v) effectively control the number of maize weevil and its F_1 for 120 days after treated (DAT). Additionally, the same results on the control of maize weevil were obtained from crude extract of Noi-naa seed at the concentrations of 5 and 10% (w/v) whereas the concentration of 2.5% (w/v) could control the number of maize weevil for 90 DAT. Moreover, all concentrations of crude extract from Noi-naa seed could effectively control the number of F_1 maize weevil for 120 DAT. The effects of crude extracts from Waan-nam root and Noi-naa seed, on maized seed germination were also evaluated. The between-paper method was employed for germination test. It was found that maize seeds treated with crude extract from Waan-nam root almost completely lost their germination percentage while seed germination was high up to 90 DAT when treated with crude extract from Noi-naa seed at 2.5% (w/v) concentration.

Key words : insecticidal plant extract, maize weevil control, Waan-nam, Noi-naa, Lian

INTRODUCTION

Maize Weevil : *Sitophilus zeamais* Motschulsky (Coleoptera : Curculionidae) is one of the most serious, internal feeding pests of maize seed and grain. *S. zeamais* are found in all warm and tropical parts of the world (Dobie *et al.*, 1984). Maize insect pests are moved and distributed around the world by means of the stored product transportation. Moreover, the differences of stored condition, and regional environments can bring about survival of maize weevil.

Maize weevil and rice weevil (*Sitophilus oryzae* L.) can infest many kinds of agricultural stored products such as maize, sorghum, wheat, barley, rice and paddy (rough rice) (Chankaewmanee, 1997) by internal feeding. Seed stored for six months was infested 22 percent

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(Sukprakarn *et al.,* 1996) resulted in light weight seed, lower food quality and lower germination percentage. Control of maize weevil can be done in several ways such as management and clean storage, reduce seed humidity, hot/cool temperature control, vacuum storage, seed treated by some materials, insecticides and fumigant treated. In order to reduce post harvest loss and food quality loss, organically alternative controlling methods are needed. Lately, several reports indicated the insecticidal actions of certain plant species. Additionally, in Thailand, the existence of tropical medicinal flora is abundance and awaits investigation. Therefore, it may be very useful for farmers if some of such plant extracts with insecticidal effect against insects such as the maize weevil are found. Moreover, these extracts should not react as pollutants and/or should not be the compounds that bring about insect resistance. Expectation, if the extracts control maize weevils, is that importation of insecticides will decrease. Plant extracts from Waan-nam (*Acorus calamus* L.), Noi-naa (*Annona squamosa* L.) and Lian (*Melia azedarach* L.) have been found to have insecticidal action and can be used for controlling maize weevil.

The objectives of this study were to determine the toxicity and the efficacy of the crude extracts of some medicinal plants in controlling maize weevil. The effect of the crude extracts of some medicinal plants on maize seed germination was also studied.

MATERIALS AND METHODS

Culture of maize weevil, *Sitophilus zeamais* Motsch.

Stock cultures of maize weevil were obtained by collecting adults maize weevil from the storage room at the National Corn and Sorghum Research Center, Pakchong, Nakorn Ratchasima. The cultures were kept in a plastic box (17.5 × 25 × 9.5 cm) and wide mouth jars covered with filter papers. The filter paper was sealed with glue at the top of the jar to prevent the infestation of stored grain mites. The food media on which the test insects were cultured were seeds corn var. Pacific 328 that had 10.59% moisture content.

In order to obtain adults of known age from insect cultures, 100 unsexed adults were added to 200 g fresh culture media in a glass jar. After 3 days of egg-laying period, the adults were removed by means of sifting from the culture media and a new generation was obtained from the hatched eggs in approximately 30 to 45 days. The insect culture was reared at 27±3°C and 80±20% RH in the laboratory of the Entomology Research Building, Department of Entomology, Faculty of Agriculture, Kasetsart University, Bangkok.

1. The toxicity of some medicinal plant extracts to maize weevil

1.1Criteria for selecting plant species

Plants without damage from insect and plants known to have insecticidal effects both by the local people and researchers were the criteria for selecting plant species. The plant samples were, then, air-dried under normal room temperature until extraction. From the above criteria, 3 plant species were selected for this investigation.

1.2 Extraction of medicinal plants

Each plant sample was extracted using of the same extraction procedures modified from

Table 1 List of plant species, common names and Thai names including plant parts.

Plant species	Common name (Thai name)	Plant parts
Acorus calamus L.	Sweet flag (Waan-nam)	Rhizomes
Annona squamosa L.	Sugar apple (Noi-naa)	Seeds
Melia azedarach L.	Bastard cedar, Persian lilac (Lian)	Leaves

several authors work (Butterworth and Morgan, 1971; Roongsook, 1992 and Palaharn, 1996). This involved chopping of the selected plant samples and weighed 500 g. After weighing, the chopped sample was completely soaked in 1,000 ml of 95% ethanol for 3 days and then filtered. The sample was extracted twice. After that ethanol was evaporated with evaporator. The ethanolic crude extract was kept at 4°C in a refrigerator for further studies.

1.3 Screening for insecticidal action and toxicity tests of some medicinal plant extracts to maize weevil

4 concentrations, i.e. 25, 50, 75 and 100 percent (w/v). The ethanolic crude extracts were used in the screening test. The extract of each sample was dissolved in the solvent (95% ethanol). Then the solution was ready for screening test using the residual exposure method (contact method). One ml of solution was dropped onto the filter paper No. 1, 70 mm diameter. The treated filter paper was air-dried under the laboratory conditions, thereafter, transferred into petridish. Then the glass ring (5.0 cm diameter, 2.5 cm height) was placed on the treated filter paper as the confining cage for the test insects. Twenty adult maize weevils, *S. zeamais* at the age of 7-10 days were introduced onto each treated filter paper inside the cage. Then the cage was covered with the petridish cover of which 6-8 holes were made to allow air circulation. Observation was made at 24 hours after treating. The number of dead and alive insects were recorded

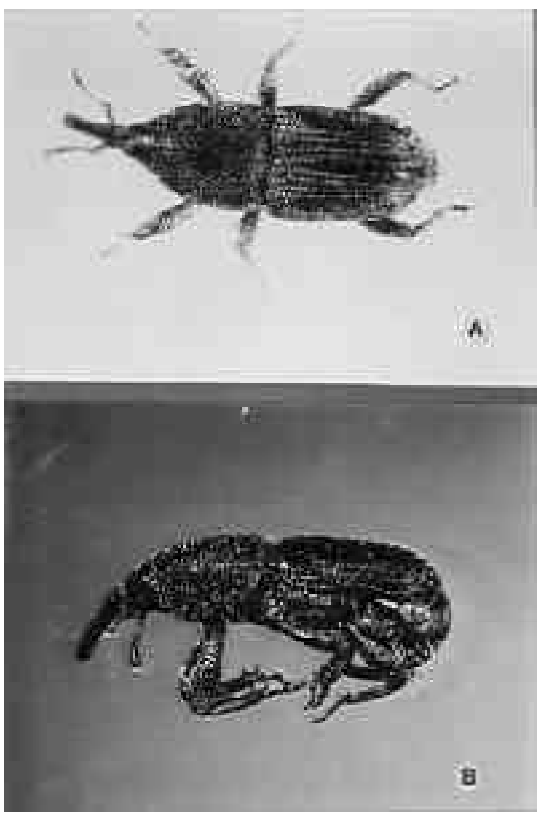

Figure 1 Adult of maize weevil, *Sitophilus zeamais* Motsch.
A. Dorsal view
B. Lateral view

Figure 2 Waan – nam , *Acorus calamus L.*
A. Leaves
B. Rhizomes

and occasional control death was corrected by Abbott's formula (Abbott, 1925).

The percentage of mortality is corrected by Abbott's formula :

$$\% \text{ Corrected mortality} = \frac{\% \text{ test mortality} - \% \text{ control mortality}}{100 - \% \text{ control mortality}} \times 100$$

Therefore, the extracts that showed insecticidal action were used in toxicity study and the method used in toxicity study was similar to the screening test except the concentrations which serial dilution technique was employed. This experiment was a completely randomized design with five replications and four levels of concentration as treatments. Observation of each treatment was made at 24 hours after treating. Data on insecticidal action testing were recorded and calculated using the probit analysis (Finney, 1971) to obtained LC_{50} values. In this toxicity test, ethanolic crude extracts of plant part of each species were used, i.e. rhizome of Waan-nam and seed of Noi-naa.

2. Efficacy of crude extracts of some medicinal plants to control maize weevil

2.1 Efficacy test

Two ethanolic crude extracts were used for maize seed treatment employing a completely randomized design with four replications. Maize seeds were treated with the 50 ml of the ethanolic crude extracts at the rates of 2.5, 5 and 10% w/v per 1 kg of seeds. The treated seeds were left to dry under laboratory conditions. Thereafter, 100 g of seeds were transfered into each four wide-mouth

Figure 3 Noi-naa, *Annona squamosa* L.
A. Fruit
B. Seeds

Figure 4 Lian, *Melia azedarach* L.
A. Leaves
B. Leaves and branch

glass jars. Then about 20 adult maize weevils at the age of 7-10 days were released into the jar and the top was glued to prevent infestation of the store grain mite . The jars were kept in the laboratory at 27°C and 80% RH. Ten days later, dead and alive maize weevils were counted and were taken out of the jars. Fifty-five days after, new maize weevils were counted and maize seeds were checked for damage and undamage.

2.2 Residual test

The methods used in this study were similar to the efficacy test except the periods to release the maize weevils into the treated seeds. The seeds were treated with crude extract at the rates of 2.5, 5 and 10% w/v per 1 kg of seed. One hundred gram of treated seeds were stored in the jar for 30, 60, 90 and 120 days before introducing twenty adult maize weevils into the jar. The observation was made for each storage period, on the number of dead and alive maize weevils.

3. The effect of crude extracts of some medicinal plants on maize seed germination

3.1Germination test

The germination test was performed by the use of between-paper method (rolled method). One hundred seeds of maize were sampled from each treatment of the efficacy test and residual test. The double pieced paper towel (25 cm × 40 cm) was soaked in water and was stretched on the table. Then maize seeds were laid onto the paper towel and covered with another damp paper towel. After that, paper towels with maize seeds rolled and kept in the plastic box under laboratory conditions of 27±3°C and 80±20% RH. Four days later, the paper towels were opened and normal seedlings were counted (Duangpatra, 1986). Data were recorded and calculated for the germination percentage.

RESULTS AND DISCUSSION

1. The toxicity of some medicinal plant extracts to maize weevil

1.1 Selection of plant samples

Three species of plants were collected in Bangkok and Nakorn Ratchasima province during the investigation, namely: rhizomes of Waan-nam (*Acorus calamus* L.), seeds of Noi-naa (*Annona squamosa* L.) and leaves of Lian (*Melia azedarach* L.).

1.2 Extraction of medicinal plants

Samples of the three test plants were extracted for bioactive principles, and screened for insecticidal activities against the maize weevil. The results of plant extract are shown in Table 2.

1.3 Screening and toxicity test of some medicinal plants extracts to maize weevil

1.3.1 Screening test

The crude extracts of three plant parts were screened of insecticidal activities against the maize weevil, *S. zeamais* at the age of 7-10 days. The results revealed that only crude extracts at the concentration of 25% w/v from Waan-nam and

Table 2 The weight of crude extract of three plant samples extracted with 95% ethyl alcohol.

Plant common name	Plant part	Weight of sample (g)	Weight of crude extract (g)
Waan-nam	Rhizome	500	28.08
Noi-naa	Seed	500	24.35
Lian	Leaves	500	11.31

Noi-naa had the insecticidal activities against maize weevils, causing mortality at 24 hours of 82.50% and 35.00%, respectively. The crude extract of Lian did not kill the maize weevil although high concentration of 100% w/v was used (Table 3).

1.3.2 Toxicity testing (LC_{50}) of plant crude extracts of Waan-nam and Noi-naa on maize weevil

Plant crude extract of Waan-nam was tested against maize weevils at 5 concentrations; 0 (ethyl alcohol 95%), 5, 10, 20 and 40% (w/v). The results in Table 4 and 6 shows that the crude extract from rhizome of Waan-nam was toxic against maize weevil, *S. zeamais* with an LC_{50} value of 11.7341% (w/v). The regression lines are shown in Figure 5. The results were more or less agreed with Roongsook (1992) who reported that the LC_{50} value for toxicity of crude extract from rhizomes of Waan-nam to diamondback moth, *Plutella xylostella* was 6.5% (w/v).

Plant crude extract of Noi-naa was tested against maize weevils at 5 concentrations; 0 (ethyl alcohol 95%), 25, 30, 35 and 40% (w/v). Crude extract from seed of Noi-naa was found to show the toxicity against maize weevil with an LC_{50} value of 32.3434% (w/v). The results are shown in Table 5, 6 and the regression lines in Figure 6. Roongsook (1992) also reported the same result for toxicity of crude extract from seed of Noi-naa to diamondback moth with an LC_{50} value of 0.50% w/v.

The summarized results in Table 6 and Figure 7 show that crude extract of Waan-nam was more

Table 3 Screening activities of crude extracts from tested plants against the maize weevil adults, 7-10 days old, under laboratory conditions, 27±3°C and 80±20% RH.

Plant	Plant part	Corrected mortality at 24 hours (mean, %)[1/]
Waan-nam	Rhizome	82.50
Noi-naa	Seed	35.00
Lian	Leaf	0

1/ Means at 24 hours after treated with crude extract at 25% (weight/volume) and calculated by the use of Abbott's formula (Abbott, 1925).

Table 4 Mortality percentage of maize weevil, *S. zeamais* as affected by crude extract of Waan-nam, *A. calamus* L. 24 hr. after treated under the laboratory conditions.

Dose (% w/v)	Log dose (x)	Total treated	No. dead adult/treatment	% corrected mortality	Empirical probit (y)
Treated check[1/]	0.0000	100	0	0	0.0000
5	0.6990	100	23	23	4.2619
10	1.0000	100	50	50	5.0008
20	1.3010	100	62	62	5.3023
40	1.6021	100	85	85	6.0356

1/ treated check = 95% ethyl alcohol

Table 5 Mortality percentage of maize weevil, *S. zeamais* as affected by crude extract of Noi-naa, *A. squamosa* L. 24 hr. after treated under laboratory conditions.

Dose (% w/v)	Log dose (x)	Total treated	No. dead adult/treatment	% corrected mortality	Empirical probit (y)
Treated check1/	0.0000	100	1		
25	1.3979	100	21	20.20	4.182
30	1.4771	100	37	36.36	4.6529
35	1.5441	100	51	50.50	4.9873
40	1.6021	100	91	90.90	6.2787

1/ treated check = 95% ethyl alcohol

effective on maize weevil than that of Noi-naa. However, lower slope of 1.84 was found for Waan-nam extract whereas Noi-naa extract had higher slope, 8.7559 (Table 6). It seemed that maize weevil was more sensitive to Noi-naa extract than Waan-nam extract. According to Roongsook (1992) the crude extract from leaves of Lian, *M. azedarach* L. was used only for screening test because of the toxicity of this plant to diamondback moth was quite low. Palaharn (1996) also confirmed that three crude extracts were effective to beet armyworm, *Spodoptera exigua* Hubner. Percentage corrected mortality of three plants at 72 hours were ranked in decreasing orders as 82.14% for ethanolic crude extract from seed of Noi-naa, 79.31% for leaves of lian and 62.06% for rhizome of Waan-nam. However, in this experiment crude extract of the Lian leaves was harmless to maize weevils.

2. The efficacy of crude extracts of some medicinal plants to control maize weevil

2.1Efficacy test

Table 7 shows the efficacy test of medicinal plant extracts on maize weevil when treating maize seeds for 10 days. The results showed that 5 and

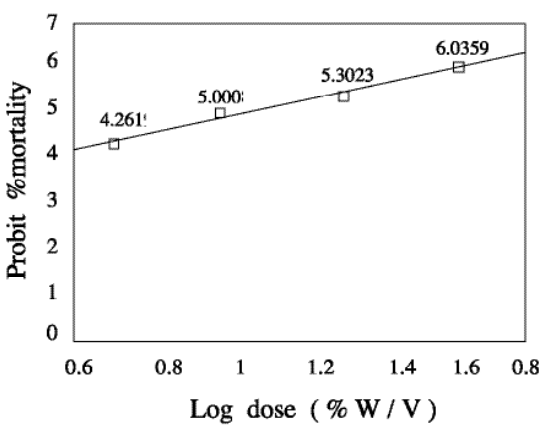

Figure 5 Probit mortality line of maize weevil, *S. zeamais* as affected by crude extract of Waan – nam, *Acorus calamus* L.

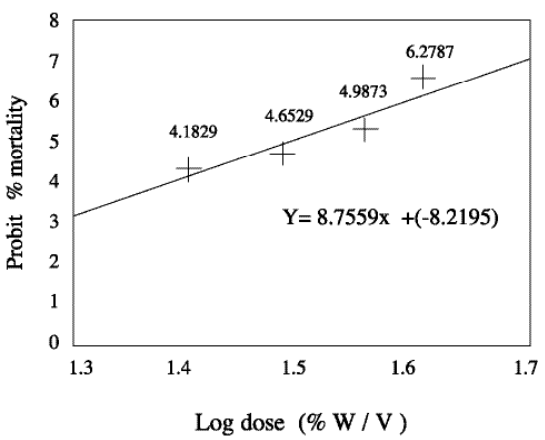

Figure 6 Probit mortality line of maize weevil, *S. zeamais* as affected by crude extract of Noi – naa, *Annona squamosa* L.

Table 6 Toxicity of two ethanolic crude extracts against maize weevil, *S. zeamais* (Coleoptera : Curculionidae)

Plants	LC_{50} (% w/v) (95% CI.)	Slope ± SE
Waan-nam	11.7341(9.7959-13.8455)	1.8400±0.0373
Noi-naa	32.3434(31.2103-33.5909)	8.7559±0.0079

10% w/v concentrations of Waan-nam rhizome extracts, 2.5, 5 and 10% w/v concentrations of Noi-naa seed extracts and the standard check (pirimiphos methyl) killed maize weevil 100%, whereas, 2.5% w/v concentrations of Waan-nam rhizome extract killed maize weevil at 96.25%.

The data from Table 8 shows the number of adults of F_1 maize weevil developed in treated seeds for 55 day. The results showed that all treatments except treated check (ethyl alcohol 95%) completely controlled the number of adult of F_1 of maize weevil ranging from 0-0.25.

2.2Residual test

Residual effects of medicinal plant extracts on maize weevil when treating seed for 30, 60, 90 and 120 days are shown in Table 9. It was found that 10% w/v concentration of Waan-nam rhizome extract, 5 and 10% w/v concentrations of Noi-naa seed extracts and standard check gave residual effect for 120 days long. The percentage of dead maize weevil ranged from 86.25-100% whereas, 2.5% w/v concentration of Noi-naa seed extract had residual effect for 90 days long killing maize weevil up to 93.75% w/v after which its residual activity declined. In addition, 5% w/v concentration of Waan-nam rhizome extract could completely control maize weevil only for 60 days (Table 9).

Considering concentrations, Waan-nam at 10% w/v concentration gave the best result in controlling maize weevils (120 days). The same was true for Noi-naa crude extracts at 5 and 10% w/v concentrations. To control maize weevil, Noi-naa crude extract at 5% w/v concentration is recommended because of cost competitiveness. Neem extract consisted of azadirachtin 0.002% at the concentrations of 5, 10 and 20 ml/kg gave good protection of seed for 120 day (Nilpanit *et al*, 1992). The result of this experiment was in line with Nilpanit *et al.* (1992).

According to this investigation, the seeds treated with crude extracts of Waan-nam and Noi-naa at 2.5, 5 and 10% (w/v) concentrations and standard check for 30 and 60 days (Table 10) completely controlled the number of adults of F_1 maize weevil, allowing only up to 1.25 adults to emerge. However, for the treated check for 30 and 60 days, number of adults of F_1 maize weevil

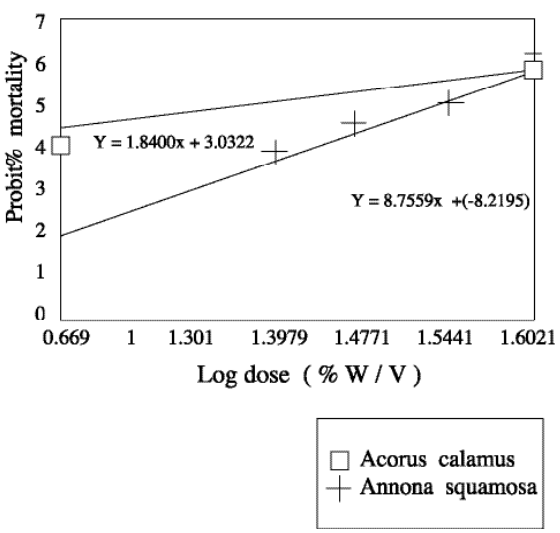

Figure 7 Probit mortality line of maize weevil, *S. zeamais* as affected by Crude extract of Waan – nam, *Acorus calamus L.* and Noi – naa, *Annona squamosa* L.

Table 7 Percentage of dead maize weevils after introducing into maize seeds treated with crude extracts for 10 days.

Treatments	Percentage of dead maize weevil (%)
Waan-nam 2.5% w/v	96.25 b
Waan-nam 5.0% w/v	100 a
Waan-nam 10% w/v	100 a
Noi-naa 2.5% w/v	100 a
Noi-naa 5.0% w/v	100 a
Noi-naa 10% w/v	100 a
Standard check[3/]	100 a
Treated check[2/]	2.50 c
CV (%)	2.26

[1/] Means followed by a common letter in the same column are not significantly different at 5% level of DMRT
[2/] Treated check = 95% ethyl alcohol
[3/] Standard check = pirimiphos methyl at the rate of 2 ml of pirimiphos methyl/300 ml of water/100 kg of seed

Table 8 Number of emerging adults of F_1 maize weevil in maize seeds treated with crude extracts for 55 days.

Treatments	Number of emerged maize weevil[1/]
Waan-nam 2.5% w/v	0.00 b
Waan-nam 5.0% w/v	0.00 b
Waan-nam 10% w/v	0.00 b
Noi-naa 2.5% w/v	0.25 b
Noi-naa 5.0% w/v	0.00 b
Noi-naa 10% w/v	0.00 b
Standard check[3/]	0.00 b
Treated check[2/]	38.50 a
CV (%)	134.71

[1/] Means followed by a common letter in the same column are not significantly different at 5% level of DMRT
[2/] Treated check = 95% ethyl alcohol
[3/] Standard check = pirimiphos methyl at the rate of 2 ml of pirimiphos methyl/300 ml of water/100 kg of seed

Table 9 Percentage of dead maize weevils after introducing into maize seeds treated with crude extracts for 30, 60, 90 and 120 days.

Treatments	Percentage of dead maize weevil (%)[1/]			
	30 days	60 days	90 days	120 days
Waan-nam 2.5% w/v	73.75 b	70.00 b	16.25 c	18.75 d
Waan-nam 5.0% w/v	98.75 a	100 a	52.50 b	75.00 bc
Waan-nam 10% w/v	100 a	100 a	98.75 a	100 a
Noi-naa 2.5% w/v	100 a	100 a	93.75 a	65.00 c
Noi-naa 5.0% w/v	100 a	100 a	88.75 a	86.25 ab
Noi-naa 10% w/v	100 a	100 a	97.50 a	98.75 a
Standard check[3/]	100 a	100 a	100 a	100 a
Treated check[2/]	5.00 c	1.25 c	0.00 c	2.50 e

[1/] Means followed by a common letter in the same column are not significantly different at 5% level of DMRT
[2/] Treated check = 95% ethyl alcohol
[3/] Standard check = pirimiphos methyl at the rate of 2 ml of pirimipho smethyl/300 ml of water/100 kg of seed

emerged were 37.75 and 56.00, respectively. It seemed that treated check was the least toxic to F_1 maize weevil. The result from the seed treated for about 90 days indicated that the seed treated with Waan-nam at 5, 10% w/v, Noi-naa at 2.5, 5.0, 10% w/v concentrations and standard check controlled number of adult of F_1 maize weevil allowing up to 4.75 adult emerged, while Waan-nam at 2.5% w/v concentration gave different result, up to 14.75 adults emerged. Additionally, treated check allowed 72.75 adults of F_1 maize weevil to emerge. When seed were treated for 120 days, all treatments were equally effective in controlling maize weevil but in the treated check number of adults F_1 maize weevil was as great as 56.0.

It was also found that Waan-nam at 10% w/v and Noi-naa at 2.5, 5, 10% w/v concentrations and standard check gave the longest residual effects (120 days) while Waan-nam at 2.5 and 5.0% w/v concentrations gave the shorter residual effect (60 days) (Table 10). However, among Noi-naa group, Noi-naa crude extract at the concentration of 2.5% w/v was recommended so as to save the budget.

3. Study of the effect of crude extracts of some medicinal plants on maize seed germination

3.1The germination test

The germination percentages of seed treated with crude extract of Waan-nam at different concentrations and for different periods were significantly different from treated check and standard check. They were ranging from 10.00-16.25%. It showed that all concentrations of crude extracts of Waan-nam group affected seed germination right after seeds were treated (Table 11).

The germination percentage of seed treated with crude extracts of different concentrations of Waan-nam was low and not recommend for maize seed treatment. Pingsutiwong and Wattanakij (1996) suggested that seed germination percentage of field corn (*Zea mays* Linn.) must not be lower than 75%. The results of this experiment clearly showed that Waan-nam crude extracts reduced maize seed germination percentage.

Acceptable germination percentage of maize

Table 10 Number of adults of F_1 maize weevil emerging in maize seeds treated with crude extracts for 30, 60, 90 and 120 days.

	Percentage of dead maize weevil (%)[1/]			
	Days	Days	Days	Days
Waan-nam 2.5% w/v	1.25 b	1.25 b	14.75 b	13.00 b
Waan-nam 5.0% w/v	0.00 b	0.00 b	4.75 c	2.50 b
Waan-nam 10% w/v	0.25 b	0.00 b	0.00 c	0.25 b
Noi-naa 2.5% w/v	0.25 b	0.50 b	1.25 c	5.50 b
Noi-naa 5.0% w/v	0.75 b	0.00 b	3.25 c	2.25 b
Noi-naa 10% w/v	0.25 b	0.00 b	0.75 c	0.50 b
Standard check[3/]	0.00 b	0.00 b	0.00 c	0.00 b
Treated check[2/]	37.75 a	56.00 a	72.75 a	56.00 a

[1/] Means followed by a common letter in the same column are not significantly different at 5% level of DMRT

[2/] Treated check = 95% ethyl alcohol

[3/] Standard check = pirimiphos methyl at the rate of 2 ml of pirimiphos methyl/300 ml of water/100 kg of seed

seed (>80%) was obtained from crude extracts of Noi-naa at 2.5, 5, 10% w/v concentrations, standard check and treated check up to 120 days after seed treatment. However, if 90% germination was required, the standard check gave the best result of up to 120 days whereas a better result was achieved when seeds were treated with crude extract of Noi-naa at the concentration of 2.5% w/v and from treated check, up to 90 days. In addition, maize seeds treated with crude extracts of Noi-naa at 5 and 10% w/v concentrations gave germination percentages of approximately 90% within the period of 60 days. It was obvious from the standard check gave greater germination percentage than treated check and Noi-naa crude exracts (Table 11). The assumption was that the use 95% ethyl alcohol as solvent for extraction of both medicinal plants led to the decrease of the germination percentage of maize seed.

However the result in Table 11 showed that seed treated with crude extract of Noi-naa at the concentration of 2.5% w/v gave the longest residual effect for 90 days as similar to those of the standard check and the germination percentage of seed was not decreased. Thus, treated with crude extract of Noi-naa at the concentration of 2.5% w/v is to be recommended.

CONCLUSION

The laboratory studies of medicinal plant extracted from 3 plant species with 95% ethyl alcohol for insecticidal activities against maize weevil can be concluded as follows :

1. Two species of medicinal plants were found to contain the insecticidal principles against maize weevil, i.e. Waan-nam rhizomes, *Acorus calamus* L. and Noi-naa seeds, *Annona squamosa* L. Concerning the toxicity of Waan-nam rhizome and Noi-naa seeds extract to maize weevil, Waan-nam rhizome extract was found to be toxic to maize weevil with an LC_{50} value of 11.73% w/v and Noi-naa seeds extract was toxic with an LC_{50} value of 32.3434% w/v, but maize weevil was more sensitive to Noi-naa extract than Waan-nam extract.

2. Among Waan-nam crude extracts, maize

Table 11 The germination percentage of maize seeds after treated seeds with crude extracts and introduced 20 adults of maize weevil for 10 days.

Treatments	Germination percentage of maize seeds after treated (%)[1/]				
	0 days	30 days	60 days	90 days	120 days
Waan-nam 2.5% w/v	16.00 c	16.25 b	14.00 d	15.00 c	14.75 c
Waan-nam 5.0% w/v	11.75 d	11.25 c	14.50 d	12.00 c	13.75 c
Waan-nam 10% w/v	10.00 d	13.50 b	13.25 d	14.25 c	14.25 c
Noi-naa 2.5% w/v	96.75 ab	95.25 a	91.75 bc	91.50 b	82.50 b
Noi-naa 5.0% w/v	95.50 b	95.00 a	90.00 c	87.00 b	83.50 b
Noi-naa 10% w/v	95.75 ab	94.75 a	89.50 c	89.50 b	81.25 b
Standard check[3/]	99.25 a	99.50 a	98.25 a	98.50 a	93.25 a
Treated check[2/]	98.50 ab	96.25 a	95.50 ab	90.25 b	83.50 b

1/ Means followed by a common letter in the same column are not significantly different at 5% level of DMRT

2/ Treated check = 95% ethyl alcohol

3/ Standard check = pirimiphos methyl at the rate of 2 ml of pirimiphos methyl/300 ml of water/100 kg of seed

seed treated with 10% w/v concentration of Waan-nam rhizome extract could kill and control F_1 maize weevil for 120 days long. This residual effect was longer than that of the 5.0% w/v of Waan-nam rhizome extract which killed and controlled F_1 maize weevil for 60 days.

Among Noi-naa crude extracts, maize seed treated with 5.0 and 10% w/v concentrations of Noi-naa crude extract killed maize weevil for 120 days long. This residual effect was longer than that of the 2.5% w/v concentration of Noi-naa seed extract which killed maize weevil for 90 days long. Additionally, all treatments of Noi-naa seed extract could kill F_1 maize weevil for 120 days long.

3. Considering seed germination percentage, maize seed treated with Waan-nam crude extracts had very low germination percentage. These treatments were not suitable for seed maize. Among seed treated with Noi-naa crude extracts, only Noi-naa crude extract at the concentration of 2.5% w/v did not decrease germination percentage until 90 days after treatment. However, the use of 95% ethyl alcohol as solvent for extraction of both medicinal plants led to the decrease in germination percentage of the maize seed.

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