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Utilization of Soapberry as a Natural Surfactant in Cashew Nut Shell Liquid Bioinsecticide Formulation in Soybean Pest Management

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Abstract.
The demand for soybean has been steadily increasing year after year. Pests are one of the most significant barriers to increasing soybean production. The goal of this study was to determine what concentration of soapberry fruit extract to use as an adjunctive ingredient in cashew nut shell liquid (CNSL) formulations to obtain the best pest control effect and soybean growth and yield. This study used a randomized complete block design with a single factor: soapberry extract concentration. The research included four treatments: application of CNSL formulations containing 4%, 3%, 2%, and 0% soapberry extract, application of CNSL formulations containing 1 g/liter detergent, synthetic pesticides (Fastac 1-2 liters/ha), and no pesticides as a control. Insecticide applications were effective against grasshopper and pod-sucking bugs in soybean cultivation; the CNSL with 3%, 4% soapberry and the CNSL with detergent had effectiveness comparable to the synthetic insecticides. Soybean growth was unaffected by any of the CNSL formulations or synthetic insecticide applications. However, using a CNSL formulation with 4% soapberry increased soybean yield as much as using a synthetic insecticide; it did not differ significantly from using a CNSL formulation with detergent. The soybean yield was highest in the CNSL formulation with detergent.

Keywords: Keywords: soybean, soapberry, CNSL, pest

1. Introduction

Soybean is one of the most nutritious food commodity as a source of vegetable protein and low in cholesterol and also the price is affordable. Along with increasing population and increasing public welfare, the demand for soybean commodity continues to increase from year to year.

The amount of domestic soybean needs is quite high, while national soybean production tends to fall from 907 thousand tons in 2010 to 424.2 thousand tons in 2019. Soybean productivity (yield per hectare) amounted to 54.74 qu/ha in 2020 [1]. This soybean needs are used for the processed industry (tofu, tempe, tauco) which reaches

83.7%, for seed needs reaches 1.2%, for animal feed 0.4%, and others 14.7% [2, 3]. Whereas the national soybean production in 2014 was 998,000 tons of dry beans [1] even the national production of soybeans in 2015 only reached 963,180 tons, which was only 64.21% from the data of soybean production target of the Directorate General of Food Crops which was 1.5 million tons [4].

One of the main obstacles in increasing soybean production is an attack of pests, where without control, plants damaged by pest attacks can reduce yields up to 80% [5]. The use of pesticides, especially synthetic pesticides, is widespread because they are considered to be the fastest and most effective in dealing with pest problems. However, its use turns out to cause harm such as pest resistance, pest resurgence, killing of natural enemies and environmental pollution problems that are very dangerous for humans. The use of chemical pesticides needs to be managed so as not to be used as the only alternative pest control. The use of natural ingredients is one alternative to overcome pest problems. Botanical pesticides made from natural ingredients will be more easily decomposed and do not pollute the environment, and are relatively safe for humans and livestock [6, 7, 8, 9].

Today, with the growing concept of organic farming, the use of chemical pesticides has begun to decrease, and has begun to shift to control techniques using botanical pesticides that are more environmentally friendly. The use of natural ingredients, especially those from plants as one of the pest control strategies that have good opportunities in the framework of the implementation and socialization of integrated pest control (IPM). Botanical pesticides are made by extracting certain parts of a plant by processes that do not change their chemical structure [10].

Cashew Nut Shell Liquid (CNSL) has the potential as a natural pesticide. Cashew nut shell which has only been a waste has chemical compounds such as phenolic that can function as pesticides. From previous studies on CNSL, it had shown its potential as a pesticide, as it is used to control *Cricula trifenestrata* larvae (pests in cinnamon and cashew) and post-harvest pest insects (*Sitophilus* spp. and *Tribolium castaneum*). The results showed that CNSL was able to kill the larvae and adult of *Sitophilus* spp. from 22.5 to 55% at a concentration of 6.25-50%, it also resulted in the inhibition of larval development to become pupae between 37.5-60% and pupae to adult between 12.5-25% [11]-[12]. While the other [13] found that CNSL seed treatment formulation at a concentration of 20% proved effective in maize weevil control. Aside from being an insecticide, it is also effective as a molluscicide. CNSL effectively affected the female reproductive organs (ovaries) of the golden snail *Pomacea canalicullata* and reduced egg hatching to 70% [14]. Therefore, CNSL is thought to be potential as a botanical pesticide to control pests in soybean cultivation.

Botanical pesticide applications will be better if added with additional ingredients (adjuvants) so that the use of pesticides is more effective in controlling pests. Adjuvants are additional ingredients that can be surfactants, solvents, stickers, diluents or perfumes mixed with pesticides so that the pesticides are more effective and efficient in controlling pests.

Botanical pesticide applications often use soap or detergent as an adjuvant ingredient with the aim of increasing extraction, and as a surfactant to increase distribution of pesticide ingredients on the target surface. Several types of plants are known to have soap-like properties so that they are expected to replace soap or detergent when applying botanical pesticides so become more environmentally friendly.

In the research, soapberry (*Sapindus rarak*) fruit extract was used to replace detergent. The active compound in soapberry fruit is saponin, which is a glycoside. Saponins in soapberry have a bitter taste and can be used as natural adjuvants. Saponins have strong surfactant activity, form stable foam, are emulsifying agents and form micelles such as detergents [7, 15].

This study was conducted to determine the concentration of soapberry as a natural adjuvant ingredient in CNSL biopesticides formulation that was most effective in controlling pests and to produce the best growth and yield of soybeans.

2. Materials and methods

The research had been carried out in the experimental field of Mercu Buana University Yogyakarta. The research had been done from July to October 2016. The materials that had been used in this research are Grobogan variety soybean seeds, soapberry fruit, CNSL, methanol, detergents, water, chemical pesticides (Fastac), manure, and fertilizer (TSP, urea, KCl).

The research was a single factor experiment, with seven treatments which were arranged in a Randomized Complete Block Design (RCBD). The treatment factor in this study was the concentration of soapberry solution as adjuvant material in CNSL biopesticide formulation. The treatments were consisted of P1 = CNSL+4% soapberry solution, P2 = CNSL+3% soapberry solution, P3 = CNSL+2% soapberry solution, P4 = CNSL+0% soapberry solution (without soapberry solution), P5 = CNSL+detergent 1g per liter, P6 = Chemical pesticides (Fastac 1-2 liters per ha), and P7 = Without pesticides as a control.

Preparation of CNSL formulation began with making a solution of 100% stock solution was made from CNSL which was added with methanol solvent in a ratio of 1 : 1. In this study, 20% CNSL biopesticide formulation was used from stock solution. The application in the field was carried out by making 10 liter solution by dissolving 0.1% CNSL formulation, so that in 10 liters the solution contained 10 ml of CNSL formulation.

Making soapberry solution was by dissolving five soapberry fruits into 500 ml of hot water by kneading and precipitating for approximately 24 hours. After being precipitated, the water was filtered. From the obtained soapberry extract could be applied with 15 liters of water. Addition of soapberry extract adjuvant material in CNSL formulation was carried out according to predetermined concentration treatments.

Pesticide spraying was done after the plants were two weeks after planting, and stopped at two weeks before harvesting. Spraying was carried out in the afternoon at intervals of 7 days, with the same spray volume each experiment unit.

Soybean harvesting was carried out at 72 days after planting. Harvesting soybeans was characterized by most deciduous leaves and the fruit began to change color from green to brownish yellow.

3. Result and discussion

In the pest observation, it were identified the emergence of several insect pests namely grasshoppers, consisting of green grasshopper *Atractomorpha crenulata* from the family Pyrgomorphidae and brown grasshopper *Valanga nigricornis* from the family Acrididae [16]. There were also found pod-sucking bug Riptortus linearis which is a member of the family Alydidae and several types of caterpillars namely leaf roller caterpillar *Lamprosema indicata* from the family Pyralidae and armyworm *Spodoptera litura* from the family Noctuidae [16]. The caterpillar pests that appeared were very few in population and were not evenly distributed so that they were considered unimportant.

In general, the population density of pests was not much. In this study the most abundant population of pests was pod-sucking bugs. Pod-sucking bug is the main pest of soybean plants. According to [17] adult is brown with a yellowish white line along the lateral side of the body. The female body length is 13-14 mm, while males are 11-13 mm. According to [6] pod-sucking bug eggs are grayish in color, and usually found on the bottom surface of the leaves in groups, the egg phase is 6-7 days long. The nymphs go through five instars of different shapes, colors and sizes. Pod-sucking bugs suck both young and old pods. The young pods which has been attacked by pod-sucking bugs become empty (do not produce seeds), while the old pods which has been attacked, the seeds become wrinkled and black spots.

The treatment of soapberry solution concentration as an adjuvant ingredient in CNSL formulation had no effect on the population of green grasshoppers and brown grasshopper. The treatment also did not give effect to the pod-sucking bugs population.

Table 1: Pesticide efficacy to grasshopper and pod-sucking bug (%) of CNSL formulation with various concentrations of soapberry solution as adjuvant ingredient

Treatment	Kinds of pest							
	Grasshoppers			Pod-sucking bug				
	2 wap	3 wap	4 wap	3 wap	4 wap	5 wap	6 wap	7 wap
CNSL+4%	50,75	100	100	100	100	100	100	66,67
CNSL+3%	100	100	100	0	66,67	66,67	0	33,33
CNSL+2%	50,75	0	66,67	0	100	0	0	33,33
CNSL+0%	0	0	33,33	0	66,67	0	0	0
CNSL+det	50,75	0	66,67	0	0	33,33	100	33
Synth instcd	0	0	100	0	0	66,67	100	100

Note : wap = weeks after planting

det = detergent

Because in general the pest population was not much, the effect of treatment in this study looks insignificant. Based on the observation of pest species and population, even though the treatment had no effect but pest population after application was tended lower than pest population before application, and also showed some high efficacy values. The efficacy of applied pesticides was calculated based on the pest population that appeared. In general, CNSL biopesticide formulation with adjuvant soapberry fruit extract had efficacy against grasshoppers and pod-sucking bugs. Efficacy tended to be high in CNSL+4% soapberry solution and CNSL+3% soapberry solution, while the highest efficacy of pesticides on pod-sucking bugs was CNSL+4% soapberry solution. The efficacy datas can be seen at Table 1.

In addition to the efficacy of pesticides, was also observed the level of intensity of pest attacks. The treatment of various concentration of soapberry solution as an adjuvant in CNSL formulation had no effect on the intensity of plant damage by grasshoppers and pod-sucking bugs attacks, but at the age of seven weeks after planting affected the intensity of grasshoppers damage.

Note : The mean value followed by the same letter in the same column shows no significant difference according to the F test or DMRT test of 5%

: wap = weeks after planting

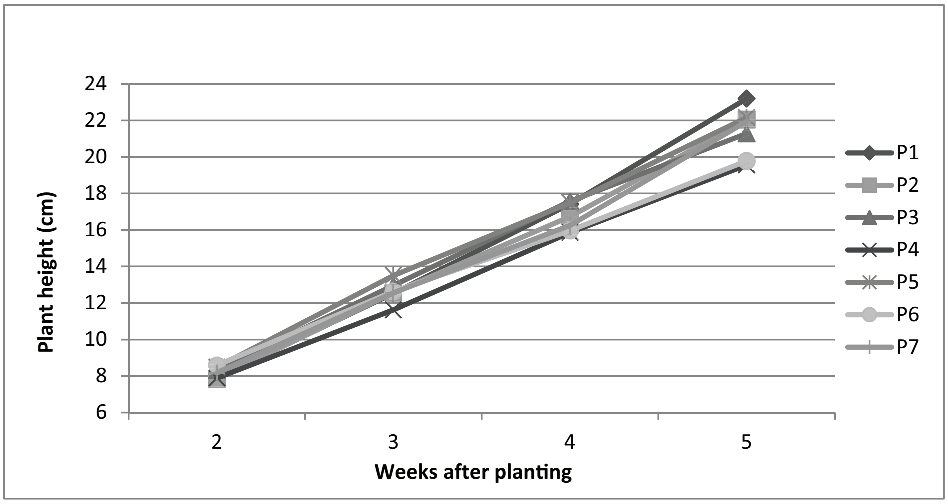
Table 2: Damage intensity by grasshoppers at 2, 3, 4, 5, 6, 7 weeks after planting and pod-sucking bugs at 9 weeks after planting.

Treatment	Kinds of pest						
	Grasshoppers						Pod-sucking bugs
	2 wap	3 wap	4 wap	5 wap	6 wap	7 wap	9 wap
CNSL+4%	3,33a	2,22a	3,60a	3,39a	5,24a	8,20b	3,95a
CNSL+3%	2,50a	2,09a	3,47a	4,25a	4,95a	8,50b	4,17a
CNSL+2%	3,33a	2,78a	3,58a	5,84a	6,84a	11,91ab	4,42a
CNSL+0%	4,17a	3,89a	4,30a	4,30a	5,70a	9,57ab	4,28a
CNSL+det	3,33a	2,36a	3,00a	4,33a	6,17a	10,61ab	4,31a
Synth insc	2,50a	2,08a	3,83a	4,72a	7,13a	10,99ab	3,88a
Control	3,33a	4,19a	4,97a	5,78a	8,33a	13,83a	4,67a

The influence of soapberry fruit extract as an adjuvant ingredient in CNSL formulation on pest conditions in soybean cultivation in this study, was predicted to be caused by the presence of active compounds contained in CNSL and soapberry fruit. CNSL contains anacardic acid, cardol and cardanol [18] which is an insecticide active compound. Previous researchers [11, 19] showed that CNSL had the potential as a botanical insecticide, which was in accordance with the statement of [19] that anakardic acid could function as an insecticide, could inhibit the work of prostaglandin synthetase enzymes, which are enzymes needed for the formation of prostaglandins that play a role in insect physiological and reproductive systems, was able to reduce the rate of oviposition, reduced the percentage of successful development of insect stadia, antifeedant until it caused death.

CNSL could be as effective as synthetic insecticides in controlling grasshoppers, but with the addition of 3 and 4% lerak solution could improve the effectiveness of CNSL formulations so that it was more effective in reducing the intensity of grasshoppers pest attacks and significantly lower than the control, as shown in Table 2. According to [20] soapberry fruit contains compounds from groups of saponins, sesquiterpenes, alkaloids and steroids besides that there are also anthraquinones, tannins, phenols, and flavonoids. The content of secondary metabolites in the soapberry fruit causes detergent-like properties that are emulsifiers and surfactants thereby increasing the effectiveness of CNSL formulations, even more effective than CNSL + detergent formulations. This effectiveness is likely due to the presence of other secondary metabolites in soapberry fruit extracts which are also toxic, thus increasing the insecticidal properties of CNSL formulations

Application of CNSL biopesticide formulation with the addition of soapberry adjuvant solution at various concentrations of 2, 3, and 4% or CNSL with detergent formulations



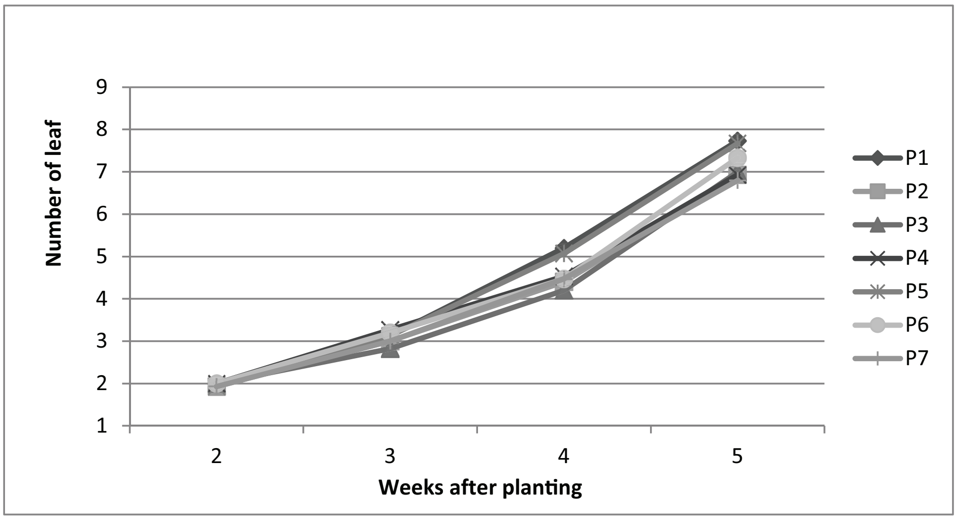
Note : P١ = Formulation CNSL + ٤ ٪ soapberry solution
P٢ = Formulation CNSL + ٣ ٪ soapberry solution
P٣ = Formulation CNSL + ٢ ٪ soapberry solution
P٤ = Formulation CNSL + ٪٠ soapberry solution (without soapberry solution)
P٥ = Formulation CNSL + detergent ١g/liter
P٦ = Synthetic insecticide (Fastac ١-٢ liter/ha)
P٧ = Without pesticide

Figure 1: Soybean plant height with application of CNSL formulations with various concentrations soapberry solution as adjuvant.

did not affect plant height and number of soybean leaves and was not different from the results of synthetic insecticide application. The rate of increase in soybean height can be seen in Figure 1, while the rate of increase in the number of soybean leaves is shown in Figure 2.

All insecticide treatments in the experiment did not cause differences in plant growth components, namely plant height, number of leaves, number of productive branches, flowering time and dry weight of plants. This showed that the treatments of soapberry solution concentration (0-4%) as an adjuvant ingredient in CNSL biopesticide formulation did not give a significant effect, meaning that the growth of soybean was not different from other treatments. This was predicted due to low pest population density and the intensity of pest attacks so that it did not have a significant impact. Population density of all types of pests only ranged from 0 to 1 per plant, while the intensity of grasshopper pest attacks during plant growth only ranged from 2-12% and even the intensity of pod-sucking bug attacks only ranged from 3-4%, all of the damage intensity were still classified as mild attack intensity (<25%) [21].

Pest attacks did not affect the growth and health of soybean leaves so photosynthesis was not disturbed and the growth of vegetative or generative organs of plants also occured normally and did not differ in all treatments. Therefore plant height, number of branches and flowering time were also not different for all treatments (Table 3.)



Note : P1 = Formulation CNSL + 4 % soapberry solution
P2 = Formulation CNSL + 3 % soapberry solution
P3 = Formulation CNSL + 2 % soapberry solution
P4 = Formulation CNSL + 0% soapberry solution (without soapberry solution)
P5 = Formulation CNSL + detergent 1g/liter
P6 = Synthetic insecticide (Fastac 1-2 liter/ha)
P7 = Without pesticide

Figure 2: Soybean plant height with application of CNSL formulations with various concentrations soapberry solution as adjuvant.

Table 3: Growth variables of soybean with application of CNSL formulations with various concentrations soapberry solution as adjuvant ingredient.

Treatment	Number of productive branches	Flowering time	Plant dry weight
CNSL+4%	4,60 a	35,33 a	3,29 a
CNSL+3%	4,13 a	35,33 a	2,67 a
CNSL+2%	3,87 a	35,33 a	1,67 a
CNSL+0%	3,80 a	36,33 a	2,30 a
CNSL+det	4,13 a	36,00 a	2,41 a
Synth instcd	3,73 a	35,33 a	2,68 a
Control	3,33 a	35,33 a	2,44 a

Note : the mean value followed by the same letter in the same column indicate no significant difference in effect between treatments according to the F test of 5% level.

Leaves are the site of photosynthesis where the photosynthetic results will affect the biomass produced by plants and the nutrient content in plants. Photosynthates will be expressed in plant dry weight, which is the most accurate growth variable to show plant growth conditions. The dry weight of soybean plants in this study was also not significant in all treatments, but the application of CNSL formulation with 4% of soapberry solution tended to give the heaviest dry weight (Table 3.). This was presumably because the CNSL formulation with 4% of soapberry solution had relatively high efficacy (Table 1.)

and was able to reduce the lowest intensity of grasshoppers and pod-sucking pest attacks (Table 2.), so that photosynthate in plants was higher.

Table 4: Yield variables of soybean with application of CNSL formulations with various concentrations soapberry solution as adjuvant ingredient.

Treatment	number of pods per plant	number of filled pods per plant	Dry seed weight per plant	Dry seed weight per ha
CNSL+4%	31, 93 a	28,93 a	6,69 a	2,38 ab
CNSL+3%	29,07 a	25,00 a	6,67 a	2,31 b
CNSL+2%	25,47 a	22,33 a	6,16 a	2,26 b
CNSL+0%	25,20 a	21,80 a	5,75 a	2,21 b
CNSL+det	28,33 a	24,87 a	6,19 a	2,48 a
Synth instcd	23,27 a	22,13 a	6,46 a	2,39 ab
Control	22,20 a	18,20 a	4,86 a	2,15 b

Note : the mean value followed by the same letter in the same coloumn indicate no significant difference in effect between treatments according to the F test or DMRT of 5% level.

The treatment of variations in soapberry concentration as adjuvant ingredient in CNSL formulation had no effect on some of the observed soybean yield variables, which included the number of pods per plant, number of filled pods per plant, and dry seed weight per plant. Application of CNSL formulation with 4% extract of soapberry fruit produced dry seed weight per hectare as high as synthetic insecticide and was greater than control. While the application of CNSL formulations with detergents gave the highest and most significant results with control but not significantly different from the application of CNSL formulations with 4% lerak or synthetic insecticides (Table 4.).

CNSL biopesticide formulation with 4% soapberry could have higher soybean yield because plant growth also tended to be higher so that it could provide better growth of pods and seeds. Whereas the application of CNSL with detergent formulations was also higher and significantly different from the control allegedly due to the smaller intensity of pod-sucking bugs *R. linearis* attacks (Table 2.), especially during pod filling because the critical period of plants against pod-sucking attacks is the stage of filling seeds [22].

On the other hand, higher damage intensity of pod-sucking bugs could reduce the yield of soybean. That's because as a result of the attack of pod sucking bugs. The symptoms are pods or seeds attacked will usually show spots and discoloration of soybean grains. Furthermore, the seeds and pods are deflated, the pods fall, the seeds become rotten, black, wrinkled seed skin, and brown spots on the seed coat. Heavy attacks often result in sterile, colored seeds [22].

4. Conclusion

Based on the results of the research that had been carried out, conclusions could be drawn as follows :

Insecticide applications showed that there were efficacy against grasshopers and pod-sucking bugs in soybean cultivation, where CNSL formulations with 3 and 4% soapberry extract, and CNSL formulations with detergent, relatively had efficacy as good as synthetic insecticides. All of applications of CNSL formulations and synthetic insecticide did not cause differences in soybean growth. Application of CNSL formulation with 4% soapberry extract was able to increase soybean yield as high as the application of synthetic insecticides, and did not significantly different from CNSL formulation with detergent.

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