# Biology and biointensive management of *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae) – a pest of kidney beans wordwide

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## Abstract

Insects in the family Bruchidae are commonly called “pulse weevils” and are cosmopolitan in distribution. These beetles cause serious economic loss of legume commodities both in fields and every year. Pulses constitute the main source of protein for developing countries like India where per capita consumption of animal protein is very low. Due to their high protein quantity and quality, legumes are considered as "poor man’s meat". A large number of non-native pulse beetles have crossed geographical boundaries and becoming cosmopolitan in distribution, thus posing major pest problem worldwide. A kidney bean pest, *Acanthoscelides obtectus* (Say) (Coleoptera: Chrysomelidae) native to Central and Southern America has recently infested stored kidney beans in the Indian subcontinent. The present investigations determined life cycle, behaviour, facundity, pest status, host range and developmental compatibility on diffent legumes and different cultivars of kidney beans. Acetone and alcoholic extracts of some botanicals have been tested and proved effective to suppress facundity, egg hatch and adult longivity of the pest population under laboratory conditions.

Keywords: *Acanthoscelides obtectus,* biology, resistance, developmental compatiblity, botanical management

## 1. Introduction

Most pulses have 17- 24% protein content which are 2.3 times higher than traditional cereals. Any stored materials of plant origin are vulnerable to attack by insect pests if the pulses are dried and stored improperly. The common bean, *Phaseolus vulgaris* can be infested by the common bean weevil, *Acanthoscelides obtectus* and Mexican bean weevil, *Zabrotes subfasciatus*, both in fields and stores and rendered unfit for consumption. The geographical distribution of both species is now almost cosmopolitan (Hill, 2002; Thakur, 2012). Common bean weevil is more common in temperate environments, while Mexican bean weevil prevails in tropical environments. The indiscriminate use of chemical pesticides and fumigants in storage have led to a number of problems including insect resistance, deleterious effects to non-target organism, toxic residues in food grains and environmental pollution. Synthetic insecticides can leave potentially toxic residues in food products and can affect non-target organisms in the environment (Isman, 2006). Hence, there is a need to implement safe and eco-friendly alternatives to protect stored grain products and to restrict the use of toxic chemicals.

Plant derived extracts and phytochemicals have been intensively investigated in an effort to develop alternatives to conventional insecticides with reduced health and environmental impacts. Several researcher have explored the utility of plant products as a potential source of managing agricultural pests. Therefore, in the present investigations two plants, *Juglans regia* Linnaeus and

*Picrorhiza kurroa* Royle ex Benth have been investigated to control the *A. obtectus* in stores. *J. regia* is a member of family Juglandaceae, commonly known as walnut, is an important species of deciduous trees found principally in temperate areas across the world. Leaves have been used in the cosmetic and pharmaceutical industries (Oliviera et al., 2008) and root bark contains naphthoquinones such as juglone and bisjuglone, used in dentistry and cosmetics (Hamayun et al., 2006). In the present study leaves, of walnut were used. *P. kurroa* belongs to family Scrophulariacae, commonly known as kutki, is a small important alpine herb, growing at an altitude of 3,000-5,000 meters above mean sea level. The roots and rhizomes of *P. kurroa* are used in traditional and modern medicines for liver disorders, fever, asthma and jaundice. In Himachal Pradesh, kutki is found in the Thamsar and Dianasar areas of Bara and Chhota Bhangal in Kangra district, Pangi, Bharmaur of Chamba district, Lahaul, Kinnaur and Sirmaur. Most of the properties of this plant are attributed to an active constituent known as 'kutkin' which is a mixture of kutkoside and picroside. In the present study roots of kutki were used. Therefore, in an attempt to find natural and cheaper methods of control, bioefficacy of *J. regia* and *P. kurroa* have been tested on *A. obtectus* and methanol extract of both the plants were effective in increasing adult mortality, reducing the fecundity and F1 adult emergence.

## 2. Materials and Methods

### *2.1. Sample collection*

The infested and uninfested seeds of *P. vulgaris* were collected from different areas of the Himachal Pradesh. These seeds were cultured under controlled condition of temperature and relative humidity. Cultures were propagated in different Petri-dishes (90 mm diameter, Tarsons and 105 mm diameter, Borosil) and wire mesh cages (12×10×10 $cm^3$) along with host seeds. Adults thus emerged were identified as *A. obtecuts* according to dichotomous keys (Arora, 1977, Johnson, 1990 and Kingsolver, 2004).

### *2.2. Maintenance of cultures*

Reserve cultures of *A. obtectus* was maintained in the laboratory in 500 ml glass jars covered with muslin cloth. One pair of freshly emerged male and female were placed in each Petri-dish. A typical culture contains a pair of male and female insects. The batches of freshly laid eggs were separated regularly until the female died. Life cycle of the pests from the day of egg laying on host seeds and their development up to adult insects were carefully noted.

### *2.3. Collection and identification of the plant*

The plants were collected and then identified by a taxonomic key developed by Eichler (1883). The plant materials were washed and air dried in the shade before use. Plant extracts was prepared in different solvents according to the method of Talukdar and Howse (1994) with a few modifications. Plant extracts were prepared in methanol. Twenty grams of ground leaves of plants were separately mixed with 100 ml of different solvents, stirred for 30 min. using a magnetic stirrer and then left to stand for 24 hours. The mixture was then filtered through Whatman # 1 paper, and the solids were stirred again for 15 minutes with the same solvent and filtrates were combined. After complete evaporation of solvent, the final crude extracts were dissolved in solvent before use. Different concentration levels, 2, 4, 6, 8% were prepared and 1ml of each concentration was applied to the filter papers placed in the Petri-dishes. The papers containing different concentration of botanicals were air dried until the complete evaporation of

solvents. Concentrations used were determined after conducting preliminary experiments to standardize the doses and then used for assessing their insecticidal and seed protective effects.

Methanol (1ml each) treated filter paper placed in Petri-dishes were used as controls. Then 50g seeds of *P. vulgaris* were placed on the extract treated filter papers inside the Petri-dishes. Five pairs of freshly emerged adults of *A. obtectus* were released in different Petri-dishes which were covered for the next few days for observation. The number of dead insects in each dish was counted after 24, 48, 72 and 96 h and also up to 100% mortality. All treatments were arranged in completely randomized design and all concentration levels were replicated three times.

*2.4. Data analysis*

Percentage insect mortality was calculated using Abbott's formula (Abbott, 1925) as follows:

$$\text{Correct \% mortality} = 1 - C_n - C_T / C_T \times 100$$

Where, $C_n$ – number of insects in control and $C_T$ – number of insects in treatment.

Duncan's Multiple Range Test (DMRT) was applied to all means using SPSS–16 software.

Bioefficacy of *J. regia* and *P. kurroa* as an insecticide against *A. obtectus* was studied in terms of mortality of adult pests, numbers of eggs laid and number of $F_1$ progeny emerged.

## 3. Results and Discussion

*3.1. Biology*

To study the biology of *Acanthoscelides obtectus* on *Phaseolus vulgaris*, all observations were recorded in the laboratory under natural temperature and relative humidity. This pest starts to infest beans in field and continues to develop during storage. Life cycle is holometabolous. These bean weevil species are cosmopolitan insect pests and feed on wild and cultivated common beans (Alvarez et al., 2005, Paul et al., 2009; Thakur, 2012). This pest is multi-voltine and completes 6-8 overlapping generation in a year. This pest shows sexual dimorphism, males were active, smaller in size with vertical pygidium, whereas females bulky with sub vertical pygidium. Like other bruchids, adults of *A. obtectus* do not feed, are weak fliers, and feign death when disturbed. Freshly emerged adults copulate at any time with in the 24 hours after their emergence. During copulation male normally raises its fore and middle legs to hold the female. Copulation lasted for 4-5 minutes.

Oviposition starts within few hours after mating. The number of eggs laid per female per day was observed and the freshly emerged female laid the maximum number of eggs on the first and second day of oviposition and then oviposition decreased subsequently. The female glued only a small number of eggs to the seeds, while the majority of the eggs were released freely among the seeds. Freshly laid eggs were milky white and ellipsoidal in shape. Oviposition lasted for 7-10 days and the incubation period was 8-10 days. Since most of the eggs were not glued onto the seeds it is essential for the freshly hatched first instar larva to find and select the host seeds for the remaining stages of development and food requirements. Females of *A. obtectus* lay eggs loosely among the seeds the 1st instar larva burrows into the bean (Parsons and Credland, 2003; Paul et al., 2009; Thakur, 2012).

Further development of successive larval instars was completed inside the host seeds. All the larval instars were voracious feeders. The last larval instar prepares an emergence window before molting to pupal stage. Larval development was completed in 14 -20 days. The pupal stage also

completes development inside the host seeds and pupal development took 14-17 days. The total life cycle required 44 -54 days. Similar observations on biology, oviposition and larval - pupal development of bruchids have been observed by Southgare (1979) Thakur and Banyal (2007).

*3.2. Biointensive management*

The use of natural products is an important alternative for the control of stored product pests. In the present investigations leaves of *Juglans regia* and root extracts of *Picrorhiza kurroa* were toxic to the adults of *A. obtectu*. All application rates produced 100% mortality of both males and females compared to the controls where 100% mortality was recorded on the 17th day. Methanol extracts of *J. regia* and *P. kurroa* at 8% concentration were more effective, resulting in 100% mortality after the 6th day and 5th day respectively (Fig. 1, 2 and Table 1, 2). A 6% concentration of *J. regia* gave 100% mortality after the 7th day while same concentration of *P. kurroa* extract in methanol, resulted in 100% mortality on the 6th day. Concentration of 2 and 4% of *J. regia* gave 100% mortality after the 11th and 9th day respectively whereas the same concentration of *P. kurroa* gave 100% mortality after the 8th and 7th day respectively (Fig. 1, 2 and Table 1, 2). Essential oils and natural products affect insects as contact insecticides and also disrupt metabolic pathways (Saxena et al., 1992), act as repellents (Plarre et al., 1997), and can deter or modify oviposition (Abd-Elhady, 2012). *P. kurroa* extract was more effective than *J. regia* at all concentration levels. An 8% concentration of *P. kurroa* gave 100% mortality on the 5th day whereas *J. regia* resulted in 100% mortality on the 6th day after treatment. Renuka et al. (2014) recorded 100% mortality of *A. obtectus* after 5.66±0.33 days at 8% concentration of *Bidens pilosa* extract in methanol. Koona and Bouda (2006) prepared extracts of *Pachypodanthium staudtii* and showed that 0.16% (w/w) killed 100% adults of *A. obtectus* 96 h after treatment.

The methanol extract of *J. regia* and *P. kurroa* at all concentration levels significantly reduced the number of eggs on the seeds as compared to the control where a maximum of 142.67±4.48 eggs were recorded. An 8% methanol extract of *J. regia* and *P. kurroa* resulted in 52.33±1.45 and 50.33±2.60 eggs respectively (Table 3). In the case of a 6% concentration of *J. regia* and *P. kurroa,* total numbers of 60.33±1.45 and 71.66±1.76 eggs were observed respectively. Total numbers of 78.66±0.88 and 88.33±1.45 eggs were observed under 4% concentrations of *J. regia* and *P. kurroa* respectively and under 2% concentrations of *J. regia* and *P. kurroa* each 95.33±1.45 and 100.67±1.20 eggs were recorded respectively. However, results are contrary to the findings of Jovanovic et al. (2007) who reported ineffectiveness of *Sambucus nigra* L. and *J. regia* extracts against *A. obtectus*. Significant decrease in fecundity, fertility and $F_1$ emergence of *A. obtectus* and *Z. subfasciatus* observed when crushed leaves of *Tetradentia riparia* at 4% application rate were applied (David et al., 1998). Vanmathi et al. (2010) recorded maximum oviposition deterrent of 84.32% of *C. maculatus* against aqueous extract of *Ocimum tenuiflorum* at higher concentrations.

The methanol extract significantly reduced the F1 progeny at all concentration levels as compared to control where a maximum 114.67±6.07 F1 adults emerged. The minimum number of 30.33±1.45 and 33.66±2.02 adults emerged under 8% concentration of *J. regia* and *P. kurroa* respectively. Under 6% concentration of *J. regia* and *P. kurroa* extracts 42.35±1.76 and 50.33±2.02 adults emerged respectively. Whereas in 4% concentration of *J. regia* and *P. kurroa* 88.33±1.45 and 62.66±2.02 and under 2% concentration 100.67±1.20 and 33.66±1.76 adults emerged (Table 3). The extracts of *Urtica dioica* L. and *Taraxacum officinale* L., were tested against the bean weevil, *A. obtectus* for insecticidal potential to protect stored legume seeds in terms of their repellency, toxicity and reduction of F1 progeny and significant insecticidal

activities, effectiveness in repellency and reduction in F1 progeny exhibited by 100% concentrated extract was recorded (Jovanovic et al., 2007). High mortality rates and inhibition of F1 progeny production of *C. maculatus* were recorded by contact with seeds treated with essential oil of *Aatemisia judaica* (Abd-Elhady, 2012). The powder of orange peel applied at 15 gm against *Z. subfasciatus* significantly reduced the F1 progeny (Dawit and Bekelle, 2010).

The present study thus showed that the methanol extracts of *J. regia* and *P. kurroa* were effective against *A. obtectus* at all application rates in increasing mortality, decreasing fecundity and decreasing progeny emergence. The plant extracts were significantly different from the controls at all concentrations applied and best results were obtained at 8% application of plant extracts. Both plants could be used as potential botanical insecticides for stored grain pests but more research is required for commercial development on an enlarged scale.

**References**

Abbott, W.S., 1925. A method of computing the effectiveness of insecticides. Journal of Economic Entomology 18, 265-267.

Abd-Elhady, H.K., 2012. Insecticidal activity and chemical composition of essential oil from *Artemisia judaica* L. against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of Plant Protection Research 52, 347-352.

Alvarez, N., Hossaert-McKey, M., Rasplus, J.Y., McKey, D., Mercier, L., Soldati, L., Aebi, A., Shani, T., Benrey, B., 2005. Sibling species of bean bruchids: a morphological and phylogenetic study of *Acanthoscelides obtectus* Say and *Acanthoscelides obvelatus* Bridwell Schwester Arten der Bohnen Bruchiden: eine morphologische und phylogenetische Studie über *Acanthoscelides obtectus* und *A. obvelatus*. Journal of Zoological Systematics and Evolutionary Research 43, 29-37.

Arora, G.L., 1977. Taxonomy of the Bruchidae (Coleoptera) of Northwest India. Part 1. Oriental Insects Supplement 7, 1-132.

David, K.W., Florence, V.D., James, L.C., Luc, V.P., 1998. Oviposition patterns in two species of bruchids (Coleoptera: Bruchidae) as influenced by the dried leaves of *Tetradentia riparia*, a perennial mint (Lamiales: Lamiaceae) that suppresses population size. Environmental Entomology 21, 1121-1129.

Dawit, K.J., Bekelle, J., 2010. Evaluation of orange peel *Citrus sinensis* (L.) as a source of Repellent, Toxicant and Protectant against *Zabrotes subfasciatus* (Coleoptera: Bruchidae). Momona Ethiopian Journal of Science 2, 61-75.

Eichler, A.W., 1883. Syllabus der Vorlesungen iiber specielle und Medicinisch-Pharmaceutische Botanik. 3rd ed.

Hamayun, M., Afzal, S. Khan, M.A., 2006. Ethnopharmacology, indigenous collection and preservation techniques of some frequently used medicinal plants of Utror and Gabral, district Swat, Pakistan. African Journal of Traditional, Complementary and Alternative Medicines 3, 57-73.

Hill, D.S., 2002. Pests of Stored Food stuffs and Their Control. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Isman, M.B., 2006. Botanical insecticides, deterrents and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology 51, 45-66.

Johnson, C.D., 1990. Systematics of the seed beetle genus *Acanthoscelides* (Bruchidae) of Northern South America. Transactions of the American Entomological Society 116, 297-618.

Jovanovic, Z., Kostic, M., Popovic, Z., 2007. Grain-protective properties of herbal extracts against the bean weevil *Acanthoscelides obtectus* Say. Industrial Crops and Products 26, 100-104.

Kingsolver, J. M., 2004. Hand book of Bruchidae of the United States and Canada. Vol. 1. U.S. Department of Agriculture, Agricultural Research Service, Technical Bulletin 1912. 324 pp.

Koona P, Bouda H., 2006. Biological activity of *Pachypodanthium staudtii* (Annonaceae) against the Bean Beetle *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae). Journal of Applied Science Research 2, 1119-1131.

Mallqui, K.S.V., Oliveira E.E., Guedes, R.N.C., 2013 Competition between the bean weevils *Acanthoscelides obtectus* and *Zabrotes subfasciatus* in common beans. Journal of Stored Products Research 55, 32-35

Oliviera, I., Sousa, A., Ferreira, I., 2008. Total phenols, antioxidant potential and antimicrobial activity of walnut (*Juglans regia* L.) green husks. Food Chemistry and Toxicology 46, 2326-31.

Parsons, D.M.J., Credland, P.F., 2003. Determinants of oviposition in *Acanthoscelides obtectus*: a nonconformist bruchid. Physiological Entomology 28, 221-231.

Paul, U.V., Lossini, J.S., Edwards, P.J., Hilbeck, A., 2009. Effectiveness of products from four locally grown plants for the management of *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman) (both Coleoptera: Bruchidae) in stored beans under laboratory and farm conditions in Northern Tanzania. Journal of Stored Product Research 45, 97-107.

Plarre R., Poschko M., Prozell S., Frank A., Wohlgemuth R., Phillips J.K. 1997. Effects of oil of cloves and citronerol, two commercially available repellents, against the webbing clothes moth *Tineola bisselliella* Hum. (Lepidoptera: Tineidae). Journal of Pest Science 70, 45– 50.

Renuka, Thakur, D.R., Sharma, R.K., 2014. Bioefficacy of *Bidens pilosa* L. against *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman), stored pests of kidney beans, worldwide. International Journal of Agriculture and Crop Sciences 7, 1470-1477.

Renuka, Thakur, D.R., Sharma, R.K., 2014. Bioefficacy of *Bidens pilosa* L. against *Acanthoscelides obtectus* (Say) and *Zabrotes subfasciatus* (Boheman), stored pests of kidney beans, worldwide. International Journal of Agriculture and Crop Sciences 7, 1470- 1477

Saxena C.R., Dixit P.D., Harshan V. 1992. Insecticidal action of *Lantana camara* against *Callosobruchus chinensis* (Coleoptera: Bruchidae). Journal of Stored Products Research 28, 279–281.

Southgate, B.J., 1979. Biology of Bruchidae. Annual Review of Entomology 24, 449-473.

Talukdar, F.A., Howse, P.E., 1994. Repellant, toxic and food protectant effects of pithraj, *A. phanamixis* polystachya extracts against the pulse beetle, *Callosobruchus chinensis* in storage. Journal of Chemical Ecology 20, 899-908.

Thakur D.R., 2012. Taxonomy, distribution and pest status of Indian biotypes of *Acanthoscelides obtectus* (Coleoptera: Chrysomelidae: Bruchinae) – a new record. Pakistan Journal of Zoology 44, 189-195.

Thakur, D.R., Banal, H.S., 2007. Developmental attributes and larval morphology of *Caryedon crineus* Arora (Bruchidae: Coleoptera). Indian Journal of Entomology 69, 293-297

Vanmathi, S.J., Padmalatha, C., Singh, R.A.J.A., Suthakar, S., 2010. Efficacy of selected plant extracts on the oviposition deterrent and adult emergence activity of *Callosobruchus maculatus* (F.) (Bruchidae: Coleoptera). Biological Agriculture and Horticulture: An International Journal for Sustainable Production Systems 19, 19-27.

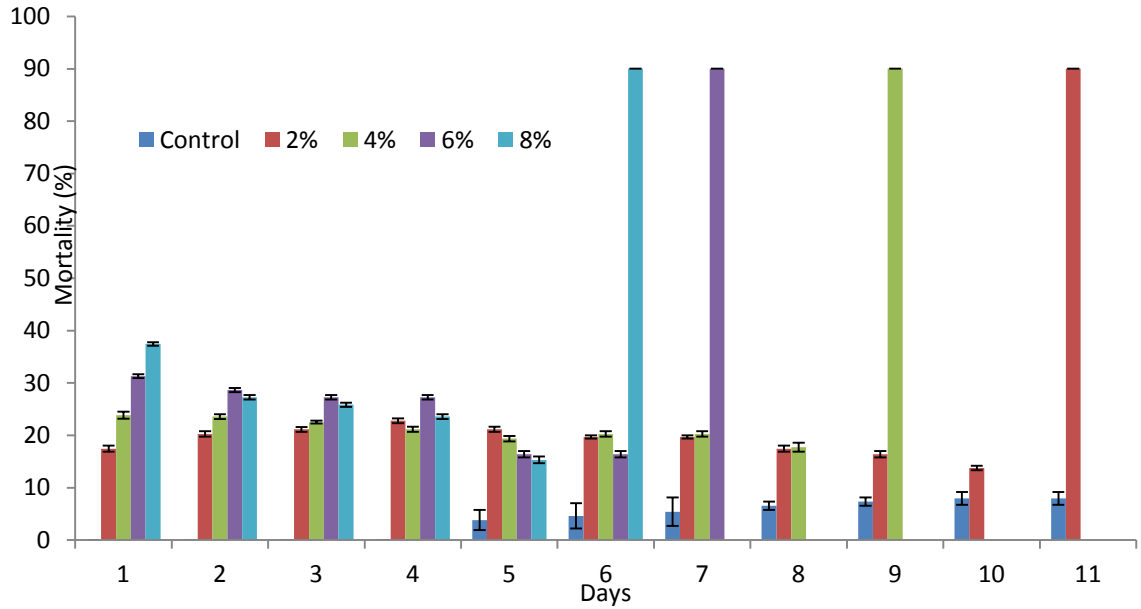


**Figure 1** Percent mortality of adult *A. obtectus* treated with different concentrations of *J. regia* extract in methanol.

**Table 1** Percent mortality of adult *A. obtectus* treated with different concentrations of *J. regia* extract in methanol.

| Dose (%) | Day wise insect mortality (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| Control | 0.00±0.00$^{e}$ | 0.00±0.00$^{d}$ | 0.00±0.00$^{e}$ | 0.00±0.00$^{d}$ | 3.82±1.91$^{d}$ | 4.62±2.41$^{d}$ | 5.42±2.71$^{c}$ | 6.53±0.79$^{c}$ | 7.33±00.79$^{c}$ | 7.94±1.22$^{c}$ | 7.94±1.22$^{b}$ |
| 2 | 17.44±0.58$^{d}$ | 20.26±0.51$^{c}$ | 21.13±0.46$^{d}$ | 22.78±0.46$^{b}$ | 21.13±0.49$^{a}$ | 19.67±0.30$^{b}$ | 19.67±0.30$^{b}$ | 17.44±0.58$^{b}$ | 16.41±0.61$^{b}$ | 13.76±0.42$^{b}$ | 90.04±0.00$^{a}$ |
| 4 | 23.83±0.68$^{c}$ | 23.58±0.45$^{b}$ | 22.52±0.27$^{c}$ | 21.13±0.49$^{c}$ | 19.36±0.52$^{ab}$ | 20.26±0.51$^{b}$ | 20.26±0.51$^{b}$ | 17.75±0.86$^{b}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ |
| 6 | 31.31±0.37$^{b}$ | 28.66±0.39$^{a}$ | 27.27±0.40$^{a}$ | 27.27±0.40$^{a}$ | 16.41±0.61$^{bc}$ | 16.41±0.61$^{c}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ |
| 8 | 37.47±0.34$^{a}$ | 27.27±0.40$^{a}$ | 25.84±0.42$^{b}$ | 23.58±0.45$^{b}$ | 15.31±0.64$^{c}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ |

Values are mean ±SE of three replicates. The data original mortality of *A. obtectus* were corrected by Abbott's formula and then transformed into arcsin √percentage values before statistical analysis. Values followed by different letters within a column are significantly different at the 5% level of probability (Duncan's Multiple Range Tests). *D (day). **90.04 represent 100% mortality of pests.

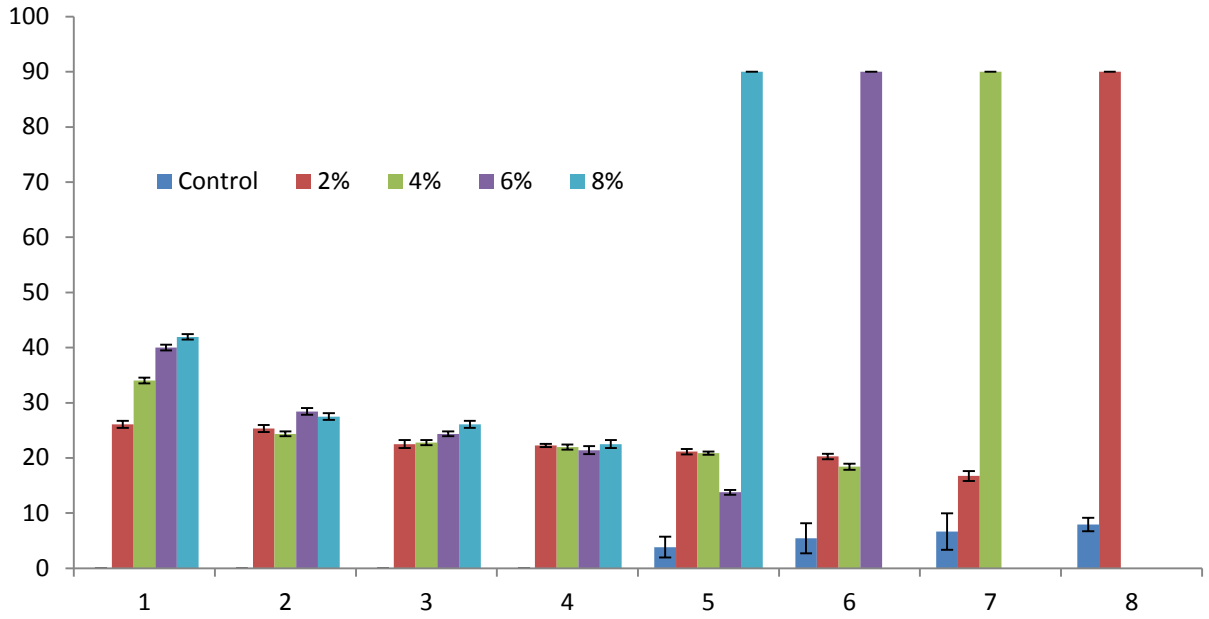


**Figure 2** Day wise percent mortality of adult *A. obtectus* treated with different concentrations of *P. kurroa* extract in methanol.

**Table 2** Day wise mortality of adult *A. obtectus* treated with different concentrations of *P. kurroa* extracts in methanol.

| Dose (%) | Day wise insect mortality (%) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Control | 0.00±0.00$^{e}$ | 0.00±0.00$^{c}$ | 0.00±0.00$^{d}$ | 0.00±0.00$^{c}$ | 3.82±1.91$^{d}$ | 5.42±2.71$^{c}$ | 6.64±3.32$^{c}$ | 7.94±1.22$^{b}$ |
| 2 | 26.08±0.63$^{d}$ | 25.34±0.64$^{b}$ | 22.50±0.72$^{c}$ | 22.25±0.27$^{a}$ | 21.13±0.49$^{b}$ | 20.26±0.51$^{b}$ | 16.73±0.90$^{b}$ | 90.04±0.00$^{a}$ |
| 4 | 34.04±0.54$^{c}$ | 24.35±0.43$^{b}$ | 22.78±0.46$^{bc}$ | 21.97±0.47$^{a}$ | 20.85±0.29$^{b}$ | 18.42±0.55$^{b}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ |
| 6 | 40.02±0.51$^{b}$ | 28.43±0.60$^{a}$ | 24.35±0.43$^{b}$ | 21.40±0.73$^{a}$ | 13.76±0.42$^{c}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ |
| 8 | 41.95±0.50$^{a}$ | 27.50±0.61$^{a}$ | 26.08±0.63$^{a}$ | 22.50±0.72$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ | 90.04±0.00$^{a}$ |

Values are mean ±SE of three replicates. The data original mortality of *A. obtectus* were corrected by Abbott's formula and then transformed into arcsin √percentage values before statistical analysis. Values followed by different letters within a column are significantly different at the 5% level of probability (Duncan's Multiple Range Tests). *D (day). **90.04 represent 100% mortality of pests.

**Table 3** Number of eggs laid and $F_1$ adults emerged of *A. obtectus* treated with different doses of *J. regia* and *P. kurroa* extracts in methanol.

| Plant | Dose (%) | Number of eggs laid | Number of $F_1$ adults emerged |
|---|---|---|---|
| *J. regia* | Control | 142.67±4.48[a] | 114.67±2.60[a] |
| | 2 | 95.33±1.45[b] | 71.66±1.76[b] |
| | 4 | 78.66±0.88[c] | 50.33±1.45[c] |
| | 6 | 60.33±1.45[d] | 42.33±1.76[d] |
| | 8 | 52.33±1.45[e] | 30.33±1.45[e] |
| | F | 236.21*** | 318.83*** |
| *P. kurroa* | Control | 142.67±4.48[a] | 114.67±2.60[a] |
| | 2 | 100.67±1.20[b] | 81.33±1.76[b] |
| | 4 | 88.33±1.45[c] | 62.66±2.02[c] |
| | 6 | 71.66±1.76[d] | 50.33±2.02[d] |
| | 8 | 50.33±2.60[e] | 33.66±2.02[e] |
| | F | 178.70*** | 270.88*** |