



Available Online at EScience Press

Plant Protection

ISSN: 2617-1287 (Online), 2617-1279 (Print)
http://esciencepress.net/journals/PP

Research Article

Evaluation of the Effect of Alkaloidal Extracts of *Duranta repens* Fruit on Some Biological Parameters of Cowpea Beetle

^aEmad Ahmed Mamood, ^bTabark Ali Hasan, ^cTara Aso Taher

^a Department of Biology, AL-Farabi University, Baghdad, Iraq.

^b Ibn Sina University of Medical and Pharmaceutical Sciences, Baghdad, Iraq.

^c Department of Biology, College of Science for Women, University of Baghdad, Baghdad, Iraq.

ARTICLE INFO

Article history

Received: 20th April, 2025

Revised: 14th July, 2025

Accepted: 17th July, 2025

Keywords

Duranta repens

Callosobruchus maculatus

Alkaloid extracts

Botanical insecticide

Biological parameters

ABSTRACT

The present study aimed to evaluate the insecticidal efficacy of alkaloid extracts from *Duranta repens* fruits at concentrations of 4%, 6%, and 8% against different developmental stages of the southern cowpea beetle (*Callosobruchus maculatus*) under laboratory conditions. The tested stages included eggs, last instar larvae, and pupae at 24 and 120 h of age. The 8% alkaloid extract exhibited the highest ovicidal activity, achieving 100% egg mortality, compared to 60% mortality at the 4% concentration. Similarly, the 8% concentration induced the highest larval mortality (82%) in the last instar stage, significantly outperforming the lower concentrations. Pupae treated at 24 h old with the 8% extract recorded a 93% mortality rate, while 120-h-old pupae showed a reduced mortality rate of 77% at the same concentration. In contrast, the 4% extract resulted in 68% and 60% mortality for 24- and 120-h-old pupae, respectively. Furthermore, the 8% alkaloid extract was most effective in protecting stored cowpea seeds, recording the lowest seed loss (6.55%) after six months of storage, compared to the 4% and 6% treatments. The study also demonstrated that seed germination was not adversely affected by any treatment across all evaluation periods (1 day, 90 days, and 180 days). Overall, the 8% alkaloid extract of *D. repens* fruits proved to be the most effective concentration in controlling *C. maculatus* and preserving seed viability during storage.

Corresponding Author: Tabark Ali Hasan

Email: tabark.bio89@ibnsina.edu.iq

© 2025 EScience Press. All rights reserved.

Introduction

Legumes such as cowpeas, chickpeas, lentils, broad beans, and peas are among the most essential food crops cultivated globally, including in Iraq. These crops are widely recognized for their high protein content and rich nutritional value, making them vital for both human and animal diets (Al-Fahdawi, 2021). Among these, cowpea (*Vigna unguiculata* L.) is extensively cultivated in East, West, and Central Africa, as well as in South America. It

thrives in semi-humid tropical climates and exhibits considerable drought tolerance (Coulibaly et al., 2009), as this climate (semi humid-tropical) is suitable for its growth and enables it to withstand soil drought conditions (Gates and Millenda, 2012). *V. unguiculata* includes several subspecies, such as the black-eyed bean, which is commonly grown in many regions worldwide, including Iraq. However, dried cowpea seeds are highly susceptible to attack by storage pests, particularly the

southern cowpea beetle (*Callosobruchus maculatus*), one of the most destructive pests of legumes both in the field and in storage. The larvae of this insect bore into the seeds, feeding on their contents and causing significant damage. The pest is capable of infesting a wide variety of legume seeds, with black-eyed cowpea being among the most vulnerable. The severity of damage increases as the larvae mature (Al-Hamdani, 2022).

When seeds are left unprotected for extended periods, particularly under favorable environmental conditions such as 30°C temperature, 70% relative humidity, and absence of light, losses can reach up to 87% of the dry weight of seeds within three to six months (Singh, 2006; Varela, 2012). The beetle can infest seeds in the field by penetrating the pods and completing its development within the seeds. Once such infested seeds are stored, emerging adults mate and lay eggs on healthy seeds, thus continuing the infestation and causing severe post-harvest losses (Hill, 1990). The cowpea weevil is commonly known as the four-spotted beetle due to the presence of four light-colored spots on its elytra, which are more prominent in females than in males. The larvae are white and curved. The pupae are free, white in color, and gradually turn yellow as they mature (Walker, 2008). The male is distinguished from the female by its larger body size. In females, the end of the abdomen is elongated and bears two dark longitudinal stripes, whereas in males, the last ring of the abdomen is curved and directed downward. The wings of the female do not fully cover the abdomen, while in the male; they extend over it (Girgis et al., 2000). The insect exists in two forms: an active, flight-capable form found in fields and a non-flying form typically present in storage environments (Zannou et al., 2003). Under optimal conditions, the female lays approximately 90 eggs that hatch within 4-6 days. The larval stage lasts about 20 days, followed by a pupal stage of around 7 days, resulting in a total developmental period of approximately 25 to 30 days (El-Sawaf, 1956).

Various pest management strategies have been explored, including chemical, biological, and physical methods. Although chemical insecticides are the most commonly used due to their immediate effectiveness and ease of application, they have significant drawbacks, including short residual action and environmental contamination. As a result, there has been a growing shift toward the use of botanically derived compounds, such as alcoholic or aqueous extracts containing bioactive constituents

like terpenes, flavonoids, and alkaloids. These plant-based compounds can act as insecticides, antifeedants, or growth regulators, interfering with feeding, mating, or development. They offer a safer, eco-friendly alternative to synthetic chemicals, with the added benefit of a longer shelf life (Massango et al., 2017).

Duranta repens is an evergreen plant that can grow as a large shrub, climbing herb, or small tree, typically ranging from 1-3 meters in height. It bears purple or light blue flowers throughout the year and produces yellow, spherical or oval fruits (Gilman, 1999; Francis et al., 2002). Native to the Americas, particularly Argentina and Mexico, this plant is widely cultivated in tropical and semi-tropical regions. It thrives in rocky and sandy soils, provided there is sufficient moisture. Under favorable conditions, it can live up to 15 years, although under drought stress it may be stunted and live for a shorter period, sometimes reaching only about 1 m in height. The genus includes several species, such as *Duranta repens*, *D. erecta*, *D. ellisia* Jacq., and *D. plumieri* Jacq.

From a medicinal standpoint, *D. repens* possesses both beneficial and toxic properties. It has shown potential in treating intestinal worms and malaria. However, the plant can be poisonous, especially to children, as its fruits contain saponins that may cause fever, vomiting, gastrointestinal irritation, and contact dermatitis (Francis et al., 2002). The chemical composition of the plant includes primary and secondary metabolites (Balandrin et al., 1985). Secondary metabolites, in particular, play important roles in plant interactions with insects, microbes, and other plants, acting as natural defenses that influence ecological dynamics (Beck and Reese, 1975). These compounds provide protection through toxic, repellent, or inhibitory mechanisms that affect insect feeding, development, and reproduction.

Among the key secondary metabolites in *D. repens* are alkaloids, phenolics, and terpenoids. Alkaloids are nitrogen-containing compounds that occur in various forms such as salts with plant acids e.g., quinic and meconic acid, glycosides e.g., solanine, amino acid derivatives e.g., piperine, or esters e.g., cocaine, atropine. Most are colorless crystalline substances, though some, like berberine, are yellow. Alkaloids are widely used in pest control due to their potent biological activities (Jacobson and Crosby, 1971). Phenolic compounds are water-soluble and often bound to sugar molecules as glycosides, stored in plant cell vacuoles. One of the

simplest is coumarin, derived from phenylalanine. Phenolics, including flavonoids and tannins, are broadly distributed in plants and serve key roles in resistance to herbivory. Flavonoids, present in all plant parts including fruits, pollen, roots, and wood, regulate numerous physiological functions and include insecticidal compounds such as rotenoids. Tannins are high-molecular-weight compounds (500-3,000 Da) found in almost all plant tissues and contribute significantly to plant defense (Harborne, 1973). Terpenoids are lipid-soluble, cyclic compounds found in the cytoplasm or in specialized secretory structures, and sometimes in chloroplasts as carotenoids. Volatile oils, which are primarily composed of mono- and diterpenes, constitute a major group of terpenoids. These oils are responsible for the characteristic aroma of many plants and possess strong insecticidal and repellent activities (Harborne, 1973).

Given the insecticidal potential of alkaloids derived from *D. repens* fruits, the present study aimed to evaluate the effectiveness of alkaloid extracts at concentrations of 4%, 6%, and 8% in influencing the biological performance of *Callosobruchus maculatus*, specifically targeting eggs, late larval instars, and pupae after 24 and 120 h of exposure; determining the germination percentage of seeds treated with these extracts after 1, 90, and 180 days; and assessing the degree of protection provided by the treated seeds against insect infestation after six months of storage.

Materials and Methods

Insect rearing

Two colonies of cowpea weevils were established and maintained:

Colony A

Colony A was established for the collection of eggs and last instar larvae. Insects were obtained from infested cowpea seeds and transferred to plastic containers (10 × 17 cm) containing uninfested black-eyed bean seeds to obtain last instar larvae. To prevent the emergence of adults, containers were covered with muslin cloth secured with rubber bands.

Colony B

Colony B was maintained to obtain pupae of 24 and 120 h of age. Black-eyed bean seeds were ground using an electric grinder to produce a powder substrate for oviposition. Thirty pairs of newly emerged male and female adults were introduced into each container to

establish multiple colonies (Figure 1). Pupal development was monitored at two intervals: 24 and 120 h post-pupation.

Both colonies were maintained in an incubator at $29 \pm 2^\circ\text{C}$ and $70 \pm 5\%$ relative humidity. Colonies were renewed after each generation. All experiments were conducted under the same environmental conditions.



Figure 1. Male and female adult weevils under 30× magnification.

Spray application

A manual sprayer was used to apply treatments at a distance of 15 cm from the seeds.

Collection and identification of plant material

Fruits of *D. repens* (Figure 2) were collected and taxonomically identified by the Iraqi National Herbarium. The fruits were air-dried and ground using a 50-60 mesh mill.

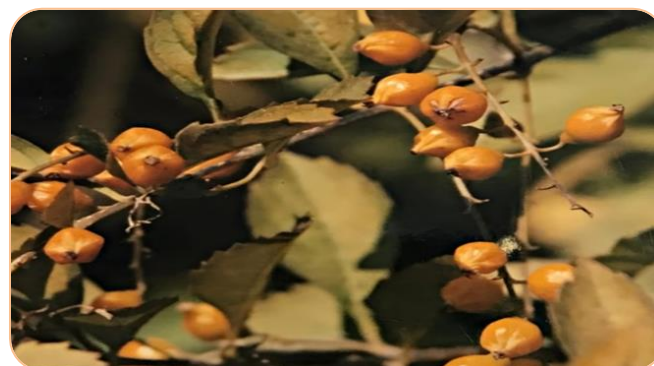


Figure 2. *Duranta* fruits (2× magnification).

Alkaloid extraction

Alkaloids were extracted from the dried fruit powder following the method of Mabry et al. (1970), and their presence was confirmed using the protocol described by Harborne (1984).

Preparation of concentrations alkaloid extract

Three concentrations of alkaloid extract viz. 4%, 6%, and 8%, were prepared. For the 4% solution, 4 g of alkaloid

extract was dissolved in 50 ml of dimethyl sulfoxide (DMSO), followed by the addition of 0.4 ml of Tween-20. The volume was adjusted to 100 ml using distilled water. The same procedure was followed for the 6% and 8% solutions. The control treatment consisted of 50 ml DMSO, 0.4 ml Tween-20, and distilled water to make up 100 ml.

Effect of alkaloid extract from *D. repens* fruit on the development of cowpea weevil

Effect on 24-h-old eggs and their development

Ninety eggs (one egg per seed) were selected and divided into three replicates of 30 eggs each (Figure 3). The eggs were treated with 4%, 6%, and 8% concentrations of alkaloid extract and placed in individual Petri dishes. The dishes were incubated, and egg development was monitored daily until hatching.



Figure 3. Eggs of the bean weevil (60× magnification).

Effect on last instar larvae and their development

Ninety last instar larvae were identified by the presence of a transparent ring on the seed surface (Figure 4), indicating readiness for pupation. Larvae were divided into replicates and treated with the same concentrations as mentioned above. Development was observed until adult emergence.



Figure 4. Last larval stage (30× magnification).

Effect on 24-h-old pupae and their development

Ninety 24-h-old pupae were isolated from Colony B (Figure 5) and divided into replicates. Treatments were applied as described previously. Pupal development was monitored until adult emergence.

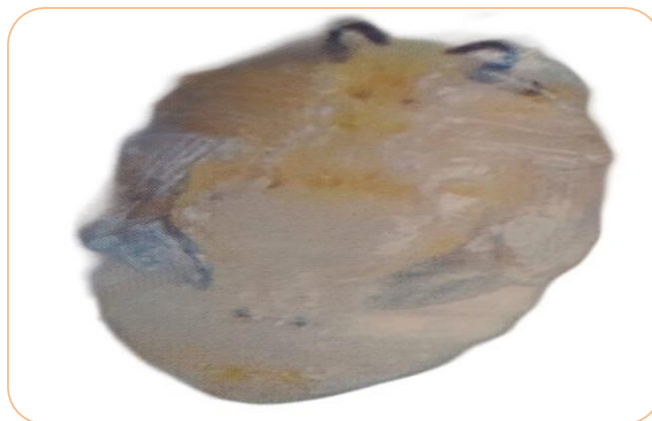


Figure 5. Pupal stage (40× magnification).

Effect on 120-h-old pupae and their development

Pupae of 120 h of age were obtained by isolating 24-h-old pupae from Colony B and incubating them until they reached 120 h. These pupae were treated similarly to the earlier bioassays and observed until emergence.

Effect of alkaloid treatment on seed protection against cowpea weevil infestation

Each treatment involved 250 g of black-eyed bean seeds divided into five replicates of 50 g each. Seeds were sprayed with 4%, 6%, or 8% alkaloid extract solutions. Treated seeds were placed in plastic containers (25 × 15 cm), and 10 pairs of adult weevils (males and females) were released per container. Containers were covered with muslin cloth and secured with rubber bands. The weight of each container was recorded initially, and weight loss was monitored monthly over six months to evaluate damage.

Effect of alkaloid treatment on seed germination

This bioassay followed the same protocol as the seed protection against cowpea weevil infestation test, but without releasing insects. Germination tests were conducted at 1, 90, and 180 days after treatment. Thirty seeds from each replicate were placed in Petri dishes containing filter paper moistened with distilled water and incubated. Germination rates were recorded for each treatment group.

Statistical analysis

Data were analyzed using the Statistical Analysis System (SAS, 2010) to determine the effects of different alkaloid concentrations on the studied parameters. Means were compared using the Least Significant Difference (LSD) test at a 5% probability level ($P < 0.05$). Mortality percentages were corrected using Abbott's formula (Abbott, 1925).

Results and Discussion

Effect of *D. repens* alkaloids on egg hatch and development of cowpea weevil

Table 1 presents the effect of alkaloid extracts of *D. repens* fruits on the egg hatching and subsequent development of *C. maculatus*. Compared to the control, which exhibited 0% egg mortality, mortality increased with extract concentration, reaching 60% at 4% and 100% at 8%. The average egg incubation period did not differ significantly among treatments. The larval period was prolonged at 6% concentration (21.44 days) compared to the control (11.94 days). The highest pupal mortality (3%) was observed at 6%, while no significant differences were found in pupal development duration. Adult emergence rates were inversely related to concentration, declining to 23% and 38% at 6% and 4%, respectively, compared to 100% in the control. Statistical analysis confirmed significant treatment effects. Using plant extracts at the egg stage is crucial to minimize damage caused by later stages. Roy et al. (2016) reported high egg mortality when *D. repens* leaf extracts were applied against *Oligonychus coffeae*, attributing this to alkaloids and terpenes that disrupt the eggshell and induce toxicity.

Effect of alkaloid extracts on the development of last larval instar of cowpea weevil

Table 2 indicates that the 8% concentration caused the highest mortality (82%) in last-instar larvae, compared to 49% at 4%. The larval period peaked at 16.30 days at 6%, while it was only 4 days in the control. Pupal mortality also increased significantly, reaching 18% at

6% compared to 2% in the control. The pupal duration was longest at 8% (8.28 days) and shortest at 4% (4.66 days). Adult emergence dropped from 95% in the control to just 3% at 8%. Female emergence was higher than males, likely due to their higher fat reserves, which might enhance resistance to phytochemicals (Koonan and Bouda, 2006). Nash et al. (1986) found that castanospermine, an alkaloid, inhibits α - and β -D-glucosidase enzymes in larval midguts, disrupting metabolism and causing mortality. Similarly, Mosaddik et al. (2007) demonstrated that ethanol extracts of *Duranta* fruit are toxic to *Tribolium castaneum* larvae, with toxicity decreasing with larval age. Chennaiyan et al. (2016) observed larval mortality and deformities in *Spodoptera litura* and *Helicoverpa* spp. following treatment with *D. erecta* leaf extracts.

Effect of alkaloid extracts on 24-h-old pupae and their development

Table 3 shows that pupal mortality at 24 h of age peaked at 93% at 8% extract concentration, declining to 68% at 4%, while the control showed only 3% mortality. The longest pupal period (5 days) was recorded at 4% and the shortest (3.5 days) at 8%. Adult emergence was significantly reduced, with only 7% emerging at 8% compared to 32% at 4%, and 97% in the control. Al-Bayati (2007) reported complete mortality in 24-h-old pupae of *C. maculatus* treated with *Melia azedarach* extract, attributing this to disruption of the hormonal system. Similarly, Chennaiyan et al. (2016) observed high pupal mortality using ethyl acetate extracts of *D. erecta*.

Table 1. Effect of alkaloid extracts from *D. repens* fruits on the hatching and developmental rates of the cowpea weevil.

% Concentration	% Egg mortality	Rate of egg incubation (Day)	Period of larval in stare (Day)	% Pupal mortality	Period of pupal in stare (Day)	Adult emergence		Total adult emergence (%)
						Male	Female	
Control	0	6.55	11.94	0	6.57	48	52	100
4	60	5.62	16.02	2	7.32	14	24	38
6	74	6.07	21.44	3	7.85	8	15	23
8	100	-	-	-	-	-	-	-
LSD	8.91	N.S	4.06	1.56	N.S	7.80	8.89	12.52

Table 2. Effect of alkaloid extracts from *D. repens* fruits on the final larval stage and its development into adult cowpea weevils.

% Concentration	% Larvae Mortality	Period of last larval in stare (Day)	% Pupal mortality	Pupal in stare (Day)	Adult emergence		Total adult % emergence
					Male	Female	
Control	2	4	2	6.05	25	70	95
4	49	12.50	10	4.66	14	27	41
6	51	16.30	18	5.70	10	21	31
8	82	15.58	15	8.28	0	3	3
LSD	9.28	3.02	6.43	1.59	4.91	6.84	8.43

Table 3. Effect of alkaloid extracts from *D. repens* fruits on the 24-h-old pupal stage and its development in the cowpea weevil.

Concentration (%)	Pupal mortality (%)	Period of pupal in stare (Day)	Adult emergence		Total adult emergence (%)
			Male	Female	
Control	3	7.10	55	42	97
4	68	5	13	19	32
6	79	4.5	9	12	21
8	93	3.5	2	5	7
LSD	10.9	2.03	6.87	6.95	11.47

Effect of alkaloid extracts on 120-h-old pupae and their development

As shown in Table 4, 8% extract caused the highest mortality (77%) in 120-h-old pupae, compared to 60% at 4%, while no mortality occurred in the control. Pupal duration was statistically similar among all treatments. Adult emergence declined from 100% in the control to 23% at 8% and 40% at 4%. Pacheco-Sanchez et al. (2012) found that alkaloids in castor plants inhibit the emergence of *C. maculatus* adults by disrupting metabolic pathways. Early-stage pupae were more susceptible to treatment than late-stage pupae.

Effect of treating cowpea seeds with alkaloid extracts on seed weight loss after six months of weevil infestation

Table 5 shows that seed weight loss was lowest (6.55%) in the 8% treatment after six months, while it reached

28.84% and 44.13% at 6% and 4%, respectively. The highest weight loss was observed in the control (78.84%). Weight loss increased over time, especially in the final three months. Significant differences were confirmed statistically. Jacobson and Crosby (1971) noted that alkaloids exhibit strong physiological toxicity and can act as feeding deterrents and repellents, reducing seed damage.

Effect of treating cowpea seeds with alkaloid extracts on germination rate after six months

As shown in Table 6, no significant differences in seed germination rates were observed among treatments after one and 90 days. However, after 180 days, germination declined to 89% at 8% concentration compared to 98% in the control. Statistical analysis revealed significant differences only between the 8% treatment and control. Overall, germination was not significantly affected by treatment duration.

Table 4. Effect of *D. repens* fruit alkaloid extract on the pupal stage (120-h-old) and its development into adult cowpea weevils.

Concentration (%)	% Mortality	Pupal	Period of Pupal in Stare (Day)	Adult Emergence		Total Adult Emergence (%)
				Male	Female	
Control	0		6.80	57	43	100
4	60		7.60	15	24	40
6	69		7.90	13	18	31
8	77		8	10	13	23
LSD	8.5		N.S	6.30	6.16	10.88

Table 5. Effect of treating cowpea seeds with alkaloid extracts from *D. repens* fruits on seed weight loss over six months following infestation by cowpea weevil adults.

Month	% Seed weight loss at				LSD
	Control	4%	6%	8%	
1	4.9340	3.3766	2.9648	0.0547	0.93
2	7.4612	4.4823	2.4330	0.19740	1.98
3	12.6608	6.1720	2.8421	0.3771	2.07
4	15.4919	8.8304	3.6730	1.0640	2.39
5	17.5406	9.6887	5.9486	2.8430	3.02
6	20.7514	11.5767	10.9812	2.0142	3.93
Total	78.8399	44.1267	28.8427	6.5504	15.03
LSD	3.25	1.53	2.19	1.30	

Table 6. Effect of treating cowpea seeds with alkaloid extracts from *D. repens* fruits on seed germination rate six months after exposure to cowpea weevil.

Treatment	% Seed germination after			LSD
	After one day	After 90 days	After 180 days	
Control	100	98	98	N.S
4	100	97	95	N.S
6	99	95	93	N.S
8	94	92	89	N.S
LSD	N.S	N.S	7.48*	

Conclusion

The results showed that the alkaloid extract of *Duranta* fruits at an 8% concentration had a pronounced effect on the eggs, last larval instar, and pupae at both 24 and 120 hours, and offered clear protection to the seeds against insect infestation six months after treatment, compared to the 4% and 6% concentrations. Considering its low cost and environmentally friendly properties, *D. repens* extract shows promise as a botanical alternative to synthetic chemical pesticides.

Recommendations

The active compounds present in the alkaloid extract should be purified and subjected to further testing to assess their specific effects on the development of the pest. Additional toxicological studies are necessary to evaluate the safety of using *Duranta repens* extracts, particularly concerning potential risks to human health when applied to seeds. Moreover, the efficacy of these alkaloid extracts should be validated under optimal storage conditions to ensure long-term protection.

Authors' Contributions

EAM, TAH, and TAT designed, formulated, and laid out the study, and conducted the experiments. TAH and TAT collected, organized, and analyzed the data, and also provided technical assistance. EAM supervised the work. EAM, TAH, and TAT wrote the manuscript, and EAM proofread the final version.

Research Funding

This research did not receive any grant from funding agencies.

Conflict of Interest

The authors declare no conflict of interest.

Sustainable Development Goals Targeted

SDG 2: Zero Hunger

SDG 12: Responsible Consumption and Production

SDG 15: Life on Land

References

- Abbott, W.S., 1925. A method for computing the effectiveness of an insecticide. *Journal of Economic Entomology* 18, 265-267.
- Al-Bayati, I.A., 2007. The effect of the oil extract of *Melia azedarach* fruits on the biological performance of the southern cowpea insect *Callosobruchus maculatus* F. under laboratory conditions. Master's thesis, College of Science for Women, University of Baghdad.
- Al-Fahdawi, B.H., 2021. A study of the effect of some plant powders and extracts on some life aspects of the southern cowpea beetle *Callosobruchus maculatus* under laboratory conditions. Master's thesis, College of Education, Al-Mustansiriya University, pp. 118.
- Al-Hamdani, K.M., 2022. The effectiveness of some physical and biological control methods against the southern cowpea beetle. Master's thesis, College of Agricultural Engineering, Al-Furat University, 86 pp.
- Mosaddik, A., Nikkon, F., Hasan, S., Rahman, M.M., Parvin, F., Haque, M.E., 2007. Pesticidal evaluation of *Duranta Repens* Linn. against *Tribolium Castaneum* (Herbst). *Natural Products* 3(2), 102-106.
- Balandrin, M.F., Klocke, J.A., Wurtele, E.S., Bollinger, W.H., 1985. Natural plant chemicals: sources of industrial and medicinal materials. *Science*, 228(4704), 1154-1160.
- Beck, S.P., Reese, J.C., 1975. Insect-plant interaction: Nutrition and metabolism. In: Wallace, J.W.,

- Mansell, R.L. (Eds.), Biochemical Interaction Between Plant and Insects, Vol. 10. Plenum Press, New York, pp. 41-42.
- Chennaiyan, V., Sivakami, R., Jeyasankar, A., 2016. Effect of *Duranta erecta* Linn (Verbenaceae) leaf extracts against armyworm *Spodoptera litura* and cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae). International Journal of Advanced Research in Biological Sciences 3(3), 2016.
- Coulibaly, O., Alene, A.D., Manyong, V., Sanogo, D., Abdoulaye, T., Chianu, J., Fatokun, C., Kamara, A., Tefera, H., Boukar, O., 2009. Situation and outlook for the tropical legumes improvement, pp. 1-27.
- El-Sawaf, S.K., 1956. Some factors affecting the longevity, oviposition and rate of development in the southern cowpea weevil *Callosobruchus maculatus* (F) (Coleoptera: Bruchidae). Bulletin of the Society of Entomology of Egypt 40(29), 29-95.
- Francis, O.K., Kerem, Z., Marker, H.P., Becker, K., 2002. The biological action of saponin in animal systems. British Journal of Nutrition 88(6), 587-605.
- Gates, B., Millenda, 2012. African legume market dynamics, 110 pp.
- Gilman, E.D., 1999. *Duranta repens*: Fact Sheet FSB-190. Institute of Food and Agricultural Sciences, University of Florida.
- Girgis, S.J., Daibes, H.K., Muhammad, M.A.K., 2000. Field Crop Insects. Ministry of Higher Education and Scientific Research, University of Mosul, pp. 330.
- Harborne, J.B., 1973. Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis. Chapman and Hall, London, pp. 287.
- Harborne, J.B., 1984. Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis, 2nd ed. Chapman and Hall, London and New York, pp. 288.
- Hill, D.S., 1990. Pests of Stored Products and Their Control. CRC Press, Boca Raton, pp. 27.
- Jacobson, M., Crosby, D.G., 1971. Naturally Occurring Insecticides. Marcel Dekker Inc., New York, pp. 585.
- Koona, P., Bouda, H., 2006. Biological activity of *Pachypodanthium staudtii* (Annonaceae) against the bean beetle *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae). Journal of Applied Sciences Research 2, 1129-1131.
- Mabry, T.J., Markham, K.R., Thomas, M.B., 1970. The Systematic Identification of Flavonoids. Springer Verlag, New York, pp. 220.
- Massango, H., Faroni, L., Haddi, K., Heleno, F., Viteri, L., Oliveira, E., 2017. Toxicity and metabolic mechanisms underlying the insecticidal activity of parsley essential oil on bean weevil *Callosobruchus maculatus*. Journal of Pest Science 90, 723-733.
- Nash, R.J., Fenton, K.A., Gatehouse, A.M.R., Bell, E.A., 1986. Effect of the plant alkaloid castanospermine as an antimetabolite of storage pests. Entomologia Experimentalis et Applicata 42(1), 71-77.
- Pacheco-Sanchez, C., Villa-Ayala, P., Montes-Belmont, R., Figueroa-Brito, R., Jimenez-Perez, A., 2012. Effects of *Ricinus communis* extract on weight and mortality of *Scyphophorus acupunctatus* (Coleoptera: Curculionidae). International Journal of Applied Science and Technology 2(1), 83-94.
- Roy, S., Muraleedharan, N., Handique, G., Rahman, A., Barua, A., 2016. Aqueous extracts of *Duranta repens* (Verbenaceae) as an alternative to control tea red spider mite *Oligonychus coffeae* (Acari: Tetranychidae). International Journal of Tropical Insect Science 36, 82-90.
- SAS Institute, 2010. SAS/STAT User Guide for Personal Computers, Release 6.12. SAS Institute Inc., Cary, N.C., USA.
- Singh, B., 2006. Safe storage of legume seeds from pests - A case study in cowpeas. ASA-CSSA-SSSA International Annual Meetings. IITAc/O.L.W. Lambourn and Co., Croydon, CR93EE, England. Academiae Scientiarum Hungaricae 7(4), 453-463.
- Varela, A.M., 2012. Cowpea damaged by cowpea beetles and weevils (*Callosobruchus* spp.). ICIPE.
- Walker, K., 2008. Cowpea weevil *Callosobruchus maculatus*. Pest and Diseases Image Library. Updated 25 January 2008. Available online: <http://padil.gov.au>.
- Zannou, E.T., Galitho, I.A., Huignard, J., Monge, J.P., 2003. Life history of flight morph females of *Callosobruchus maculatus* F. Journal of Insect Physiology 49, 575-582.