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Concentration effects of chili and ginger extracts against diamondback moth (*Plutella xylostella* L.) on round cabbage

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Abstract
Diamondback moth (*Plutella xylostella* L.) is a major pest of cabbage and other vegetables in the Brassicaceae family. The management and control of this cosmopolitan and economic pest has been a challenge in tropical regions. Reliance on chemical insecticides have led to resistance, natural enemy suppression, contaminated residues, risks to chemical poisoning and other environmental contamination. Therefore, the need to utilize non-host spice plants is an alternative. For this study, we focus on different concentration levels of two local spice plants; (1) chili (*Capsicum frutescens* L.) and (2) ginger (*Zingiber officinale* R.). Based on previous studies, extracts from both plants have been able to reduce pest infestation in vegetables. There were nine (9) treatments (T): T_1=3ml of chili extract L^{-1} *v/v*, T_2=6ml of chili extract L^{-1} *v/v*, T_3=9ml of chili extract L^{-1} *v/v*, T_4= 3ml of ginger extract L^{-1} *v/v*, T_5= 6ml of ginger extract L^{-1} *v/v*, T_6= 9ml of ginger extract L^{-1} *v/v*, T_7=3ml of pure water L^{-1} *v/v*, T_8=6ml of pure water L^{-1} *v/v* and T_9=9ml of pure water L^{-1} *v/v*. From these treatments, 6ml chili was effective in lowering the defoliation (%) and was able to produce high leaf area index (LAI) regardless of increasing rainfall. Ginger 9ml produced high LAI and low defoliation in spite of increasing rainfall. Rainfall (mm) was an important environmental factor affecting the abundance, LAI and defoliation.

Keywords: *Plutella xylostella* L., *Capsicum frutescens* L, *Zingiber officinale* R, leaf area index, defoliation, abundance

Introduction

Diamondback moth (*Plutella xylostella* L.) is a major pest of cabbage and other vegetables in the Brassicaceae family. *P. xylostella* is a cosmopolitan and important economic pest in tropical regions and globally (Zhang *et al*. 2016) [41]. Use of chemical pesticides have led to resistance, natural enemy suppression, contaminated residues, risks to chemical poisoning and other environmental contamination (Obeng-Ofori & Ankrah 2002; Timbilla & Nyarko 2004; Ntow *et al*. 2006; Fening *et al*. 2011; Iamba & Malapa 2020) [31, 40, 30, 12, 17]. The moth is a destructive pest at Vudal and throughout East New Britain Province (Iamba & Yoba 2019) [20]. The focus in controlling *P. xylostella* has now shifted from chemical to botanical pesticides that have repellent and deterrent effect (Coulibaly *et al*. 2002) [8]. Plants that have insecticidal properties can be sourced locally and thus provides a low-cost technique to manage insect pests (Iamba & Masu 2020) [21]. Extracts from leaves, flowers, fruits and seeds of insecticidal plants have been applied to repel ovipositing females, reduce feeding activity and cause larval mortality of *P. xylostella* on treated cabbage leaves (Shin-Foon & Yu-Tong 1993; Chen *et al*. 1996; Charleston *et al*. 2005; Abbasipour *et al*. 2010) [38, 7, 6, 1]. Botanical pesticide is an essential input in any plant protection program since they encourage the activity of natural enemies to supress pests (Gentz *et al*. 2010) [13]. A push-pull system exists when non-host plant extracts are applied to reduce oviposition of insect pest while enhancing the activity of parasitoids in crops (Liu *et al*. 2007) [26]. Various semiochemicals are involved in a push-pull system which can repel pests, attract natural enemy populations or lure both counterparts to meet (Pyke *et al*. 1987; Miller & Cowles 1990; Pickett *et al*. 1997; Agelopoulos *et al*. 1999) [33, 28, 32, 3].

For this study, we focus on different concentration levels of two local spice plants; (1) chili (*Capsicum frutescens* L.) and (2) ginger (*Zingiber officinale* R.). Extracts from both plants were able to reduce pest infestation in vegetables and crops (Iamba & Yoba 2019; Iamba & Malapa 2020; Iamba & Masu 2020) [20, 21].

The aim is to determine the concentration level of the two extracts that can effectively suppress the activity of *P. xylostella* on round cabbage (*Oleracea* var. *capitata).* Round cabbage (*O.* var. *capitata)* is highly susceptible to attack of *P. xylostella* in Vudal agroecosystem. From previous studies, chili (*C. frutescens)* extract has been utilized as an effective control of *P. xylostella* due to its antifeedant and deterrent properties (Iorizzi *et al*. 2000; Khan *et al*. 2000; Iamba & Yoba 2019) [23, 25, 20]. Cabbages treated with chili and other botanical extracts produced comparable yield (Begna & Damtew 2015) [5]. A high infestation in control treatment (no extract) was evident due to absence of barrier against feeding larvae of *P. xylostella* (Reuben *et al*. 2006; Iamba & Malapa 2020) [34, 21]. On the other hand, Ginger (*Z. officinale*) contains repellent properties and has been effective in repelling Dipteran insects such as *Culex tritaeniorhynchus* and *Anopheles subpictus)* (Govindarajan 2011) [14]. Ginger extract inhibited the emergence of adult *C. cramerella*, therefore it was recommended for application (Saripah *et al*. 2019) [37]. Several studies have shown that the volatile chemical constituents from extract of *Z. officinale* deterred insect pests (Escoubas *et al*. 1995; Agarwal *et al*. 2001) [10, 2].

Materials and Methods

(a) Study site

The study was carried out at the academic crops section at PNG University of Natural Resources and Environment (PNG UNRE) campus in East New Britain, Papua New Guinea (PNG). The experimental site is located 51m above sea level approximately at 4º 21’ 01.90” S and 152º 00’ 33.44” E (Iamba & Yoba 2019; Iamba & Yoba 2020) [20, 21]. The academic crops section is an experimental site allocated for research studies especially on tropical crops. PNG UNRE is an Agricultural and Environmental institution that supports the sustainable management of natural resource in Agriculture, Fisheries, Forestry and Animal Sciences. The soil type is sandy loam, well-drained, fertile, calcareous and generally alkaline in nature (Iamba & Yaubi 2021) [22]. Sandy loam soil possess good binding traits and has extensively been used as an adequate medium for raising seedlings (Howcroft 2002) [16]. With sandy loam soils, soil sterilization is not mandatory except if infection occurs. The climate is classified as tropical with a great deal of rainfall experienced all year round even in the driest month. The atmosphere is mostly humid with an average rainfall of 2780 mm per annum and a mild dry season. The average daily humidity ranges from 77-79% with temperature of 27-29 °C (Iamba *et al*. 2021) [22]. According to Howcroft (2002) [16], these environmental conditions are highly suitable for tree cultivation such as balsa and other crops as well.

(b) Nursery

A nursery was established prior to the study by sowing of cabbage seeds in nursery trays at the nursery house. The variety of round cabbage (*Oleracea* var. *capitata*) used for this study is K-K cross. K-K Cross is an improved medium-sized hybrid of *Oleracea* var. *capitata* which is popular in tropical and sub-tropical countries because of its high heat tolerance and early maturity (58 days after transplant). Approximately 300 seeds were sown while experimental plots were constructed in the field. Cabbage seedlings were nurtured for three (3) weeks in the nursery house to ensure acclimatization before transplanting. Acclimatization process was done to habituate the seedlings to the field environmental conditions. Seedlings that are raised in nursery have higher chance of survival than direct sown seeds. Due to acclimatization process, they can withstand the harsh weather conditions when transplanted into field experimental plots.

(c) Experimental design

Site clearance and plot preparation occurred three (3) weeks prior to nursery phase to allow for solarization. Bushes were cleared, soil tilled and unwanted weeds were removed. Proper drainages were constructed to remove excessive water and to avoid any possibility of waterlog conditions. The prepared plots were divided into experimental plots following a Complete Randomized Block design (CRBD). The plot size, planting distance and plant density followed standard measurements in cabbage cultivation (Iamba & Yaubi 2021) [22]. Each plot had a dimension of 2x2m (4m^2) with a spacing of 40cm between plants and 50cm between rows. Therefore, each plot had a plant density of 20 plants per plot [(4m^2/ (0.4 x 0.5)]. There were nine (9) treatments (T): T_1=3ml of chili extract L^{-1} *v/v*, T_2=6ml of chili extract L^{-1} *v/v*, T_3=9ml of chili extract L^{-1} *v/v*, T_4= 3ml of ginger extract L^{-1} *v/v*, T_5= 6ml of ginger extract L^{-1} *v/v*, T_6= 9ml of ginger extract L^{-1} *v/v*, T_7=3ml of pure water L^{-1} *v/v*, T_8=6ml of pure water L^{-1} *v/v* and T_9=9ml of pure water L^{-1} *v/v*. Each concentration level (treatment) was replicated three times. There were total of twenty-seven (27) experimental plots pertaining to 9 treatments x 3 replicates. Chili and ginger extract was selected based on their repellent and deterrent properties. A control treatment (pure water) was included and used as a reference group for comparison. During the experimental phase, there was no chemical insecticide or pesticide used nor any chemical fertilizers because the objective was to test the sole effect of the plant extracts.

(d) Plant content extraction

The stalks of ripened chili and the outer cover of the cloves of ginger were removed. Ginger was further grated using a kitchen grater to produce fine material. Both plant materials were dried in the sun for 2 weeks to remove most moisture content. Then they were grounded separately using an electric blender. About 2.5±0.5 kg of each grounded material were obtained using an electronic balance and placed in two separate desiccators. About 500ml of 75% ethanol (C_2H_6O) was added to each desiccator and covered tightly. The desiccator prevented evaporation of ethanol and protected the hygroscopic contents to react with water from humidity. The contents were left on a designated lab bench for 7 days (1 week) in order to allow the ethanol to degrade the cell walls of the materials thus releasing the chemical constituents. After 1 week, the resultant mixtures were sieved separately using a filter paper and the filtrate collected in 500ml beakers. As suggested by Fening *et al*. (2013) [11], a few drops of natural oil and soap were added to the mixture to enhance its delivery and adhesiveness on the leaf surface. The mixtures were stored in separate 1L containers with polyseal ('P') lids to prevent evaporation. Then 3ml, 6ml and 9ml of each mixture was diluted in 1L of water and sprayed using nine (9) separate hand sprayers.

(e) Sampling

Data was collected three days after spraying and three weeks after transplanting. Three (3) response variables were measured: (1) abundance, (2) defoliation (%) and (3) leaf area index (LAI). These variables were used to calculate the efficacy of each treatment on *P. xylostella*. The procedure and protocol used were similar to the ones used by Iamba and Yaubi (2021) [22]. The abundance was basically the number of *P. xylostella* caterpillar counted during each sampling time. Caterpillars were observed with less disturbance especially when opening cabbage leaves for counting. Both the leaf area index (LAI) and defoliation (%) were obtained using an application called the BioLeaf Foliar Analysis in an android phone. A sample of leaf was placed against a white paper, and a clear shot of 13-megapixel resolution was taken with the phone camera. The app did all scanning and processing of defoliation (%) and LAI. Data pertaining to each response variable was collected twice per week for a total period of 3 weeks. Three plants were randomly selected per plot and measurements on the 3 variables were recorded in a field datasheet. There were 243 data points collected per sampling time (27plots x 3 plants per plot x 3 variables per plant). Since data was collected twice per week, a total of 486 data points were recorded per week. Therefore in three weeks of sampling, a grand total of 1,458 data were recorded. Rainfall data was collected from the university weather station at Vudal and a weekly (5 days) average was computed and used for analysis.

(e) Data analysis

The data on response variables showed asymmetric pattern meaning they were not normally distributed according to Shapiro-Wilk test ($p<0.05$). To correct the skewness in data distribution, Generalized Linear Model (GzLM) was used. The data were log transformed and analysed using the Poisson exponential family function (link = log) in RStudio (version 4.0.3). Since Poisson had a lower Akaike's information criterion (AIC), it was more suitable to use than Gamma exponential family. As an estimator and statistical criteria, the AIC estimated the quality of both models. The root-mean-square error (RMSE) as a measure of Maximum Likelihood Estimation (MLE) was also used in estimating the Poisson model. The RMSE in Poisson model (RMSE=7.07) was lower than linear model (RMSE=104.24) across all tested variables therefore Poisson GzLM family was chosen as a suitable model for data analysis. RMSE measured the difference between predicted values and the actual values (error term). The lower the error term, the better the predictor model fits to the actual values (minimize error). Although mean and variance are known as distribution parameters for normal distribution, Poisson distribution is governed by one parameter – lambda (λ), which is the total number of events (k) divided by the number of units (n) in the data ($\lambda = k/n$). Data were fed into this Poisson model: $log(y)=\alpha + \beta_1x_1 + \beta_2x_2 + \ldots + \beta_px_p$, where y is the response variable, α and β are numeric coefficients, α being the intercept (sometimes by β_0), and x is the predictor/explanatory variable. As aforementioned, coefficients were calculated using the MLE method. All graphs relating to abundance, defoliation and LAI were constructed with ggplot2 package. Tukey Honest Significant Difference test (Tukey HSD) separated the means of each treatment and concentrations. Cross-factor analyses was also done to test the interaction of plant extracts and concentrations (ml) on abundance, defoliation and LAI. For graphical presentation of the factor analyses, cowplot package was integrated with ggplot2 and executed in RStudio.

Results

A total of 1,458 data points were recorded within three weeks of sampling. The diamondback moth caterpillars (*P. xylostella)* varied in their responses to different concentration levels of extracts. As shown in Table 1, the abundance of *P. xylostella* in T_1 (3ml of chili extract L^{-1} *v/v*) (5.37±1.20, $p<0.05$) was significantly higher than in T_2 (6ml of chili extract L^{-1} *v/v*) (4.59±0.81, $p>0.05$) and T_3 (9ml of chili extract L^{-1} *v/v*) (3.96±1.31, $p>0.05$). There was no significant difference between T_2 and T_3 ($p>0.05$). Abundance in T_4 (3ml of ginger extract L^{-1} *v/v*) (5.52±0.84, $p>0.05$) was statistically similar to T_5 (6ml of ginger extract L^{-1} *v/v*) (5.52±0.83, $p>0.05$). Abundance in T_6 (9ml of ginger extract L^{-1} *v/v*) was significantly lower (3.76±0.73, $p<0.05$). The abundance was not statistically significant in T_7 (3ml of pure water L^{-1} *v/v*) (3.98±0.73, $p>0.05$), T_8 (6ml of pure water L^{-1} *v/v*) (3.31±0.56, $p>0.05$) and T_9 (9ml of pure water L^{-1} *v/v*) (3.78±0.70, $p>0.05$). Control treatment (pure water) did not influence the abundance of *P. xylostella* caterpillars.

Table 1: The concentrations (Conc.) were used as treatments in this study. Ginger extract protected cabbage plants at high concentration ($9mlL^{-1}$) while chili did so at low concentration ($6mlL^{-1}$). Control concentrations did not differ significantly in terms of abundance, LAI and defoliation (%).

Plant extracts	Conc.	‡N	Abundance		Leaf area index (LAI)		Defoliation (%)	
			†mean±SE	⸸SD	†mean±SE	⸸SD	†mean±SE	⸸SD
Chili	3ml	54	5.37±1.20 a	8.84	6.49±0.39 bc	2.90	2.69±0.36 abc	2.66
	6ml	54	4.59±0.81 ab	5.96	7.40±0.44 a	3.26	2.02±0.37 c	2.72
	9ml	54	3.96±1.31 ab	9.64	6.39±0.29 c	2.19	2.39±0.38 bc	2.77
Control	3ml	54	3.98±0.73 ab	5.37	7.22±0.43 a	3.16	2.10±0.27 c	1.98
	6ml	54	3.31±0.56 b	4.09	7.32±0.45 a	3.33	2.46±0.28 bc	2.08
	9ml	54	3.78±0.70 b	5.15	7.13±0.43 ab	3.13	2.64±0.29 abc	2.16
Ginger	3ml	54	5.52±0.84 a	6.18	6.38±0.42 c	3.11	3.39±0.40 a	2.95
	6ml	54	5.52±0.83 a	6.12	6.47±0.40 c	2.96	3.06±0.42 ab	3.11
	9ml	54	3.76±0.73 b	5.35	7.22±0.39 a	2.91	2.18±0.31 c	2.26

‡N represents the recorded frequency of each response variable.
†Means with the same letter are not significantly different at α =0.05 (HSD test).
⸸Standard deviation (SD)

Leaf area index (LAI) in 3ml (6.49±0.39, $p>0.05$) and 9ml (6.39±0.29, $p>0.05$) chili extract did not differ significantly. However an increase in LAI was noted at 6ml chili which is considered as medium concentration (7.40±0.44, $p<0.05$) (table 1). All concentration levels of control treatment did not show any significant changes in LAI ($p>0.05$). Defoliation (%) in 3ml, 6ml and 9ml of chili extract were not statistically significant ($p>0.05$) however they were lower than 3ml and 6ml of ginger extract ($p<0.05$). All concentrations of control treatment did not record at significant changes in defoliation ($p>0.05$) (table 1). Distinct differences were notable in ginger extract where 9ml (2.18±0.31, $p<0.05$) had lower defoliation than 3ml (3.39±0.40, $p>0.05$) and 6ml (3.06±0.42, $p>0.05$) (table 1).

For comparison across treatments, the abundance did not differ between 3ml chili and the two ginger concentrations, 3ml and 6ml (fig. 1). The abundance in 6ml ginger is significantly higher than that of chili and control ($p<0.05$). Abundance across 9ml of chili, ginger and control were similarly low ($p>0.05$). Low abundance of *P. xylostella* was achieved with 9ml chili and 9ml ginger (fig. 1A). LAI in 3ml chili and ginger were statistically similar ($p>0.05$) while 6ml chili produced higher LAI than that of ginger ($p<0.05$). However, 9ml ginger produced higher LAI than 9ml chili ($p>0.05$). LAI in all concentration levels of control did not differ significantly ($p>0.05$). High LAI was achieved with 6ml chili and 9ml ginger extract (fig. 1B). Defoliation (%) was high in 3ml ginger ($p<0.05$) compared to chili and control treatments. Chili 6ml recorded low defoliation (%) than control and ginger extracts ($p<0.05$). Defoliation in 9ml chili was similar to that of control treatment ($p>0.05$). There was a decrease in defoliation at 6ml however the decline was significant in 9ml ginger ($p<0.05$).

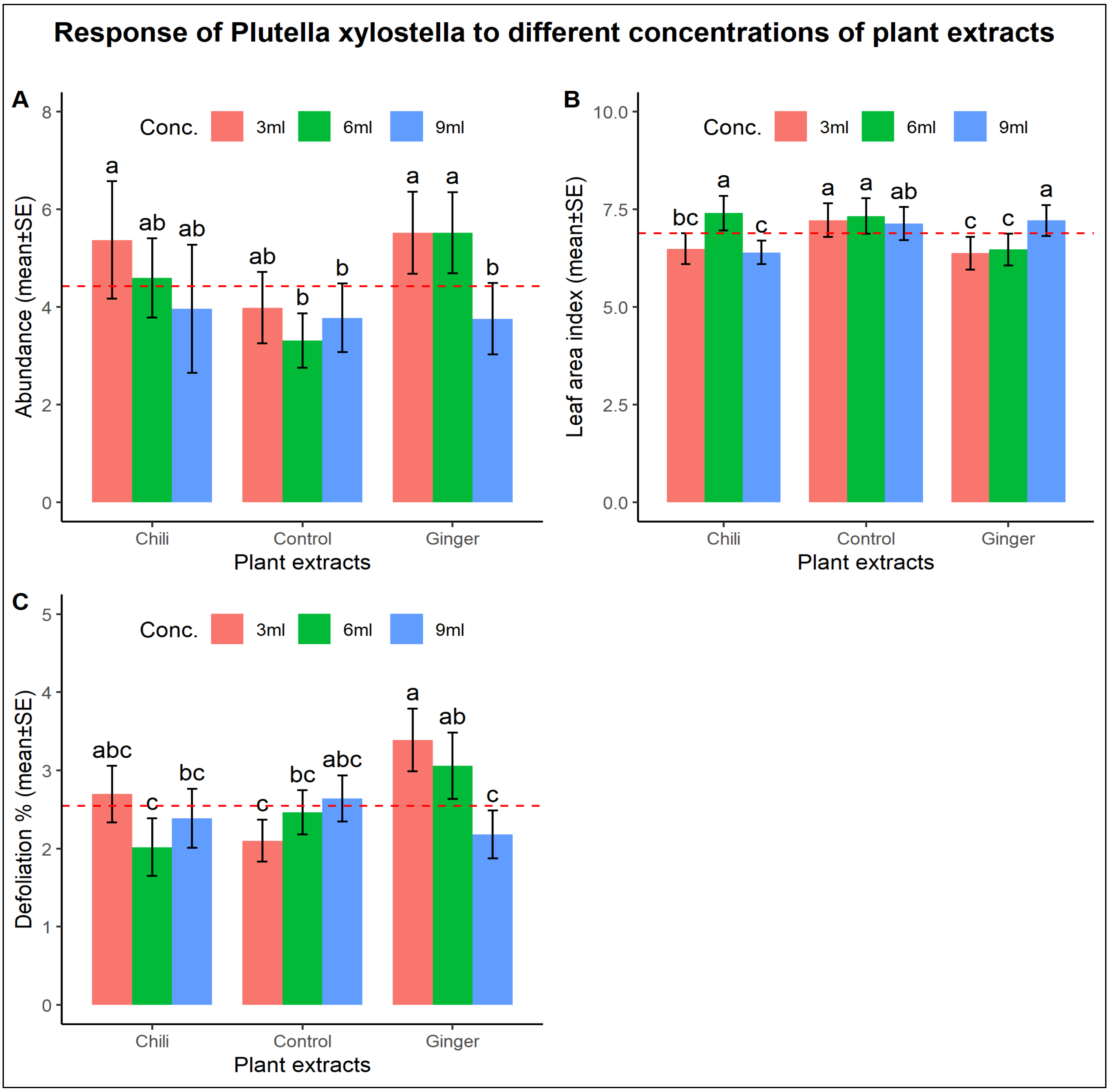

Fig 1: *Plutella xylostella* responses in terms of abundance, LAI and defoliation (%) varied in the three concentration levels. The control treatment generally had low abundance. Both 6ml and 9ml of chili showed lower abundance. Same can be seen in ginger except a significant decrease at 9ml. All concentrations of control did not differ in terms of LAI. LAI increased at 6ml chili ($p<0.05$) while decreased at 3ml and 9ml. Ginger 9ml showed increased LAI while corresponding defoliation (%) decreased. Chili and control levels had low defoliation except in 6ml chili ($p<0.05$). The horizontal dotted line represents the overall mean: (A) μ=4.42, (B) μ=6.89 and (C) μ=2.55.

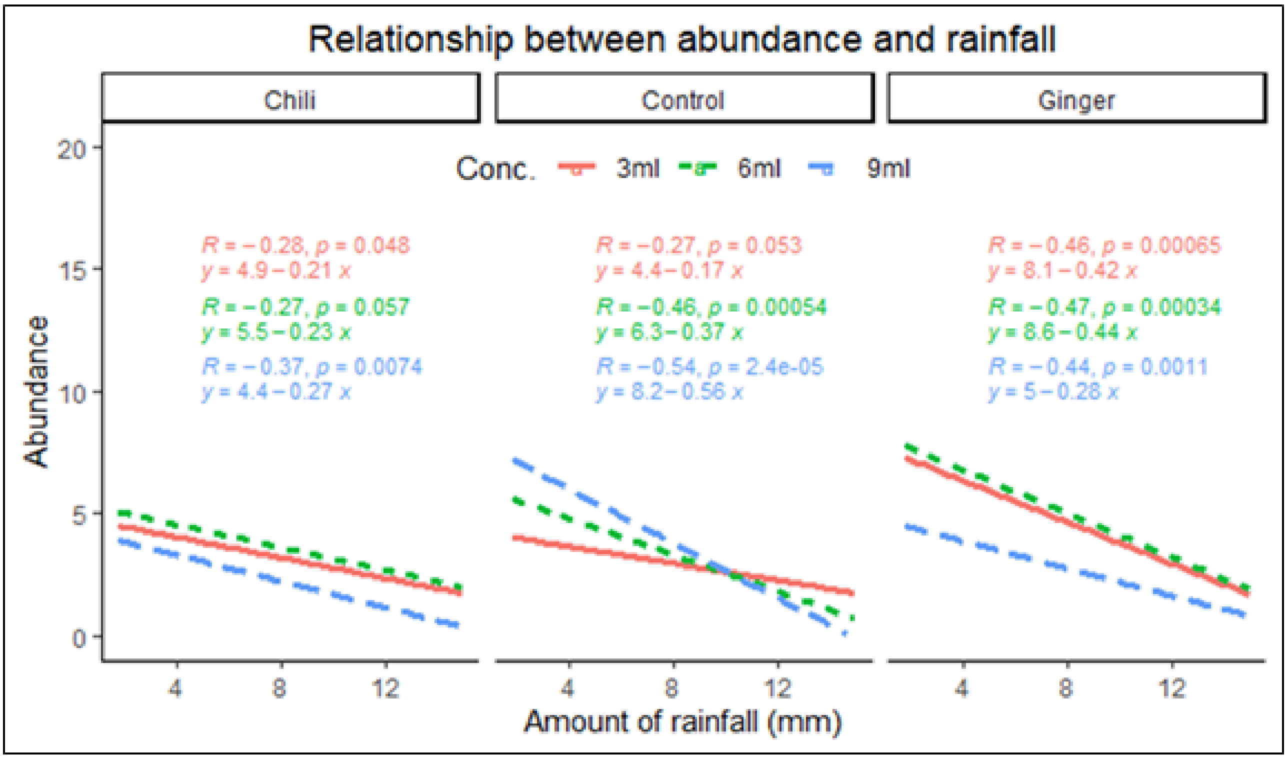

Fig 2: Abundance of *P. xylostella* was negatively correlated with rainfall. There was a decreasing trend in terms of abundance in chili, ginger and control treatments as a function of rainfall (mm). All relationships were created using Pearson correlation (R) with p-values indicating the level of statistical significance at α=0.05.

It was noted that as the amount of rainfall (mm) increased, the abundance of *P. xylostella* caterpillars decreased (fig. 2). There was a significant negative correlation between 9ml chili and abundance ($p<0.05$, r = -0.37). Chili 6ml did not have any significant correlation while a weak negative correlation was noted in 3ml chili. A significant inverse relationship was evident in 6ml and 9ml control treatments. All concentration levels of ginger had significant negative correlation with abundance: 3ml ($p<0.05$, r = -0.46), 6ml ($p<0.05$, r = -0.47) and 9ml ($p<0.05$, r = -0.44).

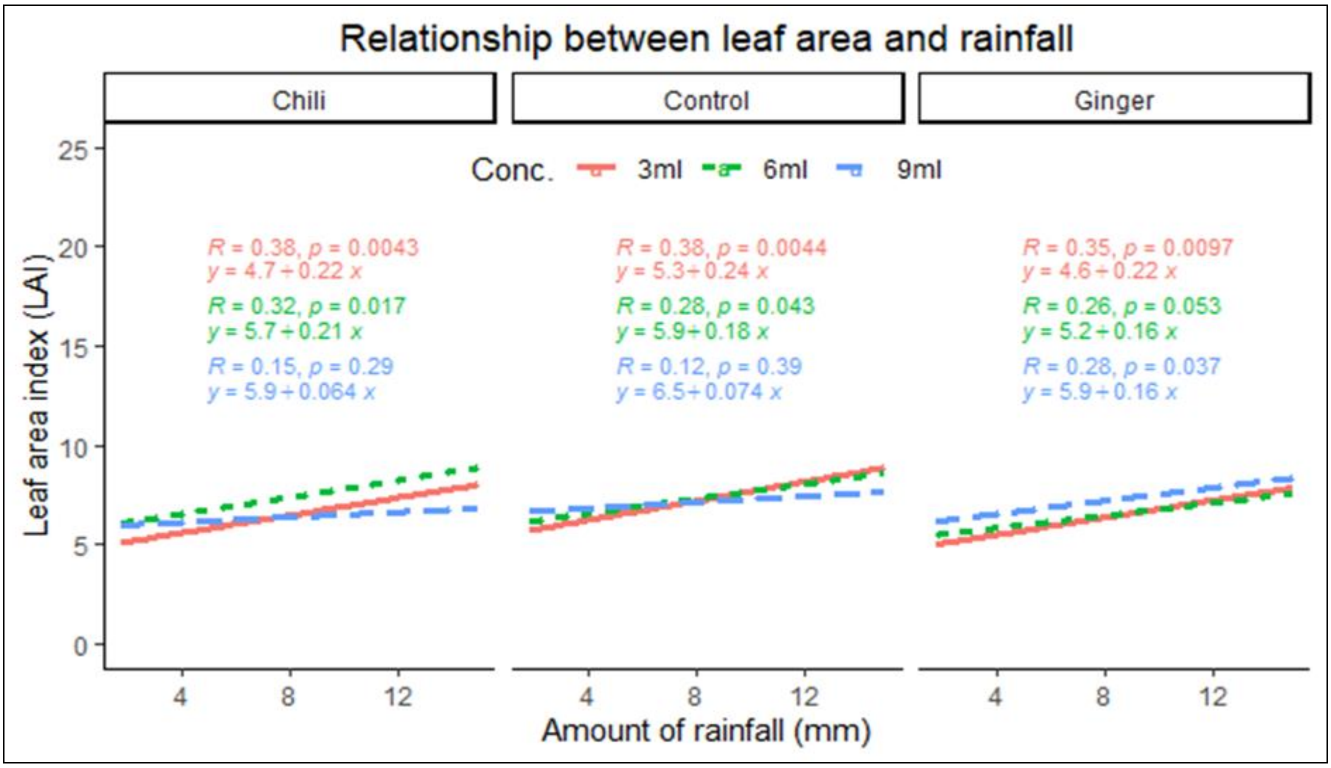

Fig 3: Leaf area index (LAI) was positively correlated with rainfall. There was an increasing trend in terms of LAI in chili, ginger and control treatments as a function of rainfall (mm). All relationships were created using Pearson correlation (R) with p-values indicating the level of statistical significance at α=0.05.

It was noted that as the amount of rainfall (mm) increased, the leaf area index (LAI) also decreased (fig. 3). There was a significant positive correlation between 3ml chili and LAI ($p<0.05$, r = 0.38). Chili 6ml also showed a significant positive correlation with LAI ($p<0.05$, r = 0.32). Chili 9ml had a weak non-significant relationship with LAI ($p>0.05$, r = 0.15). Both 3ml and 6ml control treatments had positive significant correlation with LAI while 9ml was non-significant. Ginger showed significant positive relationship at 3ml and 9ml while 6ml was non-significant.

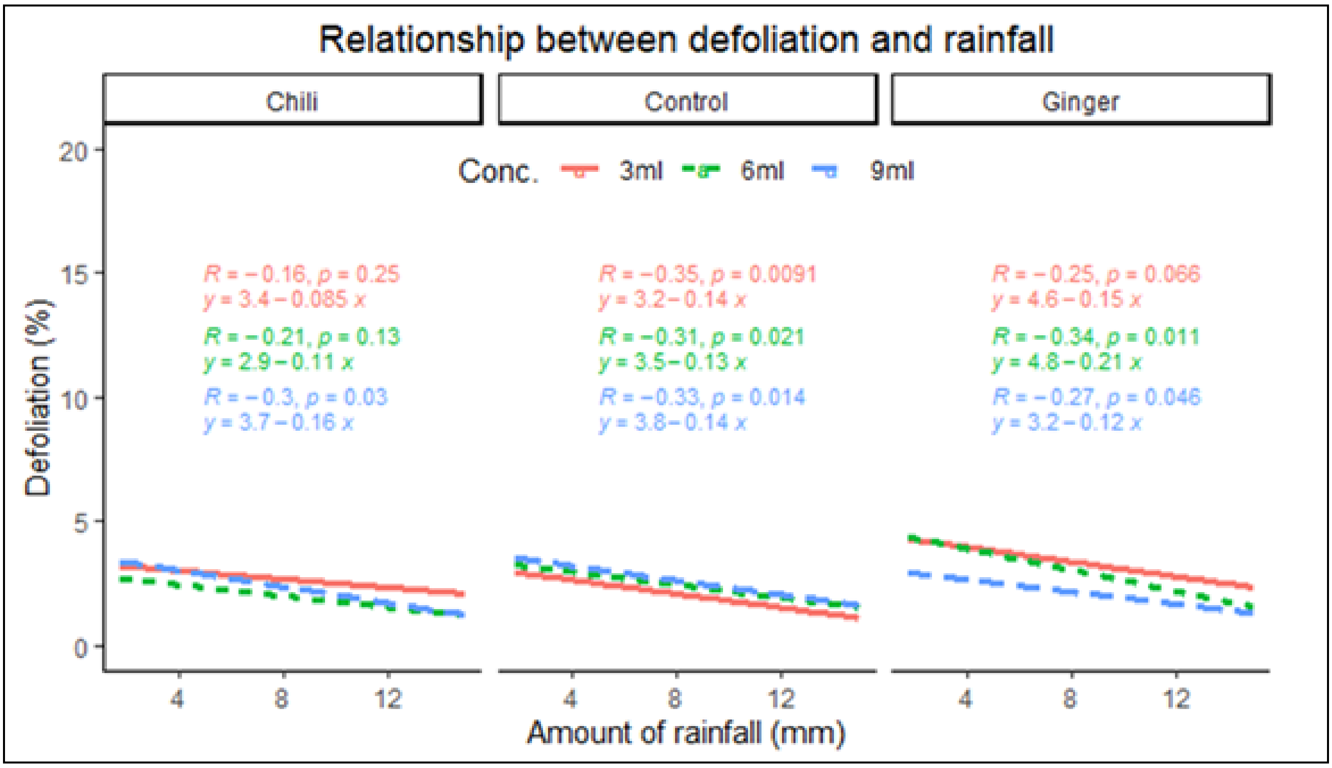

Fig 4: Defoliation (%) was negatively correlated with rainfall. A decreasing trend in terms of defoliation in chili, ginger and control treatments was noted as rainfall (mm) increased. All relationships were created using Pearson correlation (R) with p-values indicating the level of statistical significance at α=0.05.

Defoliation (%) of cabbage leaves decreased as the amount of rainfall (mm) increased (fig .4). As rainfall increased, defoliation significantly decreased in chili 9ml ($p<0.05$, r = -0.3). Both 3ml and 6ml chili showed weak negative relationship with increasing rainfall. All concentration levels of control treatment had significant negative correlation with defoliation. As rainfall increased, it reduces defoliation in cabbage plants. The negative correlation was significant in 6ml ($p<0.05$, r = -0.25) and 9ml ($p<0.05$, r = -0.27) ginger. Ginger 3ml did not show any significant relationship in terms of defoliation versus rainfall.

Discussion

The results showed that chili extract (*Capsicum frutescens*) was effective at lower concentrations (3ml L^{-1} *v/v* and 6ml L^{-1} *v/v*) than at higher dose (9ml L^{-1} *v/v*). According to a study by Iamba and Malapa (2020) [21], chili extract was effective in controlling *P. xylostella*. Due to its antifeedant and repellent properties, chili extract have proven to be an effective botanical pesticide (Iorizzi *et al*. 2000; Khan *et al*. 2000; Iamba & Yoba 2019) [23, 25, 20]. Cabbages that were sprayed with chili extract were able to produce good yield (Begna & Damtew 2015) [5]. Chili 6ml was able to provide better protection to cabbage leaves therefore the defoliation is significantly lower than ginger and control treatment. In the absence of chili extract, *P. xylostella* caused notable defoliation to cabbage plants and damage severity was high (Reuben *et al*. 2006) [34]. Chili contains active phytochemical family of capsaicinoids, diterpenoids, flavonoids, saponins, and phenolic compounds which are lethal against insect pests including *P. xylostella* (Iorizzi *et al*. 2000; Madhumathy *et al*. 2007; Begna & Damtew 2015) [23, 27, 5]. Studies on chili extract showed that it is compatible with natural enemies of *P. xylostella* at application rate of 10ml L^{-1} *v/v* (Iamba & Yoba 2019) [20]. Since predators such as *W. auropunctata* R and *Epilachna* spp consumes their prey whole, therefore they are most succumb to the toxicity of chemical pesticides (Theiling & Croft 1988) [39].

On the other hand, ginger extract was effective at higher concentration (9ml L^{-1} *v/v)* than at lower doses (3ml L^{-1} *v/v* and 6ml L^{-1} *v/v*). Ginger is considered a repellent plant that can be incorporated into a push system to discourage oviposition (Liu *et al*. 2007) [26]. According to an experiment carried out by Iamba and Masu (2020) [21], ginger (*Zingiber officinale)* was effective in reducing oviposition than marigold extract. Ginger contains insecticidal compounds such as arcurcumene, b-myrcene, 1,8-cineole, citral, and zingiberene which helps as repellents and deterrents against insect pests (de Melo *et al*. 2011; Bayala *et al*. 2014; Hamada *et al*. 2018) [9, 4, 15]. The volatile chemical constituents of ginger extract have proven to deterred insect pests (Escoubas *et al*. 1995; Agarwal *et al*. 2001) [10, 2]. The antifeedant property of ginger extract disrupted the growth activity of *Spodoptera litura* F larvae1 (Sahayaraj & Sekar 1996; Sahayaraj 1998) [36, 35].

Our study showed mix results on the effectiveness of chili at the lowest (3ml L^{-1} *v/v*) and highest dose (9ml L^{-1} *v/v*) which can be subjected to few factors. This result supports an experiment by Ishii *et al*. (2010) [24], where the repellent activity of chili against *S. zeamais* L adults were unverified and had weak repellent activity. Neem extract provided the highest repellent effect against pests of dried fish followed by chili (Nowsad *et al*. 2009) [29]. Rainfall had a significant effect on abundance of *P. xylostella*, leaf area and defoliation. Plant extracts applied on foliar can be washed away by heavy rains and are constantly being exposed to other adverse weather conditions such as humidity and temperature (Iamba & Masu 2020) [21]. However for this study, relative humidity and temperature did not have any significant effect on ginger and chili extracts. We assume 9ml chili to be too toxic to natural enemies therefore abundance and defoliation did not significantly differ from control treatments. Under increasing rainfall, 6ml chili contributed to low defoliation (%) and was able to produce high LAI (fig. 3). Increasing rainfall did not have any significant effect on abundance of *P. xylostella* at 6ml chili. Concurrently, ginger 9ml produced high LAI, low defoliation and low abundance of *P. xylostella* in spite of increasing rainfall (fig. 4).

Conclusion

Local spice plants such as chili and ginger are locally available and can be readily utilized to manage insect pests in crops. From this study, 6ml chili contributed to low defoliation (%) and was able to produce high LAI regardless of increasing rainfall (fig. 3). Ginger 9ml produced high LAI and low defoliation in spite of increasing rainfall (fig. 4). Further study can look into quantifying natural enemies (i.e. predators/parasitoids) at each concentration levels and determining their compatibility. Referencing from previous studies, chili is an effective botanical extract however further investigation can test for more concentration levels in order to reach a point of equilibrium between *P. xylostella* and natural enemies. Weather parameters such as rainfall, humidity and temperature also influence the dynamics of plant attack and needs to be taken into consideration.

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