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Novel Insecticides as Seed Protectants for the Management of Storage Pests of Hybrid Maize

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ABSTRACT

The efficacy of newer insecticides with novel modes of action *viz.,* flubendiamide, emamectin benzoate, spinosad, thiodicarb, indoxacarb and lufenuron were evaluated against the storage pests of hybrid maize. Toxicity bioassay studies were conducted against lesser grain borer, *Rhyzopertha dominica* and red flour beetle, *Tribolium castaneum*. Differential toxicity of newer insecticides was observed with the two test insects where *R. dominica* was found to be more susceptible than *T. castaneum.* All the newer insecticides provided good control (> 86%) of *R. dominica* within three days of exposure to treated maize seed compared to chemical check deltamethrin (76.7 %) and untreated control (0%). Emamectin benzoate (100%), spinosad (93.3) followed by thiodicarb (73.3) were found effective against *T. castaneum* than deltamethrin which recorded less than 50 % adult mortality at 15 days after exposure. Twelve months after storage, spinosad and emamectin benzoate proved to be the best treatments with no insect damage on treated maize followed by thiodicarb, indoxacarb, lufenuron (1.3 %) and deltamethrin (2.9%) compared to untreated control (13.73 %). There are no significant differences in quality parameters viz., oil%, protein %, starch and moisture content of treated seed up to 12 months of storage. The germination of maize seed was decreased to 54 % in untreated control within nine months of storage, where the germinability was maintained above certification standards (>80%) with all other treatments except flubendiamide (78 %). Hence, these novel insecticides have the potential to be more effective and safer chemicals and would be a valid addition to pest management programs of storage pests of hybrid maize.

Key words : Hybrid Maize, Emamectin benzoate, *Rhyzopertha dominica, Tribolium castaneum,* Seed quality, Storage pests, Spinosad.

Maize (*Zea mays*, L., Poaceae), is a very versatile crop, growing in all sorts of edaphic, altitudinal and fertility conditions, which explains its global adaptability. It is the third most important cereal in India, after wheat and rice with an area of 7.89 m ha under cultivation producing 15.09 mt, with an average productivity of 1904 kg ha^{-1} (CMIE, 2010). Development of hybrids in maize increased demand for high quality seeds by the farmers for obtaining higher crop productivity. The improved quality seed should possess good germination, optimum moisture content and be free from diseases and insect pests as per seed certification standards. Harvested maize stored as bagged seed in store houses is extremely vulnerable to insect infestations.

Post harvest losses caused by insect pests are an important concern in maize storage. The primary damage in stored maize seed is due to lesser grain borer (*Rhyzopertha dominica* Fab.), followed by secondary attack by red flour beetle (*Tribolium castaneum* Herbst.) and rice moth (*Corcyra cephalonica* Stainton).Current management strategies to overcome the storage menace by these insects involved the use of conventional insecticides such as malathion, chlorpyriphos and deltamethrin. Concerns over environmental and human health along with increased insect resistance to existing insecticides have driven researchers to find safer insecticides that are environmentally benign. Hence, the present investigation was carried out to evaluate the efficacy of new insecticides on the storage pests of maize and their effect on the long term storability and quality of hybrid maize seeds.

MATERIAL AND METHODS

Laboratory and storage studies were conducted at Seed Research and Technology Centre, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad, Andhra Pradesh, India to evaluate the relative toxicity of newer insecticides against economically important insect pests and their residual effect on the long term on farm storage of hybrid maize seeds. Freshly harvested certified hybrid maize seed (DHM-117) with high germination (> 95%) and low moisture content (<10%) purchased from Breeder Seed production Unit, S.R.T.C., Rajendranagar, Hyderabad, Andhra pradesh was frozen at –20 ºC for one week to kill any internal infestation of storage insects

The insect species used in bioassays included the lesser grain borer, *R. dominica* (F.) (Coleoptera: Bostrichidae) and red flour beetle, *T. castaneum* (Herbst) (Coleoptera: Tenebrionidae). The insect cultures were reared on clean untreated rough rice. All insect colonies were maintained and all bioassays were conducted at, 27 ± 5°C, 65 ± 5 % relative humidity (RH) under laboratory conditions.

Six newer reduced risk insecticides, chemical check deltamethrin and an untreated control were evaluated and are listed as follows: untreated controls, 2.0 ppm flubendiamide (Fame), 4.0 ppm emamectin benzoate (Proclaim), 2.0 ppm spinosad (Tracer) , 2.0 ppm thiodicarb (Larvin), 2.0 ppm indoxacarb (Avaunt) , 5.0 ppm lufenuron (Cigna) and 1.0 ppm deltamethrin. Each insecticide treatment was applied to maize at the rate of 15 ml of formulated spray solution for 3 kg seed and untreated controls were sprayed at the same rate with distilled water. Each treatment was replicated three times and applications were made indoors .After each replicate sample was treated, it was shade dried and packed in a 2 kg capacity gunny bag and were stored under ambient conditions with no environmental controls.

Toxicity bioassay studies

The tests were carried out in 250 ml plastic containers, each containing 100 g of hybrid maize seed. The experiment was conducted in completely randomized design with eight treatments and three replications. The seeds were mixed with required quantities of insecticides until the coverage on the surface of the seeds was relatively consistent. Ten insects of *R. dominica* and *T. castaneum* adults were introduced into each container. The adult mortality was recorded on 1, 3, 5, 7 and 15 days after release.

Storability studies

Freshly harvested hybrid maize seed with high germination and vigor was used for the storage studies. Required quantity of insecticides was diluted in 5 ml of water to treat one kg of seed for proper coating. After drying in shade, seeds were packed in 2 kg capacity gunny bags. Similarly, untreated control was maintained for comparison. The experiment was conducted in completely randomized design with eight treatments and three replications. The seeds were analyzed for insect damage, germination, seedling vigor and weight loss (%) at three months interval up to twelve months of storage. Quality parameters like protein %, starch content, oil % and moisture content were recorded using NIRT grain analyzer using non destructive sampling method at three months interval. The number of damaged seeds in each replication were counted after taking a random sample of 100 g seeds and converted to per cent insect infestation. The seed moisture content of the treatments was determined by "Kett's PM 600" moisture meter. The weight loss due to insect infestation was calculated by deducting the final weight from the initial weight and converting to per cent weight loss. Seed germination was measured using standard paper towel method as per the ISTA rules (1999). Germinated seeds were counted on 10th day and ten germinated seedlings were selected from each replication of the treatment for calculating the seedling vigor index. The shoot and root length of each of the 10 seedlings were measured in centimeters and total length of the seedling was calculated. The seedling vigor index and percent avoidable loss were calculated by using the following formulas (Abdul-Baki and Anderson, 1973).

Seedling vigor index (SVI) = Germination (%) x Total seedling length (cm)

$$\% \text{ Avoidable loss} = \frac{\text{Wt. of control sample} - \text{Wt. of Test sample}}{\text{Wt. of control sample}} \times 100$$

The data were subjected to suitable transformation wherever necessary and analysed by adopting completely randomized design as suggested by Panse and Sukhatme (1978).

Table 1. Toxicity of newer insecticides on stored grain pests of hybrid maize.

Chemical	% Adult mortality (Days after treatment)								
	Rhyzopertha dominica				*Tribolium castaneum*				
	1	3	5	7	1	3	5	7	15
Flubendiamide 2ppm	13.3	86.7	96.7	100.0	0.0	13.3	16.7	26.7	53.3
	(21.1)	(68.9)	(83.8)	(90.0)	(0.0)	(13.1)	(19.2)	(30.0)	(46.9)
Emamectin benzoate 4ppm	56.7	100.0	100.0	100.0	23.3	90.0	90.0	90.0	100.0
	(53.1)	(90.0)	(90.0)	(90.0)	(28.8)	(71.6)	(71.6)	(71.6)	(90.0)
Spinosad 2 ppm	96.7	100.0	100.0	100.0	0.0	33.3	73.3	86.7	93.3
	(83.9)	(90.0)	(90.0)	(90.0)	(0.0)	(33.9)	(59.2)	(68.9)	(81.1)
Thiodicarb 2 ppm	70.0	100.0	100.0	100.0	0.0	10.0	50.0	60.0	73.3
	(56.9)	(90.0)	(90.0)	(90.0)	(0.0)	(18.4)	(45.0)	(51.9)	(59.7)
Indoxacarb 2 ppm	36.7	100.0	100.0	100.0	0.0	0.0	23.3	26.7	50.0
	(36.6)	(90.0)	(90.0)	(90.0)	(0.0)	(0.0)	(28.1)	(48.0)	(45.0)
Lufenuron 5 ppm	33.3	96.7	100.0	100.0	3.3	3.3	13.3	43.3	46.7
	(34.9)	(83.8)	(90.0)	(90.0)	(6.15)	(6.1)	(17.7)	(45.8)	(43.1)
Deltamethrin 1 ppm	30.0	76.7	83.3	83.3	10.0	16.7	20.0	26.7	50.0
	(32.2)	(65.9)	(66.1)	(66.1)	(18.4)	(23.9)	(26.6)	(30.8)	(45.0)
Control	0.0	0.0	0.0	0.0	0.0	0.0	20.0	23.3	26.7
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(23.9)	(28.8)	(30.9)
CD @ 5%	28.1	15.7	7.57	8.41	12.4	20.5	19.7	25.0	13.4

Figures in parentheses are arcsine transformed values

Table 2. Effect of newer insecticides on moisture content and insect damage on hybrid maize.

Chemical	Insect damage (%)				Moisture content			
	3M	6M	9M	12M	3M	6M	9M	12M
Flubendiamide 2ppm	1.3	3.6	3.73	5.1	10.7	10.0	7.9	10.4
	(6.55)	(10.84)	(11.1)	(12.98)				
Emamectin benzoate 4ppm	0.0	0.0	0.0	0.0	10.8	9.9	8.1	10.4
	(0.0)	(0.0)	(0.0)	(0.0)				
Spinosad 2 ppm	0.0	0.0	0.0	0.0	10.8	10.0	7.9	10.3
	(0.0)	(0.0)	(0.0)	(0.0)				
Thiodicarb 2 ppm	0.0	0.0	1.6	1.3	10.8	10.0	8.1	10.5
	(0.0)	(0.0)	(7.25)	(6.55)				
Indoxacarb 2 ppm	0.0	0.0	1.3	3.4	10.8	10.0	8.1	10.4
	(0.0)	(0.0)	(6.55)	(10.54)				
Lufenuron 5 ppm	0.0	0.0	0.0	1.3	10.8	10.1	7.9	10.5
	(0.0)	(0.0)	(0.0)	(6.55)				
Deltamethrin 1 ppm	0.0	0.0	3.67	5.83	10.7	10.1	7.7	10.4
	(0.0)	(0.0)	(10.58)	(13.8)				
Control	0.8	7.4	9.6	24.4	10.9	10.1	7.9	10.5
	(5.14)	(15.72)	(17.82)	(29.3)				
CD @ 5%	0.74	2.27	2.57	4.23	NS	NS	NS	NS

*Figures in parentheses are arcsine transformed values M: months after storage

RESULTS AND DISCUSSION

Effect of insecticides on adult mortality

Differential toxicity of newer insecticides was observed with the two test insects under study where *R. dominica* was found to be more susceptible to newer insecticides than *T. castaneum.* (Table1). Among the insecticides, spinosad was found to be significantly superior with 96.7 % mortality of *R. dominica* within one day of exposure followed by emamectin benzoate, thiodicarb and indoxacarb which have resulted in 70.0 and 56.7 % adult mortality respectively. All the newer insecticides provided good control (86.7 - 100%) of *R. dominica* within three days of exposure to treated maize seed compared to chemical check deltamethrin (76.7 %) and untreated control (0%). Complete mortality of *R. dominica* adults was obtained by all the newer insecticides under study within seven days of exposure.

T. castaneum was found to be relatively less susceptible to the test insecticides. At 24 hours after exposure, none of the insecticides were found effective against *T. castaneum* with a record of very less adult mortality (0 - 23 %) (Table1). But emamectin benzoate recorded 90% adult mortality on third day of exposure which was significantly superior to all other insecticides (0 to 33.3 %) compared with chemical check deltamethrin (16.7 %) and untreated control (0 %). Same trend was continued up to seven days where emamectin benzoate and spinosad recorded highest mortality of *T. castaneum (*90 % and 86.7 % respectively). Three newer insecticides *viz.,* emamectin benzoate (100 %), spinosad (93.3 %) followed by thiodicarb (73.3 %) were found superior to deltamethrin and other test insecticides which recorded less than 50 % adult mortality compared to untreated control even after 15 days after exposure. Similar results were also reported by Bonjour *et al.* (2008) on stored wheat. Huang *et al.* (2004) reported that field strains of red flour beetle have developed 20-7.5 X resistance than laboratory strains and also reported that *T. castaneum* is the least susceptible species to spinosad than other stored grain beetles. Athanassiou (2008) reported that one ppm spinosad can cause adult mortality of *R. dominica* up to 6.3%, while our results indicate that 100% mortality occurs at 2 ppm dose after 72 hours. Thus the results are in line with that of Athanassiou (2008) who further reported that *T. castaneum* is less susceptible to spinosad and survival can be high at high dose rate and increased exposure time.

Storability studies

Effect of insecticides on insect damage in hybrid maize

Three months after storage, (Table 2) all the newer insecticides were found to be effective with no insect damage (0 %) at par with the chemical check deltamethrin compared to untreated control (0.8 %). As indicated in Table 2, six months after storage, all the newer insecticides except flubendiamide (3.6%) maintained their supremacy with no insect damage and as good as deltamethrin compared to untreated control (7.4%). Even nine months after storage, spinosad, emamectin benzoate, thiodicarb, indoxacarb and lufenuron performed better (< 2%) compared to deltamethrin (3.67 %) and untreated control (9.6 %). Twelve months after storage, spinosad and emamectin benzoate proved to be the best treatments with no insect damage on treated maize followed by thiodicarb and lufenuron (1.3 %), indoxacarb (3.4 %) and deltamethrin (2.9 %).

Highest seed damage of 24.4 % was recorded with untreated control. Flubendiamide is found to be significantly inferior to all other newer insecticides with high insect damage (5.1%). The results of the experiment clearly showed that all the insecticides except flubendiamide were found effective in protecting the maize seed from insect damage up to 12 months of storage without any adverse effect on germination and vigor of the seed.

Effect of insecticides on moisture content in hybrid maize

The effect of insecticidal seed treatments on moisture content of seed at different storage intervals was found non significant and which was observed below Indian Minimum Seed Certification Standards (10 %) in all the treatments. It clearly showed that none of the insecticides when applied as seed treatment affected seed moisture content (Table 2).

Effect of insecticides on germination of hybrid maize seed

There were no significant differences in seed germination up to three months of storage and all the treatments maintained > 90% germination and

Table 3. Effect of newer insecticides on germination and seedling vigor of hybrid maize.

Chemical	Germination (%) *				Seedling Vigor Index			
	3M	6M	9M	12M	3M	6M	9M	12M
Flubendiamide 2ppm	98.0 (85.2)	99.3 (86.2)	78.0 (61.8)	65.0 (53.9)	1818	2284	1650[d]	1174 [a]
Emamectin benzoate 4ppm	99 (87.3)	99.3 (87.3)	85.0 (67.2)	70.0 (56.4)	1713	2637	1760[b]	1449[a]
Spinosad 2 ppm	99 (85.4)	99.3 (86.2)	82.0 (65.1)	68.0 (55.4)	1659	2431	2023[a]	1363[a]
Thiodicarb 2 ppm	99 (87.3)	99.3 (87.3)	84.0 (66.7)	65.0 (54.8)	1963	2396	1806[a]	1410[a]
Indoxacarb 2 ppm	100 (90.0)	99.6 (88.1)	83.0 (65.7)	62.0 (51.8)	2057	2576	1786[a]	1136[a]
Lufenuron 5 ppm	100 (90.0)	96.3 (79.1)	85.0 (67.2)	69.0 (56.1)	1853	2483	1705[b]	1279[a]
Deltamethrin 1 ppm	100 (90.0)	97.0 (80.3)	81.0 (63.9)	63.0 (52.6)	1742	2553	1687[c]	1205[a]
Control	100 (90.0)	85 (65.7)	54.0 (47.8)	44.0 (41.9)	1796	2015	1627[d]	766[b]
CD @ 5%	NS	6.59	8.98	7.52	NS	NS	257	313

*Figures in parentheses are arcsine transformed values M: months after storage

Table 4. Effect of newer insecticides on oil %, protein and starch content of hybrid Maize.

Chemical	Oil %				Protein %				Starch %			
	3M	6M	9M	12M	3M	6M	9M	12M	3M	6M	9M	12M
Flubendiamide -2ppm	6.0	6.2	6.3	6.0	12.8	12.5	12.4	12.6	67.1	66.6	64.3	67.0
Emamectin benzoate- 4 ppm	6.1	6.1	6.2	6.1	12.7	12.5	12.3	12.7	66.8	66.8	64.4	67.0
Spinosad -2 ppm	6.0	6.1	6.3	6.1	12.6	12.5	12.4	12.6	66.9	66.5	64.3	67.0
Thiodicarb - 2 ppm	6.2	6.1	6.3	6.1	12.5	12.5	12.3	12.6	66.9	66.5	64.4	66.6
Indoxacarb -2 ppm	6.0	6.2	6.2	6.0	12.6	12.6	12.3	12.5	66.8	66.5	64.5	66.8
Lufenuron- 5 ppm	6.1	6.2	6.4	6.1	12.7	12.5	12.4	12.6	66.9	66.5	64.4	66.8
Deltamethrin - 1 ppm	6.0	6.1	6.5	6.0	12.7	12.7	12.4	12.5	61.0	66.6	64.2	66.9
Control	6.0	6.2	6.1	6.0	12.7	12.5	12.2	12.6	66.7	66.7	64.3	67.1
CD @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

were at par with untreated control (100 %). But the germination was dropped to 85 % in the untreated maize seed after six months of storage (Table 3). All the new insecticides were found to be effective in maintaining the germinability of seed above certification standards (>80%) up to nine months of storage and at par with deltamethrin , the germinability in untreated control was up to 54% . After 12 months of storage, the germinability of seeds was dropped below certification standards (<80%) in all the insecticidal treatments.

Effect of insecticides on seedling vigor index of hybrid maize seed

Studies on seedling vigor index of hybrid maize indicated that the vigor of seed decreased with the increase in storage period (Table 3).There were no significant differences in seedling vigor of maize seed up to six months of storage. Further, significant differences were observed among the insecticidal treatments after nine months of storage where spinosad recorded highest seedling vigor (2023) at par with thiodicarb and indoxacarb (1806 and 1786 respectively) followed by emamectin benzoate (1760) and lufenuron (1705) which performed better than deltamethrin (1687). Flubendiamide proved inferior with lowest record of seedling vigor (1650) which is at par with untreated control (1627).Though there was decrease in seedling vigor of the seed, all the insecticidal treatments including flubendiamide recorded significantly higher seedling vigour in the range of 1174 to 1449 compared to untreated control (766) after twelve months of storage. These results are in line with the findings of Ghelani et al (2009) who reported that emamectin benzoate and spinosad were effective against storage pests *viz., R. dominica, T. castaneum and C. cephalonica* up *to nine* months of storage of pearl millet without affecting the germination and vigor of seed. Data recorded on the quality parameters *viz.*, oil%, protein % and starch content of treated seed indicated that there were no significant differences in quality of hybrid maize seed up to 12 months of storage. (Table 4.)

Effect of insecticides on adult emergence and avoidable weight loss of hybrid maize

All the insecticidal seed treatments except flubendiamide recorded significantly low adult population of *R. dominica* and *T. castaneum* compared to untreated control after 12 months of storage. Lowest population of *R. dominica* was observed in treatment with emamectin benzoate and spinosad (6 insects/ 500 g seed). Flubendiamide recorded highest population of *R. dominica* (68 insects/500 g seed) which is significantly higher than untreated control (40 insects/500 g seed) and chemical check deltamethrin (9 insects / 500 g seed).Surprisingly flubendiamide recorded low number of *T. castaneum* adults (3insects / 500 g seed) at par with spinosad(3 insects / 500 g seed) compared to emamectin benzoate(10 insects / 500 g seed) and untreated control (15 insects / 500 g seeds). While, the lowest population of *T. castaneum (*1.0/ 500 g seed) was found in treated maize seed with thiodicarb, indoxacarb and deltamethrin.

Effect of insecticides on seed quality parameters of hybrid maize seed

All the insecticidal seed treatments caused varying degree of seed damage in hybrid maize and reduced number of emerged adults as well as the weight loss of the grains. The percent avoidable weight loss of treated maize seeds was higher compared to the grains that received no treatment. Highest avoidable weight loss was recorded in seeds treated with emamectin benzoate and spinosad (11.41 % in both) followed by indoxacarb (10.74%) compared to chemical check deltamethrin (9.39 %). There are a number of studies that document effectiveness of contact insecticides when stored-product insects are exposed on treated surfaces for fixed time intervals (Arthur, 1999; Toews *et al.*, 2003). Liang *et al*., (2002) reported the persistent insecticidal activity of spinosad for 12 months against insect pests under on-farm storage of corn. Research revealed the strong larvicidal effects of spinosad on storage pests of corn and sunflower seeds (Huang and Subrahmanyam, 2004) and storage pests of stored wheat (Flinn *et al.,* 2004).These research findings are in line with that of Bonjour et al. (2008) and Yousafnezhad (2007) who reported that spinosad provided long term control on *R. dominica* and *T. castaneum* population up to 96 weeks.

In summary, the newer reduced risk insecticides *viz.,* spinosad and emamectin benzoate with their novel modes of action protected the hybrid maize seed from infestation and damage of storage insects up to twelve months of storage. Hence, these novel insecticides have the potential to be more effective and safer chemicals and would be a valid addition to pest management programs of storage pests and can be used for long term safe storage without any quantitative and qualitative losses of hybrid maize seed.

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LITERATURE CITED

Abdul-Baki A A and Anderson J D 1973 Vigor determination in soybean seeds by multiple criteria. *Crop Science*, 13: 630-633.

Arthur F H 1999 Survival of red flour beetles (Coleoptera: Tenebrionidae) on concrete partially treated with cyfluthrin. *Journal of Economic Entomology,* 92: 981-987.

Athanassiou C G, Kavallievator N G, Yialtilis A E, Vayias B J, Mourtas C S and Tomanvoic Z 2008 Influence of temperature and relative humidity on efficacy of spinosad against Red flour beetle species. *Journal of insecticide Science*, 8(60): 1-8.

Bonjour E L, Phillips T W and Pitts J T 2008 Spinosad provides long-term protection for stored wheat. *General Session on Stored Grains*: 1189-1193.

CMIE 2010 Centre of Monitoring India Economy Pvt. Limited. Apple Apetile, Mumbai, India

Flinn P W, Subramanyam B and Arthur F H 2004 Comparison of aeration and spinosad for suppressing insects in stored Wheat. *Journal of Economic Entomology,* 97:1465-1473.

Huang F and Subrahmanyam B 2004 Responses of *Corcyra cephalonica* (Stainton) to Pyrimiphos-methyl, Spinosad and combina tions of Pyrimiphos-methyl and synergized Pyrethrins. *Pest Management Science,* 60: 191-198.

Huang F, Subramanyam B, Towes TD 2004 Susceptibility of laboratory and field strains of four stored product insect species to spinosad. *Journal of Economic Entomology,* 97 (6): 2154-2159.

International Seed Testing Association 1999 International Rules for Seed Testing. *Seed Science and Technology, Supplement rules,* 27: 25-30.

Liang F, Subrahmanyam B and Arthur F H 2002 Effectiveness of spinosad on four classes of Wheat against five stored –product insects. *Journal of Economic Entomology,* 95: 640-650.

Panse V G and Sukhatme P V 1978. *Statistical Methods for Agricultural Workers*. 3rd edn., ICAR, New Delhi, p.347.

Toews M D, Subramanyam B and Rowan J M 2003 Knockdown and mortality of adults of eight species of stored-product beetles exposed to four surfaces treated with spinosad. *Journal of Economic Entomology*, 96: 1967-1973.

Ghelani Y H, Dhedhi K K, Joshi H J, Raghvani K L and Dangaria C J 2009 Effect of insecticidal seed treatment on viability of pearl millet seed during storage. *Karnataka Journal of Agricultutal Sciences. 22 (3- Spl. Issue): 633-634.*

Yousafnezhad R and Asghar P A 2007 Effect of spinosad on *Tribolium castaneum* (Coleoptera: Tenebriionidae) and *Sitophilus oryzae* (Coleoptera: Cruculionidae). *Pakistan Journal of Biological Sciences*, 10(1): 2505-2509.

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