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Efficacy of rhizome crude extracts organic pesticide against insect-pests and its impact on glutinous corn (*Zea mays* L. var. *ceratina*) Production

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Abstract

The intractable increasing cost of synthetic pesticides is certainly intense in the coming production years. Looking into this viewpoint the farmers have to look for alternative actions to withstand their farming business profitability. Rhizome crude extracts can be an alternative for synthetic pesticides. This study was conducted to assess the effect of rhizome crude extracts against glutinous corn seedling maggots, corn earworm, corn borer, armyworm, and aphids; evaluate the effect of rhizome crude extracts on the growth and yield of glutinous corn, and determine the profitability of glutinous corn production using rhizome plants as a source of organic pesticide. The treatments were as follows: T_0 – No pesticide applied; T_1 – Potable water alone; T_2 – Ginger crude extracts; T_3 – Turmeric crude extracts; T_4 – Galangal crude extracts; and T_5 – Shampoo ginger crude extracts. Results revealed that insect-pests and their damage on glutinous corn crop were significantly lessened by the application of rhizome crude extracts regardless of sources. This contributed to the significant stover yield and harvest index performance of treated plants with rhizome crude extracts thus obtained a profitable yield compared to those plants without any pesticide applied.

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Introduction

Corn is one of the most important cereal grains in the world (Arnarson, 2019). It is considered a versatile crop because it is not only consumed by humans and animals but also used as raw materials for industrial and agricultural purposes (Duong, 2020).

Glutinous corn is one of the types of corn. It is considered as one of the main sources of income of the farmers (Cabrido, 2018). However, glutinous corn is prone to common corn insect-pests. It might be the reason why glutinous corn decreased its production thus led the farmers to have a problem raising this crop (FAO 2019; Estes, 2016).

Insect-pest is one of the major biotic factors affecting the growth and yield of crops (Liliane and Charles, 2020). A severe incidence of pests can lead the crop to decrease its yield (Cerda *et al.*, 2017). The trending insect-pest in corn nowadays is the fall armyworm. This pest brought serious damage to the corn crop (Chemwita *et al.*, 2020). Other insect-pests such as corn seedling maggots, corn earworm, corn borer, etc. also contributed to the reduction of corn production (Kumar *et al.*, 2018). There are many recommended synthetic pesticides for corn (Bessin and Jhonson, 2017), however, it is expensive and there is a tendency to pollute the environment and may be dangerous to human health.

Proper crop protection is important to attain better yields while eliminating the negative effects on the environment and human health. Many articles revealed that there are a lot of organic pesticides as an alternative for synthetic pesticides, one of which is botanical crude extracts from plants that have pesticidal properties. Rhizome plants are discovered to be the best sources of botanical pesticides (Khan *et al.*, 2014; Hossain *et al.*, 2008). Pandi *et al.* 1993, studied the insecticidal constituents of rhizome plants. He found that there are compounds that have contact toxicity against larvae of the polyphagous insect-pest *Spodoptera littoralis*. Nine compounds including the most active sesquiterpenoids xanthorrhizol and furanodienone showed pronounced toxicity against neonate larvae of *S. littoralis* in a contact residue bioassay. It means to say that rhizome plants have strong pesticidal properties and has been proven that could control insect-pests (Chaubey *et al.*, 2011; Singh *et al.*, 2012; de Souza Tavares *et al.*, 2016). This can be proof that rhizome crude extracts can be used as an organic pesticide for crops.

The intractable increasing cost of synthetic pesticides is certainly intense in the coming production years. Looking into this viewpoint the farmers have to look for alternative actions to withstand their farming business profitability. President Gloria Macapagal Arroyo signed Executive Order 481 on the Promotion and Development of Organic Agriculture in the Philippines on December 27, 2005. Then, Former Agriculture Secretary Domingo F. Panganiban signed Administrative Order No. 9 series of 2006 or the Implementing Rules and Regulations (IRR) of EO 481 (Gov.Ph 2005).

The Department of Agriculture has come up with programs and projects in support of EO 481. Thus, the application of bio-organic inputs such as botanical pesticides on crops is highly encouraged in response to the program.

Since there are limited studies on rhizome crude extracts as an alternative organic pesticide, hence this study was conducted to (1) assess the effect of rhizome crude extracts against glutinous corn seedling maggots, corn earworm, corn borer, armyworm, and aphids; (2) evaluate the effect of rhizome crude extracts on the growth and yield of glutinous corn, and (3) determine the profitability of glutinous corn production using rhizome plants as a source of organic pesticide.

Materials and methods

Land Preparation

An area of 647.5m^2 was plowed and harrowed twice at the weekly interval to pulverize the soil. This was done to incorporate the weeds in the soil and provide good soil conditions for seed germination. Furrows were made at a distance of 0.75m between rows after the second harrowing.

Experimental Design and Treatments

The experimental area of 647.5m² was laid out in Randomized Complete Block Design (RCBD) with three replications. Each replication was divided into six (6) plots measuring 5m x 4.5m. There were 18 plots in the experiment. Each plot had six rows. Each row had 20 hills of glutinous corn. An alleyway of 1 m was provided between replications and between treatment plots including at the outside portions of the plots to facilitate farm operations and data gathering. The treatments were designated as follows:

T_0 – No pesticide applied

T_1 – Potable water alone

T_2 – Ginger extracts (*Zingiber officinale*)

T_3 – Turmeric extracts (*Curcuma longa*)

T_4 – Galangal extracts (*Alpinia galangal*)

T_5 – Shampoo ginger extracts (*Zingiber zerumbet*)

Fig. 1. Rhizome plants used in the study as treatments: (a) ginger; (b) turmeric; (c) galangal; and (d) shampoo ginger.

Rhizome Collection and Extracts Preparation

Rhizomes were bought from the nearest sources. These were washed to remove dirties and undesirable parts. These were extracted using an electric juicer. Each extracted juice from different rhizomes was put in a clean bottle.

Application of Treatments

The rhizome crude extracts were applied as foliar spray diluted at a ratio of 5 tablespoons to 1 liter of water and sprayed to plants at weekly intervals. This was done at 7, 14, 21, 28, 35, 42, and 49 days after planting (DAP). The dilution rate of rhizome crude extracts varies in each application schedule by increasing the amount as the plant grew. The older the plants, the higher is the dilution rate of the treatments. The actual amount of treatments is indicated in Table 1.

Table 1. Actual amount of diluted treatments (L plot^{-1}).

Days after planting (DAP)	7	14	21	28	35	42	49
L plot^{-1}	1	2	3	4	5	6	7

Application of Fertilizer

The organic fertilizer used in the experiment was fully decomposed chicken dung. It was applied uniformly in the furrows and were incorporated into the soil in each treatment plot two weeks before planting (WBP) at the rate of 10t ha^{-1}

Identification of Insect-pests

Before the actual experiment, an area of 500m² was planted with glutinous corn crop purposely to observe and identify what common insect-pests and their damage on glutinous corn. This was conducted until the boiling stage. Five (5) insect-pests were commonly observed attacking the crop. These are corn maggot, earworm, corn borer, armyworm, and aphids.

These insect-pests and their damage on glutinous corn crops were identified by the Entomologists.

Data Gathered

Insect-pests Incidence

Number of Corn Seedling Maggot Plot^{-1} – this was done by counting the number of corn seedling maggot 1 day before and 3 days after the first application of the treatments (6 and 10 DAP, respectively) within the harvestable area (13.5m²) in each plot.

To consider the missing hills, this was calculated using the formula:

Adjusted number of corn seedling maggot (plot^{-1}) =

$$\frac{\text{Number of corn seedling maggot}}{\text{Number of plants in the harvestable area}} \times 72 \text{ hills}$$

Number of Earworm, Corn borer, and Armyworm Plot^{-1} – this was done by counting the number of an earworm, corn borer, and armyworm within the harvestable area (13.5m^2) in each plot at 30, 40, 50, and 60 DAP and harvest. To consider the missing hills, this was calculated using the formula:

Adjusted number of specific insect-pests (plot^{-1}) =

$$\frac{\text{Number of insect-pests}}{\text{Number of plants in the harvestable area}} \times 72 \text{ hills}$$

Number of plants with the presence of aphids plot^{-1} – this was done by counting the plants with the presence of aphids within the harvestable area (13.5m^2) in each plot at 30, 40, 50, and 60 DAP and at harvest. To consider the missing hills, this was calculated using the formula:

Adjusted number of plants with aphids (plot^{-1}) =

$$\frac{\text{Number of plants with aphids}}{\text{Number of plants in the harvestable area}} \times 72 \text{ hills}$$

Percent damage of glutinous corn due to insect-pests

% damage of plants plot^{-1} (due to corn seedling maggot) – this was done by counting the plants damaged by corn seedling maggots within the harvestable area (13.5 m^2) 3 days after the first application of treatments (10 DAP). This was calculated using the formula:

% damaged by corn seedling maggot =

$$\frac{\text{No. of damaged plants}}{\text{No. of plants in the harvestable area}} \times 100$$

% damage of plants plot^{-1} (due to insect-pests) – this was done by counting the plants damaged by insect-pests within the harvestable area (13.5 m^2) 1 day before harvest. This was calculated using the formula:

% damaged by insect-pests =

$$\frac{\text{No. of damaged plants}}{\text{No. of plants in the harvestable area}} \times 100$$

Agronomic Characteristics

Number of days from planting to tasseling - this was determined by counting the number of days from planting to Vt stage or 50% of the population reached tasseling [begins when hanging pollen (male flower) visible at the top of corn plant]. Number of days from planting to silking - this was determined by counting the number of days from planting to R1 stage or 50% of the population reached silking or when the silks are visible at the tip of the husk.

Number of days from planting to boiling stage - this was recorded by counting the number of days from planting up to the time when 80% of the population reach the R3 (boiling stage). Ears are ready to be harvested when the kernels contain milky juice and the silks are brown and dry. However, the husk is still green and supple. To test, kernels can be pierced and bitten to observe the milky juice. Plant height (cm) - this was determined by measuring 10 sample plants in each treatment plot from ground level up to the tip of the tallest plant part using a meter stick. This was done 14, 28, 42, and 56 DAP.

Fresh stover yield (t ha^{-1}) - this was determined by weighing the fresh stalks including the husks of the sweetcorn ears within the harvestable area in each treatment plot after removing the ears using the formula.

Adjusted Stover Yield was calculated using the formula:

Adjusted Stover Yield (t ha $^{-1}$) =

$$\frac{\text{Weight of Stover Yield (t ha}^{-1}\text{)}}{\text{No. of hills harvested}} \times 72 \text{ hills}$$

Yield and Yield Components

Number of ears plant^{-1}- this was determined by counting the developed ears of ten (10) sample plants within the harvestable area of each treatment plot.

Ear length (cm) - this was determined by measuring the 10 sample dehusked ears in each treatment plot from the base to the tip of the ear with kernels using a ruler at harvest. Ear diameter (cm) - this was determined by measuring the diameter of 10 sample dehusked ears in each treatment plot using a vernier caliper.

Number of marketable ears plot^{-1} - this was obtained by counting the dehusked marketable ears within the harvestable area in each treatment plot. To consider the missing hills, this was calculated using the formula:

$$\text{No. of marketable ears (plot}^{-1}) = \frac{\text{No. of marketable ears}}{\text{No. of hills harvested}} \text{ X 72 hills}$$

Ears were considered marketable when the following criteria were met:

a. The dehusked ear should be 15cm and above in length.
b. The dehusked ear should be 5cm and above in diameter.
c. The dehusked ear should be 0.25kg and above in weight.
d. The kernels of the dehusked ear should be large and filled out the ear.
e. The dehusked ear should be free of damage by insect pests, diseases, etc.
f. The dehusked ear should bear complete kernels in each cob row, firm, and no soft spots and blemishes.

Number of non-marketable ears plot^{-1} - this was obtained by counting those dehusked ears within the harvestable area in each treatment plot not classified as marketable. To consider the missing hills, this was calculated using the formula:

$$\text{No. of non-marketable ears} = \frac{\text{No. of non-marketable ears}}{\text{No. of hills harvested}} \text{ X 72 hills}$$

Weight of marketable ears (t ha^{-1}) - this was obtained by weighing the dehusked marketable ears within the harvestable area in each treatment plot. Weight of marketable ears in kilogram ha^{-1} was computed using the formula:

$$\text{Wt. of marketable ears (t ha}^{-1}) = \frac{\text{Wt. (kg plot}^{-1})}{\text{Harvestable area (13.5 m}^2)}$$

Weight of non-marketable ears (t ha^{-1}) – this was the weight obtained from those ears not classified as marketable ears from each treatment plot at harvest. This was calculated using the same formula used in the calculation of the weight of marketable ears. Total ear yield (t ha^{-1}) – The weights of marketable and non-marketable ears (t ha^{-1}) were summed up to obtain the total yield.

Statistical Tool Used

Analysis of variance (ANOVA) was done using the Statistical Tool for Agricultural Research (STAR). Treatment means comparison was done using the Tukey's or Honestly Significant Difference (HSD) test.

Production Cost and Return Analysis

The production cost was determined by recording all the expenses incurred throughout the conduct of the study from land preparation up to harvesting. These include fertilizers, materials, and labor that were used in the conduct of the experiment. Total cost (material, labor, etc.) incurred was subtracted from the gross income to obtain the net income. The gross income was determined by multiplying the marketable ear yield of each treatment plot by the current market price of glutinous corn per kilogram. The gross income, net income, and return on investment were determined using the following formula:

Results and discussion

Insect-pests Incidence

Table 2 shows the effects of rhizome crude extracts on insect-pests incidence. Insect-pests on glutinous corn were affected by different rhizome crude extracts. Statistical analysis revealed that continuous application of rhizome crude extracts from 7 DAP up to 49 DAP at weekly intervals reduced the incidence of insect-pests on glutinous corn compared to those plants without any pesticides applied.

Incidence of corn seedling maggots had significantly decreased at a range of 79 – 85% (Table 2) in plants applied with rhizome extracts from 1 day before and 3 days after the first application of treatments (6 and 10 DAP, respectively). On the other hand, those plants without any pesticides applied, corn seedling maggots increased their population at a range of 25 – 30% (Table 2). Moreover, rhizome extracts significantly controlled the incidence of earworms, corn borers, armyworms and minimized the occurrence of aphids on glutinous corn from 30 DAP to harvest at a range of 43 – 46%, 33 – 38%, 36 – 46%, and 25 – 39%, respectively (Table 2). However, these insects rapidly multiplied in plants without pesticides applied at a range of 75 – 78%, 32 – 47%, 51 – 59%, and 19 – 21%, respectively (Table 2).

This result proves that rhizome plants can control and kill insects. Hikal *et al.* 2017 also reported that rhizome extracts reduced insect-pests population on crops. This also confirms the findings of Aryani and Auamcharoen, 2019 that rhizome extracts controlled corn grain weevils and other destructive larvae and insects. Thus, the use of rhizome extracts is recommended for controlling insect-pests occurrence to attain better yields (Rahman *et al.*, 2016).

Table 2. Effect of rhizome extracts on percent (%) change of corn seedling maggots from 6 DAP to 10 DAP and earworms, corn borer, armyworm incidence, and plants with aphids occurrence on glutinous corn from 30 DAP to harvest.

Insect-pest	Original No. of population (6 DAP)	New No. of Population (10 DAP)	Population Change (%)
Corn seedling maggots			
T_0	32.00	41.67	30.22b
T_1	33.67	42.00	24.74b
T_2	34.00	5.33	-84.32a
T_3	34.67	7.33	-78.86a
T_4	35.67	5.00	-85.98a
T_5	35.33	7.00	-80.19a
Earworm	(30 DAP)	(At harvest)	
T_0	24.33	43.33	78.09b
T_1	24.00	42.00	75.00b
T_2	12.33	7.00	-43.23a
T_3	12.33	7.00	-43.23a
T_4	12.33	6.67	-45.90a
T_5	24.33	5.67	-54.01a
Corn borer			
T_0	12.67	18.33	44.67b
T_1	13.67	18.00	31.68b
T_2	8.00	5.00	-37.50a
T_3	8.00	5.00	-37.50a
T_4	8.00	5.33	-33.38a
T_5	7.67	5.00	-34.81a
Armyworm			
T_0	23.67	37.67	59.15b
T_1	25.33	38.33	51.32b
T_2	15.00	9.67	-35.53a
T_3	14.33	9.00	-37.19a
T_4	15.33	9.00	-41.29a
T_5	14.33	7.67	-46.48a
Plants with aphids			
T_0	14.33	17.33	20.94b
T_1	13.67	16.33	19.46b
T_2	6.67	5.00	-25.04a
T_3	7.67	4.67	-39.11a
T_4	7.33	4.67	-36.29a
T_5	8.00	5.67	-29.13a

Percent (%) Damage of Plants and Ears Plot^{-1} by Insect-Pests

Fig. 2 shows the results of % damage of plants and ears due to the attack of insect pests. Statistical analysis revealed that there was less damage of seedlings, plants and ears applied with rhizome extracts compared to those plants without any pesticides applied at 10 DAP, a day before harvest and harvest, respectively. Insect-pests damage was 10-12% from seedlings to ears to those plants applied with rhizome crude extracts. This was significantly lower than those plants without pesticides applied (41-45% damage). This might be due to the less insect-pests incidence in all plants treated with rhizome extracts. Tembo *et al.* 2018 also reported that botanical pesticides lessened the incidence of pests thus minimized crop damage.

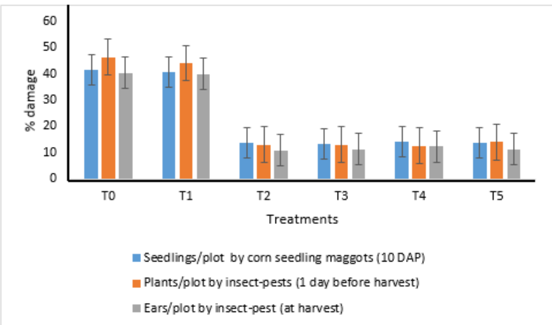
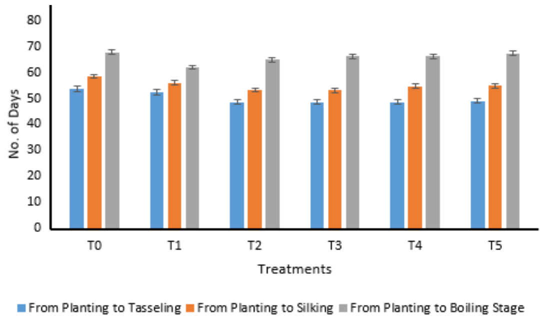


Fig. 2. Percent damage by insect-pests on glutinous corn as applied with different rhizome crude extracts.

Agronomic Characteristics and Harvest Index

Fig. 3 shows that the application of different rhizome crude extracts affected the growth (except plant height and maturity) and harvest index of the glutinous corn crop. All plants applied with rhizome crude extracts were significantly taller, reached maturity earlier except at the boiling stage. It may be due that untreated plants with rhizome extracts recovered under the boiling stage. It can be contributed by the favorable condition and the fertilizer applied. Moreover, plants applied with rhizome crude extracts had obtained stover yield and harvest index significantly higher than those plants without any pesticides applied. This might be due to the incidence of insect-pests on the plants (Table 2) that affects the plant weigh and harvest index development of glutinous corn crop. This result confirms the report of Donatelli *et al.* 2017 that insect-pests occurrence and damage affected the stover yield and harvest index of crops.

The lower the insect-pests incidence, the higher is the stover yield and harvest index.



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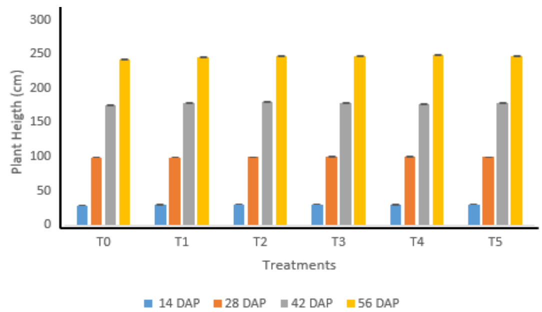

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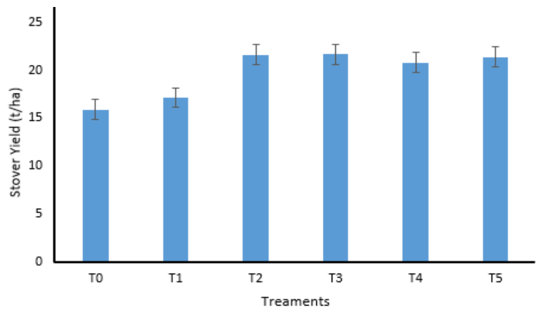

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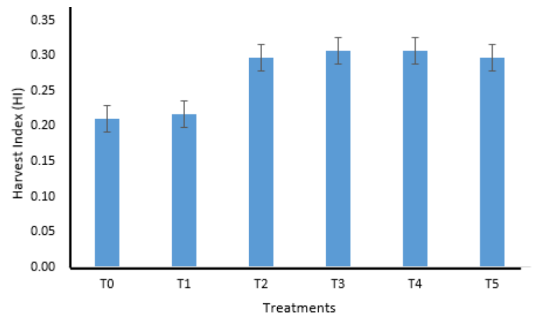
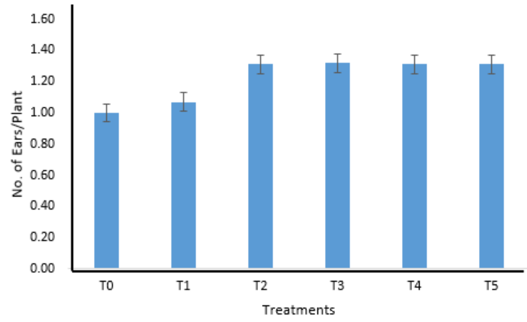


(d)

Fig. 3. Agronomic characteristics of glutinous corn: (a) number of days from planting to tasseling, silking, and boiling stage; (b) plant height (cm); (c) stover yield (t ha^{-1}); and (d) harvest index (IH) as applied with rhizome crude extracts.

Yield and Yield Components

Fig. 4 revealed that the ear yield of the glutinous corn crop was affected by the application of different rhizome crude extracts except for ear diameter (Fig. 4b) and the number of non-marketable ears (Fig. 4c). All treated plants with rhizome crude extracts had significantly produced more (Fig. 4a) and longer (Fig. 4b) ears. This contributed to the higher number of marketable ears (Fig.4c), thus attained a total ear yield (Fig. 4d) significantly higher than those plants without any pesticides applied. All of these might be due to the influence of insect-pests incidence (Table 2),% damage (Fig. 2), and the growth performance of glutinous corn (Fig. 3). Sulong *et al.* 2019 reported that pest incidence on maize can affect the yield. The higher the pest incidence, the lower is the yield of maize (Assefa, 2020).



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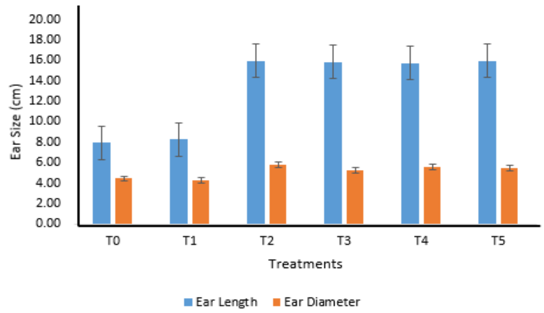

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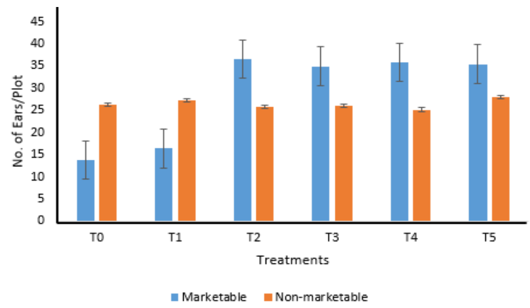

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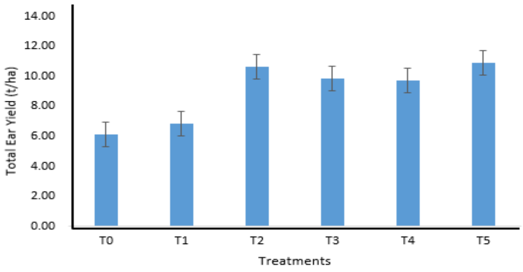

(d)

Fig. 4. Yield and yield components of glutinous corn: (a) number of ears plant^{-1}; (b) ear size (cm); (c) number of marketable and non-marketable ears plot^{-1}; and (d) total ear yield (t ha^{-1}) as applied with different rhizome crude extracts.

Production Cost and Return Analysis

All plants applied with rhizome crude extracts obtained higher gross income, net income, and return on investment (ROI) compared to plants without any pesticides applied (Table 3). Results showed that the higher marketable ear yield greatly contributed to the increase in gross income. The highest net income of PhP 49,213.00 ha^{-1} was obtained from plants applied with shampoo ginger (*Zingiber zerumbet*) extracts (T_5) followed by plants applied with galangal (*Alpinia galangal*) extracts (T_4) (PHP 47,874.00 ha^{-1}) and plants applied with turmeric (*Curcuma longa*) extracts (T_3) (PHP 47,624.00 ha^{-1}) due to their high marketable ear yield obtained and slightly lower production cost. Plants applied with ginger (*Zingiber officinale*) extracts also performed well, however it gained slightly lower than shampoo ginger, galangal, and turmeric. It is due to the higher amount of incurred gingers.

ROI is a profitability ratio that calculates the profits of an investment as a percentage of the original cost. For example, the plants applied with shampoo ginger (*Zingiber zerumbet*) extracts (T_5) got the highest ROI of 53.18%; it means that in every 1 peso invested, there is a gain of PHP 0.5318.

Glutinous corn plants applied with different rhizome crude extracts were profitable except T_0 and T_1. This might be due to the lesser incidence of insect-pests and better growth that contributed to the marketable ear yield of treated plants with rhizome crude extracts organic pesticide.

Table 3. Cost and return analysis of glutinous corn crop as applied with different rhizome crude extracts organic pesticide.

Treatment	Marketable Ear Yield (t ha^{-1})	Gross Income* (PHP ha^{-1})	Production Cost (PHP ha^{-1})	Net Income (PHP ha^{-1})	ROI (%)
T_0	2.15b	53,750.00	65, 785.00	-12,035.00	-18.29
T_1	2.85b	71,250.00	86,347.00	-15,097.00	-17.48
T_2	5.62a	140,500.00	93,485.00	47,015.00	50.29
T_3	5.04a	138,500.00	90,876.00	47,624.00	52.41
T_4	5.55a	138,750.00	90,876.00	47,874.00	52.68
T_5	5.67a	141,750.00	92,537.00	49,213.00	53.18

Gross income was computed based on the current wholesale/farm gate price of glutinous corn at PhP 25.00 kl^{-1} in the locality.

Conclusions

Based on the results, this can be concluded that the application of rhizome crude extracts as organic pesticide lessened the incidence of insect-pests and their damage on glutinous corn crop; enhanced the growth and yield and improved the profitability of glutinous corn crop. It has a positive and profitable impact on glutinous corn production. This can likewise be a basis of proof that rhizome crude extracts can address the problems on the cost and environmental adverse effects of synthetic pesticides face by farmers nowadays.

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