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Research Article

Integrated Management in Boosting Up *Capsicum annuum* L. Production Using Integrated Farming and Biopesticide

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Abstract

Background and Objective: Chilli is highly susceptible to various types of pests and diseases that affect both yield quality and quantity. Therefore, this study aimed to determine the potential of intercropping practices and bio-pesticide application on the chilli's growth performance, pest severity and yield. **Materials and Methods:** The study was performed using *Capsicum annuum* (chilli) as the main crop, while *Citrus hystrix* (kaffir lime), *Curcuma longa* (turmeric) and *Cosmos caudatus* (king salad) were used as the plant species for intercropping. Four pesticide treatments were applied including the chemical pesticide as control. **Results:** Results indicated that the differences between all measured parameters were found to be highly significant ($p<0.01$) for both intercropping and pesticide except for the fresh weight of chilli fruit. The differences between all measured parameters namely, plant height, stem diameter, crown diameter, fresh weight of chilli fruit and pest severity were also highly significant ($p<0.01$) with plant age. The results also found that the combination of intercropping (chilli × king salad) and bio-pesticide (neem extract) resulted in greater stem and crown diameters, lowest pest severity and the heaviest weight of chilli fruit compared to other combination, including the control (chemical pesticide) treatment. **Conclusion:** Therefore, it was concluded that the application of intercropping of chilli and king salad together with neem extract as a biopesticide produce a greater yield in terms of quantity and quality compared to conventional planting method which practices mono-cropping and applying chemical pesticide.

Key words: Intercropping, biopesticides, chilli, growth performance, pest severity

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Chilli (*Capsicum annuum* L.) is widely cultivated in South East Asia, including Malaysia, Indonesia and Thailand. Chilli comprised about 11.4% of the total vegetable production in Malaysia and is listed as one of the nine major crop vegetables. Chilli is one of the important vegetables and the demand for it is always high throughout the year. To meet this demand, the Malaysian government had to import 39% of chillies from neighbouring countries such as Thailand and Vietnam. There are several diseases that attack chilli plants such as the pepper mosaic virus, grey mold, powdery mildew and anthracnose. The effects of diseases on the chilli plants lead to a decrease in economic output in the field. Pests typically are more mobile and multiply faster than beneficial insects. Chillies are affected by numerous pest attacks during the growing season. The pests which cause major problems to chilli plants are mostly sucking pests such as the aphid and whitefly[1].

The application of pesticides plays an important aspect in agriculture and biopesticides is a good solution that can sustain the natural environment while ensuring quality of production. A biopesticide is a formulation made from naturally occurring substances to control pests by non-toxic mechanisms and in an eco-friendly manner; hence, they gain importance all over the world. Biopesticides offer many advantages associated with environmental safety, target-specificity, efficacy, biodegradability and suitability in Integrated Pest Management (IPM) programs[2]. Thus, biopesticides are promising alternatives to manage environmental pollution caused by conventional pesticides[3]. One example of biopesticides is Neem (*Azadirachta indica*) plant extract that can function at different stages and in multiple ways. Primarily, it acts as an antifeedant against insect larvae on crop leaves treated with the neem product.

Most herbs and spices have a strong odour and some of them have attractive colours. A strong odour from herbs has the potential to prevent insects and pests from attacking the plants around them. Brightly coloured herbal flowers also could lure natural enemies which will then destroy pests around the plant. Some researchers have implemented flowering plants as strips within crops as a method to improve the accessibility of pollen and nectar that are required for optimal reproduction, fecundity and longevity of many natural enemies of pests. *Phacelia tanacetifolia* strips have been applied in wheat, sugar beets and cabbage farms, leading to the increase in the number of aphidophagous predators (especially syrphid flies) and a reduction in aphid populations[4]. Previous study proved that intercropping of Fabaceae and Asteraceae families' results in an increased crop yield, maximized resource consumption and improved productivity of the cultivation system[5]. Because of these beneficial characteristics of the herbs and spices, they have the potential to be planted together with a high value crop such as chilli which has various pests and disease risks.

Intercropping is a potentially beneficial system of crop production. It can be defined as the growing of two (or more) crops simultaneously on the same area of land at the same time[6]. Intercropping can provide yield advantages compared to sole cropping. Intercropping systems may produce higher yields compared to monocultures and reduce the harmful impact of agriculture on the environment. Specifically, intercropping may improve soil conservation, fertility and crop quality, reducing the incidence of weeds, diseases and insect pests[7,8]. A combination of suitable herbs or spices in an intercropping planting system might have a huge potential in controlling pests or diseases and at the same time increase the production of the main crop. Previous studies reported less numbers of the pest, silver leaf whitefly (*Bemisia tabaci*) and lower incidence of begomovirus infections on tomato when planting intercropped with coriander[9]. Another research noted that when eggplant was grown with maize as a border crop and coriander or marigold as an intercrop, the incidence of leafhopper and whitefly pests was the lowest[10]. Maize probably acted as a barrier crop to block the movement of leafhoppers due to its tall height.

In Malaysia, research and practice of intercropping planting system are scarce and those that were carried out usually involved were intercropping in oil palm and rubber plantations. Thus, this study was conducted to determine the response of an intercropping system and biopesticides on the growth and yield of chilli and its resistance to the pests and diseases compared to the conventional method of monocropping and use of chemical pesticides.

MATERIALS AND METHODS

Study area: The study plot was established from August-December, 2018 at Rhu Tapai Agricultural Centre, Kuala Terengganu, Terengganu, Malaysia at the latitude of 5°30'48.6"N and longitude of 102°58'38.5"E.

Study design: The size of the study plot was 13×40 m. The study plot was divided into four plots which were: The monocropping of *C. annum*; *C. annum* integrated with *C. hystrix*; *C. annum* integrated with *C. longa* and C. *annum* integrated with *C. caudatus*. The *C. annum* seedlings were planted with 1×1 m planting distance. For the intercropping plots, the distance between the intercropping crops was 2×2 m, while the *C. annum* plants were planted within the row with 1x1 m planting distance. The *Capsicum annuum* (chilli) Hybrid-461 was selected for use in this study because it is one of the most common chilli varieties planted by farmers in Malaysia. The seeds were supplied by the Pertubuhan Peladang Kuala Terengganu. A total of 160 *C. annuum* seeds were selected and sown in sowing trays for a one-month period. The seedlings were then transferred to the field and cultivated using an open fertigation system. For these intercropping plants, application of fertilizer and other management activities were done based on common agricultural practices in order to ensure all the plants were healthy.

Application of biopesticide extracts and chemical pesticides: In this study the biopesticide extracts were produced from neem leaves and garlic (*Allium sativum*) cloves. Two hundred grams of fresh neem leaves and 200 g of garlic cloves were separately homogenized in one liter of deionized water using a blender. The blended solutions were then filtered using muslin cloth and the filtrates were sprayed onto the whole chilli plants from bottom to the top with an average dosage of 50 mL for each plant. For the chemical pesticides, the commercial brand used by farmers in Malaysia which is Zesban EC Chlorpyrifos 21.2% was applied where 2.4 mL of the chemical pesticide was diluted into 1000 mL of deionized water and sprayed onto the whole chilli plants with an average dosage of 50 mL per plant. The prepared biopesticides (plant extracts) and the commercial chemical pesticide were applied to the respective plots according to the Table 1. The study plots were assigned using a Randomized Complete Clock Design (RCBD) encompassing a total of 10 replicates. The pesticides were applied every two weeks starting from the first two weeks after planting until the chilli was harvested.

Table 1: List of treatments involved in the study

Number	Treatment
1	Monocropping + No pesticide
2	Monocropping + Chemical pesticide
3	Monocropping + Garlic extract
4	Monocropping + Neem extract
5	Intercropping chili with kaffir lime
6	Intercropping chili with turmeric
7	Intercropping chili with king salad
8	Intercropping chili with kaffir lime + Garlic extract
9	Intercropping chili with kaffir lime + Neem extract
10	Intercropping chili with turmeric + Garlic extract
11	Intercropping chili with turmeric + Neem extract
12	Intercropping chili with king salad + Garlic extract
13	Intercropping chili with king salad + Neem extract

Data collection: The parameters measured for this study encompassed the growth performance (plant height, stem diameter, crown diameter), number of chilli fruit, fresh weight of chilli fruit and pest severity. The data of growth performance and pest severity were recorded fortnightly from the second week after planting while the fresh weight of chilli fruits was recorded after harvest. As noted in Table 2, the modification of pest severity scoring was based on a percentage of the pest infestation[11].

Statistical analysis: All the data recorded were analyzed using factorial analysis of variance (ANOVA). The plant age was considered as one of the factors or independent variables in order to clearly define the growth performance instead of being directly analysed using the repeated measure analysis. The combined analysis for the correlation coefficient between parameters measured was performed using the bivariate (Pearson) correlation analysis. The statistical analysis was performed using IBM SPSS statistics software version 20.0, IBM Corp, Armonk, USA.

Table 2: Pest severity scale

Scale	Pest infestation (%)	Level
0	0	No pest infestation
1	1-25	Scattered appearance of a few pests on the plant
2	26-50	Severe infestation of pests on any one branch of the plant
3	51-75	Severe infestation of pests on more than one branch or half portion of the plant
4	76-100	Severe infestation of pests on the whole plant

RESULTS

Growth performance of chilli plant: Growth is a very important aspect to consider when studying living things, especially plants. The growth rate of plants is closely related to their surroundings and environment such as soil, light and air as plants produce foods from resources obtained around them. Normally, healthy plants will produce an optimum amount of yield. Table 3 summarized the effects of 13 treatments on plant height, stem diameter and crown diameter throughout the experimental period. The highest plant height (28.9 cm) was obtained from king salad intercropping plot plus application of neem extract, followed closely by kaffir lime intercropping plot (28.7 cm). The lowest height was shown by the chilli in the control plot at only 21.8 cm. Chilli plants applied with chemical pesticide planting without intercropping had the second lowest value at 22.6 cm. In this study chilli plants were grown in polybag using a fertigation system, so that competition issue for nutrients uptake between plants did not exist. The difference in the plant height could be due to the favorable environment condition such as sufficient source of sun light and humidity to enable the stem to grow well. Intercropping systems reduce wind speed, provide shade and increase infiltration, so conserving soil water and improving soil structure[12].

For the stem diameter, there was no significant effect of the treatments at $p<0.05$. The stem diameter for all treatments ranged from 4.0-5.7 cm. The results for crown diameter analysis showed that chilli plant intercropped with king salad and applied with neem extract had the largest crown diameter at 22.8 cm followed by chilli plant applied with neem extract (21.9 cm). These results were significantly different at p-value of 0.001. The application of chemical pesticides also resulted in smaller crown diameter at only 19.9 cm. Crown of plant formed from branches and leaves, the plant which sprayed with neem extract does not attack by the pest, so both the plant and crown grows well. Previous studies[13] stated in the study that spraying tomato plants with 20% aqueous neem leaf extract somewhat decreased early blight incidence and disease severity and also marked a decrease in both disease incidence and severity after two and four weeks of inoculation. The present study also observed the possibilities of neem leaf extract in controlling *A. solani* and *F. oxysporum* and highlights on results encouraging the possible application in agriculture after field investigations. Instead of controlling disease, the antifeedant properties also existed in neem compounds supports to protect the plants[14]. Pests commonly do not develop a resistance to neem-based pesticides. Neem pesticides are mostly water soluble thus it will encourage the plant growth.

Pest severity of chilli: In this study, pest severity was assessed to investigate the efficiency of intercropping and biopesticides in reducing the pest infestation in chilli production. Based on the Table 4, pest severity was lowest (0.6 score) in chilli plant intercropped with king salad and applied with neem extract, followed by chilli plant applied with neem extract (0.8 score). These results were lower than plants applied with chemical pesticides which showed 0.9 score. The highest pest severity was observed from chilli plant intercropped with turmeric and applied with turmeric extract which is 2.27 score. Based on the analysis, the effects of intercropping and biopesticides on pest severity are very diverse.

Neem performs as a biopesticide at different stages and in multiple ways. Mostly it acts as antifeedant where when an insect larva wants to feed the leaf which is treated with neem product, due to the presence of azadirachtin, melandriol and salanin, there is an antiperistaltic wave in the alimentary canal

Table 3: Effects of different treatments on the growth of chilli plant

Treatments	Plant height (cm)	Stem diameter (cm)	Crown diameter (cm)
Monocropping + No pesticide	21.8 ± 0.83^{a}	4.5 ± 0.30^{ab}	18.6 ± 0.87^{ab}
Monocropping + Chemical Pesticide	22.6 ± 0.81^{a}	4.6 ± 0.32^{ab}	19.9 ± 0.91^{bc}
Monocropping + Garlic extract	23.3 ± 0.58^{a}	4.0 ± 0.27^{a}	19.1 ± 0.58^{bc}
Monocropping + Neem extract	24.3 ± 0.73^{ab}	4.9 ± 0.33^{ab}	21.9 ± 0.95^{cd}
Intercropping Kaffir lime	28.7 ± 1.03^{c}	5.7 ± 0.42^{b}	18.2 ± 0.74^{ab}
Intercropping Turmeric	25.6 ± 0.90^{ab}	4.7 ± 0.34^{ab}	18.0 ± 0.81^{ab}
Intercropping King salad	25.5 ± 0.96^{ab}	5.0 ± 0.31^{ab}	21.7 ± 0.96^{cd}
Intercropping Kaffir lime + Garlic extract	26.9 ± 0.79^{bc}	4.7 ± 0.32^{ab}	14.8 ± 0.56^{a}
Intercropping Kaffir lime + Neem extract	26.6 ± 0.79^{bc}	5.0 ± 0.36^{ab}	17.7 ± 0.81^{ab}
Intercropping Turmeric + Garlic extract	27.7 ± 0.69^{bc}	5.0 ± 0.31^{ab}	17.7 ± 0.63^{ab}
Intercropping Turmeric + Neem extract	25.1 ± 0.91^{bc}	5.3 ± 0.36^{ab}	20.0 ± 0.92^{bc}
Intercropping King salad + Garlic extract	23.5 ± 0.77^{a}	4.5 ± 0.30^{ab}	20.0 ± 0.93^{bc}
Intercropping King salad + Neem extract	28.9 ± 0.90^{c}	5.6 ± 0.40^{b}	22.8 ± 1.18^{d}
p-value	0.000**	0.124^{ns}	0.000**

Mean values with the same letter in the same row for each factor are not significantly different at $p<0.05$, ±: Standard error **: Significant at $p<0.05$

Table 4: Pest severity of chilli fruit assessed using 0-4 scale

Treatments	Pest severity
Monocropping + No pesticide	1.7±0.13[cd]
Monocropping + Chemical Pesticide	0.9±0.10[ab]
Monocropping + Garlic extract	1.4±0.13[bc]
Monocropping + Neem extract	0.8±0.11[ab]
Intercropping kaffir lime	1.1±0.11[ab]
Intercropping turmeric	1.6±0.12[cd]
Intercropping king salad	1.6±0.14[cd]
Intercropping kaffir lime + Garlic extract	2.2±0.17[d]
Intercropping kaffir lime + Neem extract	1.4±0.13[bc]
Intercropping turmeric + Garlic extract	2.2±0.17[d]
Intercropping turmeric + Neem extract	1.1±0.09[ab]
Intercropping king salad + Garlic extract	1.8±0.15[cd]
Intercropping king salad + Neem extract	0.6±0.10[a]
p-value	0.000**

Mean values with the same letter in the same row for each factor are not significantly different at p<0.05, ±: Standard error, **: Significant at p<0.05

Table 5: Number of chilli pod and fresh weight of chili

Treatments	Number of fruit	Fresh weight (g)
Monocropping + No pesticide	5.6±0.95[ab]	14.8±2.22[a]
Monocropping + Chemical Pesticide	8.4±0.92[bc]	20.8±2.23[ab]
Monocropping + Garlic extract	4.3±0.77[a]	13.4±2.23[a]
Monocropping + Neem extract	9.4±1.07[cd]	28.5±3.25[bc]
Intercropping Kaffir lime	10.4±1.32[cd]	22.3±3.24[ab]
Intercropping Turmeric	5.9±1.05[ab]	20.7±3.50[ab]
Intercropping King salad	9.7±1.14[cd]	26.3±2.54[ab]
Intercropping Kaffir lime + Garlic extract	5.3±0.77[ab]	17.3±2.79[ab]
Intercropping Kaffir lime + Neem extract	6.2±0.79$_{bc}$	28.5±3.21[bc]
Intercropping Turmeric + Garlic extract	6.9±0.72[bc]	18.5±1.71[ab]
Intercropping Turmeric + Neem extract	10.7±1.28[cd]	23.6±3.048[ab]
Intercropping King salad + Garlic extract	4.5±0.64[a]	18.2±2.38[ab]
Intercropping King salad + Neem extract	11.9±1.30[d]	40.1±3.36[c]
p- value	0.000**	0.000**

Mean values with the same letter in the same row for each factor are not significantly different at p<0.05, ±: Standard error, **: Significant at p<0.05

and this produces something similar to vomiting sensation in the insect. It is a very remarkable property of neem product and unique in nature, as it works on juvenile harmone[14].

The main component of neem oil, leaves, flowers and fruits with insecticidal properties is Azadirachtin. Azadirachtin, along with other related triterpenoids such as Azadirachtin B, salannin and nimbin, are the active ingredients in neem plant based bioinsecticides and their action is by disrupting insect's growth performance and deterring their feeding. It is considered as a botanical pesticide with exceptional growth regulating and biocidal efficacy along with deterrent effects on the ovipositing and feeding of insects[15].

There was very little pest incidence and injury in castor intercropped with cluster bean, cowpea and groundnut compared to the castor monocrop[16]. Moreover, these systems were more efficient in agronomically especially in terms of equivalent yields and land equivalent ratio. These systems can be concluded as better protected from pest attacks, resulting in higher yields and profit. Previous studies also stated that intercropping potentials to be a very promising practice in the decreasing and controlling pests and diseases[17]. One component crop in an intercropping system may act as a barrier against the spread of pest and diseases.

Number of chilli fruit and fresh weight of chilli fruit: Production of chilli fruits is very significant as it is the key measurement for successful of farm management practice. Table 5 presents the mean number of chilli fruits and fresh weight of the chilli fruit harvested at the end of the experimental period.

The results showed that chilli plant intercropped with king salad plus application of neem extract produced the highest number of fruits with 11.9 fruits, followed by chilli intercropped with turmeric plus application of neem extract (10.7 fruits).On the other hand, the lowest number of chilli fruit was obtained from chilli plant applied with garlic extract only. For the parameter of fruit fresh weight, the highest mean

amount of fresh weight was obtained from chilli intercropped with king salad applied with neem extract as a biopesticide with weighed of 40.1 g, followed by chilli plant applied with neem extract as a biopesticide with weight of 28.5 g. The lowest weight was indicated by chilli intercropped with a king salad plot applied with garlic extract as a biopesticide at only 13.4 g.

Results from this study have proved that the production of chillies was higher when chilli planted in the intercropping system and applied with biopesticides compared to the conventional practices where chilli planted solely and applied with chemical pesticides. In comparison with chemical pesticides, the use of biopesticides is cheaper and this will benefit farmers economically. Specifically, results of chilli's fresh weight related with the pest severity. The less severity of chilli plant was at plot intercropping king salad with application of neem extract where the same plot produces highest fresh weight of chilli. It means that when the plant was less attack by the pest, it will produce more chilli and had a better growth performance. A research noted that an analysis of 62 Integrated Pest Management (IPM) research and development projects in 26 countries, covering over 101.5 million farm households, showed that integrated pest management leads to substantial reductions in pesticide and over 60% of the agricultural projects which applied integrated pest management resulted in both a reduction in pesticide use (average reduction 75%) and an increase in yields (average increase 40%)[18].

Typically, with the application of standard fertilizer, chilli plants with less pest severity have a great potential to produce the highest yield and this was proven in our study where intercropping chilli with king salad×biopesticide (neem extract) resulted in the highest fresh weight which was about 2300 g. As stated by research[19] the application of biopesticides is safe for consumer consumption and at the same time suppresses the insect pests effectively. A recent study[20] found that all neem derivatives suppressed the population of jassid and thrips below the economic threshold level. The study found that 5% neem oil and neem seed water extract recorded the highest percentage mortality of the target pests. It proved that application of plant products for the control of insect pests is a good solution with less residual action, more eco-friendly and is more specific against the target pest. Vegetables treated with biopesticides can be harvested and sold directly without any chemical residues which may contain toxic elements detrimental to human health.

CONCLUSION

This study has proven that intercropping chilli with kaffir lime, king salad and turmeric and applying neem and garlic as biopesticides have significantly influenced the growth of chilli plants, production of chilli fruits and reduced pest severity on the crop. The best treatment found in this study was the intercropping chilli with king salad and applied with bio-pesticide (neem extract) in comparison to other treatments. This combination of treatment can be suggested to replace the utilization of chemical pesticide which commonly applied by farmers in Malaysia.

SIGNIFICANCE STATEMENT

This study discovered the potential resource for biopesticide and intercropping plant to enhance the production of chilli. This study will help the researchers to uncover the critical areas of chilli production thus, a potential of biopesticide and the intercropping system was explored.

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