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ORIGINAL RESEARCH ARTICLE

Susceptibility and reproductive capability of *Callosobruchus maculatus* (Coleoptera: Bruchidae) to *Datura metel* extracts as potential cowpea grains protectant

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Abstract

In this study we evaluated the toxicity of *Datura metel* on susceptibility and reproductive capability of *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Datura metel* leaves powder was extracted with hexane, ethyl acetate, chloroform, acetone and methanol using Soxhlet apparatus and tested at 50, 100 and 150 µl/20 g cowpea seeds corresponding to 2.5, 5 and 7.5 µl/g. Mortality of *C. maculatus*, percentage reduction of eggs laid, egg hatchability, reduction in adult emergence, infestation, tolerance and weight loss were calculated at a different time of exposure. The lowest LD_{50} (0.202 µl) recorded was with ethyl acetate extract at 96 h of exposure, followed by methanol extract (9.45 µl) at 72 h of exposure. The mortality rate after 96 h exposure was ethyl acetate > methanol > acetone > hexane > chloroform. At 2.5 and 5 µl/g, methanol extract significantly ($p < 0.05$) reduced percent egg laid (59.92% and 59.31% respectively). Ethyl acetate extract of *D. metel* resulted in the lowest percentage of egg hatchability at 2.5 µl/g (15.0%), 100 µl (22.63%) and 7.5 µl/g (23.89%). Percent reduction in adult emergence was highest in methanol extract treated grains at 5 µl/g (89.33%) and 7.5 µl/g (91.67%). While, percent tolerance was lowest in ethyl acetate treated grains at 2.5 µl/g (72.80%) and 7.5 µl/g 58.67%) respectively. The lowest percentage weight loss in 7.5 µl/g was 2.50% (chloroform), followed by methanol (2.57%) and ethyl acetate (2.87%) with no significant difference ($p > 0.05$) among used solvents. *D. metel* proved effective against *C. maculatus* infestation and enhanced storability of cowpea grains.

Keywords Egg hatchability · Eggs laid · Mortality · Percent tolerance · Reproductive capabilities

Introduction

One of the greatest constrictions towards ensuring food security is the mitigation of post-harvest loss of stored food grains quality and quantity against stored product insect infestation. The cowpea beetle, *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) is a major post-harvest pest of stored highly nutritious pulse grains that causes sizeable loss to cowpea in terms of germination impairment, nutritional and weight loss when not effectively managed (Langyintuo et al. 2003; Oluwafemi 2012; Ndong et al. 2012; Mailafiya et al. 2014; Tiroesele et al. 2014; Kpoviessi et al. 2018). Contamination of stored cowpea grain with the powdery waste and damaged seeds through adult exit holes reduces its market price.

For several years now, the chemical control method remains the foremost and active routine means of protecting and controlling stored food grains against insect infestation and grain/seed damage (Adesina et al. 2012). The inadequacy in the use of synthetic insecticide to human health, environment vulnerability, and residue in food grains have raised apprehension and curiosity in probing for an unconventional material that is least injurious or mild to the environment and such is the use of medicinal and aromatic plants as natural source insecticide.

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The use of botanical insecticides can be dated back as early as the beginning of agriculture, but it was neglected after the modern agricultural system introduced synthetic chemicals. It is noteworthy that several researchers have resorted again to the use of plants as natural available pesticide alternatives. Many plants have been investigated and screened to contain hundreds of secondary metabolites that are biologically active against various insect pests (Akinkurolere 2007; Adesina et al. 2012; Awosolu et al. 2018). These bioactivities included stomach poison, feeding deterrent, repellent, oviposition deterrent, or inhibitory and growth regulatory effects. So far, only a few of botanical insecticides were commercialized, in spite of rich plant resources that occur, particularly in tropical and subtropical countries (El-Massad et al. 2012).

Datura metel L. belongs to the Solanaceae family, and commonly found in Asia and Africa. It is known as thorn or devil's apple, Jimson weed, angel's trumpet, Myaramuo (Igbo), Zakami (Hausa) and Apikan (Yoruba) (Abdullahi et al. 2003). *Datura metel* is an herbaceous, leafy plant which can grow up to 200 cm in height. The leaves are alternate and can be up to or more than 26 cm long and 21 cm wide. *Datura metel* is believed to be a medicinal plant widely used in phytomedicine to cure diseases and various parts of the plant (leaves, seeds, roots, and fruits) are used for different purposes in herbal medicine (Imo et al. 2019). In view of this, the objective of this study is to evaluate the susceptibility and reproductive capabilities of *Callosobruchus maculatus* (Coleoptera: Bruchidae) to *Datura metel* extracts.

Materials and methods

Collection and preparation of *Datura metel* extracts

Fresh leaves of *D. metel* were collected from a refuse dump site in Owo, Ondo State. A Sample of the plant was identified at the herbarium, Department of Forestry and Wood Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria where specimens of the plant were deposited for further reference. The plant samples were air-dried for a period of two weeks in a shade. The crisp dried plant leaves were then pulverized into powder using an electric milling machine. Thereafter, the powder was further sieved with $1mm^2$ perforations and were packed in black ploythene bags and stored in a cool dry place prior to use.

Pulverized plant leaves (200 g) were used for the extraction in a Soxhlet apparatus for 7—8 h sequentially with a series of solvents of increasing polarity namely: hexane, ethyl acetate, chloroform, acetone, and methanol followed by evaporation until the solvent was dried. The extracts were collected and stored in an amber coloured glass vial and then kept in the refrigerator at 4 °C with proper labeling prior to use.

Rearing and maintenance of *Callosobruchus maculatus*

Stock culture of *Callosobruchus maculatus* used was obtained from naturally infested grains sourced from food grain dealers. The insects were reared and maintained on cowpea grains in a kliner jar under ambient laboratory conditions of temperature 30 + 2 °C, relative humidity 65 + 5% and 12 h light and darkness regime (Adesina et al. 2016). Adult insects in the jar were maintained for seven days to mate and oviposit and were subsequently removed from the jar. From this stock culture, subcultures of the insect were reared on a local susceptible variety of cowpea in 1L plastic jars covered with muslin cloth, secured firmly by a rubber band in the laboratory to allow for aeration and prevent the escape of insect in order to obtain insect of the same age (1–2 days old). Insects used for the bioassay were taken from this stock.

Source of cowpea seeds

Cowpea seeds were purchased from a local market in Owo, Ondo State. Uninfected cowpea seeds with no feeding holes were selected and bagged in a polyethylene bags prior to experiments, the cleaned cowpea seeds were disinfected by storing in a deep freezer at -5 °C for one week to kill any immature stages or egg laid (if any). Twenty-four hour prior to research, the stored cowpea was removed from the freezer and air-dried on the laboratory bench to attain the normal room temperature so as to prevent mouldiness (Olotuah et al. 2007).

Toxicity of *Datura metel* extracts on survival of Adult Callosobruchus maculatus

Each plant extract was admixed at 50, 100 and 150 µl/20 g (2.5, 5 and 7.5 µl/g) of clean and uninfected cowpea seeds in a Petri dish respectively. The cowpea seeds and extracts were thoroughly mixed with a glass rod for about 2 min to ensure uniform coating of the seeds. Petri dishes were left open for 2 min to ensure dryness of the extracts (Adesina and Mobolade-Adesina 2016). Thereafter, 10 unsexed newly emerged adult *C. maculatus* of 1–2 days old were introduced. A negative control made of untreated seeds was also set up. The Petri dishes were covered with Petri plates, sealed with paraffin wax and were arranged in the laboratory at room temperature. The whole experiment was replicated three times. The survival of the *C. maculatus* adult was recorded after every 24 h for four (4) days. At each observation the dead insects were removed, counted and recorded to

calculate percentage adult survival. Insects were considered dead on failure to respond to pricking using a safety pin. The experiment was maintained under ambient laboratory conditions of temperature 30 + 2 °C, relative humidity 65 + 5% and 12 h light and darkness regime (Adesina et al. 2016).

Toxicity of *Datura metel* extracts to *Callosobruchus maculatus* reproductive potential

After 96 h of *C. maculatus* infestation from contact toxicity as described above under same conditions, all living insects were removed, and the dishes with treated seeds and control were kept undisturbed in the laboratory for hatching adult emergence to take place. Inhibition of adult *C. maculatus* reproductive potential by *D. metel* extracts was determined based on the number of eggs laid and percentage egg hatchability at 4 and 6 days after infestation respectively (Howe and Currie 1964) and emergence of F1 progeny. The number of eggs laid on treated and control seeds were counted using a hand lens, and percentage reduction in the number of eggs laid was calculated as follows:

$$\% \text{ Reduction} = \frac{A - B}{A} x100$$

A = Number of eggs laid in control dish, B = Number of eggs laid in treated dish. Total number of eggs hatched were counted 6 days after removal of living insects, to determine the percentage egg hatchability. Hatched eggs were determined based on the presence of larval frass (Arun et al. 2001) and changed in transparent egg or fresh egg colour into white opaque and presence of excreta within the egg chorion (Sushmita et al. 2019).

$$\% \text{ egg hatchability} = \frac{\text{Mean number of eggs hatched}}{\text{mean number of eggs laid}} \times 100$$

On the same experimental units, at 28 days after treatment (DAT) the number of adults emerged from the treated cowpea was counted and recorded. Percentage adult emergence reduction was calculated thus;

$$\% \text{ Adult reduction emergence} = \frac{C - D}{C} \times 100$$

C = Number of emerged adults from control dish, D = Number of emerged adults from treated dish (Adesina et al. 2015).

Effect of *Datura metel extracts* on percentage infestation and weight loss

The grain damage (percentage infestation and tolerance) was determined by counting damaged seeds and adult emergence holes on the surface of the stored grains, 28 days after infestation (Adesina and Mobolade-Adesina 2020). Data for percentage infestation and weight loss were collected after sieving the treated and control dishes of insects and frass through a 3 mm sieve (Idoko and Adesina 2013).

$$\% \text{ infestation} = \frac{\text{number of seeds with adult exit hole}}{\text{total number of seeds}} \times \frac{100}{1}$$

(Deshpande et al. 2011)

$$\% \text{ insect tolerance} = \frac{\text{Number of seeds without adult exit hole} - \text{Number of seeds with adult exit hole}}{\text{Number of seeds with adult exit hole}} \times \frac{100}{1}$$

(Adesina et al. 2020).

The weight loss (%) of cowpea seeds in the treated and control sets was calculated after reweighing of the seeds at the termination of the experiment:

$$\% \text{ weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times \frac{100}{1}$$

(Ileke and Oni 2011)

Statistical analysis

The experiment was laid out in a Completely Randomized Design with three replications. The effectiveness of *D. metel* extracts on insect infestation and damage was determined by calculating mortality (%), reduction in egg laid (%), egg hatchability (%), adult emergence (%), tolerance (%) infestation (%) and weight loss (%) of treated and control. All the data were reported as mean value ± SE. The statistical analysis was performed by one-way analysis of variance (ANOVA) and significant treatment means were compared by using Duncan New Multiple Range Test (DNMRT) at the 5% level of significance ($P < 0.05$). Prior to ANOVA, arcsine transformation (x /100) was applied to all calculated percentages to meet the conventions of normality and homogeneity of variance (Asiry and Zaitoun 2020).

Table 1 Effect of contact toxicity of *Datura metel* extracts on adult *Callosobruchus maculatus* survival

Exposure Time (hrs)	plant extract	Concentration (µl/g)		
		2,5 µl/g	**5** µl/g	**7.5** µl/g
24	Hexane	18.44 ± 0.23b	33.21 ± 0.01b	50.77 ± 0.00c
	Ethyl acetate	33.17 ± 0.04d	46.67 ± 1.67c	71.57 ± 0.01e
	Chloroform	26.57 ± 0.01c	33.21 ± 0.01b	39.25 ± 0.20d
	Acetone	26.56 ± 0.03c	33.21 ± 0.12b	33.21 ± 0.00b
	Methanol	26.56 ± 0.00c	45.00 ± 1.15c	50.77 ± 0.00c
	Control	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a
48	Hexane	33.17 ± 0.04b	50.44 ± 0.33b	56.46 ± 0.33c
	Ethyl acetate	39.22 ± 0.01d	50.75 ± 0.02b	90.00 ± 2.89d
	Chloroform	50.75 ± 0.02c	56.83 ± 0.04c	56.76 ± 0.03c
	Acetone	50.23 ± 0.23c	50.51 ± 0.26b	50.77 ± 0.04b
	Methanol	50.51 ± 0.25c	50.75 0.02b	56.79 ± 0.40c
	Control	7.33 ± 1.45a	7.33 ± 1.45a	7.33 ± 1.45a
72	Hexane	50.75 ± 0.02b	62.44 ± 1.00b	90.03 ± 0.03c
	Ethyl acetate	45.00 ± 2.89b	56.76 ± 0.03d	90.00 ± 5.77c
	Chloroform	62.29 ± 1.15c	63.43 ± 0.01b	71.56 ± 0.00b
	Acetone	63.43 ± 0.01c	71.23 ± 0.33c	71.57 ± 0.01b
	Methanol	63.29 ± 0.14c	63.43 ± 0.01b	71.54 ± 0.02b
	Control	11.33 ± 1.86a	11.33 ± 1.86a	11.33 ± 1.86a
96	Hexane	56.83 ± 0.04b	71.22 ± 0.34b	90.67 ± 0.67b
	Ethyl acetate	93.33 ± 3.33d	93.33 ± 3.33d	96.66 ± 3.33bc
	Chloroform	58.12 ± 0.88b	93.33 ± 3.33d	100.00 ± 0.00c
	Acetone	71.23 ± 0.33c	88.33 ± 1.67c	90.00 ± 1.15b
	Methanol	71.57 ± 0.01c	72.56 ± 1.00b	88.67 ± 1.33b
	Control	13.33 ± 1.67a	13.33 ± 1.67a	13.33 ± 1.67a

Mean with the same alphabet down the column are not significantly different using DNMRT at $p > 0.05$

Results

In Table 1, results shown the contact toxicity of *D. metel* extracts on adult *C. maculatus* survival. At 24 h exposure, insects treated with *D. metel* ethyl acetate extract had the highest survival recorded in 2.5, 5 and 7.5 µl/g (33.17, 46.67 and 71.57% respectively). There was no significant difference ($p > 0.05$) in *C. maculatus* survival when reared in contact with extract of acetone (50.23%), methanol (50.51%) and chloroform (50.75%) *D. metel* extracts using 5 µl/g at 48 h exposure time and also, 63.43, 63.29 and 62.29% respectively for 72 h exposure. At 96 h exposure, *D. metel* ethyl acetate extract applied at 50 µl achieved highest adult *C. maculatus* survival rate (93.33%). The result shows non-significant difference ($p > 0.05$) between the survival rate attained by *D. metel* ethyl acetate (93.33%) and chloroform extracts (93.33%) at 5 µl /g (96.66%) and 7.5 µl/g (100%) respectively.

Lethal dose of *D. metel* extract that kill 50% of *C. maculatus* was presented in Fig. 1. The least LD_{50} (0.202 µl) recorded was in the *D. metel* ethyl acetate extract at 96 h after exposure, followed by methanol extract (9.45 µl) at 72 h.

For the dosage 2.5 and 5 µl/g (Table 2), methanol extract of *D. metel* was the highest in reducing egg laying (59.92 and 59.31%). While, *D. metel* ethyl acetate extract at 7.5 µl/g was the highest and significantly different ($p < 0.05$) from

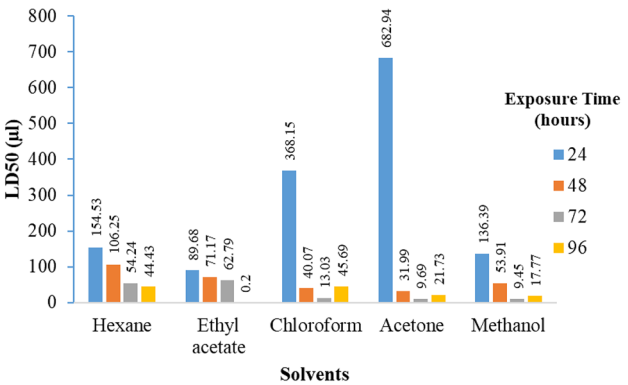

Fig. 1 LC_{50} of *D. metel* extract on *C. maculatus*

Table 2 Effect of contact toxicity of *Datura metel* extracts on *Callosobruchus maculatus* reproductive capabilities

	Concentration (µl/g)			
	plant extract	2.5 µl/g	5 µl/g	7.5 µl/g
% Reduction of egg laid	Hexane	40.34 ± 0.00c	40.74 ± 0.00b	44.06 ± 2.00b
	Ethyl acetate	12.41 ± 0.10d	21.71 ± 0.35f	83.38 ± 0.04d
	Chloroform	30.56 ± 0.03bc	50.24 ± 0.12e	74.17 ± 0.04e
	Acetone	32.69 ± 1.33b	54.37 ± 0.14c	60.03 ± 0.03c
	Methanol	56.92 ± 0.06d	59.31 ± 0.10d	61.72 ± 0.10c
	Control	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a
% Egg hatchability	Hexane	80.38 ± 0.01d	63.81 ± 0.06d	45.33 ± 0.33 cd
	Ethyl acetate	15.00 ± 0.0a	22.63 ± 0.11a	23.89 ± 0.13a
	Chloroform	22.00 ± 1.00b	33.21 ± 0.00b	34.33 ± 3.33b
	Acetone	67.77 ± 0.01c	51.63 ± 0.02c	48.31 ± 0.15d
	Methanol	65.85 ± 0.03c	60.67 ± 0.67 cd	48.03 ± 0.01d
	Control	100.0 ± 0.00e	100.0 ± 0.00e	100.0 ± 0.00e
% Reduction in adult emergence	Hexane	22.21 ± 0.01b	40.92 ± 0.00b	88.33 ± 1.67c
	Ethyl acetate	50.51 ± 0.26 cd	50.57 ± 0.02d	86.67 ± 3.33bc
	Chloroform	46.06 ± 2.67c	61.57 ± 0.67e	75.36 ± 2.67b
	Acetone	48.55 ± 0.33c	48.21 ± 0.01c	90.33 ± 0.33d
	Methanol	45.33 ± 0.33c	89.33 ± 0.67f	91.67 ± 1.67d
	Control	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a

Mean with the same alphabet down the column are not significantly different using DNMRT at $p > 0.05$

other extracts. Ethyl acetate extract of *D. metel* achieved the lowest percentage egg hatchability recorded for all the measurement used (15.0% (50 µl), 22.63% (5 µl/g) and 23.89% (150 µl)), with significant difference ($p < 0.05$) from other extract. The highest percentage reduction of *C. maculatus* adult emergence was recorded in cowpea treated with 2.5 µl/g ethyl acetate (50.51%) extract of *D. metel* but not significantly different ($p > 0.05$) from chloroform (46.06%), methanol (45.33%), and acetone (48.55%) extracts of *D. metel* respectively Percent Reduction in adult emergence was highest with the *D. metel* methanol extract in 5 µl/g (89.33%) and 7.5 µl/g (91.67%).

Contact toxicity of *D. metel* extracts on grains' susceptibility to infestation is presented in Table 3. In 2.5 µl/g, *D Datura metel* extracts of hexane (13.39%), ethyl acetate (16.31%), chloroform (15.47%) and control (16.49%) exhibited non significantly difference ($p > 0.05$) but exerted significantly difference ($p < 0.05$) from *D. metel* acetone (9.03%) and methanol extracts (8.52%). Likewise, acetone and methanol extracts of *D. metel* was not significantly different ($p > 0.05$) from each other but grains treated with *D. metel* methanol extract had the lowest percentage infestation in 5 and 7.50 µl/g (8.22 and 6.01%). Percent tolerance was lowest with ethyl acetate extract of *D. metel* (72.80%

Table 3 Effect of contact toxicity on *Callosobruchus maculatus* susceptibility to infestation on stored grains

	Concentration (µl/g)			
	plant extract	2.5 µl/g	5 µl/g	7.5 µl/g
% Infestation	Hexane	13.69 ± 0.00b	12.25 ± 0.13b	9.38 ± 0.03ab
	Ethyl acetate	16.31 ± 0.06b	12.33 ± 0.08b	6.00 ± 0.58a
	Chloroform	15.47 ± 0.02b	13.37 ± 0.19b	8.55 ± 0.17b
	Acetone	9.03 ± 0.03a	8.91 ± 0.01a	8.71 ± 0.01b
	Methanol	8.52 ± 0.01a	8.22 ± 0.11a	6.01 ± 0.01a
	Control	16.49 ± 0.04b	16.49 ± 0.04c	16.49 ± 0.04c
% Tolerance	Hexane	79.33 ± 3.33a	79.22 ± 0.03b	77.48 ± 0.25c
	Ethyl acetate	72.80 ± 0.15a	76.69 ± 0.65ab	58.67 ± 0.67a
	Chloroform	81.45 ± 0.17b	76.06 ± 0.00ab	71.16 ± 0.03b
	Acetone	90.00 ± 0.00c	81.67 ± 1.13b	79.37 ± 0.33c
	Methanol	81.47 ± 1.13b	74.61 ± 0.41a	61.47 ± 0.20ab
	Control	100.0 ± 0.00d	100.0 ± 0.00c	100.0 ± 0.00d

Mean with the same alphabet down the column are not significantly different using DNMRT at $p > 0.05$

Table 4 Effect of *D. metel* extracts on percentage weight loss of treated grains

Contact toxicity			
Plant extracts	**2.5** µl/g	**5** µl/g	**7.5** µl/g
Hexane	5.43 ± 0.01c	5.24 ± 0.00b	4.07 ± 0.03b
Ethyl acetate	5.83 ± 0.0c	3.63 ± 0.32c	2.87 ± 0.13c
Chloroform	8.33 ± 0.0b	3.33 ± 0.33c	2.50 ± 2.89c
Acetone	5.41 ± 0.06c	5.12 ± 0.07b	3.71 ± 0.05b
Methanol	4.41 ± 0.33c	3.97 ± 0.24c	2.57 ± 0.17c
Control	21.75 ± 0.07a	21.75 ± 0.00a	21.75 ± 0.07a

Mean with the same alphabet down the column are not significantly different using DNMRT at $p > 0.05$

and 58.67%) in 2.5 and 7.5 µl/g respectively. Meanwhile, *D. metel* methanol extract was lowest (74.61%) in 5 µl/g, but not significantly different ($p > 0.05$) from ethyl acetate (76.69%) and chloroform (76.06%) extracts of *D. metel*.

In Table 4, the lowest percentage weight loss of treated grain in 2.5 µl/g was methanol extract of *D. metel* (4.41%) but not significantly different ($p > 0.05$) from hexane (5.43%) and ethyl acetate (5.83%) extracts of *D. metel*. In 5 µl/g, percentage weight loss ranges from 3.33% (chloroform) to 21.75% (control). The lowest percentage weight loss (2.50%) was recorded in 7.5 µl/g chloroform *D. metel* extract followed by methanol *D. metel* extract (2.57%) and ethyl acetate *D. metel* extract (2.87%) with no significant difference ($p > 0.05$).

Discussion

Plant materials are regarded as a storehouse of bioactive chemical compounds that can serve as an alternate source of insect control measures to synthetic insecticides or fumigants in order to guarantee food security in third-world countries where the bulk of food crop production lies in the hands of resource-poor subsistence farmers, that lack modern storage know-how.

D. metel shows contact toxicity against *C. maculatus* in this study, as every parameter considered was significantly different from the untreated grains. This congruent with other reports on *Datura* spp as a potential bioinsecticide against stored grain pests (Habib et al. 2011; Nilesh et al. 2016; Obadofin et al. 2018). This particular ability is suggested to be due to the phytochemical content of this plant, has its solvent extract contains alkaloids, tannins, cardiac glycosides, flavonoids, carbohydrates, amino acids, and phenolic compounds (Al-Snaf 2017; Krishnan et al. 2017). Some of these metabolites might be toxic to the insect body system by blocking the ion channels, inhibit enzymes, or interfere with neurotransmission, loss of coordination, and death (Aniszewski 2007).

In this study, different solvents were employed to extract metabolites from *D. metel* against *C. maculatus* survival. Within 24 and 96 h of exposure, ethyl acetate extract of *D. metel* achieved the highest mortality recorded, followed by methanol. The polarity of plant material in a particular solvent also determines its effectiveness against an insect pest. This determine the level in which bioactive metabolites in the plant will be fully extracted. The mortality rate of different *D. metel* extracts on *C. maculatus* after 96 h of exposures is ethyl acetate > methanol > acetone > hexane > chloroform. Highest mortality of ethyl acetate extract is in accordance with Adesina and Mobolade-Adesina (2020) where an ethyl acetate extract of *Anchomanes difformis* achieved highest mortality when compare with acetone, hexane and methanol extract. Also, Khalequzzaman and Islam (1992) reported that the methanolic extract of *D. metel* leaf was more toxic than other extracts on *T. castaneum*.

The methanolic extract of *D. metel* effectively reduced egg laid at lower measurement while ethyl acetate was most effective at the highest measurement level. Botanical has been reported to affect the oviposition activity of insect pests of the stored products (Adesina and Ofuya 2015). This may be due to the changes induced by toxic metabolites in the physiology and behaviour of the adult which now reflect on their egg-laying capacity. This deterrent activity range was 30.56—83.38% and this was within the range of 12.31—84.66% reported by Jayakumar (2010) when considering different plants extract against *C. maculatus*.

It was also observed that egg hatchability was obviously affected by ethyl acetate extract of *D. metel* followed by chloroform. Reduction in egg hatchability was also observed by Khani et al. (2013) and it was attributed to phytochemical action of the compound present in the plant extract. Contact toxicity of ethyl acetate extract of *D. metel* also induced much reduction on adult emergences at the lowest measurement used while methanol extract attained the highest adult emergence reduction at higher measurement. The plant oil could as well block the air passage (micropyle region) of the egg chorion, leading to embryo death as a result of oxygen depletion and therefore reduces adult emergence (Pandey et al. 2011). Akinneye et al. (2018) examined the contact toxicity of *Cleistopholis patens* and *Eugenia aromatica* powders on *Sitophilus zeamais* eggs, the powder significantly reduced the number of adults that emerged. It was further revealed from this study, that the percentage infestation of *C. maculatus* was mostly reduced by methanol extract of *D. metel* in all measurements. Also, ethyl acetate also achieved the lowest infestation at 150 µl and had the least tolerance *C. maculatus*, followed by methanol.

There was a significant difference in the percentage weight loss on cowpea treated (8.33–2.50%) and untreated

(21.75%). This can be related to the adult emergence and percentage infestation observed in this study, which is as a result of antifeedant, repellent and suppressant properties possess by *D. metel*. These three aforementioned properties debar the insect from making contact or having a bite on the grain after the plant ingestion (Haghighian et al. 2008).

Conclusion

The contact toxicity of *D. metel* against *C. maculatus* and its potential to protect cowpea grain have been studied. Ethyl acetate has proven to be most effective among the solvent used for extraction. This study suggest the possibility of using these extracts as cowpea natural protectant against *C. maculatus*. Further studies are recommended to identify the bioactive compounds responsible for the insecticidal activity present in the plant and also to know the site of action in the insect body system.

Author contributions JM conceived, designed and supervised the experiment; AJ conducted the experiment and collected all needed data; Y analysed the data and interpreted the results; TE collected and prepared the plant extract and sourced for relevant literatures and FP prepared the manuscript draft. All authors read and approved the manuscript.

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Declarations

Research involving human participants and /or animals The research work did not involve animals.

Conflict of interest The authors declare that they have no conflict of interest.

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