

9. Manufacturing techniques are needed which will produce uniform containers without roughened spots, creases, folds, and similar areas where insects penetrate most easily.
10. Repellents offer a possible solution

to the problem of keeping insects out of packaged food. Toxicity is shown by many compounds, especially phenol derivatives, and the effects due to repellency are thereby obscured.—7-20-43.

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## A Report on Insect Infestation of Stored Grain in California

E. G. LINSLEY and A. E. MICHELbacher, *University of California, Berkeley*

The following report is based upon a survey of approximately one hundred and twenty-eight infested granaries<sup>1</sup> in ninety-seven localities of California. This number represents about 75 per cent of the granaries actually examined. The remaining 25 per cent were found to be uninfested, although a great many of these were new construction and freedom from insect infestation was therefore probably due to this fact and not to sanitary practices. However, where sanitary practices had been strictly followed little or no infestation was found about granaries of several years standing.

The localities surveyed (Fig. 1) have been roughly grouped into four main areas on the basis of differing environmental conditions. These are the Sacramento Valley, the San Joaquin Valley, the Coastal area from Monterey Bay south to

Los Angeles County, and the southern interior of Los Angeles, Riverside, and Imperial Counties.

*Sacramento Valley.* Mackie & Carter (1937) reported a survey of granaries in the Sacramento Valley in 1933 which revealed that the four primary pests of stored grain were present in the following order of abundance: (1) the granary weevil, *Sitophilus granarius* (Linn.). (2) the Angoumois grain moth, *Sitotroga cerealella* (Oliv.), (3) the rice weevil, *Sitophilus oryza* (Linn.) and (4) the lesser grain borer, *Rhyzopertha dominica* (Fab.) The results of our survey of this area agree with the report of Mackie and Carter, although at the present time the lesser grain borer seems to be on the increase and may eventually surpass the rice weevil in importance.

*San Joaquin Valley.* In this region the rice weevil assumes more importance and in the southern portion of the area it is

<sup>1</sup> For comparable warehouse surveys, see Mackie & Carter (1937: 276) and Doane (1918: 313).

more destructive than the granary weevil. The lesser grain borer and Angoumois grain moth were found sparingly, although near Merced two bins of barley were found which had been nearly destroyed by the former.

*Coastal Area.* In the coastal counties the granary weevil was fairly abundant, the rice weevil rarely important. The Angoumois grain moth was scarce and the lesser grain borer was not encountered.

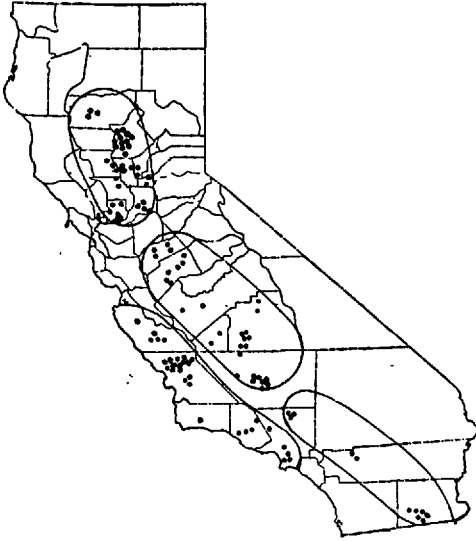


FIG. 1.—Location of infested granaries surveyed. Enclosed areas indicate Sacramento Valley, San Joaquin Valley, Coastal Region and Southern Interior areas respectively.

*Southern Interior Area.* In this region the rice weevil is of primary importance and in Imperial County it replaced the granary weevil in all of the granaries examined. This latter county also appeared to be well infested with the less grain borer. The Angoumois grain moth was common.

**PRIMARY GRAIN PESTS.**—In this group we have placed the species which attack whole grain at normal moisture contents prevailing in storage. Considering the state as a whole, the granary weevil must be regarded as the most important pest of whole grain. It was present in 60 per cent of the infested granaries encountered. However, its relative importance diminishes as one progresses southward and that of the rice weevil increases (Table 1). In Imperial County the latter displaces the former. The Angoumois grain moth

and lesser grain borer are most important in the Sacramento Valley and southern interior area. In the San Joaquin Valley they are local in occurrence and along the coast the lesser grain borer appears to be absent. However, it has only been known from California since 1933. (Mackie and Carter 1937). In no case was the Angoumois grain moth found in destructive numbers. Apparently serious damage is limited to grain where harvest is long delayed.

Table 1.—Comparison of the frequency of occurrence of granary insects in the major California grain storage areas. The ratios indicate number of granaries in which the species were present in relation to number of infested granaries examined.

SPECIES	SACRAMENTO VALLEY	SAN JOAQUIN VALLEY	COAST	SOUTHERN INTERIOR
<b>Primary</b>				
<i>Sitophilus granarius</i>	31:42	15:37	18:33	3:16
<i>Sitophilus oryza</i>	6:42	16:37	7:33	10:16
<i>Rhyssopertha dominica</i>	2:42	3:37		3:16
<i>Sitotroga cerealella</i>	11:42	2:37	2:33	6:16
<b>Secondary</b>				
<i>Oryzaephilus surinamensis</i>	28:42	19:37	14:33	8:16
<i>Oryzaephilus mercator</i>		6:37	3:33	3:16
<i>Tenebroides mauritanicus</i>	10:42	11:37	3:33	3:16
<i>Tribolium confusum</i>	30:42	13:37	15:33	12:16
<i>Tribolium castaneum</i>	2:42	14:37	5:33	9:16
<i>Laemophloeus pusillus</i>	12:42	10:37	3:33	3:16
<i>Laemophloeus ferrugineus</i>	3:42	9:37	7:33	5:16
<i>Ephestia kühniella</i>	9:42	2:37	5:33	
<i>Plodia interpunctella</i>	4:42	2:37	2:33	
<i>Aphomia gularis</i>				1:16
<i>Corcyra cephalonica</i>				1:16
<b>Minor or Incidental</b>				
<i>Attagenus piceus</i>	1:42	2:37	2:33	
<i>Perimegaloma variegatum</i>	1:42	2:37	3:33	
<i>Trogoderma versicolor</i>		5:37	3:33	2:16
<i>Trogoderma sternalis</i>		2:37	1:33	
<i>Anthrenus verbasci</i>		2:37	2:33	
<i>Cathartus quadricollis</i>	4:42		2:33	
<i>Ahasverus advena</i>	10:42	7:37	10:33	1:16
<i>Aglenus brunneus</i>			1:33	
<i>Typhaea stercorea</i>	10:42	1:37	5:33	1:
<i>Cryptophagus inscitus</i>		1:37	2:33	
<i>Cryptophagus cellaris</i>		1:37	1:33	16
<i>Cryptophagus</i> sp.	4:42			
<i>Henoticus californicus</i>	1:42	2:37	1:33	
<i>Enicmus minutus</i>	4:42	1:37	1:33	
<i>Enicmus crenatus</i>			1:33	
<i>Cartodera filum</i>			1:33	
<i>Melanophthalma americanum</i>	1:42	1:37	1:33	
<i>Alphitophagus bifasciatus</i>	3:42	3:37	4:33	
<i>Gnathocerus cornutus</i>			2:33	1:16
<i>Palorus ratzeburgii</i>	1:42	2:37		1:16
<i>Alphitobius ataperinus</i>		1:37	3:33	2:16
<i>Alphitobius piceus</i>	4:42	2:37		1:16
<i>Tenebrio molitor</i>	1:42			
<i>Tenebrio obscurus</i>	7:42	3:37	2:33	
<i>Plinus hirtellus</i>	1:42		4:33	2:16
<i>Plinus tectus</i>			2:33	
<i>Plinus gandolphei</i>	1:42	1:37		
<i>Trichogenius globulus</i>			1:33	1:16
<i>Carpophilus dimidiatus</i>		3:37		
<i>Haptoncus luteolus</i>	1:42			
<i>Pyralis farinalis</i>	9:42	2:37	2:33	3:16
<i>Hoffmanophila pseudo-spretella</i>	1:42		1:33	1:16
<i>Endrosis lacteola</i>			1:33	
<i>Paraneura simulella</i>			1:33	
<i>Scenopinus fenestralis</i>	2:42		2:33	
<i>Lepinotus patuelis</i>			2:33	
<i>Liposcelis divinatorius</i>	1:42	1:37	2:33	

SECONDARY PESTS.—In this category we have placed the common grain feeding insects which frequent granaries but rarely attack whole grain at the moisture content which prevails in normal storage. Most of these are associated with the primary pests and follow closely upon their attack.

The commonest and most ubiquitous of the secondary pests are the confused flour beetle, *Tribolium confusum* J. duV. and the saw-toothed grain beetle, *Oryzaephilus surinamensis* (Linn). Both were more or less equally common throughout the state, and frequently were the only pests encountered. To the southward the confused flour beetle encounters more and more competition from the rust-red flour beetle, *Tribolium castaneum* (Herbst). However, the latter does not replace the former in the southernmost part of the state as the rice weevil does the granary weevil, and the two exist together in the same granaries.

The flat grain beetles (*Laemophloeus* spp.) are encountered only a little less frequently than the flour beetles and saw-toothed grain beetle. In general they appear to parallel the flour beetles in distribution, the flat grain beetle, *L. pusillus* (Schön), roughly coinciding with the rust-red flour beetle, the rust-red grain beetle, *L. ferrugineus* (Stephens), with the confused flour beetle.

The moths were probably not adequately sampled. However, it appeared that the Mediterranean flour moth, *Ephestia kühniella* Zeller and the Indian meal moth, *Plodia interpunctella* (Hbn.) were fairly common granary insects, although in the Sacramento Valley, some

of the records probably apply to the cacao moth, *Ephestia elutella* Zeller. None of these moths appeared to be very destructive although *Ephestia* spp. were rather commonly found breeding on the surface of bulk stored grain. These moths were encountered less frequently in the southern interior region, although the rice storage moth, *Aphomia gularis* Zeller and the rice moth *Corcyra cephalonica* Stainton were found only in that area.

MINOR AND INCIDENTAL SPECIES.—Thirty-seven species of minor or incidental granary insects were encountered. Most of these were abundant only where grain was out of condition. Locally *Trogoderma versicolor* (Creutzer) and *Attagenus piceus* (Olivier) may have been responsible for some slight damage but the remainder of the species are probably to be regarded as indicators of unsanitary conditions rather than as pests.

CONCLUSIONS.—(1) There are four main insect pests of stored whole grain in California, the granary weevil, the rice weevil the Angoumois grain moth, and the lesser grain borer. The first is the most important species in northern California, the second in southern California.

(2) Among the secondary species, the saw-toothed grain beetle, confused flour beetle, and rust-red beetle are common and almost equally widespread. The rust-red flour beetle and flat grain beetle become more abundant from north to south.

(3) Many minor or incidental species are associated with grain in the state. The majority of these are indicators of unsanitary conditions or that the grain is out of condition.—7-6-43.

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