Qatar Univ. Sci. J. (1994), 14 (1): 103-112

ABUNDANCE OF INSECTS AND MITES INFESTING STORED GRAIN AND ANIMAL FEED IN RIYADH AND DAMMAM PROVINCES, SAUDI ARABIA

By

ZAKY M. F. ROSTOM*
College of Education, King Faisal University, Al Ahsaa, Saudi Arabia
* Permanent address: Entomology Department, Faculty of Science, Ain Shams University, Abbassiah, Cairo, Egypt.

إنتشار الحشرات والثلم التي تصيب الحبوب المخزونة وعلف الحيوان في منطقتي الرياض والدمام بالمملكة العربية السعودية

زكي محمد فتحي رستم

تم مسح الحشرات والثلم التي تصيب القمح والذرة ونخالة القمح المخزونة في صوامع مصنعي الرياض والدمام بالمملكة العربية السعودية ، وكذا من عينات من التراب ومن حبوب من السوق المحلية بكلا المنطقتين ، وذلك خلال موسمين ١٩٨٧ و١٩٨٨ . وقد وجد أن الأصابة بمجموعة الحشرات المتغذية على الحبوب ، والمعبر عنها بأقل مربعات انحرافات ، تأثرت بعوامل الموسم والمنطقة والارتفاع داخل الصومعة ونوع الغذاء المستخدم وفترة التخزين أو أخذ العينات أثناء الموسم (الاثار الرئيسية والتفاعلات) ، واختلفت الإصابة كثيراً باختلاف العوامل المستخدمة في ٩ نماذج أختيرت للمقارنة ، وعلى ذلك فللتنبؤ بإصابة المواد المخزونة بالمتغذيات على الحبوب يوصى بتوصيف الظروف التخزينية بكل دقة .

أما بالنسبة للإصابة بمجموعة الحشرات والثلم غير المتغذية على الحبوب فلم تتأثر في أغلب الأحوال بالعوامل المدروسة ، وشملت تلك المجموعة مفترسات وطفيليات على درجة كبيرة من الأهمية ، ودور تلك المجموعة الأخيرة في خفض الإصابة بالمتغذيات على الحبوب يلزمه دراسة مستفيضة .

Key Words: Granivorous insects, Saudi Arabia, Stored grain.

ABSTRACT

Insects and mites infesting wheat, maize and wheat bran, stored in plants at Riyadh and Dammam, Saudi Arabia, were scanned in 2 seasons, 1987 and 1988. Grains from the local markets and dust from both provinces were also surveyed. Infestation of these commodities by a granivorous group of pests, expressed as least squares means of sum of the pests, was found to be dependent upon factors of season, province, height inside bin, type of commodity and storing/sampling period within season (main effects and interactions). Infestation differed pronouncedly according to the factors included in 9 models selected for comparison. Accordingly, to predict infestation of stored commodities by granivorous pests, it was recommended to specify storage conditions precisely. Infestation by another non-granivorous group of pests was, in most cases, not affected by the factors studied. The latter group included predators and parasites of extreme importance, thus their role in suppressing infestation by the granivorous species requires detailed study.

INTRODUCTION

Identification and relative abundance of some insect and mite species infesting grain and animal feed stored in bins and general stores in Saudi Arabia was previously carried out [1]. These pests were classified into 2 main groups, a granivorous group including 16 insect species, and a non-granivorous group containing 26 insect species and 7 mite species. Data surveying the effects of environmental factors like season, province, height inside bin, type of commodity and storing period, on the extent of infestation by insects and mites in Saudi Arabia, are not available. This encouraged further studied towards this goal.

MATERIALS AND METHODS

Sampling techniques

Commodities used in this survey were: locally cultivated wheat variety Yocora Saudi 2, wheat bran (animal feed) obtained from the same lot of wheat grain, and maize imported from Dubai. These commodities were stored in Riyadh and Dammam plants (Grain Silos and Flour Mills Organization, "G.S.F.M.O."), for two seasons, 1986/1987 and 1987/1988. The Riyadh area is a central arid locality, while the Dammam region lies on the western humid cost of the Arabian Gulf. Samples of grain were taken periodically from several heights inside bins and the effects of season, province, height inside bin, type of commodity and storing period of infestation was recorded.

In the Riyadh plant, wheat was stored in 10 concrete star bins, each 29.3 m high and filled with about 350 tons of grain. Complete filling of bins was accomplished in December at the beginning of each storing season, and storage extended for about 11.5 months. Five bins of wheat were treated as controls, viz., exposed to routine treatment of fumigation with pesticides and/or recycling, whenever found necessary during storage. The other five bins of wheat were not exposed to any treatment during the entire storing period (experimental bins). The limited amount of maize (260 tons) was stored in one star bin only, and was treated as control commodity, due to its high susceptibility to infestation and heating. At each sampling period, wheat was obtained from one experimental and one control bin, and these bins were not used again. Maize samples were obtained from the same bin at each sampling period. Five samples of wheat, each about 1 kg, were obtained from 3 different heights inside each bin, an uppermost, a lowermost and at about mid way of the bin. The 5 samples from the upper height were taken by a grain sampler, 1.5 m in length. The bin was then discharged completely and samples representing the lower height were obtained during the first 5 min. of discharge, 1 kg every minute. Samples representing mid way of the bin were similarly obtained during the 70th - 75th min. of discharge. The latter time was predetermined in a separate bin, by placing plastic colored blocks midway of grain during filling. Periodic samples of maize were taken from an upper and a lower heights only to avoid unnecessary disturbance of grain. Maize samples from the lower height were obtained by partially discharging the bin manually from the lower outlet for 5 min., 1 kg every min.

Wheat bran was kept in a store of final products at the plant, packed in 50 kg. bags, treated as control, and 5 samples, each 1 kg, were taken from a different bag each sampling date.

In the Dammam plant, due to the limited space available, only 2 concrete star bins were used, each 28 m high and filled with 255 tons of wheat. Wheat in one bin was treated as the control and in the other as the experimental grain. To avoid superfluous disturbance of grain, periodic samples of wheat were only obtained from upper and lower height of both bins. Maize and wheat bran were kept in an animal feed store in the Dammam plant, and treated as bran in the Riyadh plant.

Grain samples

At the beginning of each storing season, 5 random samples from stocks of all commodities, 1 kg each, were obtained from the upper height only (A and G samples, representing base line data, at storing period of 19 $\pm$ 9.7 days). During each season, periodic sampling was made from both plants in February, April, June, September and November (B, C, D, and F in 1987, at 60.2 $\pm$ 5.1, 118 $\pm$ 12.1, 189.2 $\pm$ 11.6, 272.2 $\pm$ 11.6 and 335.2 $\pm$ 11.6 days respectively, and H, I, J, K and L in 1988, at 23.8 $\pm$ 15.9, 70.3 $\pm$ 16.3, 133.0 $\pm$ 16.1, 208.8 $\pm$ 35.7, 292.8 $\pm$ 18.5 and 341.5 $\pm$ 16.0 days respectively).

Dust samples

Dust was collected from the Riyadh and Dammam plants by hand sweeping 2 places: the floor around the upper openings of wheat bins, and a store of final product of animal feed. Dust was obtained on the same dates as the grain commodities.

Private stores

Samples of local wheat grown in Saudi Arabia, wheat and maize imported from Dubai, United Arab Emirates, and wheat bran were obtained from the local markets in Riyadh and Dammam cities, to represent commercial private stores. Three samples of each commodity, each about 2 kg, were purchased. These were obtained at the same date of getting regular samples from the Riyadh and Dammam plants. Such commodities, although of unknown storage history, represented material ready for direct human and animal consumption.

Moreover, in April 1988, 300 - 500 kg of each of experiment wheat, maize and bran, were obtained from Dammam plant, packed in 50 kg bags, and placed in a concrete store (10 x 6 x 3.5 m) in an open area in the campus of King Faisal University (KFU), Dammam City. These commodities were treated as experiment materials and sampled at 53, 171, 222 and 249 days of storage (corresponding to I, J, K and L periods, respectively). Samples were taken from new bags at each sampling period.

Extraction of insects and mites

Three replicates of each sample (25 gm of bran, 50 gm of grain, and up to 25 gm of dust, each), were extracted by Tullgren funnels for 24 hr. Numbers of specimens/sample were calculated and recorded as "estimated numbers/kg sample".

Statistical analysis:

Infestation was calculated as the sum of estimated numbers of insects/kg sample of all granivorous or non-granivorous species. Main effects and interactions between five factors used (season, province, height inside bin, type of commodity and storing/sampling period within season) upon infestation were analyzed by the GLM test, and the results were expressed as least squares means ± standard errors (LSM ± S.E.), utilizing the following linear model:

$Y_{ijklmn} = U + SS_i + P_j + Ht_k + C_l + Sd_m + SS{*}P_{ij} + SS{*}Ht_{ik} + SS{*}C_{il} + SS{*}SD_{im} + P{*}Ht_{jk} + P{*}C_{jl} + P{*}SD_{jm} + Ht{*}C_{kl} + Ht{*}SD_{km} + C{*}SD_{lm} + e_{ijklmn}$, where:

Y_{ijklmn} = the nth sum of estimated numbers of granivorous or non-granivorous species /kg sample for the I j k l m classes; U = grand mean; SS_i = ith effect of season, I = 1,2 (1 = 1987, 2 = 1988); P_j = jth effect of province, j = 1,2 (1 = R, 2 = Dammam); Ht_k = kth effect of height inside bin, k = 1, 2, 3 (1 = uppermost, 2 = mid way, 3 = lower-most); C_l = lth effect of type of commodity, 1 - 10 types (experimental and control wheat, maize, bran, 2 types of dust, local and imported wheat, maize and bran from local markets); SD_m = mth effect of storing/ sampling period. m = 2nd to 6th period in each season (B-F and H-L in 1987 and 1988, respectively); 1st periods at each season (A and G samples) were excluded from the model as they were taken from upper height only, and because almost no infestation was recorded in both samples; $SS{*}P_{ij}$ = interaction between season and province; $SS{*}Ht_{jk}$ = interaction between season and height; $SS{*}C_{il}$ = interaction between season and type of commodity; $SS{*}SD_{im}$ = interaction between season and storing/sampling period; $P{*}H_{jk}$ = interaction between province and height; $P{*}C_{jl}$ = interaction between province and type of commodity; $P{*}SD_{jm}$ = interaction between province and storing/sampling period; $Ht{*}C_{kl}$ = interaction between height and type of commodity; $Ht{*}SD_{km}$ = interaction between height and storing/sampling period; $C{*}SD_{lm}$ = interaction between type of commodity and storing/sampling period; e_{ijklmn} = random error, assumed normal distribution with zero mean and equal variance.

To facilitate comparison, the main effects and interactions of selected combinations of the 5 factors tested were presented as 9 models, e.g. in model 1 factors of season (SS: 1987 & 1988), province (P: Riyadh & Dammam), height inside bin (Ht: upper & lower), type of commodity (C: wheat in experiment or control bin) and storing/sampling period (SD: B-F & H-L in seasons 1987 & 1988, respectively) were statistically analyzed by the LSM±S.E. technique. Results of the main effects of the 5 factors and their interactions (SS*P, SS*Ht, SS*SD, P*Ht, P*C, P*SD, Ht*C, Ht*SD and C*SD) were expressed as LSM±S.E. of infestation of commodities by sum of granivorous or non-granivorous group of pests. The GLM test was executed by SAS program. Levels of significance were either non significant (N.S: > 0.05%), significant (S : 0.05 - 0.01%) or highly significant (H.S: < 0.01%).

RESULTS

1. Infestation of bulk commodities by granivorous group of insects (Table 1)

1.1 Main effects

Season affects infestation significantly in models 4, 5,6 (1988 > 1987) and 8 (1987 > 1988). In models 1, 2, 3 and 7 differences between both seasons were N.S.

Province had positive effects in all models tested. However, in models 1, 5 and 7 infestation in Dammam > Riyadh, while in model 8 the reverse was true.

Height infestation at the upper height inside bin that at the lower height in models 3 and 4, while the reverse was true in model 1. In model 2 difference between heights was N.S.

Commodity infestation in maize > wheat and/or bran in models 3, 6 and 8. In model 1 infestation in experiment wheat > control wheat. Differences were N.S. in models 2 and 7.

Storing/sampling period except in model 2, infestation in commodities stored in Riyadh and Damam plants (models 1, 3, 4, 5 and 6) showed a significant trend of increase with increasing storing period. In models 7,8 and 9 maximal infestation occurred at D and J sampling periods (1987 and 1988 seasons, respectively).

1.2 Interactions between factors the interactions between the above mentioned factors proved to have significant non-significant effects on infestation in different models selected as follows:

Season*Province season affected infestation in both provinces significantly in models 5 (Dammam > Riyadh in 1988, and N.S. difference in 1987), 7 (Dammam > Riyadh in 1987, and N.S. difference in 1988) and 8 (Riyadh > Dammam in 1987, and N.S. difference in 1988). Non significant interactions were obtained in model 1.

Season*Height season affected infestation at different heights significantly in models 1 (lower height > upper height in 1987, and N.S. difference in 1988), 2 (upper height > middle height in 1988, and N.S. difference in 1987) and 4 (upper height > lower height in 1988, and N.S. difference in 1987). Non significant interactions were obtained in model 3.

Season*Commodity Season affected infestation of different commodities significantly in models 1 (experiment wheat > control wheat in 1987, and N.S. difference in 1988), 6 (bran > control maize in 1988, and N.S. difference in 1987) and 8 (height in bran, followed by maize and local wheat, and least in imported wheat in 1987; in 1988 maize > other 3 commodities). Non significant interactions were obtained in models 2, 3 and 7.

Season*Storing/Sampling period season affected infestation at different storing periods significantly, and peaks of infestation were detected in different periods (F and J in 1987 and 1988, respectively, in model 1; L in 1988 in model 3; F and L in 1987 and 1988, respectively in model 4; K in 1988 in models 5 and 6; D-E in 1987 and I 1988 in model 8). Non significant interactions were obtained in models 2 and 7.

Province*Height province affected infestation at different heights significantly in model 1 (lower > upper height in Dammam, and N.S. difference in Riyadh).

Table 1

Main effects of, and interactions between, 5 factors on infestation of 10 types of commodities by a granivorous group of insects; results expressed in least squares means of infestation standar error (LSM S.E.) of 9 different selected combinations of factors (models); means having the same letters were significantly different; B-F = samples B, C, D, E and F; C= type of commodity; CM = maize in control bin; Cwt = wheat in control bin; DA and DB = dust collected from around upper openings of wheat bins and from a store of animal feed, respectively; DM = Dammam; Ewt = wheat in experiment bin; Ht = height inside bin; H-L = samples H, I, J, K and L; IM = imported maize from local market; IW = imported wheat from local market; KFU = store at King Faisal University campus at Dammam city; LB = wheat bran from local market; LH = lower height inside bin; LW = local wheat from local market; MH = height inside bin; P = province; RD = Riyadh; PR = probability; SD = storing / sampling period; SS = season; UH = upper height inside bin; WB = wheat bran; N.S, S and H.S. = non-significant > 0.05%, significant between 0.05-0.01% and highly significant differences < 0.01%, respectively

Model / Factor		1	2	3	4	5	6
SS		87,88	87,88	87,88	87,88	87,88	87,88
P		RD, DM	RD	RD	RD	RD,DM	DM
Ht		UH, LM	UH, MH, LH	UH, LH	UH, LH	—	—
C		EW, CW	EW, CW	EW, CW, CM	CM	WB	CM, WB
SD		B-F, H-L	B-F, H-L	B-F, H-L	B-F, H-L	B-F, H-L	B-F, H-L
				I. Main Effects			
SS							
87		50.9±16.4	1.11±0.43	13.8±10.0	39.3±18.6a	113.1±132.6a	186.1±136a
88		33.4±13.8	0.65±0.43	36.9±10.0	108.7±18.6a	654.7±132.6a	634.4±136a
PR		0.416 N.S	0.446 N.S	0.105 N.S	0.012 S	0.006 H.S	0.024S
P							
DM		83.3±16.4a	—	—	—	744.4±134.1a	—
RD		1.00±13.8a	—	—	—	23.3±131.3a	—
PR		0.002 H.S	—	—	—	0.0003 H.S.	—
Ht							
LH		68.6±14.6a	1.00±0.52	4.0±10.0a	10.0±18.6a	—	—
MH		—	0.64±0.52	—	—	—	—
UH		15.8±14.6a	1.00±0.52	46.7±10.0a	138.0±18.6a	—	—
PR		0.008 H.S	0.885 N.S	0.003 H.S.	0.0001 H.S.	—	—
C							
E. Wt.		61.8±14.6a	0.89±0.43	1.33±12.3a	—	—	—
C.Wt		22.6±14.6a	0.87±0.42	0.67±12.3b	—	—	—
C.M		—	—	74.0±12.3ab	—	—	76.1±136a
WB		—	—	—	—	—	44.4±136a
PR		0.049 S	0.979 N.S	0.0001 H.S.	—	—	0.001 H.S.
SD							
B,H		1.67±21.8a	0.00±0.68a	0.00±15.9a	-0.00±29.4a	0.00±232.3a	0.0±235.5a
C,I		7.92±21.8b	2.22±0.68a	2.78±15.9b	3.33±29.4b	160.0±232.3b	156.7±235.5b
D,J		51.7±20.3c	0.52±0.67	3.33±15.9c	10.0±29.4c	236.7±232.3c	260±235.5c
E,K		37.9±32.7	0.56±0.68	11.7±15.9d	33.33±29.4d	1720.0±232.3abcd	1745.0±235.5abcd
F,L		111.7±21.8abc	1.11±0.68	108.9±15.9abcd	323.3±29.4abced	186.7±232.3d	300.0±235.5d
PR		0.003 H.S	0.185 N.S	0.001 H.S.	0.001 H.S	0.001 H.S	0.001 H.S
				II Interactions			
SS *	P						
87	DM	100.8±26.4ab	—	—	—	228.9±189.7a	—
87	RD	1.00±19.5ac	—	—	—	-2.76±185.5b	—
88	DM	65.9±19.5cd	—	—	—	1260.0±189.7abc	—
88	RD	1.00±19.5bd	—	—	—	49.4±185.5c	—
PR		0.416 N.S	—	—	—	0.012 S	—
SS *	Ht						
87	LH	100.8±21.7abc	2.00±0.74a	5.33±14.2a	12.0±12.3a	—	—
87	MH	—	1.33±0.74	—	—	—	—
87	UH	0.97±21.7a	0.00±0.74	22.2±14.2b	66.7±26.3b	—	—
88	LH	36.3±19.5b	0.00±0.74	2.67±14.2c	8.00±26.3c	—	—
88	MH	—	0.05±0.74ab	—	—	—	—
88	UH	30.5±19.5c	2.00±0.74b	71.1±14.2abc	209.3±26.3abc	—	—
PR		0.019 S	0.016 S	0.071 N.S	0.008 H.S	—	—
SS *	C						
87	E.Wt	91.9±21.7ab	0.89±0.60	1.33±17.4a	—	—	—
87	C. Wt	9.96±21.7a	1.33±0.60	0.67±17.4b	—	—	—
87	C.M	—	—	39.3±17.4c	—	—	143.3±192.3a
87	WB	—	—	—	—	—	228.9±192.3b

Table 1 Contd.

Model Factor		1	2	3	4	5	6
88	E. Wt	31.7±19.4b	0.89±0.60	1.33±17.4d	—	—	—
88	C. Wt	35.2±19.7	0.41±0.60	0.67±17.4e	—	—	—
88	C.M	—	—	108.7±17.4abcde	—	—	8.89±192.3c
88	WB	—	—	—	—	—	260.0±192.3abc
PR		0.032 S	0.466 N.S.	0.074 N.S	—	—	0.004 H.S
SS *	SD						
87	B	-0.00±30.9ab	0.00±0.96	0.00±22.4a	0.00±41.6ab	0.0±328.5a	0.0±333.1a
87	C	1.67±30.9cd	2.22±0.96	1.11±22.4b	0.00±41.6cd	6.67±328..5b	3.33±333.1b
87	D	10.4±26.3ef	1.11±0.96	5.56±22.4c	16.7±41.6e	80.0±328.5c	183.3±333.1c
87	E	45.8±57.6g	0.00±0.96	20.0±22.4d	60.0±41.6f	266.7±328.5d	330.0±333.1d
87	F	196.7±30.9ac eghijkl	2.22±0.96	42.2±22.4e	120.0±41.6acghi	360.0±328.5e	600.0±333.1e
88	H	3.33±30.9hm	0.00±0.96	-0.00±22.4f	-0.00±41.6gj	0.0±328.5f	0.0±333.1f
88	I	14.2±30.9i	2.22±0.96	4.44±22.4g	6.67±41.6k	313.3±328.5g	310.0±333.1g
88	J	93.0±30.9bdfjm	0.08±0.9	1.11±22.4h	3.33±41.6hl	393.3±328.5h	336.7±333.1h
88	K	30.0±39.9k	1.11±0.96	3.33±22.4i	6.67±41.6a	3173.3±328.5abce dfghi	3160.0±333.1abcd efghi
88	L	26.7±30.9I	0.00±0.96	175.6±22.4abcdef ghi	526.7±41.6bdefijk lm	13.3+328.5	0.00+333.1i
PR		0.001 H.S,	0.468 N.S	0.005 H.S	0.0001 H.S	0.0001 H.S.	0.0001 H.S
P *	Ht						
DM	LH	136.2±21.7abc	—	—	—	—	—
DM	MH	—	—	—	—	—	—
DM	UH	30.5±21.7a	—	—	—	—	—
RD	LH	1.00±19.5b	—	—	—	—	—
RD	MH	—	—	—	—	—	—
RD	UH	1.00±19.5c	—	—	—	—	—
PR		0.008 H.S	—	—	—	—	—
P *	C						
DM	E.Wt	122.2±21.6abc	—	—	—	—	—
DM	C. Wt	44.5±21.8a	—	—	—	—	—
DM	C.M	—	—	—	—	—	—
DM	WB	—	—	—	—	—	—
RD	E. Wt	1.33±19.5b	—	—	—	—	—
RD	C. Wt	0.67±19.5b	—	—	—	—	—
RD	C.M	—	—	—	—	—	—
RD	WB	—	—	—	—	—	—
PR		0.05 S	—	—	—	—	—
P *	SD						
DM	B,H	3.33±30.9ab	—	—	—	-0.00±328.5a	—
DM	C,I	13.3±30.9cd	—	—	—	306.7±328.5b	—
DM	D,J	103.4±26.4acefghi	—	—	—	373.3±328.5c	—
DM	E,K	75.0±57.6k	—	—	—	342.7±328.5abcde fghi	—
DM	F,L	222.7±30.9b delmnop	—	—	—	360.0±328.5d	—
DM	B,H	-0.00±30.9fl	—	—	—	0.00±328.5e	—
DM	C,i	2.50±30.9gm	—	—	—	13.3±328.5f	—
RD	D,J	0.00±30.9hn	—	—	—	100.0±328.5g	—
RD	E,K	0.83±30.9io	—	—	—	13.3±328.5h	—
RD	F,L	1.67±30.9jp	—	—	—	13.3±328.5I	—
PR		0.004 H.S	—	—	—	0.0001 H.S	—
Ht *	C						
LH	E.Wt	97.8±20.2abc	1.33±0.74	1.33±1.74a	—	—	—
LH	C.Wt	39.4±20.2a	0.67±0.74	0.67±17.4b	—	—	—
LH	C.M	—	—	10.0±17.4c	—	—	—
MM	E.Wt	—	0.00±0.74	—	—	—	—
MM	C. Wt	—	1.29±0.73	—	—	—	—
UH	E. Wt	25.7±20.1b	1.33±0.74	1.33±17.4d	—	—	—
UH	C.Wt	5.78±20.1c	0.67±0.74	0.67±0.74	—	—	—
UH	C.M	—	—	138.0±17.4abcde	—	—	—
PR		0.326 N.S	0.313 N.S	0.0002 H.S	—	—	—

Table 1 Contd.

Factor	Model	1	2	3	4	5	6
Ht *	SD						—
LH	B,H	2.50±30.9a	0.00±1.17af	0.00±22.4a	0.00±41.6a	—	—
LH	C,I	11.7±30.9b	1.67±1.17	2.22±22.4b	3.33±41.6b	—	—
LH	D,J	49.5±28.3c	0.00±1.17bcg	4.44±22.4c	13.3±41.6c	—	—
LH	E,K	63.4±41.6d	0.00±1.17de	2.22±22.4d	6.67±41.6d	—	—
LH	F,L	215.8±30.9abcdef ghi	3.33±1.17abdfghij klmn	11.1±22.4e	26.7±41.6e	—	—
MH	B,H	—	0.00±1.17hno	—	—	—	
LH	C,I	11.7±30.9b	1.67±1.17	2.22±22.4b	3.33±41.6b	—	—
LH	D,J	49.5±28.3c	0.00±1.17bcg	4.44±22.4c	13.3±41.6c	—	—
LH	E,K	63.4±41.6d	0.00±1.17de	2.22±22.4d	6.67±41.6d		
MH	C,I	—	1.67±1.17	—	—	—	—
MH	D,J	—	1.55±1.13	—	—	—	—
MH	E,K	—	0.00±1.17ip	—	—	—	—
MH	F,L	—	0.00±1.17jq	—	—	—	—
UH	B,H	0.83±30.9e	0.00±1.17kr	0.00±22.4f	-0.00±41.6f	—	—
UH	C,I	4.17±30.9f	3.33±1.17ceopqrst	3.33±22.4g	3.33±41.6g	—	—
UH	D,J	53.9±28.4g	0.00+.17ls	2.22±22.4h	6.67±41.6h	—	—
UH	E,K	12.4±41.6h	1.67+1.17	21.1±22.4I	60.0±41.6H	—	—
UH	F,L	7.50±30.9I	-0.00+1.17mt	206±22.4ab cdefghi	620.0±41.6a bcdefghi	—	—
PR		0.002 H.S	0.345 N.S	0.0001 H.S	0.0001 H.S	—	—
C *	SD						
E. Wt	B,H	-0.0±30.9a	0.00±0.96	0.00±27.5a	—	—	—
E. WT	C,I	5.00±30.9b	2.22±0.96	3.33±27.5b	—	—	—
E. Wt	D,J	67±27.8c	0.00±0.96	-0.00±27.5c	—	—	—
E. Wt	E,K	41.4±41.6d	-0.00±0.96	-0.00±27.5d	—	—	—
E.WT	F,L	195.0±30.9a bcdefghi	2.22±0.96	3.33±27.5e	—	—	—
C. Wt	B,H	3.33±30.9e	0.00±0.96	-0.00±27.5f	—	—	—
C. Wt	C,E	10.8±30.9f	2.22±0.96	1.67±27.5g	—	—	—
C.Wt	D,J	36.0±28.9g	1.03±0.93	-0.00±27.5h	—	—	—
E. Wt	E,K	34.4±41.6h	1.11±0.96	1.67±27.5I	—	—	—
C.Wt	F,L	28.3±30.9i	0.00±0.96	-0.00±27.5j	—	—	—
C.M	B,H	—	—	-0.00±27.5k	—	—	0.00±333.1a
C.M	C,I	—	—	3.33±27.5l	—	—	6.67±333.1b
C.M	D,J	—	—	10.0±27.5m	—	—	146.7±333.1c
C.M	E,K	—	—	33.3±27.5n	—	—	63.3±333.1d
C.M	F,L	—	—	323.3±27abcdefg hijklmn	—	—	240.0±333.1e
WB	B,H	—	—	—	—	—	0.00±333.1f
WB	C,I	—	—	—	—	—	306.7±33.3.1g
WB	D,J	—	—	—	—	—	373.3±333.1h
WB	E,K	—	—	—	—	—	3426.7±333.1a bcdefghi
WB	F,L	—	—	—	—	—	360.0±333.Ii
PR		0.029 S	0.413 N.S	0.0001 H.S	—	—	0.0001 H.S

Factor	Model 7	8	9
SS	87,88	87,88	88
P	RD, DM	RD, DM	KFU
Ht	—	—	—
C	DA,DB	LW, IW, IM, LB	EW, CM,WB
SD	B-F, H-L	B-F, H-L	I-L
	I. Main Effects		
SS	LSM±S.E	LSM±S.E	LSM±S.E
87	95.3±17.2	85.0±12.1a	—
88	54.0±21.1	40.5±12.1a	—
PR	0.134 N.S	0.01 S	—

Table 1 Contd.

Model Factor		7	8	9
P				
DM		123.3±17.0a	38..0±12.1a	—
RD		26.1±21.2a	87.5±12.1a	—
PR		0.006 H.S	0.004 H.S	—
C		DA 60.2±18.8	L.W 46.3±17.1a	E.Wt. 256.7±53.4
—		DB 89.1±18.4	I. W 10.7±17.1bc	C.M 251.7±53.4
		—	I. M 108.0±17.1ab	WB 336.7±53.4
—		—	L.WB 86.0±17.1c	—
PR		0.256 N.S.	0.0004 H.S.	0.462 N.S
SD				
B,H		33.9±26.6a	25.0±19.2ab	—
C,I		74.3±27.7b	83.3±19.2ac	I 24.4±61.7abc
D,J		151.6±27.7abc	116.3±19.2bde	J 444.4±61.7ad
E,K		26.7±27c	63.8±19.2d	K 393.3±61.7b
F,L		86.9±40.5	25.4±19.2ce	L 264.4±61.7cd
PR		0.014 S	0.003 H.S	0.003 H.S
		II Interactions		
SS *	P			
87	DM	191.7±24.1abc	43.3±17.1a	—
87	RD	-0.97±24.6b	126.7±17.1abc	—
88	DM	54.9±23.9a	32.7±17.1b	—
88	RD	53.2±34.7c	48.3±17.1c	—
PR		0.0007 H.S	0.497 S	—
SS *	C			
87	—	DA 85.3±24.1	L.W 79.3±24.2ab	—
87	—	DB 105.4±24.6	I.W 6.67±24.2acd	—
87	—	—	I.M 104.7±24.2c fgh	—
87	—	—	L.B 149.3±24.2b dijk	—
88	—	DA 35.1±28.7	L.W 13.3±24.2fil	—
88	—	DA 72.9±27.3	I.W. 14.7±24.2gjm	—
88	—	—	I.M. 111.3±24.2e lmn	—
88	—	—	L.B 22.7±24.2h kmn	—
PR		0.726 N.S	0.015 S	—
SS *	SD			
87	B	1.73±40.1ab	40.8±27.1a	—
87	C	103.3±28.3c	63.3±27.1b	—
87	D	216.7±38.2ac defgh	192.5±27.1abc defghi	—
87	E	40.0±38.2d	102.5±27.1cjklm	—
87	F	115.0±38.2b	25.8±27.1djm	—
88	H	66.0±35.0e	9.17±27.1eko	—
88	I	45.4±40.1f	103.5±27.1fnopq	—
88	J	86.6±40.1g	40.0±27.1g	—
88	K	13.3±38.2h	25.0±27.1hlp	—
88	L	58.8±71.5	25.0±27.1im	—
PR		0.162 N.S	0.006 H.S	—
P *	C			
DM	—	DA 112.5±24.6a	L.W 64.7±24.2ab	—
DM	—	DB 134.1±23.4bc	I.W 8.00±24.2cd	—
DM	—	—	I.M 43.3±24.2ef	—
DM	—	—	L.B 36.0±24.2gh	—
RD	—	DA 8.0±28.4ab	L.W 28.0±24.2ij	—
RD	—	DB 44.2±28.1c	I.W 13.3±24.2kl	—
RD	—	—	I.M 172.7±24.2a cegik	—
RD	—	—	L.B 136.0±242b dfhjl	—
RD		0.774 N.S	0.002 H.S	—

Table 1 Contd.

Model Factor		7	8	9
P *	SD			
DM	B,H	63.5±35.0a	48.3±27.1ab	__
DM	C,I	105.4±40.1	42.5±27.1cd	__
DM	D,J	246.7±38.2abc	60.0±27.1e	__
DM	E,K	53.3±38.2b	15.0±27.1fgh	__
DM	F,L	147.5±38.2def	24.2±27.1ijk	__
RD	B,H	4.2±40.2cd	1.67±27.1lmn	__
RD	C,I	43.3±38.2e	124.2±27.1acfilo	__
RD	D,J	56.6±40.1	172.5±27.1bdegjmp	__
RD	E,K	0.0±38.2f	112.5±27.1hknq	__
RD	F,L	26.3±71.5	26.7±27.1opq	__
PR		0.358 N.S	0.014 S	__
C*	SD			
__	B,H	DA 26.7±38.2ab	L.W 80.0±38.3a	__
__	C,I	DA 5.4±40.1cde	L.W 101.7±38.3x'	E.Wt I 6.67±106.9abcde
__	D,J	DA 120±40.1c	L.W 28.3±38.3bcd	E. Wt J 820.0±106.9afgh hijkl
__	E,K	DA 33.3±38.2fg	L.W 3.33±38.3e fgh	E. Wt K 106.7±106.9fmn
__	F,L	DA 115.0±51.5	L.W 18.3±38.3ijk	E. Wt L 93.3±106.9gpqr
__	B,H	DB 41.1±37.2h	I.W 1.67±38.31 mno	__
__	C,I	DB 143.3±38.2adfi	I.W. 3.33±38.3p qrs	__
__	D,J	DB 183.3±38.2beghjk	I.W 8.33±38.3t uvw	__
__	E,K	DB 20.0±38.2ij	I.W 36.7±38.3xyz	__
__	F,L	DB 57.9±51.5k	I.W 3.33±38.3 a'b'c'd'	__
__	B,H	__	I.M 8.33±38.3e'f'g'h'	__
__	C,I	__	I.M 178.3±38.3 beilptxa'e'i'j'k'l	C.M I 13.3±106.9hstuv
__	D,J	__	I.M 191.7±38.3 acfjmquyb'm'f'n'o 'p'	C.M J 340.0±106.9bis
__	E,K	__	I.M 121.7±38.3 gnrvc'g'q'r	C.M K 580.0±106.9 cmptwxy
__	F,L	__	I.M 40.0±38.3 i'm's'	C.M L 73.3±106.9jwza'
__	B,H	__	L.B 10.0±38.3 j'n'q't	__
__	C,I	__	L.B 50.0±38.3k'o'u	WB I 53.3±106.9kxb'c'
__	D,J	__	L.B 236.7±38.3a dhkoswzd'h'r's't' u'v'w'x'	WB J 173.3±106.9lyd'e'
__	E,K	__	L.B 93.3±38.3v'	WB K 493.3±106.9nquzb'd'
__	F,L	__	L.B 40.0±38.3lp'w'	WB L 626.7±106.9a'c'e'
PR		0.156 N.S	0.006 N.S	0.001 H.S

Province*Commodity province affected infestation of different commodities significantly in models 1 (experiment wheat > control wheat in Dammam, and 8 (in Riyadh infestation was highest in maize and bran, followed by local wheat and imported wheat, while in Dammam infestation in commodities differed N.S.). Non significant interactions were obtained in model 7.

Province*Storing/sampling period province affected infestation at different storing periods significantly, and peaks of infestation were detected in different periods (D, F, J and L in Dammam in model 1; E and K in Dammam in model 5; C, E, I and K in Riyadh in model 8). Non significant interactions were obtained in model 7.

Height*Commodity at the lower and upper heights infestation was significantly higher in maize than in experiment and control wheat in model 3. Non significant interactions were detected in models 1 and 2.

Height*Storing/sampling height affected infestation at different storing periods significantly, and peaks of infestation were detected in variable periods (F and L at lower height in model 1, and F and L at upper height in models 3 and 4). Non significant interactions were obtained in model 2.

Commodity*Storing/sampling period type of commodity affected infestation at different storing periods significantly, and peaks of infestation were detected in different periods (F and L in experiment wheat in model 1; F and L in maize in model 6; C-E and I-K in maize, D and J in bran in model 8; J, K and K-L in experiment wheat, maize and bran, respectively, in model 9). Non significant interactions were obtained in models 2 and 7.

2. Infestation of bulk commodities by non granivorous group of insects and mites (data non tabulated)

2.1 Main effects

Commodity Infestation was significantly affected in models 6 (maize > bran) and 9 (maize > experiment wheat and bran).

Province Infestation in Dammam > Riyadh in model 8.

Storing/sampling period in model 9 infestation peaked at K period.

2.2 Interactions between factors

Province*Commodity: province affected infestation in different commodities significantly in models 7 (dust from a store of animal feed > from around openings of bins in Dammam, and the reverse was valid in Riyadh) and 8 (maize > local and imported wheat and bran in Riyadh, and N.S. differences in Dammam).

Commodity*Storing/Sampling period infestation in different commodities was affected significantly by storing/sampling period and showed variable peaks in models 8 (in maize and bran at C and 1 periods at 1987 & 1988, respectively) and 9 (in experiment wheat and maize at K period at 1988).

DISCUSSION

Models used in comparison had different interacting factors which lead to specific results for each model. In general, infestation of commodities by the granivorous pests was, in most cases, dependent upon the main effects of, and the interactions between, factors investigated (season, province, height inside bin, type of commodity and storage/sampling period). Infestation by the non-granivorous pests was primarily not affected by these factors. This was mostly due to the very low number of individuals extracted. Non-granivorous species, however, included predators and parasites of extreme importance and interest, and their role in suppressing the level of infestation by granivorous insects should be investigated. Accordingly, to predict incidence and population levels of either group, storage conditions must be carefully specified.

Parallel data dealing with main effects and interactions between prevailing factors on infestation are unavailable, though the effects of one or more factors have been discussed, e.g. height inside bin [2, 3, 4, 5, 6, 7, 8 and 9], storage period and/or seasonal changes [10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 and 23); and type of commodity [24, 25, 26, 27 and 28].

ACKNOWLEDGMENT

Thanks are due to KACST, Saudi Arabia, for funding this project, number AT - 7 - 164, to G.S.F.M.O. for providing all necessary facilities in Riyadh and Dammam plants; and to Prof. Dr. H. Mansour, Faculty of Agriculture, Ain Shams University, for his valuable help in statistical analysis.

REFERENCES

[1] **Rostom, Z.M.F., 1993.** Survey of some granivorous and non-granivorous insects and mites of stores in Saudi Arabia. J. Stored Prod. Res., 29(1): 27-31.

[2] **Fleurat-Lessard, F., 1976.** Influence of humidity on the development of mite population in stored oilseed and grain. Bull. Oepp (Organ Eur Mediterr. Prot. Plant), 6 (5): 391-398.

[3] **Smith, L.B., 1978.** Ecology of stored grain in the Canadian prairies: I. The distribution and size of a low density population of *Cryptolestes forrugineus.* Can. Entomol., 110 (12): 1281-1292.

[4] **Cole, D.B.** and **P.D. Cox, 1981.** Studies on 3 months species in a Scottish port silo, with special reference to overwintering *Ephestia kuhniella.* J. Stored Prod. Res., 17 (4): 163-182.

[5] **Navarro, S., T.G. Amos** and **P. Williams, 1981.** The effect of oxygen and carbon dioxide gradients on the vertical dispersion of grain insects in wheat. J. Stored Prod. Res., 17 (3): 101-108.

[6] **Armitage D.M., P.G. Day** and **G.J. Lewis, 1983.** The effect of aeration on the vertical distribution of grain beetles in wheat. Bull Entomol. Res., 73 (2): 233-238.

[7] **Keever, D.W., 1983.** Distribution patterns of lesser grain borer *(Rhyzopertha dominica)* in towers of wheat and effects of the presence of the granary weevil *(Sitophilus granarius)*. J. Econ. Entomol., 76 (3): 492-495.

[8] **Zdarkova, E., P.H. Verner and J. Novosa, 1993.** dispersion and distribution of mites and beetles in stored grain. J. Stored grain. J. Stored Prod. Res., 19 (2): 73-80.

[9] **Hagstrum, D.W., 1987.** Seasonal variation of stored wheat environment and insect populations. Environ. Entomol., 16 (1): 77-83.

[10] **Wafa, A.K., M.A. Zaher, A.H. El-Kifl and M.A. Hegazy, 1966.** Population density of mites found with stored wheat in Egypt. Bull. Soc. Entomol. Egypt, 50: 233-239.

[11] **Singh, K., 1977.** Seasonal variations in the population of insect pests of stored products in West Bengal. Indian J. Ecol., 4 (2): 212-127.

[12] **McGaughey, W.H., E.B. Dicke and J.H. Schesser, 1978.** Indian meal moth infestation of farm-stored wheat in Kansas. J. Econ. Entomol., 71 (3): 503-506.

[13] **Smith, L.B. and S.R. Loschiavo, 1978.** History of an insect infestation in durum wheat during transport and storage in an inland terminal elevator in Canada. J. Prod. Res., 14 (4): 169-180.

[14] **Hurlock, E.T., D.M. Armitage and B.E. Llewellin, 1980.** Seasonal changes in mite (Acari) and fungal populations in aerated and unaerated wheat stored for 3 years. Bull. Entomol. Res., 70 (4): 537-548.

[15] **Reichmuth, C., H.U. Schmidt, A.R. Levinson and H. Z. Levinson, 1980.** Seasonal occurrence of the warehouse moth *(Ephestia elutella)* in West Berlin, Germany granaries as well as the corresponding timed application of control measures. Z. Angrew. Entomol., 89 (1): 105-111.

[16] **Cogburn, R.R. and K.M. Vick, 1981.** Distribution of Angoumois grain moth *(Sitotroga cereallella)*, almond moth *(Ephestia casutella)* and Indian meal moth *(Plodia interpunctella)* in rice fields and rice storage in Texas, USA, as indicated by pheromone-baited adhesive traps. Environ. Entomol., 10 (6): 1003-1007.

[17] **Tseng, Yi-Hsiung, 1981.** Ecological notes on mites infesting stored products in Taiwan. J. Agric. Assoc. China New Ser., 0 (113): 48-56.

[18] **Stratil, H.H., H.U. Stratil and W. Knnelle, 1981.** Ecological studies of mite infestation at the surface layer of stored grain. Z. Angew. Entomol., 92 (2): 113-120.

[19] **Sinclair, E.R., 1982.** Population estimates of insect pests of stored products on farms on the Darling Downs, Queensland, Australia. Aust. J. Exp. Agric. Anim. Husb., 22(114/115): 127-132.

[20] **Chakrvorthy, S., Das H. Chandra and Das N. Ranjan, 1983.** Seasonal changes in densities of some insect pests in a population on stored grains. Environ. Ecol., 1 (1): 11-14.

[21] **Storey, C.L., D.B. Sauer and D. Walker, 1983.** Insect population in wheat, corn and oats stored on the farm. J. Econ. Entomol., 76 (6): 1323-1330.

[22] **Maurya, K.R., B. Dev and Z. Jamil, 1984.** Population patterns of *Androlaelaps casalis* (Acarina Laelapinae) in stored grains from Lucknow (India). Biol. Mem., 9 (2): 151-154.

[23] **Ramzan, M. and B.S. Chapal, 1989.** Effect of initial infestation levels of three common species of stored grain pests on their population build - up at constant laboratory conditions. J. Res., Punjab Agric. Univ., 26 (1): 71-76.

[24] **Pagliarini, N., 1979.** Studies on the mites of stored cereals in Yugoslavia. Rec. Adv. Acarol., 1: 305-309.

[25] **Al-Badry E.A., G.N. Rizk and S.M. Hafez, 1980/1981.** Frequency of occurrence of predaceous and parasitic mites inhabiting stored products. Mesopotamia J. Agric., 15: 223-234.

[26] **Maurya, K.R., Z. Jamil and B. Dev, 1982.** Mite-infestation-pattern in various stored products in Lucknow (India). Biol. Mem., 7 (2): 116-120.

[27] **Terho, E.O., L. Leskinen, K. Husman and L. Karenlampi, 1982.** Occurrence of storage mites in Finnish farming environments. Allergy (Copenh.,) 37 (1): 15-20.

[28] **Cline, L.D. and H.A. Highland, 1985.** Survival, reproduction and development of 7 species of stored - product insects on the various food components of lightweight, high-density, prototype military rations. J. Econ. Entomol., 78 (4): 779-782.