Comparative efficacy of storage bags, storability and damage potential of bruchid beetle

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Abstract Groundnut during storage is attacked by number of stored grain pests and management of these insect pests particularly bruchid beetle, *Caryedon serratus* (Oliver) is of prime importance as they directly damage the pod and kernels. In this regard different storage bags that could be used and duration up to which we can store groundnut has been studied. Super grain bag recorded minimum number of eggs laid and less damage and minimum weight loss in pods and kernels in comparison to other storage bags. Analysis of variance for multiple regression models were found to be significant in all bags for variables viz, number of eggs laid, damage in pods and kernels, weight loss in pods and kernels throughout the season. Multiple comparison results showed that there was a high probability of eggs laid and pod damage in lino bag, fertilizer bag and gunny bag, whereas super grain bag was found to be more effective in managing the *C. serratus* owing to very low air circulation.

Keywords *Arachis hypogaea* L. · *Caryedon serratus* · Percent damage · Percent weight loss · Super grain bag

Introduction

Groundnut, *Arachis hypogaea* L. is an important oilseed crop grown in semi-arid regions of Asia and Africa. Groundnut is

often stored as nuts in shell or as kernels. More than 100 insect species are known to feed on stored groundnut. The Groundnut bruchid beetle, *Caryedon serratus* (Oliver) which belongs to family Chrysomelidae, sub family Bruchinae (Kingsolver 2004) is one of the major storage pest, affecting the groundnut produce and is widely distributed across Asia (Kingsolver 1970; Harish et al. 2012b) and Africa (Feakin 1973; Delobel 1989). The primary infestation starts from the field, which is critical in the establishment of bruchids during storage (Conway 1983). The post-harvest loss in groundnut is estimated to be between 20 and 25 % of the production in Asia (Azeemuddin 1993). No recent estimates are available, however laboratory studies shows that eight pairs of adults per 100 g pods can cause 70–80 % damage in stored groundnuts (Harish et al. 2012a). These damaged pods and kernels are further prone to aflatoxin contamination making it unfit for human consumption (Nesci et al. 2011). Aluminium phosphide a common grain preservative is extensively used all over the world particularly in the developing countries. However, recent research showed it was quite poisonous and could cause serious toxic effects to lungs, heart and blood vessels resulting in pulmonary oedema, shock and arrhythmias (Abder-Rahman 1999). Groundnut is used directly for consumption and oil extraction. Use of pesticides result in accumulation of residues in food which is hazardous to human health. Therefore, use of biorational methods of pest control is more appropriate. In this regard the study was carried out to ascertain the efficacy of different storage bags on storability and damage potential *C. serratus*.

Material and methods

The laboratory study was conducted at Entomology section of Directorate of Groundnut Research (DGR), Junagadh, during the year 2010–2011 (*rabi*-summer) and 2011–2012 (*khari*f). Four different storage bags (lino bag, fertilizer bag, gunny bag

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Table 1 ANOVA of the effect of storage bags and storage period (months) on number of eggs laid, damage and weight loss caused by *C. serratus*

Source of variance	DF	Mean sum of squares				
		Number of eggs laid	Damage pods (%)	Damage kernels (%)	Weight loss pods (%)	Weight loss kernels (%)
Bags	3	8504.2*	7481.6*	10209.9**	7342.9*	9401.5*
Year × bags	3	612.8**	521.9**	311.7**	505.0**	429.3**
Duration	5	9517.7*	19645.7**	16323.7**	20324.3**	16610.9**
Year × duration	5	1276.0**	178.3**	495.6**	178.4**	640.5**
Bags × duration	15	445.9**	374.5*	433.0**	347.4**	418.7**
Year × bags × duration	15	88.6**	116.5**	119.6**	93.3**	112.7**
Error	138	13.7	37.9	31.2	31.4	32.1

*Significant ($p=0.05$), **Highly significant ($p=0.001$)

Each observation is based on four replicate, *DF* Degrees of freedom

and super grain bag) were used. Freshly emerged adults on the day of release were collected from the mother culture maintained in the lab and paired. Groundnut variety, GG-2 was used, each bag was filled with 5 kg of groundnut pods and 50 pairs of adults were released in each bag then bags were sealed and kept undisturbed. Experiment was laid out in two factorial complete randomized design with four replications, every month a 100 g sample was drawn from each treatment and observations were recorded on number of eggs laid, number of damaged and undamaged pods and kernels, weight of damaged and undamaged pods and kernels. Damage percentage was determined using the formula, Pod damage (%) = (Number of damage d pods/ $\text{total number of pods}$) × 100 and similarly, kernel damage was also calculated, weight loss was calculated using the formula

Weight loss of pods(%) = (weight of damaged pods/total weight of pods) × 100 and similarly, weight loss in kernel was also calculated.

Statistical analysis

Two factorial complete randomized design was employed and analyzed using DSAASTAT software (Onobri 2007) and analysis of variance was worked out. Differences between means were considered significant at $p<0.05$ by LSD test.

Multiple regression analysis was done using StatistiXL software (Onobri 2007). In Multiple regression one dependent variable, pod damage (Y), was regressed against two independent variables, storage period in months (X_1) and number of eggs laid (X_2). The simplest model for a multiple regression analysis is to include all of the independent X variables in the predictive equation for the dependent Y variable *i.e.*

$Y = a_0 + a_1X_1 + a_2X_2$ where the terms a_1 & a_2 are coefficients for each independent X variable, with a_0 & a_1

constant. A multiple regression analysis was performed on this data-set to see whether dependent variable pod damage can be explained by linear relationships with the two independent variables. In Multiple comparison test of slope and intercept for eggs laid and pod damage, we have compared simple linear regression equations for both the seasons. Slopes of the regression equation were compared by performing analysis of variance. A common slope was provided which gives an average slope for the variables, similarly intercepts of the regression equations were also compared by performing analysis of variance.

Results and discussion

Analysis of variance indicated that there was a significant difference among the different bags used for storage, storage period and seasons, for number of eggs laid, percent damage in pods and kernels and percent weight loss in pods and kernels. Interaction between storage bags and storage period was also found significant.

Super grain bag was significantly superior over other storage bags and recorded minimum number of eggs laid (216.1); damage to pods (37.7 %) and kernels (33.7 %) and weight loss in pods (38.2 %) and kernels (33.8 %). However, maximum number of eggs laid, in fertilizer bag (2325.2) followed by gunny bag (1988.3). Damage to pods and kernels and weight loss in pods and kernels was high in fertilizer bag

Effect of storage period (months) showed that during different months of storage number of eggs laid between first and sixth month the number of eggs laid were 25.8, 44.1, 16.0 and 32.1 eggs and 3387.2, 3838.9, 457.2 and 3476.0 in lino bag, fertilizer bag, super grain bag and gunny bag, respectively. Damage and weight loss in pods caused after 1 month of storage was 7.3 and 7.1 % (lino bag), 15.5

Table 2 Number of eggs laid, percent damage and percent weight loss caused by bruchid beetle in different storage bags during different months of storage

Bags	Months	Eggs (nos)	Damage (%)		Weight loss (%)	
			Pod	Kernel	Pods	Kernels
Lino bag	1	25.8	7.3	10.8	7.1	8.9
		(5.1) ^a	(15.6) ^b	(19.0) ^b	(15.4) ^b	(17.3) ^b
	2	303.1	33.0	55.0	32.5	51.7
		(17.3)	(34.8)	(47.9)	(34.4)	(46.0)
	3	1330.5	91.3	94.4	92.1	91.2
		(36.2)	(73.7)	(76.5)	(74.3)	(72.8)
Lino bag total	4	2429.8	95.5	95.4	95.7	94.3
		(46.9)	(78.7)	(79.0)	(78.3)	(77.8)
	5	3236.2	98.5	96.2	98.6	96.1
		(54.1)	(85.0)	(80.0)	(85.2)	(80.1)
	6	3387.2	99.1	97.8	99.3	97.9
		(55.6)	(86.1)	(83.9)	(86.7)	(84.1)
Fertilizer bag	1	1785.4	70.8	74.9	70.9	73.4
		(35.8)	(62.3)	(64.4)	(62.4)	(63.0)
	2	44.1	15.5	12.5	16.1	11.8
		(6.4)	(23.0)	(20.5)	(23.5)	(19.9)
	3	875.5	47.2	65.4	46.4	62.7
		(29.6)	(43.3)	(54.4)	(42.8)	(52.7)
Fertilizer bag total	4	2090.7	87.2	89.9	87.4	87.8
		(45.7)	(70.6)	(71.7)	(70.6)	(69.7)
	5	3614.2	90.3	89.6	91.0	89.2
		(57.5)	(74.9)	(74.1)	(73.9)	(74.1)
	6	3487.9	95.5	93.0	94.9	91.8
		(57.5)	(81.3)	(77.6)	(80.7)	(77.1)
Super grain bag	1	3838.9	95.7	91.9	96.2	89.7
		(59.4)	(81.5)	(76.1)	(82.0)	(74.8)
	2	2325.2	71.9	73.7	72.0	72.2
		(42.7)	(62.4)	(62.4)	(62.3)	(61.4)
	3	16.0	5.7	3.8	4.7	3.1
		(4.0)	(13.8)	(11.2)	(12.5)	(10.1)
Super grain bag total	4	55.3	10.1	7.5	9.9	7.5
		(7.4)	(18.5)	(15.8)	(18.4)	(15.9)
	5	115.3	28.0	21.0	28.7	20.0
		(10.7)	(31.8)	(27.0)	(32.1)	(26.3)
	6	227.3	40.0	37.0	41.8	35.9
		(15.1)	(39.2)	(37.4)	(40.3)	(36.8)
Super grain bag total	7	425.7	73.4	68.1	68.1	69.3
		(20.3)	(59.7)	(57.1)	(56.2)	(57.9)
	8	457.2	69.0	64.6	75.9	66.9
		(20.5)	(57.1)	(54.7)	(61.4)	(56.2)
	9	216.1	37.7	33.7	38.2	33.8
		(13.0)	(36.7)	(33.9)	(36.8)	(33.9)

Table 2 (continued)

Bags	Months	Eggs (nos)	Damage (%)		Weight loss (%)	
			Pod	Kernel	Pods	Kernels
Gunny bag	1	32.1	8.7	9.3	8.8	9.0
		(5.5)	(16.9)	(17.3)	(17.0)	(17.0)
	2	537.8	38.9	55.6	33.8	51.7
		(23.2)	(37.9)	(48.4)	(35.0)	(46.0)
	3	1665.0	81.8	88.1	84.8	86.0
		(40.6)	(66.0)	(70.1)	(68.3)	(68.4)
	4	2798.2	86.5	86.9	87.5	84.8
		(51.6)	(71.9)	(72.9)	(73.0)	(71.6)
	5	3420.7	92.4	88.8	92.4	86.7
		(56.4)	(78.5)	(75.9)	(78.5)	(74.5)
	6	3476.0	96.2	94.1	96.6	93.2
		(57.1)	(82.0)	(80.0)	(82.4)	(79.1)
Gunny bag total		1988.3	67.4	70.5	67.3	68.6
		(39.0)	(58.9)	(60.8)	(59.0)	(59.4)
Grand total		1578.8	62.0	63.2	62.1	62.0
		(32.6)	(55.1)	(55.4)	(55.1)	(54.4)
Bags	SEm ±	0.5	0.9	0.8	0.8	0.8
	LSD(0.05)	1.5	2.5	2.3	2.3	2.3
Duration	SEm ±	0.7	1.1	1.0	1.0	1.0
	LSD(0.05)	1.8	3.0	2.8	2.8	2.8
Bags × duration	SEm ±	1.3	2.2	2.0	2.0	2.0
	LSD(0.05)	3.7	6.1	5.5	5.5	5.6
Year × bags × duration	SEm ±	1.8	3.1	2.8	2.8	2.8
	LSD(0.05)	5.2	8.6	7.8	7.8	7.9
	CV	11.4	11.1	10.0	10.2	10.4

Each observation is based on three replicate, figures in the parenthesis are ^a square root and ^b arcsine transformed values

and 16.1 % (fertilizer bag), 5.7 and 4.7 % (super grain bag), 8.7 and 8.8 % (gunny bag), respectively. However, after 3 months of storage it recorded more than 80 % damage and weight loss in all the storage bags except super grain bag which recorded 28 % damage and weight loss. Similarly damage and weight loss in kernels caused after 1 month of storage was 3.8 (super grain bag) to 12.5 (fertilizer bag) and

3.1 (super grain bag) to 11.8 (fertilizer bag). However, almost complete damage was observed after 3 months of storage in all bags except super grain bag which recorded 21 % kernel damage and 20 % weight loss (Tables 1 and 2). Chakraborti (2011) reported that methods of storage significantly affect the insect infestation and higher infestation was observed in synthetic cement bags. The role of low

Table 3 R² values for different storage bags during summer and *kharif* seasons

	Linobag		Fertilizer bag		Super grain bag		Gunny bag	
	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif
R ²	0.97	0.89	0.90	0.89	0.86	0.92	0.92	0.90
R	0.98	0.94	0.95	0.94	0.93	0.96	0.96	0.95
Adj. R ²	0.97	0.88	0.89	0.88	0.85	0.91	0.91	0.89
S.E. of estimate	5.09	10.18	7.81	8.61	5.88	6.92	7.48	9.01

Fig. 1 Partial plots depicting linear regression lines of lino bag for storage period (months) and number of eggs laid

oxygen concentration is also responsible for mortality of insect in hermetic storage (Bailey 1965). Groundnut kernels treated the *Syzgium* clove powder and stored at 5.7 % moisture content in mini-polyethylene bags proved to be most efficacious (Awuah 1999).

Analysis of variance for multiple regression model was found to be significant in all bags for variables *viz*, number

of eggs laid, damage in pods and kernels, weight loss in pods and kernels during both *rabi*-summer and *kharif*. Influence of eggs laid on pod damage ranged from 86 to 97 % during *rabi*- summer and 89–92 % during *kharif* season among all the bags studied. Hence, pod damage was highly dependent on number of eggs laid on pods in each bag during both the seasons as indicated by R^2 values. The

Fig. 2 Partial plots depicting linear regression lines of super grain bags for storage period (months) and number of eggs laid

Table 4 Analysis of variance for linear regression comparison of slopes and intercepts for eggs laid and pod damage during kharif and summer seasons

Source	Eggs laid				Pod damage			
	Slope		Intercept		Slope		Intercept	
	Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif
Regression	84.4 ^{ns}	403.7 ^a	603.8 ^a	—	149.9 ^{ns}	24.2	651.3 ^a	1349.5 ^a
Residual	52.9	58.5	57.9	—	92.4	157.4	101.5	136.4

^a Highly significant^{ns} Non significant

standard error of estimates were small compared to the mean pod damage (Y) value, indicating that the multiple linear regression model was able to explain large amount of the variation in the dependent Y variable during both *rabi*-summer and *kharif* (Table 3). Regression equations for different bags were $Y=1.241+1.245 X_1+1.997 X_2$ for lino bag, $Y=4.039+6.236 X_1+0.845 X_2$ for fertilizer bag, $Y=0.344+2.119 X_1+2.352 X_2$ for super grain bag, and $Y=-2.172+5.565 X_1+1.045 X_2$ for gunny bag during *rabi*-summer and $Y=21.794+-2.082 X_1+1.155 X_2$ for lino bag, $Y=26.468+0.280 X_1+0.856 X_2$ for fertilizer bag, $Y=-0.671+4.369 X_1+1.673 X_2$ for super grain bag and $Y=24.170+-4.471 X_1+1.283 X_2$ for gunny bag during *kharif* which can be used to calculate the predicted Pod damage (Y) value. Based on these equations, regression models were found to be significant.

Partial plots of storage period in months (X_1) and number of eggs laid (X_2) suggested a significant contribution of each of the two independent variables. Partial plots examination revealed that storage period (X_1) is contributing for non-linearity and the outlier points that contribute heavily to the regression in both the seasons. But numbers of eggs laid

(X_2) are contributing for linearity in *rabi*-summer and non-linearity during *kharif* in lino bag and super grain bag (Figs. 1 and 2).

Analysis of variance was performed for comparing the slopes of four regression equations. The results showed that four regression equations have different slopes, hence common slope 5.6 was obtained to act as an average slope for relationship between storage period and number of eggs laid in different bags. Analysis of variance showed that there was significant difference in intercept, hence there were differences in elevation of regression lines during *rabi*-summer but during *kharif* there was very low probability of slope comparison and analysis of variance suggested that existence of significant differences among different storage bags (Table 4).

The multiple comparison test results showed a high probability ($P=1.0$) of number of eggs laid in lino bag, fertilizer bag and gunny bag but in super grain bag ($P=0.3$) probability of eggs laid was only 30 %. But in case storage period lino bag, gunny bag and fertilizer bag had 70 to 90 % probability of number of eggs laid during *rabi*-summer. Similarly in *Kharif* super grain bag which was found to be superior over other bags in case of number of eggs laid and

Table 5 Multiple comparison test of slope and intercept for egg laid and pod damage during kharif and summer

Group 1	Group 2	Eggs laid				Pod damage			
		Slope		Intercept		Slope		Intercept	
		Summer	Kharif	Summer	Kharif	Summer	Kharif	Summer	Kharif
Reg 1 (l)	Reg 2 (f)	1.0 ^{ns}	1.0 ^{ns}	0.3 ^{ns}	—	0.8 ^{ns}	0.9 ^{ns}	0.9 ^{ns}	0.9 ^{ns}
	Reg 3 (sg)	0.3 ^{ns}	0.0 ^a	0.0 ^a	—	0.2 ^{ns}	0.9 ^{ns}	0.0 ^a	0.0 ^a
	Reg 4 (g)	1.0 ^{ns}	1.0 ^{ns}	0.7 ^{ns}	—	0.9 ^{ns}	1.0 ^{ns}	0.5 ^{ns}	1.0 ^{ns}
Reg 2 (f)	Reg 3 (sg)	0.4 ^{ns}	0.0 ^a	0.0 ^a	—	0.6 ^{ns}	1.0 ^{ns}	0.0 ^a	0.0 ^a
	Reg 4 (g)	1.0 ^{ns}	1.0 ^{ns}	0.9 ^{ns}	—	1.0 ^{ns}	1.0 ^{ns}	0.8 ^{ns}	1.0 ^{ns}
Reg 3 (sg)	Reg 4 (g)	0.3 ^{ns}	0.0 ^a	0.0 ^a	—	0.4 ^{ns}	1.0 ^{ns}	0.1 ^a	0.0 ^a
Common		5.6	—	—	—	11.7	13.3	—	—

^a Highly significant^{ns} Non significant, l lino bag, f fertilizer bag, sg super grain bag, g gunny bag

almost zero intercept due to this difference no common slope was found to exist for all bags (Table 5).

Similarly for pod damage, a common slope 1 1.7 and 13.3 were provided to act as an average slopes for relationship between storage period and pod damage in different bags during *rabi*–summer and *Kharif*, respectively. Analysis of variance showed that there was a significant difference in slopes during *rabi*–summer, but in *kharif* there was no significant difference in slope. Intercepts were found to have significant differences in both the seasons hence there was a difference in elevations of the regression lines.

The multiple comparison test identified super grain bag being significantly superior for pod damage with only 20 % ($P=0.2$) as compared to other three bags in both the seasons with 90 to 100 % pod damage.

R values indicate a strong association between pod damage and number of eggs laid in all bags. Since the lino bag, fertilizer bag and gunny bag had perforations which allows free air circulation hence, the oxygen required for metabolism is freely imbibed from outside atmosphere which in turn increases the development of the bruchid population but not in super grain bag as there is no air circulation which creates competition for oxygen among bruchid, which lead to lesser metabolic activity and finally death of beetles and its immature stages due to asphyxiation. Similar result was reported for long-term storage under hermetically sealed containers for controlling insect pest of several commodities (Bartosik et al. 2008). Development and survival of insects in storage is strongly correlated with oxygen concentration (Dobie et al. 1991). But in the *Kharif* number of eggs laid on pods in super grain bag was low but still, pod damage was similar in all bags during initial months of storage this may be due to lower population of bruchid in all bags. Hence, during initial months there was similar pod damage in all bags, but as the storage period increased the survival rate in super grain bag was less i.e., rate of pod and kernel damage in super grain bag was less than other three bags. The incidence and damage potential of *C. serratus* was maximum during summer. Increase in the temperature from 25 to 40 °C is known to accelerate the metabolic process and also hasten the larval development and shortens generation time of *C. serratus* (Prasad et al. 2011).

Conclusion

Incidence *C. serratus* was more during summer compared to *kharif* due to more temperature and ambient condition for its reproduction and multiplication. Super grain bag was found effective in managing *C. serratus*, as it recorded minimum number of eggs laid, damage to pods and kernels, weight loss in pods and kernels than the other storage bags. Therefore, use

of super grain bag along with other control measures like sanitation may be followed for the management of *C. serratus*.

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