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Efficacy of some indigenous plant extracts as grain protectant against pulse beetle, *Callosobruchus chinensis* L.

M.A. Hossain and M.A. Haque
Department of Entomology, Hajee Mohammad Danesh Science and Technology University, Dinajpur and Department of Entomology, BAU, Mymensingh

Abstract: The experiments were conducted to study the efficacy of some indigenous leaf and seed extracts against pulse beetle, *Callosobruchus chinensis* (L.) on chickpea seeds. The botanicals were extracted by using acetone, ethanol, n-hexane, petroleum ether and water. The efficacy was evaluated by considering oviposition, adult emergence, seed infestation and weight loss caused by the insect. All the tested extracts except methi were found effective significantly to check the oviposition, adult emergence, seed infestation and weight loss as compared to control. However, acetone and ethanol extracts of neem seed provided the best protection of chickpea seed against the pulse beetle. The extracts of neem seed had no adverse effects on seed germination upto three months of storage.
Key words: Botanical extracts, oviposition, adult emergence, seed infestation, weight loss, germination, *Callosobruchus chinensis*.

Introduction

Pulses are economically important crops in Bangladesh because of their high protein content (20-40%) and are fairly good sources of vitamins, calcium and iron for the under privileged people, who can't afford animal proteins (Bhalla *et al*. 2008). After harvest of pulse crops, the farmers usually store the seeds throughout the year. The ways the pulse seeds stored are prone to the attack of the insect pests. Among the insect pests, pulse beetle, *Callosobruchus chinensis* (L.) is known as major destructive pest of chickpea in storage (Aslam 2004), which lead to a reduction of commercial value and seed germination, in addition the grains become unfit for human consumption (Atwal and Dhaliwal 2005). A survey indicated that pulse seeds were damaged 4 to 98% due to pulse beetle infestation after 6-8 months of storage (Mookherjee *et al.* 1970).

Generally the pesticides are used for the control of insect pests but due to their several drawbacks researchers are trying to adopt alternative methods of pest control (Mahmud *et al.* 2002). The use of locally available indigenous plant materials in the control of pests are an ancint technology and used in many parts of the world (Roy *et al.* 2005). The pest controlling efficacy of many plant derivatives has already been proved against several storage pests (Rahman and Talukder 2006, Mahadi and Rahman 2008). These are also having less environmental impact in terms of insecticidal hazards and could benefit our agricultural sector. Beside, these botanical pesticides are cheaper, easy to process and raw materials are available at village level. The use of simple crude botanical leaf and seed extracts is important for grain protection by resource limited farmers in developing countries like Bangladesh. The present experiment was therefore, carried out to evaluate the effects of leaf and seed extracts of some indigenous plants against pulse beetle, *C. chinensis* to protect chickpea seeds in storage.

Materials and Methods

The experiment on management of pulse beetle, *C. chinensis* by using plant extracts on chickpea seeds in storage was conducted in the laboratory of the Department of Entomology, Bangladesh Agricultural University (BAU), Mymensingh. The indigenous plant materials which are used in this study for extraction are presented in Table-1.

Table 1. List of indigenous plants tested against *C. chinensis.*

Serial no.	Common name	Scientific name	Family	Plant parts used
1	Mehogani	*Swietenia mehagoni*	Meliaceae	Seed
2	Neem	*Azadirachta indica*	Meliaceae	Seed
3	Sunhemp	*Crotalaria juncea*	Leguminosae	Seed
4	Pithraj	*Aphanamixis polystachya*	Meliaceae	Seed
5	Bishkatali	*Polygonum hydropiper*	Polygonaceae	Seed
6	Tobacoo	*Nicotiana tabacum*	Solanaceae	Leaf
7	Sweet sop	*Annona squamosa*	Annonaceae	Seed
8	Castor	*Ricinus communis*	Euphorbiaceae	Seed
9	Methi	*Trigonella foenum-graecum*	Fabaceae	Seed
10	Jatropha	*Jatropha curcas*	Euphorbiaceae	Seed
11	Tishi	*Linium usitatissimum*	Linaceae	Seed
12	Marigold	*Tagetes erecta*	Compositae	Leaf

Preparation of botanical extracts: Fresh green leaves and seeds of tested plants were collected and kept in the laboratory for 7 days for air drying followed by one day sun drying before making powder. Electric grinder was used to have coarse powder then these were passed through a 60-mesh sieve to get fine powder. Afterwards, 10 grams of each category of powder were separately mixed with 100 ml of different solvents (n-hexane, acetone, methanol, petroleum ether and distilled water), stirred for 30 minutes and left stand for next 24 hours. The mixture was then filtered through a fine cloth and again through Whatman no.1 filter paper. The filtrates were taken into round bottom flasks and condensed by evaporation of solvent in a water bath at 45^o, 50^o, 55^o, 70^o and 80^o C temperature for acetone, n-hexane, methanol, petroleum ether and water extracts, respectively

(Kamruzzaman *et al.* 2004) to make it 10 ml from which 10% concentration was prepared for experimental use.

Experimental protocol: Fifty gram of healthy chickpea seeds were taken in a plastic container (300 ml) and mixed with 10% of each tested extract (v/w) and then air dried for 30 minutes. Five pairs of newly emerged one day old adult beetles were released in each plastic container and the mouth was closed with its lid. Each treatment was replicated thrice including control. All treated containers were kept at ambient room temperature (27-30^oC) in the laboratory for oviposition. After 7 days, dead and alive beetles were removed from each container and seeds along with eggs were kept in the laboratory for further development of the insect. The efficacy of plant materials as protectant of chickpea seeds against *C. chinensis* was assessed considering oviposition, adult's emergence, seed infestation and seed weight loss done.

For the determination of oviposition of the beetle, one hundred (100) seeds were collected randomly from each plastic container of each treatment and examined under 10x magnifying glass and the number of seeds along with eggs (egg bearing seeds) and the number of eggs deposited were counted. After each observation, the grains were returned to the respective containers for the further development of the beetle. The adults were removed daily from each plastic container and the data were recorded. Percent seed infestation and weight loss were determined at the completion of adult emergence. The sample of each replicate were examined carefully and damaged and healthy seeds were separated, cleaned, counted and weighed. Percent seed infestation and weight loss were computed by using the following formulae. Percent infestation = $\frac{N_b}{T_n} \times 100$ (Enobakhare and Law-Ogbomo 2002). Where, N_b = Number of damaged seeds, T_n = Total number of seeds; Percent weight loss = $\frac{UNd - DNu}{U(Nd + Nu)} \times 100$ (Lal, 1988); Where, U = Weight of healthy seed, D = Weight of damaged seed, N_u = Number of healthy seed, N_d = Number of damaged seed.

Seed germination test: From the experiment, it was found that only neem seed extract provided maximum grain protectant against *C. chinensis*. Therefore, only neem seed extracts were assessed for the germination test. To investigate the effect of neem seed extracts on seed viability, chickpea seeds were treated with different solvent extracts of neem seed and left stand for a period of 3 months. Then, 100 seeds were taken randomly and placed in petridish separately having water soaked blotting paper at its bottom. The petridishes were placed in the laboratory under ambient room temperature. After incubation, the germinated seeds were counted and worked out the percent seed germination (Enobakhare and Law-Ogbomo 2002).

Statistical analyses: The collected data were statistically analyzed in accordance with one and Completely Randomized Design (CRD) and analyses of variance were done. The data were transformed before analyses of variance. The treatment means were compared by LSD at P<0.05 level. All statistical analyses were done through a MSTAT program in a computer.

Results and Discussion

Twelve indigenous plant extracts were evaluated for their grain protectant efficacy against pulse beetle, *C. chinensis* and their results are presented in tables 2-4.

Effect of botanical extracts on oviposition of *C. chinensis*: It is observed from the data that the effects of different plants, solvents and their interaction differed significantly (P<0.05) among the treatments on oviposition of *C. chinensis* (Tables 2-4). The mean number of eggs laid by *C. chinensis* on chickpea seeds at different treatments ranged from 31.89 to 94.33 (Table 2). Among the extracts, significantly the highest number of eggs was laid in methi (92.83) and the lowest in neem treated seed (31.89). In control treatment, number of eggs was recorded 94.33. Similarly, maximum number of egg bearing seeds/100 seeds were found in control (77.67) and minimum (27.78) in seed treated with neem extract (Table 2). Among the solvents, significantly the highest mean number of eggs was observed in water extract (53.75) followed by petroleum ether extract (50.28) and the lowest from the acetone extract (44.92) followed by n-hexane extracts (50.11) (Table 3). Similarly, number egg bearing seeds/100 seeds were found the highest in control (77.67) and lowest in acetone extract (38.36) followed by n-hexane extract (41.53) (Table 3). In the interaction of plants and solvents (Table 4), significantly the highest number of eggs was laid in petroleum ether extract of methi (99.0) followed by acetone extract of methi (97.67). Contrary, the lowest number of eggs was laid in acetone extract of neem seed (12.67) followed by ethanol extract of neem seed (15.67). In control treatment number of eggs was recorded 94.33. Similarly, the highest number of eggs bearing seeds/100 seeds were found in acetone extract of methi (82.33) followed by petroleum ether extract of methi (81.0) which is significantly identical with control (77.67). The lowest egg bearing seed was recorded in acetone extract of neem seed (11.33) followed by ethanol extract of neem seed (14.67) (Table 4).

The effect of botanical extracts on oviposition of *C. chinensis* indicated that all the tested botanicals except methi had deterrent effect on oviposition, although none of the indigenous plant materials could stop completely from egg laying of pulse beetle. These results are are in accordance with findings of Yadav and Bhargava (2005) who reported that the oviposition of pulse beetle was inhibited when mothbean (*Vigna acontifolia*) seeds treated with meem seed extracts. Bhuiyah *et al.* (2003) found that neem, castor and bishkatali extracts were effective in preventing the egg laying of *C. chinensis* in chickpea seed. AL-Lawati *et al.* (2002) and Mollah and Islam (2002) reported that the oviposition of pulse beetle markedly reduced when stored seeds were treated with different botanical extracts like neem, jatropha, sweetsop and bishkatali. It is also evident from the results that neem seed extracts of different solvents markedly reduced the fecundity of *C. chinensis* but maximum effects were exibited by acetone extract of neem seed followed by ethanol extract. Therefore, fecundity and number of egg bearing seeds of chickpea were less on acetone and ethanol extracts of neem seeds. The result of this study agreed with the findings of Akter *et al*. (2007) who stated that neem extract reduced the oviposition of pulse beetle in stored blackgram.

Table 2. Effect of different plants on oviposition, adult emergence, seed infestation and seed weight loss done by *C. chinensis* on chickpea seeds

Name of the plants	No. of eggs/100 seeds	No. of egg bearing seed/100 seeds	No. of adult emergence	Percent infestation	Percent weight loss
Mehogani	61.39 (1.77)	51.28 (1.69)	127.39 (2.09)	41.66 (40.12)	2.79 (1.65)
Neem	31.89 (1.38)	27.78 (1.34)	58.50 (1.62)	20.05 (25.07)	1.28 (1.02)
Sunhemp	45.94 (1.60)	38.78 (1.53)	94.72 (1.93)	31.75 (33.82)	2.06 (1.38)
Pithraj	50.56 (1.65)	42.44 (1.58)	106.39 (1.98)	33.94 (35.14)	2.20 (1.44)
Bishkatali	42.67 (1.56)	37.06 (1.51)	96.33 (1.91)	30.28 (32.72)	1.98 (1.34)
Tobacco	52.56 (1.67)	45.00 (1.61)	77.39 (1.82)	25.20 (29.29)	1.64 (1.21)
Sweetsop	51.67 (1.67)	43.17 (1.60)	83.89 (1.87)	28.16 (31.47)	1.79 (1.28)
Castor	62.17 (1.76)	51.83 (1.69)	125.78 (2.08)	42.20 (40.38)	2.70 (1.62)
Methi	92.83 (1.96)	76.28 (1.88)	173.28 (2.23)	56.65 (48.84)	3.39 (1.84)
Tishi	74.78 (1.86)	62.11 (1.78)	156.67 (2.19)	51.14 (45.65)	3.23 (1.79)
Jatropha	51.67 (1.67)	42.28 (1.59)	105.94 (1.99)	37.00 (37.11)	2.36 (1.50)
Marigold	69.11 (1.83)	56.89 (1.74)	137.94 (2.13)	43.56 (41.24)	2.75 (1.64)
Control	94.33 (1.97)	77.67 (1.89)	190.00 (2.28)	63.57 (52.90)	4.31 (2.07)
LSD	0.069	0.066	0.051	2.326	0.104

Figures in the parenthesis are transformed values

Table 3. Effect of different solvents on oviposition, adult emergence, seed infestation and seed weight loss done by *C. chinensis* on chickpea seeds

Name of the solvents	No. of eggs/100 seeds	No. of egg bearing seed/100 seeds	No. of adult emergence	Percent infestation	Percent weight loss
Acetone	44.92 (1.58)	38.36 (1.52)	82.25 (1.83)	26.87 (30.34)	1.69 (1.25)
Ethanol	50.22 (1.65)	42.86 (1.59)	106.50 (1.97)	34.55 (35.41)	2.19 (1.44)
n-Hexane	50.11 (1.65)	41.53 (1.58)	98.22 (1.94)	31.91 (33.87)	1.99 (1.38)
Petrolium ether	50.28 (1.66)	42.72 (1.59)	95.64 (1.93)	31.32 (33.48)	1.96 (1.36)
Water	53.75 (1.69)	44.31 (1.61)	99.50 (1.96)	32.58 (34.41)	1.96 (1.37)
Control	94.33 (1.97)	77.67 (1.89)	190.00 (2.28)	63.57 (52.90)	4.31 (2.07)
LSD	0.049	0.047	0.036	1.644	0.074

Figures in the parenthesis are transformed values

Effect of botanical extracts on adult emergence of *C. chinensis*: The mean number of adults emerged from different treatments of plant extract varied from 58.50 to 190.0 and those differed significantly (P<0.05) among the treatments (Table 2). It was observed that significantly the highest number of adults emerged from control (190.0) whereas, the lowest in neem seed (58.50) followed by tobacco leaf (77.39) and sweetsop seed (83.89) (Table 2). Among all the solvents the highest number of adults was emerged from ethanol (106.50) followed by water (99.50) (Table 3). Number of adult emergence was found significantly identical in water (99.50) and n-hexane (98.22). Significantly the lowest number of adults was emerged from acetone (82.25) followed by petroleum ether (95.64) extracts. Significantly the highest number of adult's emergence was observed in control (190.0) (Table 3). Due to interaction effect of plants and solvents, number of adult's emergence from acetone extracts of neem seed provided the highest inhibition (22.67) followed by ethanol (25.67), n-henxane (35.0) and petroleum ether (36.67) of same plant extracts (Table 4). Contrary, significantly the highest number of adults emerged from control (190.0) followed by petroleum ether extract of methi seed (183.67).

It was observed from the results of present investigation that number of adult emergence was markedly reduced by all the tested extracts but maximum inhibition was done by acetone extract of neem seed followed by ethanol extract. The results are in agreement with Dwivedi and Kumari (2000) and Dwivedi and Venugopalan (2001) and who reported that acetone extract of botanicals significantly reduced the adult population of *C. chinensis*. Sathyaseelan *et al.* (2008) also cited that some kinds of botanicals with ethanol extracts reduced the adult emergence of *C. chinensis* in green gram seeds. Mollah and Islam (2005) stated that acetone extract of sweetsop seed suppressed the adult emergence of *C. maculatus* in blackgram seeds. Mamun *et al*. (2009) also reported that acetone extract of neem seed showed highest toxicity against stored grain pest. Saxena (1989) and Rejesus *et al*. (1990) reported that neem seed extracts causes adult reduction due to presence of various semio-chemicals like azadirachtin and morgason. They also suggested that the inhibition of adult emergence could either be due to larval mortality or even reduction of egg hatching.

Effect of botanical extracts on seed infestation and weight loss done by *C. chinensis:* The seed infestation and weight loss were found significantly different (P<0.05) among the treatments of plants, solvents and their interaction (Tables 2-4). The plants had significant effect on seed infestation and weight loss in all the treatments. The infestation of seeds due to various plants ranged from 20.05 to 63.57% (Table 2). The highest infestation was found in control (63.57%) followed by methi seed extract (56.65%). Contrary, the lowest infestation was found in neem seed (20.05%) followed by tobacco leaf (25.20%) extract (Table 2). Similarly, the lowest seed weight loss found in neem seed extract (1.28%) followed by sweet sop seed extract (1.79%) whereas the highest (4.31%) in control followed by methi seed (3.39%) extract (Table 2).

Table 4. Interaction effect of different plants and solvents on oviposition, adult emergence, seed infestation and seed weight loss done by *C. chinensis* on chickpea seeds

Name of the plants	Name of solvents	No. of eggs/100 seeds	No. of egg bearing seed/100 seeds	No. of adult emergence	Percent infestation	Percent weight loss
Mehogani	Acetone	54.67 (1.74)	48.33 (1.68)	109.67 (2.04)	35.26 (36.39)	2.49 (1.58)
	Ethanol	55.33 (1.74)	48.33 (1.68)	117.00 (2.06)	37.40 (37.66)	2.63 (1.62)
	n-Hexane	60.00 (1.77)	51.00 (1.70)	129.00 (2.10)	40.76 (39.64)	2.39 (1.54)
	Petrolium ether	57.00 (1.75)	43.67 (1.63)	134.33 (2.13)	42.68 (40.76)	2.98 (1.72)
	Water	47.00 (1.67)	38.67 (1.58)	84.33 (1.92)	30.32 (33.35)	1.97 (1.40)
Neem	Acetone	12.67 (1.09)	11.33 (1.04)	22.67 (1.35)	7.82 (16.16)	0.55 (0.74)
	Ethanol	15.67 (1.19)	14.67(1.16)	25.67 (1.40)	9.24 (17.65)	0.70 (0.83)
	n-Hexane	23.67 (1.37)	21.33 (1.32)	35.00 (1.54)	11.81 (20.03)	0.70 (0.83)
	Petrolium ether	23.00 (1.35)	22.00 (1.33)	36.67 (1.56)	13.26 (21.30)	0.58 (0.75)
	Water	22.00 (1.32)	19.67 (1.28)	41.00 (1.60)	14.61 (22.37)	0.86 (0.92)
Sunhemp	Acetone	18.33 (1.25)	16.67 (1.21)	42.67 (1.63)	15.01 (22.71)	0.82 (0.90)
	Ethanol	35.67 (1.54)	32.67 (1.50)	76.00 (1.87)	25.77 (30.41)	1.58 (1.25)
	n-Hexane	42.33 (1.61)	29.67 (1.46)	73.67 (1.85)	26.57 (30.90)	1.88 (1.36)
	Petrolium ether	40.33 (1.60)	38.33 (1.57)	93.33 (1.96)	29.03 (32.49)	1.98 (1.40)
	Water	44.67 (1.63)	37.67 (1.57)	92.67 (1.96)	30.58 (33.49)	1.77 (1.33)
Pithraj	Acetone	54.33 (1.73)	45.00 (1.65)	112.00 (2.04)	31.53 (34.03)	1.99 (1.40)
	Ethanol	39.33 (1.59)	34.67 (1.54)	101.67 (2.00)	32.62 (34.74)	1.97 (1.40)
	n-Hexane	59.33 (1.77)	50.67 (1.70)	124.00 (2.09)	38.63 (38.37)	2.39 (1.54)
	Petrolium ether	21.67 (1.33)	19.67 (1.28)	49.00 (1.68)	15.76 (23.27)	1.23 (1.10)
	Water	34.33 (1.53)	27.00 (1.42)	61.67 (1.77)	21.55 (27.51)	1.32 (1.14)
Bishkatali	Acetone	26.00 (1.40)	24.67 (1.38)	42.67 (1.62)	15.26 (22.91)	0.95 (0.97)
	Ethanol	48.67 (1.68)	42.00 (1.62)	147.00 (1.16)	37.62 (37.78)	2.79 (1.65)
	n-Hexane	20.67 (1.30)	19.33 (1.26)	51.00 (1.68)	19.01 (25.53)	1.13 (1.05)
	Petrolium ether	34.00 (1.52)	31.33 (1.48)	66.33 (1.82)	22.39 (28.11)	1.25 (1.11)
	Water	32.33 (1.49)	27.33 (1.43)	81.00 (1.91)	23.86 (29.06)	1.45 (1.20)
Tobacco	Acetone	31.00 (1.48)	27.33 (1.43)	36.67 (1.57)	12.42 (20.26)	0.84 (0.92)
	Ethanol	34.33 (1.53)	30.00 (1.47)	46.67 (1.67)	15.80 (23.41)	0.99 (0.99)
	n-Hexane	35.33 (1.54)	30.67 (1.47)	60.00 (1.77)	18.82 (25.66)	1.18 (1.08)
	Petrolium ether	56.33 (1.74)	49.33 (1.68)	57.33 (1.76)	16.08 (23.52)	1.02 (1.00)
	Water	64.00 (1.79)	55.00 (1.73)	73.67 (1.86)	24.51 (29.62)	1.50 (1.22)
Sweetsop	Acetone	33.67 (1.52)	28.67 (1.45)	41.67 (1.61)	15.37 (22.98)	0.90 (0.94)
	Ethanol	28.00 (1.43)	24.33 (1.38)	59.67 (1.77)	19.55 (26.17)	1.20 (1.09)
	n-Hexane	43.00 (1.62)	35.00 (1.53)	68.00 (1.83)	21.65 (27.64)	1.35 (1.16)
	Petrolium ether	48.33 (1.68)	40.33 (1.60)	72.00 (1.85)	25.03 (29.96)	1.54 (1.24)
	Water	62.67 (1.79)	53.00 (1.72)	72.00 (1.86)	23.77 (29.17)	1.43 (1.19)
Castor	Acetone	38.33 (1.57)	31.33 (1.48)	82.67 (1.91)	28.89 (32.34)	1.83 (1.34)
	Ethanol	61.00 (1.77)	50.67 (1.69)	130.00 (2.11)	42.38 (40.60)	2.75 (1.66)
	n-Hexane	46.33 (1.65)	40.00 (1.59)	102.67 (2.00)	33.39 (35.14)	2.10 (1.43)
	Petrolium ether	62.67 (1.79)	53.67 (1.72)	116.67 (2.06)	42.07 (40.40)	2.61 (1.61)
	Water	70.33 (1.84)	57.67 (1.76)	132.67 (2.12)	42.93 (40.91)	2.62 (1.62)
Methi	Acetone	97.67 (1.99)	82.33 (1.91)	178.33 (2.25)	57.59 (49.37)	3.42 (1.85)
	Ethanol	94.67 (1.97)	77.67 (1.89)	182.33 (2.26)	58.54 (49.91)	3.47 (1.86)
	n-Hexane	84.00 (1.92)	71.00 (1.85)	150.67 (2.18)	47.89 (43.77)	2.85 (1.69)
	Petrolium ether	99.00 (1.99)	81.00 (1.90)	183.67 (2.26)	59.40 (50.40)	3.42 (1.85)
	Water	87.33 (1.94)	68.00 (1.83)	154.67 (2.19)	52.95 (46.67)	2.87 (1.69)
Tishi	Acetone	76.33 (1.87)	64.33 (1.80)	148.00 (2.17)	48.25 (43.97)	2.98 (1.72)
	Ethanol	76.33 (1.87)	65.67 (1.81)	166.33 (2.22)	55.38 (48.07)	3.31 (1.82)
	n-Hexane	69.00 (1.83)	54.33 (1.73)	138.00 (2.14)	45.70 (42.50)	3.12 (1.77)
	Petrolium ether	69.00 (1.83)	55.67 (1.74)	143.00 (2.15)	45.85 (42.57)	2.90 (1.69)
	Water	63.67 (1.80)	55.00 (1.74)	154.33 (2.19)	48.09 (43.88)	2.77 (1.66)
Jatropha	Acetone	33.00 (1.49)	28.67 (1.44)	57.00 (1.74)	20.03 (26.39)	1.30 (1.13)
	Ethanol	55.00 (1.73)	44.67 (1.64)	107.33 (2.03)	43.37 (41.15)	2.57 (1.60)
	n-Hexane	39.33 (1.59)	32.00 (1.49)	86.00 (1.92)	29.87 (33.00)	1.78 (1.33)
	Petrolium ether	40.67 (1.60)	35.67 (1.54)	88.00 (1.93)	29.28 (32.64)	1.87 (1.36)
	Water	47.67 (1.67)	35.00 (1.52)	107.33 (2.01)	35.87 (33.56)	2.35 (1.52)
Marigold	Acetone	63.00 (1.80)	51.67 (1.71)	113.00 (2.05)	35.02 (36.25)	2.20 (1.48)
	Ethanol	58.67 (1.76)	49.00 (1.68)	118.33 (2.07)	36.98 (37.41)	2.33 (1.52)
	n-Hexane	78.33 (1.89)	63.33 (1.80)	160.67 (2.20)	48.81 (44.29)	2.99 (1.73)
	Petroleum ether	51.33 (1.70)	42.00 (1.62)	107.00 (2.02)	35.07 (36.29)	2.12 (1.46)
	Water	69.00 (1.83)	57.67 (1.76)	138.67 (2.14)	41.90 (40.30)	2.57 (1.60)
Control		94.33 (1.97)	77.67 (1.89)	190.00 (2.28)	63.57 (52.90)	4.31 (2.07)
LSD		0.17	0.17	0.13	5.70	0.26

All figures are average of 3 replications; Figures in the parenthesis are transformed values

The highest infestation was found in control (63.57%), whereas, the solvent with acetone extract provided the lowest infestation 26.87% (Table 3). The percent seed infestation was found statistically similar when seeds treated with n-hexane (31.91) and petroleum ether (31.22) as solvents. Among all the solvents acetone extract showed minimum seed weight loss (1.69%) and maximum was found in n-hexane extract (1.99%). On the other hand, the highest seed weight loss was found in control (4.31%) which was significantly different from other extracts (Table 3). The interaction effects of different plant extracts and solvents on seed infestation and weight loss caused by pulse beetle is presented in Table 4. It was observed that the seed infestation significantly influenced by the different plant extracts and solvents. The highest seed infestation was noticed in control (63.57%) followed by petroleum ether extract of methi (59.40%) and the lowest infestation was found in acetone extract of neem seed (7.82%). Among all the treatments, the highest weight loss was observed in control (4.31%) followed by ethanol extract of methi (3.47%) while the lowest seed weight loss was found in acetone extract of neem seed (0.55%) followed by petroleum ether extract of neem seed (0.58%). The results indicated that acetone and ethanol extracts of neem seed markedly reduced the seed damage and weight loss of chickpea seeds. Similar results were also cited by Umrao and Verma (2002) and Bhuiyah *et al*. (2003). They confirmed that neem seed extracts of acetone and ethanol proved best protection of pulse seeds against *C. chinensis.* The results of present findings are also comparable with the findings of Dwivedi and Kumari (2000) and Dwivedi and Venugopalan (2001) who cited that some plant leaves (*Ipomea plamata, Ficus religiosa, Tamarindus indica, Chenopodium album* etc.) extract of acetone reduced the cowpea seed damage against *C. chinensis* in storage. Malaker and Ahmed (2006) and Alice *et al*. (2007) cited that neem seed kernel extracts reduced the seed infestation against *C. chinensis*. Hosan *et al*. (2009) reported celaflor a neem based insecticides caused significant reduction of seed damage and weight loss of chickpea seeds against *C. chinensis*. The reduction of seed damage and weight loss might be due to antifeedant action of neem seed extract as reportd by Kamruzzam *et al*. (2004). Rao, *et al*. (1993) and Xie *et al.* (1995) also reported the antifeedant effect of neem leaf extract.

Effect of neem seed extracts on seed germination: The effect of neem seed extracts of different solvents on seed germination indicated that there was no significant differences ($P<0.05$) among the treatments. Seed germination ranged from 90.0 to 96.0% (Table 5). It is revealed from the results that the extraction had no adverse effect on seed germination even upto 3 months of storage period. These results are in agreement with the findings of Malaker and Ahmed (2006) who reported similar results using chickpea seeds. The results are also comparable with Raja *et al*. (2001) where they reported that green gram seeds treated with botanicals had no adverse effect on seed germination after 3 months of storage.

It is revealed from the present findings that although all the tested plant materials significantly reduced the oviposition, adult emergence, seed infestation and weight loss of chickpea seeds done by *C. chinensis* but maximum effects were exhibited by neem seed extract. Farmers may therefore use neem seed extract in their storage structure for eco-friendly management of pulse beetle.

Table 5. Effect of different neem seed extracts on germination of chickpea seeds

Treatments	Percent germination
Acetone	93.0 (9.64)
Ethanol	91.66 (9.57)
n-Hexane	90.0 (9.48)
Petrolium ether	90.33 (9.49)
Water	91.33 (9.54)
Control	96.0 (9.80)
LSD	0.257

Figures in the parenthesis are transformed values

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