Sweetpotato Organic Cultivation with Wood Vinegar, Entomopathogenic Nematode and Fermented Organic Substance from Plants

U. Pangnakorn, P. Tayamanont, and R. Kurubunjerdjit

***Abstract*—**The effect of wood vinegar, entomopathogenic nematodes (*(Steinernema thailandensis n. sp.*) and fermented organic substances from four plants such as: *Derris elliptica* Roxb, *Stemona tuberosa* Lour, *Tinospora crispa* Mier and *Azadirachta indica* J. were tested on the five varieties of sweetpotato with potential for bioethanol production *ie.* Taiwan, China, PROC No.65-16, Phichit 166-5, and Phichit 129-6. The experimental plots were located at Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Phitsanulok, Thailand. The aim of this study was to compare the efficiency of the five treatments for growth, yield and insect infestation on the five varieties of sweetpotato. Treatment with entomopathogenic nematodes gave the highest average weight of sweetpotato tubers (1.3 kg/tuber), followed by wood vinegar, fermented organic substances and mixed treatment with yields of 0.88, 0.46 and 0.43 kg/tuber, respectively. Also the entomopathogenic nematode treatment gave significantly higher average width and length of sweet potato (9.82 cm and 9.45 cm, respectively). Additionally, the entomopathogenic nematode provided the best control of insect infestation on sweetpotato leaves and tubers. Comparison among the varieties of sweetpotato, PROC NO.65-16 showed the highest weight and length. However, Phichit 129-6 gave significantly higher weight of 0.94 kg/tuber. Lastly, the lowest sweet potato weevil infestation on leaves and tubers occurred on Taiwan and Phichit 129-6.

***Keywords*—**Sweetpotato (*Ipomoea batatas*), sweetpotato weevil (*Cylas formicarius* Fabr), wood vinegar, Entomopathogenic nematode *(Steinernema thailandensis n. sp.*), fermented organic substances.

I. Introduction

SWEETPOTATO (*Ipomoea batatas* L.: family Convolvulaceae) is an important and versatile tropical food crop. The tubers are used as a subsidiary food and also as a a source of sugars and starches for industrial processing [1]. Sweetpotato production in Thailand is by small-scale farmers mainly for home consumption and as source of income. However, production is highly impaired by presence of pests, sweetpotato weevil (*Cylas formicarius* Fabr.: O.Coleoptera F. Curculionidae) is a major pest of sweetpotato worldwide; it causes damage in the field and in storage, and is of quarantine [2]. The weevil causes 60-70% yield loss, and in some areas the damage to tubers can reach up to 90% [3]. It affects all parts and all stages of plant growth. Yield loss is due to damage done by both adults and larvae infestations in tuber and vine. The weevil infestation ranges from 20 to 50% on many farms and can even reach to 100% depending on the season and variety [4]. It has caused enormous economic losses to farmers cultivating the sweet potato, in countries in Central and South America, and the South Pacific Islands [5]. Cultivars with immunity or a high level of resistance are not available. Some cultivars have low levels of resistance. Early maturing and deeply rooted varieties suffer less weevil damage and can even escape weevil infestation [6]. Chemicals are continuously used but they are harmful to natural predators. Recent research by CIP personnel in China has shown that sweetpotato yield can be increased by as much as 30 to 40% without additional fertilizer, pesticide, or genetic improvement [7].

Wood vinegar is an organic compound which is suitable for organic farming. It improves soil quality, eliminates pests, accelerates plant growth, [8]. Wood vinegar showed high efficiency as an insect repellent and had the highest efficacy in reducing pest infestation on soybean [9].

Entomopathogenic nematodes seem to be the organisms with the greatest potential for practical biological suppression of sweetpotato weevil. Entomopathogenic nematodes are reportedly effective against against the sweetpotato weevil *Cylas puncticollis* Boheman [10] and many other crop pests, particularly those found in soil inter-phase and cryptic?? habitats [11], [12].

Fermented plant extracts are most commonly applied as a plain liquid manure or plant extract. It is a dynamic practice employed by farmers who need to promote fertility and pest control using local plants. The fermented liquid organic fertilizer is an effective method for increasing growth and yields of soybean [9].

This study sought to evaluate the efficiency of wood vinegar, entomopathogenic nematodes (*Steinernema thailandensis* n. sp.), fermented organic substances from four plants and combinations of all treatments on sweetpotato cultivation.

U. Pangnakorn, is with the Faculty of Agriculture Natural Resources and Environment/Center of Academic Excellence in Postharvest technology, Naresuan University, Phitsanulok 65000 THAILAND (phone: 66-5596-2736; fax: 66-5596-2704; e-mail: udompornp@ nu.ac.th).

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P. Tayamanont, was with the Center of Agricultural Research and Development Phichit, Tumbol Rongchang, Umphoe Muang, Phichit, THAILAND.

R. Kurubunjerdjit, is with the Center of Agricultural Research and Development Phichit, Tumbol Rongchang, Umphoe Muang, Phichit, THAILAND.

II. Materials and Methods

A. Crop and Experiment Establishment

This experiment was carried out on plots at the Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Phitsanulok, Thailand. This study was undertaken from March to July 2011. The five potential varieties of sweetpotato for bioethanol production: Taiwan, China, PROC No.65-16, Phichit 166-5 and Phichit 129-6 were planted during the drought season (March 2011). Two sweetpotato vines each measuring 30 cm were planted in 1x2 meter experimental plots. Vines were disinfected with Carbofuran 5G solution for 15 min before planting. Two months after sprouting of the vines, the five treatments of wood vinegar, entomopathogenic nematode (*Steinernema thailandensis* n. sp. (Rhabditida: Steinernematidae)) and organic substances from 4 plants: (*Derris elliptica* Roxb, *Stemona tuberosa* Lour, *Tinospora crispa* Mier and *Azadirachta indica* J.) were applied to foliage at 7 days intervals, a total of 8 times, until the sweetpotato was 4 months old. The Thai strain of entomopathogenic nematode *S. thailandensis* was isolated at Department of Agriculture, Thailand [13]. The plants were watered before treatment. All of the treatments were diluted with water in a 1:200 ratio prior to spraying. The experiment was Factorial in Randomized Complete Block Design (RCD) with five treatments and three replications as follows:

1. water (control)
2. wood vinegar
3. entomopathogenic nematodes
4. fermented organic substances from plants
5. mixed (wood vinegar + entomopathogenic nematodes + fermented organic substances from plants)

B. Data Recording

The values of nutrient content in soils prior to planting and after harvesting were analyzed. The yields of sweetpotato in terms of width (cm), length, and weight (g) of tubers were recorded. Damage by sweetpotato weevils can be recognised by the holes in the vines or the tunnels in the tuber when removed from the soil. The rating score of insect pest infestation on sweetpotato were measured on the criteria as shown in Table IV.

C. Data Analysis

The data were analyzed with Factorial in Randomized Complete Block Design (RCD) and compared the significant differences by Duncan's multiple ranges test (DMRT).

III. Result

A. Effects of Wood Vinegar, Entomopathogenic Nematode and Fermented Organic Substances from Plants Treatments

Table I shows how tubers of sweetpotato respond to the application of wood vinegar, nematodes and fermented organic substances. The entomopathogenic nematode treatment gave the highest weight when compared to the other treatments (1.3 kg/tuber) followed by wood vinegar, fermented organic substances and mixed treatment, with 0.88, 0.46, and 0.43 kg/tuber, respectively. Among the varieties, Phichit 129-6 showed the highest weight of 0.94 kg/tuber. The variety PROC No.65-16 gave the largest size of tubers in terms of width and length, 9.83 cm and 10.09 cm, respectively. However, significant differences occurred in the size of tubers in response to application of the entomopathogenic nematode (Table II and III).

TABLE I
EFFECTS OF WOOD VINEGAR, ENTOMOPATHOGENIC NEMATODE AND FERMENTED ORGANIC SUBSTANCES FROM FOUR PLANTS ON WEIGHT OF SWEETPOTATO TUBERS

Treatments	**The weight of sweetpotato tubers (kg)**					**Mean**
	Varieties					
	Taiwan	**China**	**PROC No.65-16**	**Phichit 166-5**	**Phichit 129-6**	
control (water)	0.31^{de}	0.25^{de}	0.31^{de}	0.30^{de}	0.80^{bcde}	$\mathbf{0.39^{c}}$
wood vinegar	0.84^{bcde}	0.76^{bcde}	0.99^{bcd}	1.01^{bcd}	0.80^{bcde}	$\mathbf{0.88^{b}}$
EPN	1.40^{abc}	0.83^{bcde}	1.49^{ab}	0.74^{bcde}	2.02^{a*}	$\mathbf{1.3^{a}*}$
FOS	0.6^{cde}	0.47^{de}	0.34^{de}	0.25^{de}	0.66^{bcde}	$\mathbf{0.46^{c}}$
mixed	0.43^{de}	0.04^{e}	0.94^{bcd}	0.35^{de}	0.43^{de}	$\mathbf{0.43^{c}}$
Mean	$\mathbf{0.71^{ab}}$	$\mathbf{0.47^{b}}$	$\mathbf{0.81^{ab}}$	$\mathbf{0.53^{b}}$	$\mathbf{0.94^{a}*}$	**C.V. = 49.94%**

* = significant difference, Means in the followed by the same letter are not significantly different at 5% level by DMRT
Mark : EPN nematode **=** entomopathogenic nematode (*Steinernema thailandensis* n.sp)
FOS =Fermented Organic Substances from four plants (*Derris elliptica* Roxb, *Stemona tuberosa* Lour, *Tinospora crispa* Mier and *Azadirachta indica*)
mixed = treatment 2+ treatment 3+ treatment 4

TABLE II
EFFECTS OF WOOD VINEGAR, ENTOMOPATHOGENIC NEMATODE AND FERMENTED ORGANIC SUBSTANCES FROM FOUR PLANTS ON SIZE OF SWEETPOTATO TUBERS (WIDTH)

Treatments	**Width of sweetpotato tubers (cm)**					**Mean**
	Varieties					
	Taiwan	**China**	**PROC No.65-16**	**Phichit 166-5**	**Phichit 129-6**	
control (water)	8.34^{bc}	9.19^{bc}	8.81^{bc}	7.76^{bc}	8.89^{bc}	$\mathbf{8.60^{ab}}$
wood vinegar	5.13^{c}	6.7^{c}	10.65^{ab}	5.67^{c}	10.3^{ab}	$\mathbf{7.69^{b}}$
EPN	11.44^{ab}	10.85^{ab}	10.92^{ab}	7.06^{bc}	8.82^{bc}	$\mathbf{9.82^{a}*}$
FOS	14.01^{a}	6.36^{c}	9.52^{abc}	8.3^{bc}	9.35^{bc}	$\mathbf{9.51^{ab}}$
mixed	8.93^{bc}	10.27^{ab}	9.26^{bc}	10.75^{ab}	10.10^{ab}	$\mathbf{9.86^{a}*}$
Mean	$\mathbf{9.57^{a}}$	$\mathbf{8.67^{a}}$	$\mathbf{9.83^{a}}$	$\mathbf{7.91^{a}}$	$\mathbf{9.49^{a}}$	**C.V.= 21.09%**

* = significant difference, Means in the followed by the same letter are not significantly different at 5% level by DMRT
Mark : EPN nematode **=** entomopathogenic nematode (*Steinernema thailandensis* n.sp)
FOS =Fermented Organic Substances from four plants (*Derris elliptica* Roxb, *Stemona tuberosa* Lour, *Tinospora crispa* Mier and *Azadirachta indica*)
mixed = treatment 2+ treatment 3+ treatment 4

TABLE III
EFFECTS OF WOOD VINEGAR, ENTOMOPATHOGENIC NEMATODE AND ORGANIC SUBSTANCES FROM FOUR PLANTS ON SIZE OF SWEETPOTATO TUBERS (LENGTH)

Treatments	**Length of sweetpotato tubers (cm)**					**Mean**
	Varieties					
	Taiwan	**China**	**PROC No.65-16**	**Phichit 166-5**	**Phichit 129-6**	
control (water)	8.25^{abc}	5.61^{c}	6.74^{bc}	6.72^{bc}	10.14^{abc}	**7.49 ^{b}**
wood vinegar	5.13^{c}	6.7^{bc}	10.65^{ab}	5.67^{c}	10.3^{ab}	**7.49 ^{b}**
EPN	10.77^{ab}	8.83^{abc}	11.13^{ab}	7.96^{abc}	8.55^{abc}	**9.45^{a}***
FOS	10.73^{ab}	9.23^{abc}	12.28^{a}	10.17^{abc}	8.72^{abc}	**10.23^{a}***
mixed	9.33^{abc}	10.92^{ab}	9.67^{abc}	9.89^{abc}	10.59^{ab}	**10.08^{a}***
Mean	**8.84^{ab}**	**8.26^{ab}**	**10.09^{a}**	**8.08^{b}**	**9.66^{ab}**	**C.V. = 20.75%**

* = significant difference, Means in the followed by the same letter are not significantly different at 5% level by DMRT
Mark : EPN nematode = entomopathogenic nematode (*Steinernema thailandensis* n.sp)
FOS =Fermented Organic Substances from four plants (*Derris elliptica* Roxb, *Stemona tuberosa* Lour, *Tinospora crispa* Mier and *Azadirachta indica*)
mixed = treatment 2+ treatment 3+ treatment 4

B.Pests Infestations Evaluation

The results of the score evaluation rate to the insects pest infestation on sweetpotato leaves and tubers, particularly the sweetpotato weevils (*Cylas formicarius* Fabr), are shown in Table IV. The entomopathogenic nematode (*Steinernema thailandensis* n. sp.) showed the highest efficiency for insect pest control on leaves. Similarly, the lowest infestations of sweetpotato weevils occurred with the entomopathogenic nematode application. The treatment resulted in an insect damage score of 2 compared to the other treatments over all of the varieties (Table V). Among the varieties, Taiwan and Phichit 129-6 showed the lowest level of sweetpotato weevil infestation on leaves and tubers. The criteria for the ratings to insect pest infestation both on leaves and tubers of sweetpotato are shown on Fig. 1 and Fig. 2. Scores in the range between 1 to 4 indicated that the leaves and tubers were infested with sweetpotato weevil between 25% and 100%.

TABLE IV
INSECTS PEST INFESTATION IN TREATED SWEETPOTATO ON LEAVES

Treatments	**Scores of insects pest infestation on sweetpotato tubers**					**Average**
	Varieties					
	Taiwan	**China**	**PROC No.65-16**	**Phichit 166-5**	**Phichit 129-6**	
control (water)	4	4	4	3	3.5	**3.7**
wood vinegar	2	3	3	3	2.5	**2.7**
EPN	2	2	2	2	2	**2**
FOS	2	3	3	3	2.5	**2.7**
mixed	3	3	3	3	2.5	**2.9**
Average	**2.6**	**3**	**3**	**2.8**	**2.6**	

Mark : EPN nematode = entomopathogenic nematode (*Steinernema thailandensis* n.sp)
FOS =Fermented Organic Substances from four plants (*Derris elliptica* Roxb, *Stemona tuberosa* Lour, *Tinospora crispa* Mier and *Azadirachta indica*)
mixed = treatment 2+ treatment 3+ treatment 4

Note: Criteria for the ratings of insect pest infestation on sweetpotato leaves
Score 1 = leaves area were infested <25%
2 = leaves area were infested between 26 and 50%
3 = leaves area were infested between 51 and 75%
4 = leaves area were infested between 76 and100%

Fig. 1 Leaves area were infested <25%(A); leaves area were infested between 26 - 50%(B); leaves area were infested between 51 - 75% (C)

TABLE V
INSECT PEST INFESTATION IN TREATED SWEETPOTATO ON TUBES

Treatments	**Scores of insects pest infestation on sweetpotato tubers**					**Average**
	Varieties					
	Taiwan	**China**	**PROC No.65-16**	**Phichit 166-5**	**Phichit 129-6**	
control (water)	3.5	4	3.5	4	4	**3.8**
wood vinegar	3	3	4	3	3	**3.2**
EPN	2	2	2	2	2	**2.0**
FOS	2	3	3	3	2.5	**2.7**
mixed	3	3	4	3	3	**3.2**
Average	**2.7**	**3**	**3.3**	**3**	**2.9**	

Mark : EPN nematode = entomopathogenic nematode (*Steinernema thailandensis* n.sp)
FOS =Fermented Organic Substances from four plants (*Derris elliptica* Roxb, *Stemona tuberosa* Lour, *Tinospora crispa* Mier and *Azadirachta indica*)
mixed = treatment 2+ treatment 3+ treatment 4

Note: Criteria for the ratings of insect pest infestation on sweetpotato tubers
Score 1 = tubers were infested <25%
2 = tubers were infested between 26 and 50%
3 = tubers were infested between 51 and 75%
4 = tubers were infested between 76 and 100%

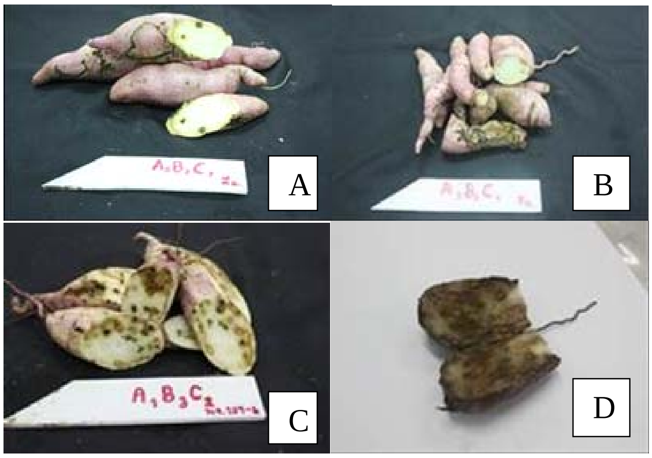

Fig. 2 Sweetpotato tubers infested <25%(A); tubers infested between 26 and 50%(B); tubers infested between 51 and 75%(C); and tubers infested between 76 and 100%(D)

F.Soil Analysis

The physical and chemical properties of the soil in guard rows and the plots of sweetpotato are shown in Table VI. The soil was clay for the guard row and silty clay in the plots. The soils had a pH of range 6.32 to 6.53 which is moderately acidic. Moisture content (%)in the guard rows was slightly lower than in the plots. There were no differences in organic matter (%OM) found between the plots and guard rows. A higher of level major nutrients (N and P) occurred in the plots compared with the guard rows, except for potassium (K) which was less with 84.53 ppm in the plots versus 103.42 ppm in the guard rows.

TABLE VI
ANALYSIS OF NUTRIENT CONTENT OF SOIL SAMPLES IN GUARD ROW AND THE PLOTS OF SWEETPOTATO

Soil Samples	Values of analysis of nutrient content in soil samples treated with treatments					
	pH	**% Moisture**	**%OM**	**Total-N**	**P (ppm)**	**K (ppm)**
guard row	6.53	2.76	2.21	0.020	7.51	103.42
in plots	6.32	2.90	2.17	0.034	8.03	84.53

IV. DISCUSSION

The response of tubers and leaves of sweet potato to wood vinegar, entomopathogenic nematodes *S. thailandensis* and fermented organic substances were studied in March to July 2011 at Phitsanulok province, Thailand. The entomopathogenic nematodes gave the highest sweet potato weights and widths. Although the highest efficiency in terms of length of the sweet potato tubers occurred with fermented organic substances treatment, the treatment with entomopathogenic nematodes was significantly different for fermented organic substances and mixed treatments. Similarly, the results of the score evaluation rate of sweetpotato weevil infestation on leaves and tubers indicated that the highest efficiency occurred with the entomopathogenic nematode treatment. The results of this study agree with those from experiments in Kenya, [10] which measured the effectiveness of two entomopathogenic nematodes against *Cylas puncticolis* Boheman, and significantly suppressed the emergence of adult weevils from the tubers. The entomopathogenic nematodes were also very effective on larvae and reduced the number of pupae significantly. Therefore entomopathogenic nematodes have field potential in controlling the weevil and may provide the local solution to this pest problem in Kenya [10].

In Srilanka, the efficacy of two entomopathogenic nematodes species against the potato weevil, *Cylas formicarius*., has been studied. In the laboratory, *Steinernema feltiae* produce 70-80% mortality of larvae, pupae and adults while in a small plot experiment under field conditions also showed significant insecticidal efficacy on the weevil thereby reducing damage to local sweetpotato varieties, CARI-426, CARI-426-13 [3]. However in Papua New Guinea, entomopathogenic fungi *Beauveria* and pheromone are used for reducing pest and disease impact on yields of sweet potato production systems [14]. Many researchers indicated that entomopathogenic nematodes have been most widely used as biological control agents in soil environments [15]. Entomopathogenic nematodes are lethal endoparasites of insects [16], [17], [18].

It is widely believed that integrated pest management (IPM) is the best way of controlling weevils [Ref]. When integrated pest management technique was used against *Cylas formicarius* on sweet potatoes in Taiwan, weevil damage to the roots was reduced from 40 to <1% [19]. Therefore using nematodes to control sweetpotato pests in certain applications may be an alternative that can add to the tools available to use in integrated pest management programs.

There is not yet any sweetpotato variety that is highly resistant to weevil attack. The efforts of research groups to develop a cultivar of sweet potato resistant to the apionid *Cylas formicarius* have concluded that an adequate source of resistance to the pest may not exist in sweet potato germplasm [20]. In this study, the five varieties of sweetpotato with potential for bioethanol production were screened and bred by Center of Agricultural Research and Development Phichit, Thailand. The varieties: Taiwan and Phichit 129-6 showed the lowest sweetpotato weevil infestations on leaves and tubers. Also Phichit 129-6 showed the highest weight of tubers.

V. CONCLUSION

Sweet potato is a promising feedstock for fuel-ethanol production in several parts of the world. This study showed that the sweet potato variety Phichit 129-6 would be a promising variety for production of fuel-ethanol. Using entomopathogenic nematodes to control pests in sweetpotato may be an effective way of reducing the dependency on chemicals,and appropriate for use in organic sweetpotato cultivation.

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