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Full Length Research Paper

Assessment of Insecticidal Activity of Some Botanical Powders and Clay against the Weevil [*Callosobruchus Maculatus* (Fab.) (Coleoptera: Chrysomelidae)] on Stored Mungbean (*Vigna Radiata* (L.)) Wilczek Seeds

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ABSTRACT: The insecticidal potential of powders obtained from *Piper guineense, Tephrosia vogelii, Xylopia aethiopica, and Carica papaya*, clay, and permethrin against cowpea beetle, *Callosobruchus maculatus* on mung bean seeds was tested in the laboratory. The tests were carried out in a laboratory environment (28+3^{0}C and 75+5%R.H.). Twenty (20) grams of mung bean seeds in plastic vials were exposed to ten (10) adult beetles (5 males and 5 females) and independently treated with varied concentrations (0, 1, 2, 3g) of the plant materials, clay, and permethrin. The treated seeds' adult mortality, oviposition, offspring emergence, seed weight loss, and viability were all evaluated. The findings revealed that mortality rose considerably (P<0.05) with greater dosages and longer exposure times. When compared to the control, oviposition and progeny emergence were significantly reduced by the botanicals. Permethrin powder outperformed the other treatments (P<0.001) in terms of insecticidal activity. When compared to the control, all of the test plant materials showed variable amounts of insecticidal activity. T. *vogelii* leaf powder had the highest seed protectant effect among the plant materials studied, with 3.0 g/ 20 g in all parameters evaluated, followed by *P. guineense* powder. The percentage of seed weight loss and seed damage reduced as treatment dosage was increased. When compared to untreated seeds, the viability and proximate composition of seeds treated with plant materials, clay, and permethrin were not changed. The existence of bioactive chemicals namely alkaloid, flavonoids, tannins, saponins, phenols, and phytates was detected by phytochemical investigations of the various plant materials. The insecticidal effects demonstrated in the study could be attributed to these phytochemical compounds. As a result of their efficacy, these test plant materials could be used as an alternative to synthetic insecticides in the control of *C. maculatus* of stored mung bean.

Keywords: *Callosobruchus maculatus*, weevils, mung bean, biopesticides, toxicity, insect mortality

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INTRODUCTION

Food legumes such as peas, beans, lentils, and groundnuts are members of the Leguminosae family (Fabaceae). They are produced primarily for their edible seeds and are also known as grain legumes. Mung bean (Vigna radiata) (Fabaceae),otherwise called green gram, is a tropical legume that originated around Thailand, India, and Pakistan before spreading to other areas of the world (Enyiukwu *et al*., 2021). Mung bean is mostly utilized for food, with the green pods used as vegetables and infrequently as forage. The crop is high in nutrients such as protein and fiber (Kudre *et al*., 2013). Mung bean has high levels of proteins, amino acids, oligosaccharides, and polyphenols, which are regarded to be the key contributors to the food's antioxidant, antibacterial, anti-inflammatory, and anti-tumor effects, as well as to have a role in the control of lipid metabolism (Kanatt *et al*., 2011; Anjum *et al*., 2011).

Mung bean contains a variety of enzymes and micronutrients. It can enhance cereal-based human diets since it is high in protein and amino acids, particularly lysine. It is low in saturated fat, salt, and cholesterol, making it an excellent choice for persons suffering from metabolic dysfunction or cardiac related challenges (Tang *et al*., 2014; Enyiukwu *et al.,* 2020; 2021). Bruchids (Coleoptera: Chrysomelidae), particularly those of the genus *Callosobruchus*, are pests of stored seeds of various legumes such as cowpea and mung bean. It is a serious insect pest that feeds on stored leguminous seeds. Infestations in stored grains continue to be a major issue. Various stages of insects, such as beetles and moths, cause economic damage and degrade the quality of food grains and their products (Akunne *et al*., 2014). Synthetic control approaches such as fumigation with carbon disulphide, phosphine etc. and dusting with pirimiphos methyl or permethrin have effectively suppressed the damaging activities of these insect pests (Akinkurolere *et al*., 2006).

However, the drawbacks posed with the use of synthetic insecticides and hazardous residues in stored grains are significant detriments to their use. Currently, studies are being conducted to investigate the usage of tropical plant components with therapeutic qualities as grain protectants (Ogunwolu *et al*., 1996; Akinkurolere *et al*., 2006). As a result, the insecticidal activities of certain plant materials and clay as grain protectants of mung bean in storage were tested in this study.

MATERIALS AND METHODS

Insect culture

The insects used to establish a laboratory colony of *C. maculatus* was obtained from a batch of infested cowpea purchased at Umuahia main market. The beetles were reared subsequently by replacement of devoured and infested seeds with fresh un-infested mung bean seeds in 3-litre plastic vials covered with muslin cloth to allow air circulation and held tightly with rubber band and maintained at an ambient temperature of 28$\pm$ 2ºC and relative humidity of 75$\pm$ 5 % for 30 days. Two day old adult beetles were obtained by sifting the stock culture a day before the experiment.

Collection of un-infested grains and plant materials

Clean un-infested mung bean varieties (SML 668 and NM 94) seeds were obtained from the Research and Training Unit of the College of Crop and Soil Sciences, Michael Okpara University of Agriculture, Umudike, Abia State. The plant materials of *Tephrosia vogelii* were sourced from a farm at Jos, Plateau State, *Piper guineense*, *Xylopia aethiopica* and *Carica papaya* were bought from Umuahia main market while Clay and Permethrin powders were bought from agrochemical shop at Umuahia (Table 1).

Table 1: Plant materials evaluated for insecticidal activity.

Scientific name	Common name	Family name	Parts used
Tephrosia vogelii	Fish bean poison	Fabaceae	Leaves
Tephrosia vogelii	Fish bean poison	Fabaceae	Stem
Piper guineense	Black pepper	Piperaceae	Fruits
Xylopia aethiopica	Guinea pepper	Annonaceae	Fruits
Carica papaya	Pawpaw	Caricaceae	Seeds
Piper guineense	Black pepper	Piperaceae	Fruits
Xylopia aethiopica	Guinea pepper	Annonaceae	Fruits
Carica papaya	Pawpaw	Caricaceae	Seeds

Preparation and application of plant materials

The plant materials were air-dried for two weeks in a well-ventilated place. The plant powders were prepared by grinding the materials using Thomas (Model ED-5) milling machine at National Root Crops Research institute, Umudike and sieved with a 0.25 µm size mesh sieve to obtain a fine uniform powder. The powders (1 kg each) were kept in air-tight jars prior to use (Okonkwo and Okoye, 1996). The dose 1.0 g, 2.0 g, and 3.0 g of each powder were measured into plastic vials containing 20 g of un-infested mung bean seeds and mixed by manual agitation of the vials. A control experiment containing no plant powder was also set up in a similar way. Each treatment was replicated three times in a Completely Randomized Design (CRD). Ten freshly emerged adults of *C. maculatus* (5 males and 5 females) were introduced into the vials and covered with muslin cloth held tightly by the perforated cover of the vial and rubber bands.

Adult mortality test

The mortality of adult beetles were recorded at 7, 14, 21 and 28 days after treatment. Insects prodded with a blunt dissecting probe were considered dead on failure to respond to three probing according to the method adopted by Udo *et al*. (2010) as:

$$\text{Percentage insect mortality} = \frac{x}{y} \text{x}100$$

Where:

x = number of dead insects
y = total number of insects examined.

Oviposition count and F_1 progeny emergence tests

The counts were taken at 7 days after treatment by pouring out seeds in each vial and counting the number of eggs laid on each seed with the aid of a magnifying lens. The newly emerged adult beetles were recorded daily by pouring out seeds from each vial and counting the number of adults that emerged daily. Each one counted is removed till 14 days after emergence.

Percentage weight loss

Percentage weight loss was calculated using the following the procedure and formula adopted by Fekadu *et al*. (2012) as:

$$\text{Percentage weight loss} = \frac{y}{z} \text{x}100$$

Where:

y = difference between initial weight and final weight of test seeds
z = initial weight of the seeds

Germination percentage

Ten healthy grains were visually selected from the experimentally treated grains from each plastic vials. The selected grains were soaked in distilled water for 3 hours. Thereafter, the seeds were placed in Petri dishes containing moistened filter paper (Whatman 1 filter paper). The Petri dishes were kept in the laboratory at room temperature. The number of germinated seeds from each Petri dish were counted and recorded from the 5th day to 10th day after soaking. The percentage germination was calculated as follows:

$$\text{Germination (\%)} = \frac{m}{n} \text{x}100$$

Where:

m = number of germinated seeds
n = total number of seeds examined

Proximate and phytochemical analysis of mung bean seeds

Standard methods based on the procedure adopted by A.O.A.C. (2000) and Kayode *et al.* (2008) were used in determination of the proximate (moisture content, ash, fat, carbohydrate, protein and crude fibre) composition of the specimens. Also the determination of phytochemical composition of the test plant materials was carried out based on the methods adopted by Enyiukwu and Awurum (2013).

Statistical analysis

Data obtained from the study were subjected to analysis of variance (ANOVA) in Genstat computer program version 12.0. Significant treatment means were separated and compared using Least Significant Difference (LSD) at 5 % level of probability.

RESULTS

The mean percentage mortality of *C. maculatus* exposed to the test plant materials, clay and permethrin on the mung bean seeds 7 days after infestation are shown in (Table 2). Permethrin caused the highest mortality of 65.59-66.14% followed by clay with 35.65-36.63%. All the plant materials exhibited varying degrees of insecticidal activities killing *C. maculatus* more than the control ($P<0.05$). Among the plant materials, *T. vogelii* leaves caused more mortality of 31.65 - 32.20 %. The least mortality was recorded by *C. papaya* seeds and *X. aethiopica* fruits with 26.32 – 27.98 % respectively.

Percentage mortality of adult *C. maculatus* exposed to plant materials 14 days after infestation is shown in (Table 3). Among the plant materials tested, *T. vogelii* leaves also caused the highest mortality 38.91–38.96% which was almost the same with *P. guineense* fruits. The least mortality was *C. papaya* with 31.95–32.00 %. At 1.0 g and 20 g *T. vogelii* stem and *P. guineense* fruits had the same effect of 33.21% on both varieties, while *X. aethiopica* and *C. papaya* were the same at 2.0 g and 3.0 g for the two varieties. The two varieties were almost at par in their performance on mortality effect against the test bruchid.

Mean percentage mortality of *C. maculatus* at 28 days after infestation is shown in (Table 4). Mortality effects progressed significantly above 70 % with *Tephrosia vogelii* leaves causing the highest mortality 57.61 - 59.32 % followed by *Piper guineense* fruits 55.32 - 58.59 % among the two varieties. *Carica papaya* seeds had the least mortality 47.47 – 48.45 %. Mortality was dosage dependent, the higher the dosage the higher the mortality

Table 2: Mean percentage mortality of adult *C. maculatus* reared and exposed to powders of selected plant materials, clay and permethrin at 7 days after treatment.

	Treatments, Mung bean Variety and Dosages (%) per 20 gram seeds Variety and Dosages (%) per 20 g mung bean seeds				
Treatment	**0.0**	**1.0**	**2.0**	**3.0**	**Mean**
A.			**Variety SML 668**		
T. vogelii leaf	13.33(21.14)	30.00(33.21)	33.33(35.22)	40.00(39.23)	29.17(32.20)
T. vogelii stem	13.33(21.14)	20.00(26.57)	30.00(33.21)	33.33(35.22)	24.17(29.03)
P. guineense	13.33(21.14)	23.33(28.78)	30.00(33.21)	36.67(37.22)	25.83(30.09)
X. aethiopica	13.33(21.14)	20.00(26.57)	23.33(28.78)	23.33(28.78)	20.00(26.32)
C. papaya	13.33(21.14)	20.00(26.57)	23.33(28.78)	23.33(28.78)	20.00(26.32)
Clay	13.33(21.14)	40.00(39.23)	43.33(41.15)	50.00(45.00)	36.67(36.63)
Permethrin	13.33(21.14)	80.00(63.43)	100.00(90.00)	100.00(90.00)	73.33(66.14)
Mean	13.33(21.14)	33.33(34.91)	40.48(41.48)	43.81(43.46)	
B.			**Variety NM-94**		
T. vogelii leaf	13.33(21.14)	26.67(31.00)	33.33(35.22)	40.00(39.23)	28.33(31.65)
T. vogelii stem	13.33(21.14)	23.33(28.78)	30.00(33.21)	33.33(35.22)	25.00(29.59)
P. guineense	13.33(21.14)	23.33(28.78)	33.33(35.22)	36.67(37.22)	26.67(30.59)
X. aethiopica	13.33(21.14)	20.00(26.57)	23.33(28.78)	30.00(33.21)	21.67(27.43)
C. papaya	13.33(21.14)	23.33(28.78)	23.33(28.78)	30.00(33.21)	22.50(27.98)
Clay	13.33(21.14)	36.67(37.22)	40.00(39.23)	50.00(45.00)	35.00(35.65)
Permethrin	13.33(21.14)	76.67(61.22)	100.00(90.00)	100.00(90.00)	72.50(65.59)
Mean	13.33(21.14)	32.86(34.62)	40.48(41.49)	45.71(44.73)	

*Figures in parenthesis are arcsine transformed values; TVL = T. vogelii leaf, TVS = T. vogelii stem, PG = P. guineense, XA = X. aethiopica, CL = Clay, PM = Permethrin

LSD (0.05) Plant materials Var. SML 668	3.57;	LSD (0.05) Plant materials Var. NM-94	3.89
LSD (0.05) Dosage (Concentrations) Var. SML 668	2.70;	LSD (0.05) Dosage (Concentrations) Var. NM-94	2.94
LSD (0.05) Plant materials x Concentration Var. SML 668	7.14;	LSD (0.05) Plant materials x Concentration Var. NM-94	7.78

Table 3. Mean percentage mortality of adult *C. maculatus* reared and exposed to powders of some plant materials, clay and permethrin at 14 days after treatment.

	Treatments, Mung bean Variety and Dosages (%) per 20 gram seeds Variety and Dosages (%) per 20 g mung bean seeds				
Treatment	**0.0**	**1.0**	**2.0**	**3.0**	**Mean**
A.		**Variety SML 668**			
T. vogelii leaf	20.00(26.57)	33.33(35.22)	50.00(45.00)	56.67(48.85)	40.00(38.91)
T. vogelii stem	23.33(28.78)	30.00(33.21)	40.00(39.23)	53.33(46.92)	35.83(36.56)
P. guineense	20.00(26.57)	30.00(33.21)	50.00(45.00)	53.33(46.92)	38.33(37.92)
X. aethiopica	20.00(26.57)	26.67(31.00)	30.00(33.21)	40.00(39.23)	29.17(32.50)
C. papaya	20.00(26.57)	26.67(31.00)	30.00(33.21)	36.67(37.22)	28.33(32.00)
Clay	23.33(28.78)	46.67(43.08)	50.00(45.00)	60.00(50.77)	45.00(41.91)
Permethrin	23.33(28.78)	100.00(90.00)	100.00(90.00)	100.00(90.00)	80.83(74.70)
Mean	21.43(27.52)	41.91(42.39)	50.00(47.24)	56.67(51.14)	
B.		**Variety NM-94**			
T. vogelii leaf	23.33(28.78)	30.00(33.21)	50.00(45.00)	56.67(48.85)	40.00(38.96)
T. vogelii stem	20.00(26.57)	30.00(33.21)	43.33(41.15)	50.00(45.00)	35.83(36.48)
P. guineense	20.00(26.57)	30.00(33.21)	50. 00(45.00)	60.00(50.77)	40.00(38.89)
X. aethiopica	20.00(26.57)	26.67(31.00)	30.00(33.21)	40.00(39.23)	29.17(32.50)
C. papaya	20.00(26.57)	23.33(28.78)	30.00(33.21)	40.00(39.23)	28.33(31.95)
Clay	26.67(31.00)	43.33(41.15)	46.67(43.08)	60.00(50.77)	44.17(41.50)
Permethrin	23.33(28.78)	100.00(90.00)	100.00(90.00)	100.00(90.00)	80.83(74.70)
Mean	21.90(27.83)	40.48(41.51)	50.00(47.24)	58.10(51.98)	

*Figures in parenthesis are arcsine transformed values

LSD (0.05) Plant materials Var. SML 668	2.82;	LSD (0.05) Plant materials Var. NM-94	2.68
LSD (0.05) Dosage (Concentrations) Var. SML 668	2.13;	LSD (0.05) Dosage (Concentrations) Var. NM-94	2.02
LSD (0.05) Plant materials x Concentration Var. SML 668	5.68;	LSD (0.05) Plant materials x Concentration Var. NM-94	3.53

effect. Permethrin and clay mustered significantly ($P<0.05$) higher insecticidal effect than the plant materials. The effect of treating mung bean seeds with plant materials on oviposition is shown in (Table 5). There was reduction in oviposition in all the treated samples compared with the control. *T. vogelii* leaves recording 48.62 – 49.05 % exhibited the best protection action, and this was statistically ($P>0.05$) the same with

Table 4. Mean percentage mortality of adult *C. maculatus* reared and exposed to powders of some plant materials, clay and permethrin at 28 days after treatment.

	Treatments, Mung bean Variety and Dosages (%) per 20 gram seeds				
	Variety and Dosages (%) per 20 g mung bean seeds				
Treatment	**0.0**	**1.0**	**2.0**	**3.0**	**Mean**
A.		**Variety SML 668**			
T. vogelii leaf	40.00(39.23)	60.00(50.77)	80.00(63.43)	96.67(83.86)	69.17(59.32)
T. vogelii stem	40.00(39.23)	60.00(50.77)	66.67(54.78)	86.67(72.29)	63.33(54.27)
P. guineense	40.00(39.23)	63.33(52.78)	76.67(61.22)	93.33(81.14)	68.33(58.59)
X. aethiopica	40.00(39.23)	50.00(45.00)	60.00(50.77)	66.67(54.78)	54.17(47.47)
C. papaya	40.00(39.23)	50.00(45.00)	56.67(48.85)	70.00(56.79)	54.17(47.47)
Clay	40.00(39.23)	80.00(63.43)	83.33(66.14)	100.00(90.00)	75.83(64.70)
Permethrin	40.00(39.23)	100.00(90.00)	100.00(90.00)	100.00(90.00)	85.00(77.31)
Mean	40.00(39.23)	59.76(52.24)	74.76(62.17)	87.62(75.55)	
B.		**Variety**	**NM- 94**		
T. vogelii leaf	40.00(39.23)	56.67(48.85)	76.67(61.22)	93.33(81.14)	66.67(57.61)
T. vogelii stem	40.00(39.23)	56.67(48.85)	70.00(56.79)	83.33(66.14)	62.50(52.75)
P. guineense	40.00(39.23)	60.00(50.77)	73.33(59.00)	86.67(72.29)	65.00(55.32)
X. aethiopica	40.00(39.23)	50.00(45.00)	60.00(50.77)	70.00(56.79)	55.00(47.95)
C. papaya	40.00(39.23)	50.00(45.00)	63.33(52.78)	70.00(56.79)	55.83(48.45)
Clay	40.00(39.23)	73.33(59.00)	80.00(63.43)	100.00(90.00)	73.33(62.92)
Permethrin	40.00(39.23)	100.00(90.00)	100.00(90.00)	100.00(90.00)	85.00(77.31)
Mean	40.00(39.23)	63.81(55.35)	74.76(62.00)	86.19(73.31)	

Figures in parenthesis are arcsine transformed values

LSD (0.05) Plant materials Var. SML 668	3.34;	LSD (0.05) Plant materials Var. NM-94	3.46
LSD (0.05) Dosage (Concentrations) Var. SML 668	2.25;	LSD (0.05) Dosage (Concentrations) Var. NM-94	2.61
LSD (0.05) Plant materials x Concentration Var. SML 668	6.68;	LSD (0.05) Plant materials x Concentration Var. NM-94	6.91

Table 5. Oviposition deterrence of *C. maculatus* on mung bean seeds treated with selected plant materials, clay and permethrin.

	Treatments, Mung bean Variety and Dosages (%) per 20 gram seeds				
	Variety and Dosages (%) per 20 g mung bean seeds				
Treatment	**0.0**	**1.0**	**2.0**	**3.0**	**Mean**
A.		**Variety SML 668**			
T. vogelii leaf	90.00(75.00)	58.67(50.03)	41.67(40.17)	26.67(30.99)	54.25(49.05)
T. vogelii stem	90.00(71.62)	68.67(56.05)	57.33(49.23)	36.67(37.25)	63.17(53.59)
P. guineense	90.00(75.00)	59.00(50.19)	45.00(42.12)	28.33(32.02)	55.58(49.83)
X. aethiopica	90.00(71.95)	69.00(56.17)	56.67(48.84)	38.00(38.05)	63.42(53.75)
C. papaya	90.00(74.88)	69.33(56.49)	58.33(49.81)	40.33(39.42)	64.50(55.15)
Clay	90.00(71.95)	47.00(43.27)	37.33(37.63)	18.67(25.59)	48.25(44.61)
Permethrin	90.00(71.95)	32.67(34.80)	10.00(18.38)	8.67(17.10)	35.33(35.56)
Mean	90.00(73.19)	57.76(49.57)	43.76(40.88)	28.19(31.49)	
B.		**Variety NM- 94**			
T. vogelii leaf	90.00(71.62)	58.67(50.01)	44.00(41.55)	27.00(31.30)	54.92(48.62)
T. vogelii stem	90.00(71.62)	69.00(56.19)	53.33(46.92)	44.00(41.55)	64.08(54.07)
P. guineense	90.00(71.61)	60.33(50.98)	47.33(43.47)	30.00(33.16)	56.92(49.80)
X. aethiopica	90.00(71.57)	70.00(56.81)	55.00(47.88)	45.00(42.13)	65.00(54.60)
C. papaya	90.00(71.61)	68.00(55.56)	58.33(49.80)	44.33(41.74)	65.17(54.68)
Clay	90.00(71.58)	49.33(44.62)	37.33(37.65)	20.00(26.49)	49.17(45.09)
Permethrin	90.00(71.62)	32.67(34.80)	13.33(21.27)	8.67(17.10)	36.17(36.20)
Mean	90.00(71.60)	58.29(49.85)	44.10(41.22)	31.29(33.35)	

*Figures in parenthesis are arcsine transformed values

LSD (0.05) Plant materials Var. SML 668	4.71;	LSD (0.05) Plant materials Var. NM-94	2.72
LSD (0.05) Dosage (Concentrations) Var. SML 668	3.56;	LSD (0.05) Dosage (Concentrations) Var. NM-94	2.09
LSD (0.05) Plant materials x Concentration Var. SML 668	9.42;	LSD (0.05) Plant materials x Concentration Var. NM-94	5.53

P. guineense fruits. Powder of *C. papaya* had the least protectant action with the highest mean oviposition count of 54.68 – 55.15 %. In the two varieties tested, all the treatments were significantly different ($P < 0.05$) from the control.

Table 6 shows the adult emergence count of *C.*

Table 6. Percentage adult emergence of *C. maculatus* on mung bean seeds treated with selected plant materials, clay and permethrin.

Treatment	Treatments, Mung bean Variety and Dosages (%) per 20 gram seeds Variety and Dosages (%) per 20 g mung bean seeds 0.0	1.0	2.0	3.0	Mean
A.		**Variety SML 668**			
T. vogelii leaf	81.00(64.23)	38.33(38.24)	21.00(27.22)	10.00(18.38)	37.58(37.02)
T. vogelii stem	80.67(64.04)	40.00(39.23)	27.00(31.29)	21.00(27.22)	42.17(40.45)
P. guineense	80.67(64.35)	38.00(38.05)	21.33(27.44)	11.67(19.89)	37.92(37.43)
X. aethiopica	81.67(64.77)	41.00(39.81)	27.33(31.50)	24.67(29.75)	43.67(41.46)
C. papaya	81.33(64.74)	39.67(38.96)	27.67(31.72)	23.33(28.81)	43.00(41.06)
Clay	81.00(64.23)	11.00(19.22	0.00(0.71)	0.00(0.71)	23.00(21.22)
Permethrin	81.00(64.23)	7.33(15.68)	0.00(0.71)	0.00(0.71)	22.08(20.33)
Mean	81.05(64.37)	30.76(32.74)	17.76(21.51)	12.95(17.92)	
B.		**Variety NM- 94**			
T. vogelii leaf	81.00(64.58)	40.00(39.23)	21.00(27.26)	11.33(19.66)	38.33(37.68)
T. vogelii stem	81.00(64.23)	40.33(39.43)	26.00(30.65)	21.33(27.50)	42.17(40.45)
P. guineense	81.00(64.19)	40.00(39.23)	21.00(27.24)	12.00(20.27)	38.50(37.73)
X. aethiopica	81.00(64.27)	41.67(40.20)	26.00(30.65)	21.33(27.49)	42.50(40.65)
C. papaya	81.00(64.19)	40.67(39.57)	26.33(30.87)	21.67(27.73)	42.42(40.59)
Clay	81.00(54.58)	13.33(21.40)	0.00(0.71)	0.00(0.71)	23.58(21.85)
Permethrin	81.00(64.27)	8.00(16.43)	0.00(0.71)	0.00(0.71)	22.25(20.53)
Mean	81.00(64.33)	32.00(33.64)	17.19(21.16)	12.52(17.72)	

*Figures in parenthesis are arcsine transformed values

LSD (0.05) Plant materials Var. SML 668 3.32; LSD (0.05) Plant materials Var. NM-94 2.94
LSD (0.05) Dosage (Concentrations) Var. SML 668 2.51; LSD (0.05) Dosage (Concentrations) Var. NM-94 2.22
LSD (0.05) Plant materials x Concentration Var. SML 668 6.64; LSD (0.05) Plant materials x Concentration Var. NM-94 5.88

Table 7. Percentage germination count of mung bean seeds treated with plant powders of selected plant materials, clay and permethrin.

Treatment	Treatments, Mung bean Variety and Dosages (%) per 20 gram seeds Variety and Dosages (%) per 20 g mung bean seeds 0.0	1.0	2.0	3.0	Mean
A.		**Variety SML 668**			
T. vogelii leaf	0.00(0.71)	46.70(43.08)	73.30(59.00)	90.00(71.57)	52.50(43.59)
T. vogelii stem	0.00(0.71)	43.30(41.15)	63.30(52.78)	86.70(68.86)	48.30(40.88)
P. guineense	0.00(0.71)	46.70(43.08)	70.00(56.79)	90.00(71.57)	51.70(43.04)
X. aethiopica	0.00(0.71)	40.00(39.23)	50.00(45.00)	80.00(63.43)	42.50(37.09)
C. papaya	0.00(0.71)	40.00(39.23)	50.00(45.00)	80.00(63.43)	42.50(37.09)
Clay	0.00(0.71)	50.00(45.00)	76.70(61.22)	93.33(83.86)	55.01(47.70)
Permethrin	0.00(0.71)	60.00(50.77)	90.00(75.00)	100.00(90.00)	62.50(54.12)
Mean	0.00(0.71)	46.70(43.08)	67.60(56.40)	84.30(68.96)	
B.		**Variety NM- 94**			
T. vogelii leaf	0.00(0.71)	50.00(45.00)	70.00(56.79)	90.00(75.00)	52.50(44.38)
T. vogelii stem	0.00(0.71)	43.33(41.15)	63.33(52.78)	83.33(66.14)	47.50(40.20)
P. guineense	0.00(0.71)	50.00(45.00)	70.00(56.79)	90.00(75.00)	52.50(44.38)
X. aethiopica	0.00(0.71)	43.33(41.15)	50.00(45.00)	76.67(61.22)	42.50(37.02)
C. papaya	0.00(0.71)	43.33(41.15)	53.33(46.92)	80.00(64.25)	44.17(38.26)
Clay	0.00(0.71)	50.00(45.00)	76.67(61.22)	93.33(77.71)	55.00(46.16)
Permethrin	0.00(0.71)	56.67(48.76)	90.00(75.00)	100.00(90.00)	61.67(53.62)
Mean	0.00(0.71)	48.09(43.89)	67.62(56.36)	87.78(72.76)	

*Figures in parenthesis are arcsine transformed values

LSD (0.05) Plant materials Var. SML 668 7.68; LSD (0.05) Plant materials Var. NM-94 3.80
LSD (0.05) Dosage (Concentrations) Var. SML 668 5.80; LSD (0.05) Dosage (Concentrations) Var. NM-94 2.67
LSD (0.05) Plant materials x Concentration Var. SML 668 15.35; LSD (0.05) Plant materials x Concentration Var. NM-94 7.60

maculatus from mung bean seeds treated with the plant materials. Adult bruchid emergence was significantly suppressed by all the plant materials (P<0.05) when compared with the control. Permethrin had the highest suppression effect followed by clay (Table 6). In terms of inhibition effects of the plant materials on the two varieties *T. vogelii* leaves had the highest suppression effect with mean count of 37.02 – 37.68 which was statistically the same with *P. guineense* fruits with 37.43 – 37.73%, but was different from *X. aethiopica* and *C. papaya*.

The results of the mean percentage germination of mung bean seeds treated with the botanical powders are presented in (Table 7). There was no significant difference among the plant materials and clay on the two test varieties. The dosage of 1.0 g/ 20 g mung bean

Table 8. Percentage seed weight loss values of mung bean seeds treated with plant material powders, clay and permethrin.

Treatment	Treatments, Mung bean Variety and Dosages (%) per 20 gram seeds Variety and Dosages (%) per 20 g mung bean seeds 0.0	1.0	2.0	3.0	Mean
A.		**Variety SML 668**			
T. vogelii leaf	42.83(40.88)	32.95(35.03)	24.92(29.94)	18.53(25.49)	29.81(32.83)
T. vogelii stem	42.83(40.88)	35.13(36.34)	27.35(31.53)	22.70(28.45)	32.00(34.30)
P. guineense	42.83(40.88)	33.17(35.16)	25.65(30.41)	19.30(26.06)	30.24(33.13)
X. aethiopica	42.83(40.88)	36.40(37.11)	27.65(31.72)	22.87(28.57)	32.44(34.57)
C. papaya	42.83(40.88)	36.73(37.31)	26.83(31.20)	22.73(28.48)	32.28(34.46)
Clay	42.83(40.88)	16.92(24.26)	0.00(0.71)	0.00(0.71)	14.94(16.64)
Permethrin	42.83(40.88)	8.63(17.04)	0.00(0.71)	0.00(0.71)	12.87(14.84)
Mean	42.83(40.88)	28.56(31.75)	18.91(22.31)	15.16(19.78)	
B.		**Variety NM 94**			
T. vogelii leaf	43.88(41.49)	32.88(34.99)	24.95(29.96)	19.13(25.94)	30.21(33.09)
T. vogelii stem	43.88(41.49)	34.4735.94)	25.63(30.40)	22.83(28.54)	31.70(34.09)
P. guineense	43.88(41.49)	33.07(35.10)	25.87(30.56)	19.52(26.22)	30.58(33.34)
X. aethiopica	43.88(41.49)	36.47(37.15)	27.73(31.78)	22.90(28.51)	32.75(34.75)
C. papaya	43.88(41.49)	36.87(37.39)	26.83(31.20)	22.78(28.51)	32.59(34.65)
Clay	43.75(41.41)	17.03(24.36)	0.00(0.71)	0.00(0.71)	15.20(16.80)
Permethrin	43.88(41.49)	7.00(15.28)	0.00(0.71)	0.00(0.71)	12.72(14.55)
Mean	43.86(41.48	28.25(31.46)	18.72(22.19)	15.31(19.89)	

*Figures in parenthesis are transformed values

LSD (0.05) Plant materials Var. SML 668 1.09; LSD (0.05) Plant materials Var. NM-94 0.83
LSD (0.05) Dosage (Concentrations) Var. SML 668 0.82; LSD (0.05) Dosage (Concentrations) Var. NM-94 0.63
LSD (0.05) Plant materials x Concentration Var. SML 668 2.17; LSD (0.05) Plant materials x Concentration Var. NM-94 1.66

Table 9. Percentage damage of mung bean seeds by *C. maculatus* treated with Plant material powders, Clay and Permethrin.

Treatment	Treatments, Mung bean Variety and Dosages (%) per 20 gram seeds Variety and Dosages (%) per 20 g mung bean seeds 0.0	1.0	2.0	3.0	Mean
A.		**Variety SML 668**			
T. vogelii leaf	75.00(60.07)	25.33(30.22)	12.67(20.84)	7.33(15.68)	30.08(31.70)
T. vogelii stem	75.00(60.02)	30.33(33.38)	21.33(27.47)	14.00(21.94)	35.17(35.70)
P. guineense	75.00(60.07)	26.00(30.65)	16.67(23.98)	8.00(16.35)	31.42(32.76)
X. aethiopica	75.00(60.07)	32.33(34.64)	25.33(30.19)	17.33(24.60)	37.50(37.38)
C. papaya	75.00(60.04)	32.00(34.44)	22.67(28.40)	15.33(22.98)	36.25(36.47)
Clay	75.00(60.05)	12.67(20.84)	0.00(0.71)	0.00(0.71)	21.92(20.58)
Permethrin	75.00(60.07)	6.00(14.18)	0.00(0.71)	0.00(0.71)	20.25(18.92)
Mean	75.00(60.06)	23.52(28.33)	14.10(18.90)	8.86(14.71)	
B.		**Variety NM 94**			
T. vogelii leaf	75.00(60.00)	25.67(30.43)	14.33(22.24)	10.00(18.38)	31.25(32.76)
T. vogelii stem	75.00(60.02)	31.33(34.01)	22.00(27.96)	15.00(22.77)	35.83(36.19)
P. guineense	75.00(60.04)	26.67(31.09)	16.67(24.04)	10.00(18.38)	32.08(33.39)
X. aethiopica	75.00(60.07)	32.67(34.82)	26.00(30.65)	18.00(25.10)	37.92(37.66)
C. papaya	75.00(60.07)	32.67(34.86)	24.00(29.32)	16.00(23.55)	36.92(36.95)
Clay	75.00(60.03)	13.67(21.68)	0.00(0.71)	0.00(0.71)	22.17(20.78)
Permethrin	75.00(60.02)	12.67(20.76)	0.00(0.71)	0.00(0.71)	21.92(20.55)
Mean	75.00(0.71)	25.05(29.66)	14.71(19.38)	9.86(15.66)	

*Figures in parenthesis are arcsine transformed values

LSD (0.05) Plant materials Var. SML 668 2.41; LSD (0.05) Plant materials Var. NM-94 2.10
LSD (0.05) Dosage (Concentrations) Var. SML 668 1.82; LSD (0.05) Dosage (Concentrations) Var. NM-94 1.59
LSD (0.05) Plant materials x Concentration Var. SML 668 4.82; LSD (0.05) Plant materials x Concentration Var. NM-94 4.19

seeds had the least percentage germination with 43.08 – 43.89 % which differed from others. The two varieties did not differ in the percentage germination counts. The results was dosage dependent, the higher the concentration of the test botanical powders, the higher the observed seed germination percentage. Permethrin had the highest germination count.

The seed weght loss of mung bean seeds treated with plant powders due to attack by *C. maculatus* is shown in (Table 8). All the plant material powders significantly reduced loss in seed weight (P<0.05). Powder of *X. aethiopica* gave the least protection to the stored mung bean with 34.57 % - 34.75%, whereas *T. vogelii* leaf had the best protection to the mung bean with 32.83 % - 33.09 % seed weight (P<0.05). The synthetic insecticide and clay were significantly different from all the plant material powders (P<0.05). Dosages of the plant material had significant effects on the reduction of loss of weight by mung bean seeds. Higher dosage reduced loss of weight significantly.

Table 9 shows the results of the percentage damage by *C. maculatus* on mung bean seeds treated with plant material powders, clay and permethrin. Among the plant materials, seeds treated with *T. vogelii* leaf powder had the least damage with 31.70 % - 32.76 % which did not differ from *P.guineense* with 32.76 % - 33.39 % but were significantly different from other plant material powders (P<0.05). Powder of *X. aethiopica* had the highest percent damage with 37.38 % - 37.66 % which did not differ from *C. papaya* with 36.47 % - 36.95 %. The higher the dosage, the less percentage damage by *C. maculatus*. Application rate of 3.0 g/20 g had the least percentage damage of mung bean seeds which was significantly different from 2.0 g and 1.0 g/20 g with 18.90% - 19.38% and 28.33% - 29.66% respectively.

Results of quantitative analysis of the phytochemical composition of the plant materials are shown in (Table 10). The phytochemical analysis of the plant materials reveals that *X. aethiopica* were highest in alkaloid, flavonoid and saponin which was significantly different (P<0.05) from other plant powders.

DISCUSSION

Results from this study shows that the treatments demonstrated insecticidal activity against *C. maculatus* and can be used for the control of the bruchids on mung bean in storage. Mortality started manifesting at 7 days after treatment and progressed to 28 days after treatment. The synthetic powder significantly (P<0.05) reduced mortality of the insects than both clay and the plant materials. At 28 days after treatment, mortality significantly (P<0.05) manifested above 70 % mortality among the treatments. *Tephrosia vogelii* leaves recorded the highest mortality among the plant materials, which could be attributed to rotenoids and fatty compounds in the leaves. This assertion agrees with Belmain *et al.* (2012) who stated that the biological activity of *T. vogelii* could be due to the presence of rotenoids in the leaves. The high mortality noted from P. guineense fruit treatment may be due to its content of piperine type of amine alkaloids. The levels of mortality from the study were in consonance with the results obtained by Emeasor *et al.* (2005) and Ekeh *et al*. (2013). The superior performance of permethrin over clay and the plant materials may be due to its strong residual activity as compared to the plant material derived insecticides which are easily degraded by light, heat and environmental microbes (Enyiukwu *et al*., 2016). However, the greater level of performance recorded from clay could be due to its fine particle size reported to have blocked insect spiracles and induced asphyxiation Nwaubani (2006). Comparative to plant materials, higher performance effects recorded from *T. vogelii* and *P. guineense* extracts over *C. papaya* and *X. aethiopica* extracts may be due to higher amount of rotenoids, piperine and fatty acids in them.

The performance effect in all the treatments significantly (P<0.05) deterred oviposition of adult *C. maculatus*. This agrees with Ashamo *et al.* (2013) and Mowang (2011) who stated that plant extracts significantly (P<0.05) reduced oviposition of *C. maculatus* compared with the control. The oviposition deterrence of the plant material powders may have been due to their high content of alkaloids, flavonoids, saponins, tannin, fatty acids, and this reduction increases as dosage increases. Among the two varieties, SML-668 had more attack than NM-94 this may be attributed to seed size and seed structure. Studies have shown that more eggs are laid on seeds that are large, whole, smooth and pristine. According to researchers, ovipositional preference has been attributed to seed coat morphology and seed size (Messina and Renwick, 1983). Results of phytochemical analysis of the test botanicals in this study are similar to those of several other researchers who found that leaves and fruits of *P. guineense* and *X. aethiopica* are rich in high concentrations of alkaloids, phenolics and monoterpenes along with some sesquiterpene hydrocarbons (Enyiukwu and Awurum, 2013; Tetang *et al*., 2018; Arvid *et al*., 2020). Asawalam and Emosairue, (2006) in their study affirmed that the potent insecticidal activity of essential oils derived from *X. aethiopica* was attributed to its high terpenoid contents which consist of a mixture of monoterpenes and sesquiterpenes. The effect of treatments on adult emergence indicated that all the treatments effectively suppressed progeny emergence of beetles. The suppression effects of the treatments were dosage dependent. This could be as a result of the presence of phytochemical compounds such as alkaloids, flavonoids, saponins, tannins and phenols, and fatty acids in the plant materials tested. These secondary metabolites have been reported as plant arsenals of attack on insects (Ogunwolu *et al*., 1996; Eloy *et al*., 2015). The percentage germination of mung bean seeds post treatment, were not affected negatively by the plant materials. The viability of the seeds tested with plant extracts, clay and permethrin were not adversely affected compared with the untreated seeds. The biological activities of the chemical compounds isolated from the

Table 10: Phytochemical composition of the plant materials used in the study.

	Composition (%) of					
Plant Materials	**Alkaloids**	**Tannin**	**Flavonoids**	**Saponin**	**Phenol**	**Phyth**
T. vogelii leaf	6.45	0.51	3.93	2.58	0.45	0.29
T. vogelii stem	3.81	1.04	0.74	4.77	1.81	0.49
P.guineense seed	2.87	0.58	9.71	2.58	0.36	0.59
X. aethiopica seed	8.61	0.22	11.13	5.41	0.68	0.80
C. papaya seed	2.77	0.21	1.12	3.51	1.57	0.69
Mean	4.92	0.52	5.33	3.77	0.97	0.57
LSD (0.05)	1.26	0.13	1.59	0.88	0.26	0.14

*Phyt = phythate

plant materials indicated that the plant materials had various compounds of insecticidal values. Plant derived volatile compounds exhibit a wide range of biological activities such as insecticidal, attractant, pheromone and anti-enzyme actions. The presence of alkaloids, flavonoids, tannins, saponins, polyphenols, terpenoids, glucosides, benzene isothiocynate and fatty acids etc. detected have earlier been reported (Pradhan *et al.*, 2012; Nwaoguikpe *et al*., 2014). These bioactive phytochemicals have been reported to demonstrate effective antimicrobial and insecticidal properties against a range of insects (Wang *et al*., 2004; Asawalam and Emosairue, 2006; Enyiukwu and Awurum, 2013), which may be the reason why the test plant materials induced mortality of *C. maculatus* and reduced their oviposition in this study.

Conclusion

The results of this evaluation demonstrated the insecticidal potentials of plant materials and clay in preserving stored mung bean seeds from decimation by *C. maculatus* without compromising the viability of the test. In this investigation, all of the plant powders demonstrated dosage-dependent insecticidal properties comparable to Permethrin. In terms of weight loss, damage and germination percentages by the insect, no significant mean difference between the two mung bean varieties used in this study was observed. The study also demonstrates that the plant materials contain bioactive secondary metabolites such as terpenoids, alkaloids, flavonoids, phenols, glucosides and fatty acids, which are known to have insecticidal properties. We therefore recommend using *T. vogelii* leaves and stem*, P. guineense* fruits, *X. aethiopica* fruits, and *C. papaya* seeds, especially at 3.0 g per 20 g seed weight, as an alternative to synthetic insecticides in the control of *C. maculatus* which decimate mung bean seeds in storage, because these plant powders are considerably safer, easily available, less expensive, and more environmentally friendly.

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