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Repellent and Growth Inhibitory Impact of Plant Extracts and Synthetic Pyrethroids on Three Strains of *Callosobruchus chinensis* L.

Sidra-Tul-Muntaha[1], Muhammad Sagheer[1]*, Mansoor-ul-Hasan[1] and Shahbaz Talib Sahi[2]

[1]*Department of Entomology, University of Agriculture, Faisalabad, Pakistan*

[2]*Department of Plant Pathology, University of Agriculture, Faisalabad, Pakistan*

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MS designed the study and analyzed the data. STM executed experimental work and wrote the article. MS, MH and STS supervised the work.

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Beetles, botanicals, conventional insecticides, cereals, deterrence, exposure time, growth inhibition, stored products.

ABSTRACT

The present research work was conducted to evaluate the repellent and growth inhibitory efficiency of five plant extracts (*Azadirachta indica, Melia azadirach, Pegnum hermala, baryosma* and *Zingiber officinale*) and three synthetic pyrethroids (bifenthrin, cypermethrin and deltamethrin) on three geographical populations of *Callosobruchus chinensis* collected during 2013 from Faisalabad, Multan and Nankana districts of Punjab, Pakistan. Three concentrations of each plant extract (5, 10, 15 and 20%) and synthetic pyrethroids (0.01, 0.02 and 0.03%) were evaluated in this study. We observed significant results with each treatment. For both repellent and growth inhibitory effects, *A. indica* and deltamethrin were most efficient among plant extracts and pyrethroids respectively. At highest dose rates, more than 90% repellency was recorded with both *A. indica* and deltamethrin. Upto 80% progeny inhibition was caused by the extract of *A. indica*. While more than 50% population of *C. chinensis* was inhibited with deltamethrin. More pronounced results were obtained at high concentrations. Plants were effective in order of *Azadirachta indica* > *Melia azadirach* > *Pegnum hermala* > *Salsola baryosma*> *zingiber officinale;* whereas effectiveness of pyrethroids was in order of deltamethrin > cypermethrin > bifenthrin. The findings of this research will be helpful in organic storage of pulses by integrating the reduced risk pesticides with plant extracts.

INTRODUCTION

Pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) also known as dhora beetle is the most destructive cosmopolitan pest of stored gram and cause both qualitative and quantitative losses in legumes (Ahmed and Din, 2009; Righi-Assia *et al*., 2010; Upadhyay *et al*., 2011). It is a pest of stored pulses in Asia and Africa (Tapondjou *et al*., 2002; Kiradoo and Srivastava, 2010). *Callosobruchus* spp. cause 12-13% loss by feeding the protein contents of grains (FAO, 1994). *C. chinensis* causes up to 10% damage to stored chick pea (Aslam *et al*., 2002), and up to 90% loss to stored gram (Qayyum and Zafar, 1978).

Synthetic pyrethroids are new class of insecticides (Kumar, 2012) which are being used since 1970s. These are neurotoxic insecticides and effect neuro-endocrine functions. Due to pyrethroids, axon of a neuron get excited and insects become inactive. They also affect sodium channel (Beeman, 1982) due to which normal neuronal signaling is interrupted (Mujeeb and Shakoori, 2012). They have great knockdown, antifeedant, rep ellent and residual effect (Hirano, 1989). They are photostable and easily degradable, even at the low dose rate (Barlow *et al*., 1971; Hadaway, 1972). Numerous insect pests are controlled more efficiently by the use of synthetic pyrethroids than carbamate and organophosphate (Srivastava, 1996). Pyrethroids are rapidly metabolized in mammalian bodies, and thus their toxicity is very restricted (Soderlund *et al*., 2002). Pyrethroids are used against household, agricultural, stored grain and animal insect pests (Hutson *et al*., 1981).

Plant materials are used against stored product pests from the ancient time (Aslam *et al*., 2002). Plant extract and oils are being used in different parts of the world (Burroughs *et al*., 1988; Koul *et al*., 2008; Ali *et al*., 2012). Plant based natural pesticides are used as an alternative insect control measure to protect atmosphere from hazardous residual insecticides (Khan *et al*., 2013). Many compounds are present in these plant extracts that have effect on insect growth, development and behavior, acting as attractants, antifeedants, repellents, toxins, fumigants and insect growth inhibitors (Singh and Jain, 1987; Champagne *et al*., 1992; Carlini and Grossi-de-Sa, 2002; Cox, 2004; Kubo, 2006). So the plant extracts have broad spectrum properties and safer to use for sustainable

* Corresponding author: sagheersharif@yahoo.com
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pest management with pesticide free environment (Kiradoo and Srivastava, 2010). Several plants have been proved effective to control stored grain insects (Ratnasekera and Rajapakse, 2009).

Keeping this in mind the present study was designed to explore the efficiency of plant extracts and pyrethroids for the evaluation of repellent and growth inhibitory effect against pulse beetles. So that in future, plant extracts can be used in IPM of stored grain pests.

MATERIALS AND METHODS

Rearing of homogenous insect culture

Heterogeneous samples of adults of *C. chinensis* were collected from infested pulses stored in grain market and farmer storages of three District Nankana Sahib, Faisalabad and Multan. The insect culture was reared in plastic jars (1.5 kg capacity) using lentils as food medium. The jars were covered with muslin cloth, tightened with rubber bands to avoid the escape of insects and were placed in cooled incubator at optimum growth conditions 30$\pm$ 2°C and 65$\pm$5 % R.H. After 3 days, adults were sieved out from the lentils, the grains having egg laying were again put into the jars and were placed again incubator for one month to get homogenous culture of *C. chinensis.* One week old beetles of *C. chinensis* from this culture were used for all bioassay studies.

Plant materials and their extracts

Fresh leaves of dhrek, *Melia azadirach,* seeds of hermal, *Pegnum harmala,* stem of khar booti, *Salsola barysoma***,** leaves of neem, *Azadirachta indica* and rhizome of ginger, *Zingiber officinale* were collected from different locations from district Faisalabad and Nankanasahib.

After drying in shade the plant parts were ground using an electrical grinder into fine powder. The powders were used to make extracts in acetone as solvent. In 250 ml flask, 50 g of plant powder was soaked in 150 ml of acetone. The flasks were placed on rotary shaker for 48 h at 220 rpm. The prepared extract was filtered and used to make different concentrations. After that, the mixture was filtered and filtrates were placed in rotary evaporator to evaporate the acetone from filtrate. The final extract was considered as stock solution to prepare further dilutions for bioassay studies. Different concentrations *viz*., 5, 10, 15 and 20% were prepared from the stock solution. Like different concentrations of pyrethroids 0.01, 0.02 and 0.03% were also prepared in acetone.

Repellent effect of plant extracts and synthetic pyrethroids

The repellence activity was determined using area preference method (Rehman and Khan, 2014). After cutting the filter papers into two equal halves one half of each paper was treated with each concentration of plant extracts and synthetic pyrethroids. After evaporation of excess solvent two halves were joined together and placed in petri dishes. 50 adults of *C. chinensis* were released in the center of treated filter papers. Repellency data was recorded after 24, 48 and 72 h.

Percent repellency was calculated following the formula used by Rehman and Khan, 2014.

$$\text{Percent Repellency} = \frac{Nc - Nt}{Nc + Nt} \times 100$$

Where, N_c is the No. of insects in control half; and N_t is the No. of insects in treated half.

Progeny inhibition studies

Twenty five pairs of insects were released in the jars containing 50 g of treated grains of each concentration. Acetone was used as a control treatment. After 7 days the released insects were removed from the jars and data regarding population inhibition was recorded after 30 and 60 days (Rehman and Khan, 2014). Percent inhibition rate was calculated using following formula:

$$\text{Percent Inhibition Rate} = \frac{Cn - Tn}{Cn} \times 100$$

Where, Cn is the No. of progeny in control jars; and Tn is the No. of progeny in treated jars.

Data analysis

Data were subjected to Analysis of Variance for mean repellence and progeny inhibition caused by both plant extracts and pyrethroids will be computed using Statistica-6 following Completely Randomized Design. Means of significant treatments were compared using Tukey's HSD test at 0.05 probability level, to check the significant difference among treatments.

RESULTS

Repellent activity of plant extracts and pyrethroids

In the case of *C. chinensis* Faisalabad strain (hereafter used FSD), highest repellency 93% was recorded with the extract of *A. indica* followed by *M. azadirach* (90%). The repellent effect of *P. hermala* and *Z. officinale* were at par, they caused 82% repellency of the test insect. *S. baryosma* was least effective of all plant extracts causing 81% repellency (Table I).

In case of *C. chinensis* Multan strain (MLN), highest repellency 90% was recorded with *A. indica* followed by *M. azadirach* (89%) and *Z. officinale* (86%). *P. hermala* and *S. baryosma* caused 76% and 77% repellency respectively. *A.*

Table I.- Repellency (%) caused by four concentrations of five plant extracts in three geographical populations (strains) of *Callosobruchus chinensis* at three exposure times.

Exposure Times	Concen-trations	Faisalabad (FSD) strain					Multan (MLN) strain					Nankana Sahib (NNS) strain				
		A. indica	*M. azadirach*	*P. hermala*	*S. baryosma*	*Z. officinale*	*A. indica*	*M. azadirach*	*P. hermala*	*S. baryosma*	*Z. officinale*	*A. indica*	*M. azadirach*	*P. hermala*	*S. baryosma*	*Z. officinale*
24	5%	60.00±1.33a	53.33±1.33a	49.33±1.33a	46.67±1.33a	50.67±1.33a	58.67±1.33a	57.33±1.33a	47.33±1.33a	45.33±1.33a	53.33±1.33a	54.67±1.33a	53.33±1.33a	45.33±1.33a	46.67±1.33a	49.33±1.33a
24	10%	70.67±1.33b	65.33±1.33b	58.67±1.33b	53.33±1.33b	57.33±1.33b	69.33±1.33b	66.67±1.33b	51.33±1.33b	54.67±1.33b	64.00±2.31bc	65.33±1.33b	65.33±1.33b	56.00±1.33b	57.33±1.33b	61.33±1.33b
24	15%	77.33±1.33bcd	70.67±3.53bcd	62.67±1.33bc	61.33±1.33c	61.33±1.33bc	74.67±1.33bc	70.67±1.33bc	61.33±1.33bc	58.67±1.33bc	69.33±1.33cd	73.33±1.33c	66.67±1.33bc	58.67±1.33bc	61.33±1.33bc	66.67±1.33bc
24	20%	85.33±1.33def	77.33±1.33cde	66.67±1.33cd	65.33±1.33cd	68.00±1.33de	82.67±1.33e	80.00±1.33de	66.67±1.33cd	68.00±1.33def	77.33±1.33ef	76.00±1.33cd	73.33±1.33de	62.67±1.33cd	65.33±1.33de	72.00±1.33def
48	5%	74.67±1.33bc	65.33±1.33b	58.67±1.33b	61.33±1.33c	65.33±1.33cd	70.67±1.33bc	65.33±1.33b	57.33±1.33b	58.67±1.33bc	61.33±1.33b	77.33±1.33cde	68.00±1.33bcd	57.33±1.33bc	56.00±1.33b	64.00±2.31bc
48	10%	77.33±3.53bcd	69.33±1.33bc	62.67±1.33bc	64.00±1.33cd	66.67±1.33cd	76.00±1.33cd	70.67±1.33bc	62.67±1.33bc	62.67±1.33cd	68.00±2.31bcd	82.67±1.33efg	72.00±2.31cde	60.00±1.33bcde	58.67±1.33bc	70.67±1.33cde
48	15%	82.67±1.33cde	74.67±1.33cde	68.00±1.33cde	69.33±1.33de	70.67±1.33def	81.33±1.33de	74.67±1.33cd	66.67±1.33cd	66.67±2.66def	73.33±1.33de	86.67±1.33gh	77.33±1.33ef	64.00±1.33def	64.00±1.33cd	74.67±1.33ef
48	20%	86.67±3.53efg	81.33±1.33ef	73.33±1.33ef	73.33±1.33ef	73.33±1.33efg	85.33±1.33ef	84.00±1.33ef	69.33±1.33d	70.67±1.33efg	84.00±1.33fg	90.67±1.33hi	81.33±1.33fg	69.33±1.33fg	66.67±1.33de	78.67±1.33fg
72	5%	78.67±1.33bcd	78.86±1.33def	60.00±1.33b	68.00±1.33de	66.67±1.33cd	74.67±1.33bc	74.67±1.33cd	61.33±1.33bc	64.00±1.33cde	73.33±1.33de	80.00±1.33def	80.00±1.33fg	65.33±1.33ef	65.33±1.33de	77.33±1.33efg
72	10%	84.00±1.33def	82.67±1.33efg	69.33±1.33def	73.33±1.33ef	74.67±1.33fg	84.00±1.33e	80.00±1.33de	65.33±1.33cd	66.67±1.33def	78.67±1.33ef	85.33±1.33fgh	85.33±1.33gh	69.33±1.33fg	70.67±1.33ef	82.67±1.33gh
72	15%	89.33±1.33fg	86.67±1.33fg	74.67±1.33f	76.00±1.33fg	78.67±1.33gh	86.67±1.33ef	84.00±1.33ef	70.67±1.33de	72.00±1.33fg	82.67±1.33fg	90.67±1.33hi	88.00±1.33hi	73.33±1.33g	74.67±1.33fg	86.67±1.33hi
72	20%	93.33±1.33g	90.67±1.33g	82.67±1.33g	81.33±1.33g	82.67±1.33h	90.67±1.33f	89.33±1.33f	76.00±1.33e	77.33±1.33g	86.67±1.33g	94.67±1.33i	92.00±1.33i	80.00±1.33h	78.67±1.33g	90.67±1.33i

Table II.- Repellency (%) caused by three concentrations of three synthetic pyrethroid insecticides in three geographical populations (strains) of *Callosobruchus chinensis* at three exposure times.

Exposure Times	Concentrations	Bifenthrin	Cypermethrin	Deltamethrin	Bifenthrin	Cypermethrin	Deltamethrin	Bifenthrin	Cypermethrin	Deltamethrin
	0.01%	54.67±1.33a	54.67±1.33a	58.67±1.33a	54.67±1.33a	58.67±1.33a	58.67±1.33a	60.00±1.33a	61.33±1.33a	64.00±1.33a
24	0.02%	62.67±1.33b	65.33±1.33b	69.33±1.33b	60.00±1.33ab	65.33±1.33b	66.67±1.33b	61.33±2.67a	69.33±1.33b	74.67±1.33b
	0.03%	64.00±1.33b	76.00±1.33c	78.67±1.33d	68.00±1.33cd	74.67±1.33c	78.67±1.33cd	72.00±1.33bc	81.33±1.33cd	82.67±1.33cd
	0.01%	73.33±1.33c	65.33±1.33b	72.00±1.33bc	58.67±1.33ab	58.67±1.33a	69.33±1.33b	69.33±1.33b	69.33±1.33b	81.33±1.33c
48	0.02%	73.33±1.33c	73.33±1.33cd	77.33±1.33cd	62.67±1.33bc	69.33±1.33bc	76.00±1.33c	77.33±1.33cd	77.33±1.33c	86.67±1.33cde
	0.03%	74.67±1.33c	80.00±1.33de	81.33±1.33de	70.67±1.33d	81.33±1.33d	82.67±1.33de	82.67±1.33de	81.33±1.33cd	92.00±1.33efg
	0.01%	76.67±1.33c	78.67±1.33cd	81.33±1.33de	73.33±1.33de	66.67±1.33b	78.67±1.33cd	80.00±1.33de	80.00±1.33cd	88.00±1.33def
72	0.02%	82.67±1.33d	85.33±1.33ef	86.67±1.33ef	77.33±1.33ef	81.33±1.33d	86.67±1.33ef	84.00±2.31de	85.33±1.33de	93.33±1.33fg
	0.03%	89.33±1.33e	90.67±1.33f	92.00±1.33f	82.67±1.33f	89.33±1.33e	90.67±1.33f	86.67±1.33e	89.33±1.33e	97.33±1.33g

indica was most active while *P. hermala* was least effective of all plant.

The results regarding repellent effect of plant extracts against *C. chinensis* Nankana Sahib (NNS)strain shows that the highest repellency 94% was recorded with *A. indica* followed by *M. azadirach* (92%) and *Z. officinale* (90%). The highest repellency by *P. hermala* and *S. baryosma* were 80% and 78%, respectively.

All plant extract treatments showed highly significant results. The repellent effect of pyrethroids was time and dose dependent. The repellency increase with the increase in concentration and exposure time. Overall results shows that the highest repellency was recorded in NNS strain followed by FSD and MLN strain.

Table II describes the repellent effect of pyrethroids which shows that in case of *C. chinensis* FSD strain, highest repellency 92% was recorded with deltamethrin which was followed by cypermethrin (90%) and bifenthrin (89%). In the case of *C. chinensis* MLN strain, highest repellency 90% was recorded with deltamethrin which was followed by cypermethrin (89%) and bifenthrin (82%). In the case of *C. chinensis* NNS strain, highest repellency (97%) was recorded with deltamethrin which was followed by cypermethrin (89%) and bifenthrin (86%).

All treatments of insecticides showed highly significant results. The repellent effect of pyrethroids was time and dose dependent. The repellency increase with the increase in concentration and exposure time. Out of all pyrethroids, highest repellency was recorded by deltamethrin in case of all strains. Deltamethrin results were most effective in NNS strain followed by FSD and MLN strains. By cypermethrin highest repellency was recorded in FSD while results were approximately same for both NNS and MLN strain. However, with bifethrin repellency was high in FSD strain which was followed by NNS and MLN strains.

Post treatment progeny inhibition of C. chinensis *caused by plant extracts*

Table III shows that in the case of *C. chinensis* FSD strain, highest inhibition (79.99%) was recorded with *A. indica* at 20% concentration after 60 days which was followed by *M. azadirach* (77.41%), *S. baryosma* (67.42%), *P. hermala* (62.90%) and *Z. officinale* (62.90%) at same concentration and time interval.After 30 days, highest inhibition (59.90%) was recorded with *A. indica* at 20% concentration which was followed by *S. baryosma* (58.38%), *M. azadirach* (57.36%), *P. hermala* (55.33%) and *Z. officinale* (50.76%) at same concentration and time interval. Of all the plant extracts used, *A. indica* was the most active plant with inhibition range 35.54-79.99% and *Z. officinale* was least effective with 27.41- 62.90% inhibition range.

In the case of *C. chinensis* MLN strain, highest inhibition (66.67%) was recorded with *A. indica* at 20% concentration after 60 days which was followed by *M. azadirach* (61.27%), *S. baryosma* (61.27%), *P. hermala* (58.41%) and *Z. officinale* (55.56%) at same concentration and time interval. After 30 days, highest inhibition (58.53%) was recorded with *A. indica* at 20% concentration, which was followed by *M. azadirach* (53.88%), *S. baryosma* (50.77%), *P. hermala* (49.74%) and *Z. officinale* (47.15%) at same concentration and time interval. Of all plant extracts used, *A. indica* was most active plant with inhibition % range 30.56-66.67% and *Z. officinale* was least effective with 25.90- 55.56%.

In the case of *C. chinensis* NNS strain, highest inhibition (80.81%) was recorded with *A. indica* at 20% concentration after 60 days which was followed by *M. azadirach* (77.49%), *S. baryosma* (75.34%), *P. hermala* (63.84%) and *Z. officinale* (58.30%) at same concentration and time interval. After 30 days, highest inhibition (70.00%) was recorded with *A. indica* at 20% concentration which was followed by *M. azadirach* (66.67%), *S. baryosma* (58.67%), *P. hermala* (50.00%) and *Z. officinale* (47.33%) at same concentration and time interval. Of all plant extracts used, *A. indica* was most active plant with inhibition % range 41.33-80.81% and *Z. officinale* was least effective with 24.67- 58.30%.

All plant extract treatments showed highly significant results. The effect of plant extracts was time and dose dependent as inhibition percentage was increasing with the increase in concentration and time interval. After 30 days, minimum values of inhibition percentage were recorded. Highest results were recorded at 20% concentration after 60 days of treatments application in case of all geographical strains of *C. chinensis* used during the study. Population of NNS strain was highly inhibited by plant extracts followed by FSD and MLN strain.

In the case of FSD strain, progeny was highly inhibited (66.67%) was by deltamethrin which was followed by cypermethrin (57.09%) and bifenthrin (49.99%) at 0.03% concentration after 60 days. In the case of *C. chinensis* MLN strain, highest inhibition (60.32%) was recorded with deltamethrin which was followed by cypermethrin (55.56%) and bifenthrin (45.39%) at same time period and dose rate. In the case of *C. chinensis* NNS strain, at 0.03% dose and after 60 days of exposure, highest repellency (70.40%) was recorded with deltamethrin which was followed by cypermethrin (61.43%) and bifenthrin (56.05%).

All plant extract treatments showed highly significant results. The effect of pyrethroids was time and dose dependent as progeny inhibition was increasing with the increase in concentration and time interval. After 30 days, minimum values of inhibition percentage were recorded.

Table III.- Population inhibition (%) in three strains of *Callosobruchus chinensis* caused by four concentrations of five plant extracts.

Exposure Times	Concen-trations	Faisalabad (FSD) strain *A. indica*	*M. azadirach*	*P. hermala*	*S. baryosma*	*Z. officinale*	Multan (MLN) strain *A. indica*	*M. azadirach*	*P. hermala*	*S. baryosma*	*Z. officinale*	Nankana Sahib (NNS) strain *A. indica*	*M. azadirach*	*P. hermala*	*S. baryosma*	*Z. officinale*
24	5%	35.54± 0.51a	34.52± 0.51a	33.51± 0.51a	30.46± 0.51a	27.41± 0.51a	30.56± 0.52a	32.63± 0.52a	27.97± 0.52a	29.01± 0.52a	25.90± 0.52a	41.33± 0.67a	38.67± 0.67a	29.33± 0.67a	30.67± 0.67a	24.67± 0.67a
24	10%	43.15± 0.51b	43.15± 0.51b	39.09± 0.51b	37.06± 0.51b	36.55± 0.51b	37.30± 0.52b	41.45± 0.52b	32.64± 0.52b	38.85± 0.52b	34.71± 0.52b	54.67± 0.67b	44.67± 0.67b	35.33± 0.67b	37.33± 0.67b	34.67± 0.67b
24	15%	50.26± 0.51c	48.22± 0.51c	44.67± 0.51c	44.17± 0.51c	41.63± 0.51c	43.52± 0.52d	46.11± 0.52d	38.86± 0.52c	44.56± 0.52c	39.89± 0.52c	61.33± 0.67c	57.33± 0.67d	41.33± 0.67c	43.33± 0.67c	40.00± 0.67c
24	20%	59.90± 0.51d	57.36± 0.88e	55.33± 0.51e	58.38± 0.51e	50.76± 0.51e	58.53± 0.52f	53.88± 0.52f	49.74± 0.52e	50.77± 0.52e	47.15± 0.52d	70.00± 1.15d	66.67± 0.67e	50.00± 0.67e	58.67± 0.67e	47.33± 0.67d
48	5%	58.06± 0.32d	55.16± 0.32d	46.12± 0.32c	45.16± 0.32c	40.96± 0.56c	41.26± 0.32c	43.81± 0.32c	38.09± 0.32c	40.00± 0.32b	38.41± 0.32c	63.09± 0.37c	53.87± 0.37c	39.85± 0.37c	47.08± 0.45d	33.21± 0.37b
48	10%	64.84± 0.32e	62.90± 0.32f	53.22± 0.32d	51.29± 0.32d	47.42± 0.32d	52.69± 0.32e	49.84± 0.32e	45.39± 0.32d	47.94± 0.32d	44.76± 0.55d	69.37± 0.37d	59.77± 0.37d	47.60± 0.37d	59.19± 0.45e	42.06± 0.37c
48	15%	73.55± 0.32f	71.29± 0.32g	58.06± 0.32f	59.35± 0.32e	54.83± 0.32f	60.00± 0.32f	58.09± 0.32g	52.38± 0.32f	52.70± 0.32e	51.43± 1.45e	73.79± 0.98e	69.00± 0.37e	54.98± 0.37f	64.57± 0.45f	51.29± 0.64e
48	20%	79.99± 0.32g	77.41± 0.32h	62.90± 0.32g	67.42± 0.32f	62.90± 0.32g	66.67± 0.32g	61.27± 0.32h	58.41± 0.32g	61.27± 0.32f	55.56± 0.32f	80.81± 0.37f	77.49± 0.37f	63.84± 0.37g	75.34± 0.45g	58.30± 0.37f

Table IV.- Population inhibition (%) in three strains of *Callosobruchus chinensis* caused by three concentrations of three synthetic pyrethroids.

Exposure Times (days)	Concentrations	Bifenthrin	Cypermethrin	Deltamethrin	Bifenthrin	Cypermethrin	Deltamethrin	Bifenthrin	Cypermethrin	Deltamethrin
30	0.01%	35.02±0.51a	38.07±0.51a	45.69±0.51a	30.57±0.52a	35.75±0.52a	42.48±0.52a	38.67±0.67a	40.00±0.67a	50.00±0.67a
	0.02%	39.08±0.51b	42.13±0.51b	49.24±0.51b	35.23±0.52b	39.89±0.52b	46.11±0.52b	42.67±0.67b	44.00±1.15b	54.67±0.67b
	0.03%	43.15±0.51c	47.21±0.51c	54.32±1.01c	41.97±0.52c	48.18±0.52d	51.81±0.52d	46.00±1.15c	48.67±0.67c	60.00±0.67d
60	0.01%	44.51±0.32c	45.80±0.32c	56.13±0.32d	36.83±0.32b	45.71±0.55c	50.16±0.32c	45.29±0.45bc	47.08±0.45c	57.40±0.45c
	0.02%	46.44±0.32d	50.32±0.32d	59.68±0.32e	41.27±0.32c	51.43±0.32e	56.19±0.32e	49.32±0.45d	52.02±0.45d	64.57±0.45e
	0.03%	49.99±0.32e	57.09±0.32e	66.77±0.32f	45.39±0.32d	55.56±0.32f	60.32±0.32f	56.05±0.45e	61.43±0.45e	70.40±0.45f

Highest results were recorded at 0.03% concentration after 60 days of application of treatments in case of all geographical strains of *C. chinensis* used during the study. Out of all pyrethroids, highest inhibition was recorded by deltamethrin in case of all strains. All pyrethroids were most effective in case of NNS which were followed by FSD and MLN strains.

DISCUSSION

The present research work was conducted to evaluate the repellent and growth inhibitory efficiency of five plant extracts (*Azadirachta indica, Melia azadirach, Pegnum hermala, Salsola baryosma* and *Zingiber officinale*) and three synthetic pyrethroids (bifenthrin, cypermethrin and deltamethrin) on three geographical populations of *Callosobruchus chinensis* collected during 2013 from Faisalabad, Multan and Nankana districts of Punjab, Pakistan. Three concentrations of each plant extract (5, 10, 15 and 20%) and synthetic pyrethroids (0.01, 0.02 and 0.03%) were used in this study. We observed significant results with each treatment. For both repellent and inhibition effects, *A. indica* and deltamethrin were most efficient. At highest dose rates, more than 90% repellency was recorded with both *A. indica* and deltamethrin. Upto 80% progeny inhibition was documented with most active *A. indica*. While more than 50% population of *C. chinensis* was inhibited with deltamethrin.

Several plants have been reported to control stored grain insects efficiently (Ratnasekera and Rajapakse, 2009). Plant extracts may work as insect growth inhibitors, repellents, antifeedants, fumigants and entomocides (Kubo, 2006; Koul *et al*., 2008). Pyrethroids are rapidly metabolized in mammalian bodies, and thus their toxicity is very restricted (Soderlund *et al*., 2002). They are less toxic to the mammals (Gupta and Kumar, 1991). Pyrethroids have great knockdown, antifeedant, repellent and residual effect (Hirano, 1989).

The foremost emphasis of the study was to elucidate the effect of plant extracts and pyrethroids on repellence activity and progeny inhibition of three different strains of *C. chinensis.* The major finding of this study was that *A. indica* plant extract provide more better results and is more effective in managing *C. chinensis*. Its efficiency was increased with the increase in dose and time interval (Rehman and Khan, 2014). Plants contain some active compounds that are likely to cause insecticidal activities, repellency and progeny inhibition (Jilani and Su, 1983; Schmutterer, 1995). The adverse effects of the *A. indica*may be due to its effect on the hormonal system of the insects (Murugan *et al*., 1999). High repellent effect has been studied by *A. indica* extract by Pradhan *et al*. (1963). Upto 30% repellency has been reported by Rehman and Khan (2014). *A. indica* extract has great effect on the oviposition reduction (Panday *et al*., 1986). Similarly, reduced progeny emergence of *C. chinensis* by the use of *A. indica* leaves extracts has been reported by Rouf *et al*. (1996), Khalequzzaman and Goni (2009) and Rehman and Khan (2014).

In our research study, the extract of *Melia azadirach* caused significant repellence as well as growth inhibition of *C. chinensis.* These results are in concordance with result of Aslam *et al*. (2002) and Mehdi and Rehman (2008) which reported high progeny inhibition of *C. chinensis* with the treatment of *spices*. Saljoqi *et al*. (2006) reported high toxic and repellent effect of *M. azadirach* extract on *Sitophilus oryzae*. Valladares *et al*. (1999) reported repellent and anti-feedant effect of *M. azadirach* extract. Khan and Marwat (2004) reported 82.50% repellency of *R. dominica* with treatment of *M. azadirach.* Toxic and feeding deterrence activities of *M. azadirach* has also been reported (Chauhan *et al*., 1987; Sexena, 1987).

Deltamethrin is one of the pyrethroid which is being used more frequently to control stored product insects (Saleem and Shakoori, 1990; Athanassiou *et al*., 2004). Resistance in *Tribolium castaneum* to deltamethrin has been reported by many authors (Champ, 1986; Collins, 1998; Daglish, 1998). Athanassiou *et al*. (2004) reported that even after 6 months of deltamethrin exposure there was no progeny recorded in *T. confusum*. Arthur (1996) reported that insecticides will keep on protecting stored product from insect damage. Pyrethroids for their activity are possible to become predominant grain protectant.

In our study *P. hermala* caused 82% repellency and more than 60% growth inhibition in all strains of *C. chinensis.* Abbassi *et al*. (2003) reported that alkaloids present in *P. hermala* are responsible for their insecticidal activity. Salari *et al*. (2012) reported low activity of *P. hermala* after 3 days of exposure against *T. castaneum,* while Jbilou *et al*. (2006) reported high insecticidal activity of *P. hermala* after 32 days of exposure on *T. castaneum*. High repellent effect has been studied by *P. hermala* against *M. persicae* by several authors. Repellent effect of different chemical compounds present in *P. hermala* on *M. persicae* has been reported (Gutierrez *et al*. 1997; Hori, 1998; Bruce *et al*., 2005).

Our results regarding the toxic effect of *S. baryosma* are in concordance with the results of Hasan *et al*. (2005) who reported good toxic effect of *S. baryosma* and cypermethrin against *Trogoderma granarium*. 80% repellency has been reported by *S. baryosma* against *Triobolium castaneum* (Sagheer *et al*., 2011) which confirms our results regarding repellent effect of *S. baryosma*. *Z. officinale* contain some alkaloids responsible for its inhibition effect (Purseglove, 1972). Carriquiriborde *et al*. (2009) reported adverse effect of cypermethrin on the growth and survival of *Odontesthes bonariensis*. Pennetier *et al*. (2009) proposed that the compounds responsible for repellence and insecticidal effect on combination can have synergistic effect against insect pests.

CONCLUSIONS

Keeping in view the results of the current work, it is concluded that plant extracts and pyrethroids are effective tools for sustainable management of stored product insect pests. But in order to avoid resistance problem these should be used only in recommended doses as well as rotation of insecticides may also be useful. Our aim should not be only to kill insect but our emphasis should be on the suppression of the next progeny of insects. So, further studies should be carried on to prepare botanical insecticide formulations so that they may be properly used by the grain handling agencies.

Statement of conflict of interest

Authors have declared no conflict of interest.

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