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Effect of various plant powders on rice weevil (*Sitophilus oryzae* Linn.) in stored wheat

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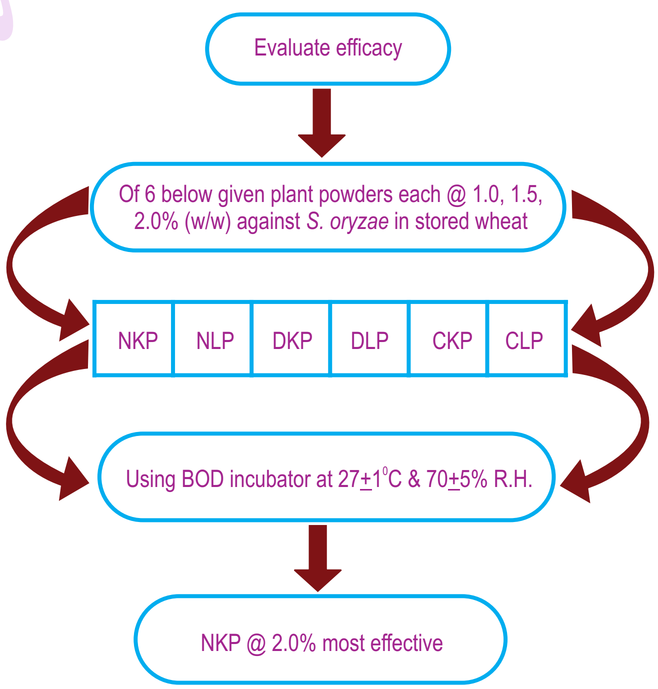
Abstract

Aim: Now-a-days usage of chemical insecticides has become more restricted and creating many environmental problems. Therefore, objective of the present study was to evaluate the alternative control measures in form of botanicals against rice weevil (*Sitophilus oryzae* L.) on stored wheat.

Methodology: Six botanicals in powder form viz., neem leaf powder (NLP), *neem* kernel powder (NKP), *dharek* leaf powder (DLP), *dharek* kernel powder (DKP), castor leaf powder (CLP) and castor kernel powder (CKP) each at the rate of 1.0, 1.5 and 2.0 % (w/w) were tested by directly mixing into wheat grains against *S. oryzae*. An aliquot of 100g wheat sample was used in each treatment for maximum of 3 replications. Three jars were also kept for untreated control. Three jars of Deltamethrin 2.8 EC were also kept as standard check. Five pairs of 1-2 week old adult insects (1:1 female to male ratio) were released into each jar. The open tops of all the jars were covered with muslin and kept inside BOD incubator at 27±1 ºC and 70±5 % R.H.

Results: Deltamethrin 2.8 EC was highly effective as all the adult insects were died within 24 hours after their release. Among various powders, NKP at 2% was found best as it showed minimum grain damage (3.84%), weight loss (1.15%) and adult emergence (16.17), while maximum inhibition rate (92.58%) over the untreated control with maximum grain damage (21.16%), weight loss (13.83%) and adult emergence (157.58 adults). The NKP was followed by DKP, NLP, DLP, CKP and CLP. Seed viability was not adversely affected by any of the plant powders used in the studies.

Interpretation: This study showed that 2% NKP the most effective compound over the other compounds and untreated control, and it can be used as botanical against *S. oryzae* in stored wheat.



Introduction

In large or small quantities, the stored wheat (*Triticum aestivum* Linn.) is attacked by several insect-pests of which rice weevil, *Sitophilus oryzae* Linn. (Coleoptera: Curculionidae), is a primary pest of wheat in storage (Mark *et al.,* 2010). The insect-pests may cause damage to the stored grains and grain products which may range from 5-10 % in the temperate where as 20-30 % in the tropical zones (Talukder 2006, Rajendran and Sriranjini, 2008), while Mohammad (2000) reported up to 10-15 % weight loss in wheat during storage. Rajashekar *et al.* (2010) reported about 20-25 % of the total food grain production (250 million tonnes) to be damaged by various stored grain insect pests in India.

The today's usual practices for the control of stored grain insect pests of wheat in the world include application of synthetic insecticides and phosphine gas during its storage (Anwar *et al*, 2003). The search for environmentally safe alternatives is the focus of research in several laboratories around the world (Silhacek and Murphy, 2006). Resistance to phosphine is so high in Australia, India and other countries, that it would cause control failures (Mau *et al.,* 2012, Ahmad *et al.,* 2013). Although the chemical insecticides are effective but their repeated use has led to several problems like residual toxicity, environmental pollution and adverse effects on food and humans (Lu and Wu, 2010) besides increasing costs of their application. Worldwide reports show that when mixed with stored grains, leaf, bark, seed powder, or oil extracts of plants reduce oviposition and suppress adult emergence of *S. oryzae*, and thereby reduce seed damage (Tripathi *et al*., 2009). Devi and Devi (2011) reported 18 plant species to show insecticidal potential and anti-ovipositional properties against *S. oryzae*.

The indigenous plant materials are mostly active against a limited number of insect species and are often biodegradable to non-toxic chemicals, hence these are potentially more suitable in the pest management programmes (Mamun *et al*., 2008a, 2008b, 2009, Yallappa *et al.,* 2012) effects against stored pests of wheat.) gave the current state of the plant derived insecticides as grain protectants with their mode of olfaction and revealed these as having a great potential against several stored product insect pests including *S. oryzae*. Moreover, these materials are cheaper and hazard free in contrast to the conventional insecticides. In view of the above facts, the present investigations were carried out to reduce the huge storage losses in wheat by *S. oryzae* through the use of plant products.

Materials and Methods

Raising insect culture : The pure culture of *S. oryzae* was raised on Punjab Agricultural University's recommended wheat variety PBW 2967 in the laboratory under controlled conditions. The insects were kept in plastic jars of size 12˝x 6˝. The open tops of jars were covered with a piece of white muslin. A counted number of adult insects were released for egg laying and removed after 24 hours of eggs laying. The new adults emerged in about 25-30 days. These newly emerged adults were transferred to the jars containing fresh wheat grains for maintaining the pure culture. The optimum temperature for raising the culture was kept between 28±5ºC and relative humidity was maintained at 70±5 %. The young adults of the test insect from the pure insect culture were used for conducting present studies.

Indigenous plant material: The indigenous plant material for evaluation included leaves and kernels of *neem* (*A. indica*), castor (*Ricinus communis* Linn.) and *dharek* (*M. azedarach*). These were shade dried for two months in room till they became hard and crispy. The finely ground powder of these plant materials was obtained by grinding their dried leaves and kernels separately in the mechanical grinder and by sieving through a 90 mesh size. The dried material of indigenous plants in form of finely ground powder was used against *R. dominica* and *S. oryzae* on wheat. The resulting fine powder was used as direct admixture to the grains at different application rates against standard check and untreated control. An aliquot of 100g grains in three replicates was taken out of this lot and put into the requisite size plastic jars for the trials. Five pairs of 1-2 week old adults (1:1 female to male ratio) were released into each jar. The open tops of all the jars were covered with muslin and tied with rubber bands. All the jars were kept in BOD incubator at 27±1 ºC and 70±5 % R.H. Three jars were also kept for untreated control. The different plant powders treatments, viz., T_1: *Neem l*eaf powder (NLP)-1.0%, T_2: 1.5% and T_3: 2.0%; T_4: *Neem* kernel powder (NKP)-1.0%, T_5: 1.5% and T_6: 2.0%; T_7: Castor leaf powder (CLP)-1.0%, T_8: 1.5% and T_9: 2.0%; T_{10}: Castor kernel powder (CKP)-1.0%, T_{11}: 1.5% and T_{12}: 2.0%; T_{13}: *Dharek* leaf powder (DLP)-1.0%, T_{14}: 1.5% and T_{15}: 2.0%; T_{16}: *Dharek* kernel powder (DKP)-1.0%, T_{17}: 1.5% and T_{18}: 2.0%; T_{19} (standard check): Deltamethrin 2.8 EC 2.8% (v/v) (14ml/0.5 L water/quintal wheat seed spread uniformly on tarpaulin laid smoothly over the pucca floor) and T_{20}: Untreated control, were applied to the requisite wheat samples for conducting the studies.

Observations record : The effect of all powders against *S. oryzae* was evaluated at 30, 60, 90 and 120 days after treatment (DAT) by making records of various physical parameters such as % grain damage, i.e., healthy grains (without holes) and insect damaged grains were separated on 1000 grain count basis. The % damage for was worked out based on damaged and undamaged grains in all treatments over untreated control; % weight loss, i.e., where a sample weighing 100g was drawn from the cleaned wheat for assessment of percent weight loss caused by *S. oryzae*. The number and weight of damaged and undamaged grain were recorded and put in the equation for determination of weight loss (Adams and Schulten, 1978); adult emergence, i.e., the numbers of adults emerged in each jar (containing 100g grain sample) were counted during different wheat storage periods to examine the adult emergence of *S.*

oryzae in different powders; % inhibition rate, i.e., it was worked out form adult emergence of *S. oryzae* as per Talukder and Howse (1994); and % seed germination, i.e., using paper towel method, a moist wax paper was placed over the smooth surface over which moist towel paper was placed and in all treatments, 100 healthy seeds were placed in 10x10 grains fashion on moist paper on moist paper laid over a smooth surface, followed by another moist paper placed over it. The data were analyzed by Completely Randomized Design (factorial CRD) using the square root transformation for the adult emergence in computer programme CPCS1 (Cheema and Singh, 1990).

Results and Discussion

There was no grain damage caused by *S. oryzae* in the deltamethrin 2.8 EC treated wheat grains for up 120 DAT, whereas, the plant powders at 1.0, 1.5 and 2.0 %, showed significant results for grain damage (Table 1). The pest caused no grain damage in NKP at 30 DAT, which had slightly increased to 0.63 % (60 DAT), 2.57 % (90DAT), and 7.17 % (120 DAT) as against untreated control, i.e., 1.50, 15.53, 28.17 and 59.43 % damage, respectively, at 30, 60, 90 and 120 DAT. The trend from high to low grain damage was subsequently followed by DKP, NLP, DLP, CKP and CLP. The powders at 1.0 and 1.5 % dosages registered high grain damage.

The lowest grain damage in NKP at 0.1 % (0.07%) by *S. oryzae* at 30 DAT was also confirmed in the findings of Mohan *et al.* (1990) who reported no grain damage on maize treated with deoiled NKP at 0.10 % by *S. oryzae*. Imti and Zudir (1997) reported higher grain damage in NLP and NKP at 1.0 % (12.34 %) in their studies conducted in contrast to lower grain damage in NLP (8.56%) and NKP (5.50%) at 1.0 % on wheat due to *S. oryzae* during present studies, which might be due their different laboratory conditions. Yadu *et al.* (2000) evaluated NKP, NLP, eucalyptus leaf powder, sarifa leaf powder and lantana leaf powder at 1.0 and 2.0 % (w/w) in stored maize and paddy to record their adverse effects on the development of *S. cereaella* and revealed NKP as the most effective based on its lesser grain damage. Similar findings for low grain damage by *S. oryzae* in NKP were reported on stored wheat in the present studies. The findings by Arya and Tiwari (2013) for the lowest grain damage by *S.oryzae* in NKP at 2.0 % on stored wheat have also confirmed the present investigations for the similar observations. However, Mishra and Pandey (2014) reported NLP at 1.0 % (w/w) as highly effective against *S. oryzae* based on low grain damage over the untreated control (9.20, 18.55 and 29.60%) in stored wheat, respectively, at 30, 60 and 90 DAT, in contrast to the grain damage (0.27, 4.27 and 8.83%) in NLP at 1.0 % over the untreated control (1.50, 15.53 and 28.17%) in the present investigations.

No weight loss in wheat by *S. oryzae* was recorded for up to 120 DAT with deltamethrin 2.8 EC, however significantly varying levels of grain weight loss were observed in all the plant powders at 1.0, 1.5 and 2.0 % (Table 1). There was no grain weight loss recorded in NKP at 30 DAT, which slightly increased to 0.14 % (60 DAT), 1.15 % (90 DAT), and 3.28 % (120 DAT) over high weight loss, i.e., 0.20, 3.61, 13.81 and 37.65 %, respectively, at 30, 60, 90 and 120 DAT in the untreated control. The trend from high to low weight loss was subsequently followed by DKP, NLP, DLP, CKP and CLP. The powders at 1.0 and 1.5 % dosages registered comparatively more weight loss.

The current investigations for lowest weight loss due to *S. oryzae* on wheat, i.e. 2.40 and 1.14 %, respectively, in NLP at 1.0 and 2.0 % were in full confirmation with Ileke and Bulus (2012) who also registered low weight loss, i.e. 2.5 and 1.3 % in *neem* powder at 1.0 and 2.0 %, respectively. The present findings for the lower grain damage (0.27, 4.27 and 8.83%), weight loss (0.04, 0.97 and 4.05%) in NLP at 1.0 % over the highest grain damage (1.50, 15.53 and 28.17%) and weight loss (0.20, 3.61 and 13.81%) in the untreated control samples also resembled to the studies conducted by Mishra and Pandey (2014) who reported *S. oryzae* to cause low grain damage (5.36, 8.43 and 16.02%) and weight loss (5.36, 7.87 and 13.13%) in NLP at 1.0 % over the untreated control having grain damage (9.20, 18.55 and 29.60%) and weight loss (8.72, 14.40 and 20.99%), respectively, at 30, 60 and 90 DAT.

The death of all released *S. oryzae* adults in grains treated with deltamethrin 2.8 EC at 2.8 % resulted into no adult emergence. In contrast, no powder treatment caused insect death but there were varied levels of hindrance effect to the adult emergence at 1.0, 1.5 and 2.0 % over the control for up to 120 DAT (Table 1). The NKP at 2.0 % registered no emergence of *S. oryzae* adults at 30DAT. The adult emergence increased to 3.67 (60 DAT), 12.33 (90 DAT), and 48.33 adults (120 DAT) over high adult emergence, i.e., 8.00, 82.00, 221.00 and 319.33 adults, respectively, at 30, 60, 90 and 120 DAT in the untreated control. A high to low trend for adult emergence was followed by plant powders viz., DKP, NLP, DLP, CKP and CLP. The plant powders at 1.0 and 1.5 % dosages registered comparatively more adult emergence.

The present findings for the lower adult emergence of *S. oryzae* (1.33adults) in NKP at 1.0 % over untreated control (8.00 adults) at 30 DAT were in somehow confirmed in the findings of Jilani and Su (1983) who comparatively reported high adult emergence of *S. granarius* adults in NKP at 1.0 % (5.16 adults) over the untreated control (20.16 adults). The higher effectiveness of NKP at 1.0 and 2.0 % in terms of low adult emergence over the untreated control on stored wheat in the current investigations was supported by Yadu *et al.* (2000) also revealed NKP at 1.0 and 2.0 % as the most effective based on lower adult emergence of *S. cereaella* in stored maize and paddy. Present studies regarding the varied levels of adult emergence of *S. oryzae* in NKP at 1.0 (42.25 adults) and 2.0 % (16.08 adults), respectively, over the untreated control (157.58 adults) were in

Table 1 : Effect of different plant powders on various physical parameters in wheat infested by *S. oryzae* during storage

Treatment	% dosage (w/w)	Adult emergence[1,2] 30	60	90	120	Mean	Per cent inhibition rate[1] 30	60	90	120	Mean	Grain damage (%)[1,4] 30	60	90	120	Mean	Weight loss (%)[1,4] 30	60	90	120	Mean
Neem leaf powder	1.0	2.33 (1.82)	26.00 (5.19)	88.00 (9.43)	157.00 (12.57)	**68.33 (7.25)**	70.57	67.94	60.14	50.41	**62.27**	0.27	4.27	8.83	20.87	**8.56**	0.04	0.97	4.05	10.13	**3.80**
	1.5	1.33 (1.52)	16.37 (4.16)	63.33 (8.01)	111.67 (10.61)	**48.18 (6.08)**	83.66	79.85	71.30	64.79	**74.90**	0.17	2.77	5.50	16.80	**6.31**	0.02	0.62	2.51	8.04	**2.80**
	2.0	0.67 (1.28)	8.67 (3.10)	33.67 (5.89)	78.67 (8.92)	**30.42 (4.80)**	92.13	89.39	84.76	75.29	**85.39**	0.07	1.53	3.57	10.53	**3.93**	0.01	0.34	1.61	4.89	**1.71**
Neem kernal powder	1.0	1.33 (1.52)	14.00 (3.87)	48.67 (7.04)	105.00 (10.29)	**42.25 (5.68)**	83.20	82.93	77.99	66.88	**77.75**	0.07	2.60	5.07	14.27	**5.50**	0.01	0.58	2.29	6.72	**2.40**
	1.5	0.33 (1.14)	8.00 (3.00)	32.00 (5.74)	83.67 (9.20)	**31.00 (4.77)**	95.83	90.26	85.50	73.60	**86.30**	0.03	1.40	3.47	10.47	**3.84**	0.00	0.31	1.56	4.99	**1.72**
	2.0	0.00 (1.00)	3.67 (2.15)	12.33 (3.65)	48.33 (7.01)	**16.08 (3.45)**	100.00	95.57	94.42	84.75	**93.69**	0.00	0.63	2.57	7.17	**2.59**	0.00	0.14	1.15	3.28	**1.14**
Castor leaf powder	1.0	5.00 (2.44)	53.33 (7.37)	127.67 (12.33)	227.33 (15.11)	**103.33 (9.31)**	37.90	34.89	31.64	28.48	**33.23**	0.73	8.83	14.67	28.47	**13.18**	0.10	2.02	6.24	13.81	**5.54**
	1.5	3.33 (2.08)	35.33 (6.03)	104.33 (10.26)	152.33 (12.38)	**73.83 (7.69)**	57.34	56.64	52.76	51.97	**54.68**	0.40	5.27	11.40	19.97	**9.26**	0.05	1.20	5.27	9.40	**3.98**
	2.0	1.67 (1.63)	14.00 (3.85)	84.00 (9.21)	125.33 (11.24)	**56.25 (6.48)**	78.44	83.13	61.96	60.52	**71.01**	0.21	2.97	9.27	12.93	**6.35**	0.02	0.66	4.25	6.04	**2.74**
Castor kernal powder	1.0	4.67 (2.38)	42.67 (6.61)	105.33 (10.31)	166.67 (12.95)	**79.84 (8.06)**	40.54	47.86	52.30	47.49	**47.05**	0.60	6.63	12.13	24.10	**10.87**	0.08	1.50	5.46	11.14	**4.55**
	1.5	2.67 (1.91)	25.00 (5.09)	82.67 (9.14)	126.33 (11.28)	**59.17 (6.86)**	66.27	69.16	62.55	60.14	**64.53**	0.23	4.30	9.07	18.00	**7.90**	0.03	0.97	4.18	8.63	**3.45**

Physical parameters (days after treatment)

Cont......

	2.0	1.33	14.67	65.00	99.67	**45.17**	83.66	82.10	70.58	68.76	**76.28**	0.20	3.13	7.10	12.67	**5.78**	0.03	0.70	3.25	5.92	**2.48**
		(1.52)	(3.95)	(8.12)	(10.03)	**(5.90)**															
Dharek leaf powder	1.0	2.00	34.00	98.67	163.00	**74.42**	75.33	58.07	55.30	48.58	**59.32**	0.50	6.00	10.30	23.33	**10.03**	0.07	1.37	4.76	11.41	**4.40**
		(1.72)	(5.91)	(9.98)	(12.80)	**(7.60)**															
	1.5	1.67	18.33	78.33	116.67	**53.75**	79.96	77.42	64.53	63.18	**71.27**	0.27	3.50	6.73	17.43	**6.98**	0.04	0.79	3.07	8.14	**3.01**
		(1.61)	(4.39)	(8.91)	(10.85)	**(6.44)**															
	2.0	0.67	11.00	50.00	81.67	**35.84**	91.53	86.41	77.33	74.33	**82.40**	0.20	1.97	5.53	11.17	**4.72**	0.03	0.44	2.52	5.19	**2.05**
		(1.28)	(3.46)	(7.13)	(9.09)	**(5.24)**															
Dharek kernal powder	1.0	1.67	19.33	64.00	129.33	**53.58**	79.96	76.20	71.03	59.25	**71.61**	0.13	3.40	6.80	17.63	**6.99**	0.02	0.76	3.09	8.42	**3.07**
		(1.61)	(4.51)	(8.06)	(11.42)	**(6.40)**															
	1.5	0.67	10.00	46.00	95.33	**38.00**	91.07	87.71	79.17	69.88	**81.96**	0.07	1.63	4.23	13.83	**4.94**	0.01	0.37	1.90	6.49	**2.19**
		(1.28)	(3.31)	(6.85)	(9.81)	**(5.31)**															
	2.0	0.33	5.00	19.00	62.33	**21.67**	95.24	93.92	91.39	80.25	**90.20**	0.00	1.40	3.20	7.93	**3.13**	0.00	0.31	1.44	3.63	**1.35**
		(1.14)	(2.44)	(4.47)	(7.95)	**(4.00)**															
Deltamethrin 2.8EC[3]	2.8***	0.00	0.00	0.00	0.00	**0.00**	100.00	100.00	100.00	100.00	**100.00**	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	**0.00**
		(1.00)	(1.00)	(1.00)	(1.00)	**(1.00)**															
Untreated control	-	8.00	82.00	221.00	319.33	**157.58**	-	-	-	-		1.50	15.53	28.17	59.43	**26.16**	0.20	3.61	13.81	37.65	**13.82**
		(3.00)	(9.10)	(14.90)	(17.89)	**(11.22)**															
	Mean	**1.98**	**22.07**	**71.20**	**122.48**		**79.09**	**76.81**	**70.77**	**64.66**		**0.28**	**3.89**	**7.88**	**17.35**		**0.04**	**0.88**	**3.62**	**8.70**	
		(1.64)	**(4.43)**	**(8.02)**	**(10.62)**																

CD (p=0.05)		CD (p= 0.05)		CD (p= 0.05)		CD (p= 0.05)	
Treatment :	0.23	Treatment:	4.32	Treatment:	0.97	Treatment:	1.83
Days after treatment:	0.10	Days after treatment:	1.98	Days after treatment:	0.44	Days after treatment:	0.82
Treatment × Days after treatment :	0.46	Treatment × Days after treatment:	8.64	Treatment × Days after treatment:	1.95	Treatment × Days after treatment:	3.66

[1]Means of three replications, [2]Figures in parentheses are the means of transformed values; [3]Deltamethrin 2.8 EC (v/v) @ 14ml per 0.5l water/quintal wheat seed spread uniformly on the tarpaulin laid smoothly over the pucca floor, [4]000 grain count basis

Table 2 : Effect of different plant powders on wheat seed germination during storage

Treatment	Dosage w/w (%)	Per cent seed germination (days after treatment) [1,2]				
		30	60	90	120	Mean
Neem leaf powder	1.0	94.00	93.00	92.33	92.00	**92.83**
	1.5	93.67	93.33	93.00	92.33	**93.08**
	2.0	93.33	93.00	93.00	93.33	**93.17**
Neem kernal powder	1.0	94.00	93.00	93.33	93.00	**93.33**
	1.5	94.33	94.00	93.33	93.33	**93.75**
	2.0	94.67	94.67	93.00	93.67	**94.00**
Castor leaf powder	1.0	94.00	94.00	94.33	93.33	**93.92**
	1.5	94.33	93.67	92.67	93.00	**93.42**
	2.0	94.33	93.33	92.33	93.33	**93.33**
Castor kernal powder	1.0	94.00	94.00	93.67	92.67	**93.59**
	1.5	93.67	92.67	94.33	93.00	**93.42**
	2.0	92.67	93.33	96.33	94.00	**94.08**
Dharek leaf powder	1.0	93.00	93.33	94.67	94.33	**93.83**
	1.5	93.33	93.33	93.67	93.33	**93.42**
	2.0	94.00	93.33	94.00	93.00	**93.58**
Dharek kernal powder	1.0	93.33	94.00	93.33	93.33	**93.50**
	1.5	94.33	93.33	94.00	93.00	**93.67**
	2.0	93.33	93.33	93.67	94.00	**93.58**
Deltamethrin 2.8EC	2.8	94.33	94.67	93.00	94.33	**94.08**
Untreated control	-	94.67	94.33	94.00	93.00	**94.00**
Mean	**93.87**	**93.58**	**93.60**	**93.27**		
		CD (p= 0.05)				
		Treatment:			NS	
		Days after treatment:			NS	
		Treatment × Days after treatment :			NS	

[1]Means of three replications; [2]1000 grain count basis

confirmation to those of Ileke and Bulus (2012) who however, reported comparatively low adult emergence of *S. oryzae* (1.0 and 0.0 adults) in *neem* powder at 1.0 and 2.0 %, respectively, over the untreated control (46.0 adults). The current findings for the low adult emergence of *S.oryzae* in NLP at 2.0 % in stored wheat were also confirmed in the findings by Arya and Tiwari (2013) who also reported the similar type of observations.

Inhibition rate was computed on the basis of adult emergence in all plant powders over untreated control. The deltamethrin 2.8 EC showed cent % inhibition of *S. oryzae* for up to 120 DAT (Table 1). A complete inhibition rate was noticed for NKP at 2.0 % at 30 DAT. The inhibition rate showed a significant decline, i.e., 95.57 % (60 DAT), 94.42 adults (90 DAT), and 84.75 adults (120 DAT). A high to low trend for inhibition rate was followed by plant powders viz., DKP, NLP, DLP, CKP and CLP. The plant powders at 1.0 and 1.5 % dosages registered comparatively low inhibition rate.

The moderate inhibition rate (repellency) of *S. oryzae* in *neem* powder at 1.0 % (62.27%) reported by Suss *et al.* (1997) confirmed the present findings for its inhibition rate in NLP at 1.0 % (76.10%). The high inhibition rate of *S. oryzae* in NKP at 2.0 % (99.12 and 87.06%) in present studies over the high adult mortality (87.70 and 82.50%) in NKP at 5.0 %, respectively, at 30 and 90 DAT by Rama Rao and Sarangi (1998) might be due to the over dosage of *neem* powder used by them. The current findings revealing lowest (77.75%) and highest (93.69%) rate of inhibition in *S. oryzae* for NKP at 1.0 and 2.0 %, respectively, on stored closely followed Ileke and Bulus (2012) who also reported lowest (95.05%) and highest (100.00%) inhibition rate, respectively, in *neem* powder at 1.0 and 2.0 %. In present findings, the highest mean inhibition rate in NKP at 2.0 % (93.58%) is also in confirmation with Arya and Tiwari (2013) who reported NKP at 2.0 % as most effective to register a highest mortality in *R. dominica* on stored wheat.

The seed germination in all treatments at 1.0, 1.5, 2.0 % and untreated control showed non-significant differences at 30, 60, 90 and 120 DAT. It ranged from 92.67-94.67 (30 DAT), 92.67-94.67 (60 DAT), 92.33-94.67(90 DAT) and 92.00-94.33 % (120 DAT). In treatment wise means, it varied from 92.83-94.08 %, and based on day wise means, it ranged from 93.00-94.67 % (Table 2).

The present findings for non-significant effects of various plant powders on seed germination is in accordance with the reports of Jotwani and Sircar (1965), Yadu *et al.* (2000), Arya and Tiwari (2013) and Kemabonta and Falodu (2013) who have reported non-significant effects of various plant powders on seed germination. A non-significant difference in seed germination in *neem* leaf powder at 1.0 % (94.00, 93.00 and 92.33%) over untreated control in the present study is also in confirmation with the study of Mishra and Pandey (2014) for seed germination (87.50, 85.00 and 81.00%)

At the end of storage, when overall means were compared, deltamethrin was found to be highly effective against *S. oryzae*. Within the respective powder categories, most powders at 1.0, 1.5 and 1.5 % were significantly different from each other in terms of their efficacy against above pest. Among various powders, 2.0 % *neem* kernel powder was found to be the most effective against *S. oryzae,* respectively, based on lowest grain damage (2.59%), weight loss (1.14%) and adult emergence (16.08 adults) in treated over untreated control samples with highest grain damage (26.16%), weight loss (13.82%) and adult emergence (157.58 adults). Neem powder treated samples registered higher inhibition rate of *S. oryzae* (93.69%). The trend of highest to lowest effectiveness was as follows : *neem* kernel powder > *dharek* kernel powder > *neem* leaf powder > *dharek* leaf powder > castor kernel powder > castor leaf powder. All the plant powders at 1.0 and 1.5 % registered comparatively less effective against the pest.

Neem kernal powder at 2.0 % was highly effective against *S. oryzae* due to minimum grain damage (3.84%), weight loss (1.15%), adult emergence (16.17), and highest inhibition rate (92.58%) over untreated control with maximum grain damage (21.16%), weight loss (13.83%) and adult emergence (157.58 adults). It was followed by DKP, NLP, DLP, CKP and CLP. There was no adverse effect of any plant powder on the seed viability.

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