SUSCEPTIBILITY OF BULGUR TO INFESTATION OF FIVE INTERNALLY-FEEDING STORED-GRAIN INSECTS AT THREE RELATIVE HUMIDITIES

by 45

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INTRODUCTION

Government officials and civil defense workers became interested in a gelatinized wheat product called bulgur in the early 1950's. Producing bulgur in the U. S., shipping it to rice-eating people in the Orient, and making products for storage in nuclear fallout shelters seemed practical and would help reduce the wheat surpluses.

Since bulgur was being shipped to tropical countries and stored under conditions making insect infestation a possibility, it was desirable to conduct experimental work to determine the susceptibility of bulgur to insects known to infest stored wheat. Information regarding insect damage was also desired by civil defense personnel.

The purpose of this research was to determine if any of the internally-feeding stored-grain insects could infest whole and cracked bulgur, and if so, what effect a bulgur diet would have on the biology of the species. Also, environmental factors such as temperature and relative humidity were to be tested and the effects on infestation and damage observed.

Tests on bulgur and wheat of similar type and under similar conditions were conducted using the lesser rice weevil, Sitophilus oryzae (L.); larger rice weevil, Sitophilus zeamais Motschulsky; granary weevil, Sitophilus granarius (L.); lesser grain borer, Rhyzopertha dominica (F.); and Angoumois grain moth, Sitotroga cerealella (Olivier).

The female of each of the 3 species of weevils chews a hole in a kernel, places an egg in it and seals it with a gelatinous material. The egg hatches and the larva feeds and develops into an adult inside the kernel. Female lesser grain borers and Angoumois grain moths lay

eggs outside the kernels. When the eggs hatch, each small larva chews its way into a kernel, feeds and develops into an adult before emerging.

REVIEW OF LITERATURE

Haley et al. (1960) reported that bulgur has been a mainstay in the diets of people in Middle Eastern countries for several hundred years. The product was produced by the family, or several families, as a cooperative project after a wheat harvest. After boiling whole wheat in open vessels until tender, spreading it out to dry, removing the bran and cracking the grain, it was possible to prepare it for eating in 15-20 minutes with a minimum amount of water or steam, and heat.

Bulgur, also known as bulgor, burgul, burghoul, boulgor, bulghour, or others, has been processed in the United States for several years. Three small companies processed bulgur for local consumption. The first large scale production started in 1955 at a plant capable of producing 100,000 pounds daily. The purpose was to increase the export of U. S. wheat to the Orient where rice was eaten and the supply inadequate (Haley et al., 1960).

Bulgur has been manufactured in several ways. In some countries wheat is soaked overnight, cooked in an open kettle for 5-6 hours, drained and dried on roof tops (Brown, 1962). Brown also reported that one large company making bulgur in the U. S. passes wheat through a presoaking stage for 16 hours starting at 125°F and ending at 150°F, cooks the soaked grain for 90 seconds at 259°F (20 psi), then passes it through a series of driers to remove the excess moisture added during cooking.

Bulgur and bulgur products became of interest to Civil Defense planners for possible usage as a food in fallout shelters. A reported long shelf-life, easy preparation, high caloric and bulk density, and relatively low protein content led to experimentation for finding suitable ways to prepare and serve bulgur under stress situation (Taylor, 1962).

No information concerning actual infestations in bulgur by insects was found in the literature. Traditionally bulgur was regarded as the nutritional equal to wheat with the added features of being more stable and more resistant to attack by insects and molds, but there seemed to be no reason why bulgur stored in insect-suitable conditions for a long period should be resistant to insect damage (Haley et al., 1960).

Additional literature citations are made where appropriate in the following sections.

MATERIALS AND METHODS

Test Media

Source. The bulgur used in the initial tests in the rearing room, in the sulfuric acid chamber and in the potassium hydroxide chamber was received from the Crete Mills, Crete, Nebraska. The hard red winter wheat was from the Manhattan area.

The Farmer's Commission Company in Hutchinson, Kansas, also supplied whole and cracked bulgur and wheat from the same stock that the bulgur was made.

Sterilization, Storage and Cleaning. The bulgur and wheat were placed in a chest freezer at -17°C for at least one week to kill any

insects that might have been in the products and then were held in cold storage at 4.4°C until used. The whole bulgur and wheat were passed through a Bates Laboratory Aspirator to remove foreign matter and deformed and partial kernels. Cracked bulgur and cracked wheat media were not aspirated because the smaller particles were desired in the media.

Particle Size. Cracked bulgur as it came from the processing plant and which satisfied the minimum and maximum standards for particle sizes allowed for government export and whole bulgur were used in tests along with whole and cracked wheat. Whole wheat was passed through a Hobart Coffee Grinder set to produce cracked wheat with particle sizes similar to the cracked bulgur.

To prepare samples of bulgur and wheat of different particle sizes, portions of the cracked bulgur and wheat were shaken in a stack of U. S. Standard wirecloth screening sieves. Particles held on the number 8, between numbers 8 and 10, 10 and 12, and 12 and 20 screens, as well as samples of the original cracked wheat and bulgur and whole wheat and bulgur (Plate I) were placed in chambers having approximately 71%, 58% and 43% relative humidities (RH). Those particle sizes will be referred to in the remainder of the paper as: >8-mesh, <8- >10-mesh, <10- >12-mesh and <12-mesh.

Moisture Control. The moisture content of the media was regulated by controlling the relative humidity in the environment.

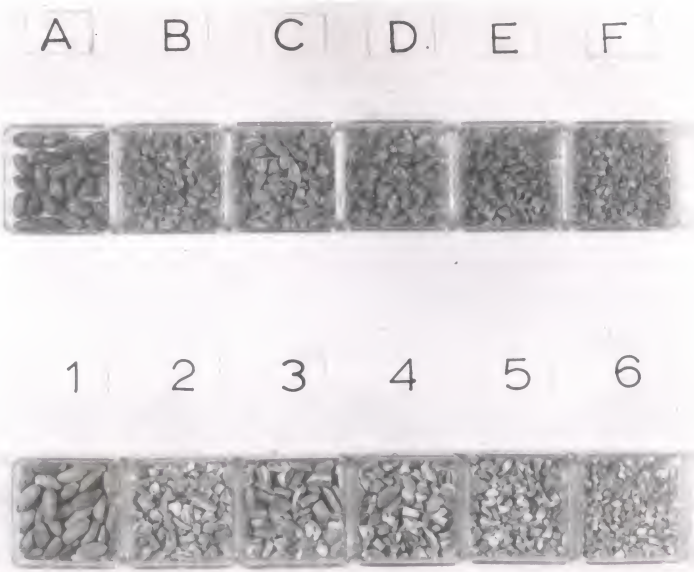
Initial tests were conducted in the Stored-Product Insects laboratory rearing room to determine whether insects would develop in bulgur held under "Optimum" conditions in which a relative humidity of

EXPLANATION OF PLATE I

The 6 bulgur particle sizes tested are labeled as follows: (A) whole; (B) cracked; (C) >8-mesh; (D) <8- >10-mesh; (E) <10- >12-mesh; and (F) <12-mesh.

The 6 wheat particle sizes listed are labeled as follows: (1) whole; (2) cracked; (3) >8-mesh; (4) <8- >10-mesh; (5) <10- >12-mesh; and (6) <12-mesh.

PLATE I



70 (±2)% and a temperature of 27.7°C were maintained at all times. The equilibrium moisture content of wheat in the rearing room was about 13.5%. Solutions of KOH and H_2SO_4 were prepared which provided 70% RH in 29 cm x 29 cm x 37 cm plastic containers. Each was placed in the rearing room where the temperature was constant. Glass platforms with legs were made to hold the small containers of bulgur and wheat above the solutions. The results of tests in those chambers were compared with those observed in tests exposed to the rearing room conditions.

Saturated solutions of strontium chloride, sodium bromide, and potassium carbonate were used in the second tests to obtain humidities of approximately 71%, 58% and 43%. Each plastic container, 29.5 cm x 19.5 cm and 10 cm, was covered with a tight fitting snap-on cover and placed in a room with a temperature of 27.7°C (Plate II).

Moisture Equilibration. In most cases the various wheat and bulgur media were placed in the appropriate environment of the pending test for 2-4 weeks to allow for moisture equilibration. If it was necessary to change the moisture content, the medium was dried in thin layers before a fan or distilled water was added to it. The amount of water added was determined by the following formula:

$$\frac{100 - \text{present \% moisture}}{100 - \text{desired \% moisture}} \times \text{wt. of grain} - (\text{wt. of grain}) = \text{wt. of water needed}$$

After the water was added to the grain, the container was sealed and rolled for at least one hour on each of 3 or 4 days. Then the moisture was checked to determine if further adjustment was necessary.

EXPLANATION OF PLATE II

Fig. 1. Humidity chamber and lid.

Fig. 2. Small plastic test box with screened hole in the lid.

PLATE II

Fig. 1

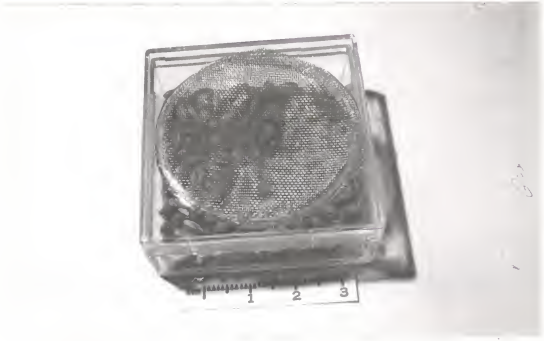


Fig. 2

Moisture Determination. Moisture content of both bulgur and wheat was determined by the air-oven method. A 10-gm sample of each medium tested was ground with a 1/4 H.P. Wiley Cutting Mill and passed through a 20-mesh screen. Five samples of approximately 2 gm each were weighed and placed in small metal cans 3 cm x 3 cm with snug fitting lids. The empty cans with lids removed were initially dried in a pre-heated Precision Scientific Oven at 130°C. Before removal from the oven the lids were put on the cans. They were placed on an aluminum rail for heat removal, then placed in a desiccator until weighed on a Type H16 Mettler Balance. The can weight was obtained, approximately 2 gm of sample were added to each can and then both were reweighed. The cans with samples were placed in the oven with the lids removed and allowed to dry for one hour at 130°C. The lids were replaced and the containers again put on the aluminum rail and then in the desiccator. The weights of the dry can and dry sample were recorded.

The moisture content of the grain was determined by dividing the weight of the sample into the amount of moisture lost while drying. The moisture content of the 5 samples was then averaged to obtain the moisture content of the stock tested.

$$\frac{\text{(wt. of can + wet sample) - (wt. of can + dry sample)}}{\text{(wt. of can + wet sample) - (wt. of can)}} \times 100 = \% \text{ moisture content}$$

Sample Size. The amount of medium placed in each of the 44 mm x 44 mm x 15 mm plastic boxes (Plate II) was dependent upon the insect used in a particular test. Eight-gm samples were weighed on an Ohaus Triple Beam Balance, placed in the boxes and infested in the initial tests at 70% RH. Four-gm samples were weighed and placed in the test boxes for infestations using eggs in later tests. Each

test box contained a hole in the top covered by 60-mesh copper wire cloth to allow air circulation. Initially the holes were 10 cm but were later enlarged to 38 mm (Plate II).

Insects

Source. The lesser rice weevil, Sitophilus oryzae (L.), was obtained in Kansas prior to 1955; the larger rice weevil, Sitophilus zeamais Motschulsky, was received from Stuttgart, Arkansas, 1955; the granary weevil, Sitophilus granarius (L.), and lesser grain borer, Rhyzopertha dominica (F.) were found in Kansas, dates unknown, the Angoumois grain moth, Sitotroga cerealella (Olivier), was started from an infestation in Anderson County, Kansas, August, 1960.

These cultures had been maintained in 1-quart, wide-mouth Mason jars approximately 1/3-filled with hard red winter wheat, in the stored-product insects rearing room at Kansas State University.

Sexing Adults. Prior to infestation of tests with weevils, the adults were sexed using rostrum characters, but in case of doubt the abdominal sternites were examined before the sex was determined (Halstead, 1962). The genitalia were rolled out of the lesser grain borer's abdomen with a dissecting needle for examination. The Angoumois grain moths were sexed by examining the abdomen for color, shape, size and the presence or absence of the male claspers at the posterior end of the abdomen.

Insects were examined beneath a binocular dissecting microscope. Adult weevils were held with a Shulco Vacuum Tweezer, Model V-100, for sexing.

Collection of Eggs. Eggs were collected on oviposition papers devised for the lesser grain borer by Gundu Rao in the Entomology laboratory. They consisted of two pieces of black construction paper held together by a thin line of glue down the center. The papers were then placed in small plastic boxes with 50 adult lesser grain borers for 24 hrs. The eggs were deposited between the two pieces of paper.

Ellington (1930) found that female Angoumois grain moths would oviposit between pieces of paper similar to that described for the lesser grain borer; Mills added refinements to this technique (1965). Strips of black construction paper were held together by a staple on one end and a line of glue extending down the center to the other end. A V-notch that extended past the shorter piece to rest the strip on the bottom of the oviposition jar was cut in the paper. This notch allowed the insects freedom of movement around the base of the strip. The oviposition jars were plastic and had metal tops. A slit in the lid allowed the strips to be put in or taken out without removing the lid. About 50 young adult moths were placed in the oviposition jar where the eggs were laid between the pieces of paper. The strip was removed from the jar 24 hours later.

Introduction of Insects to Media. Six male and 12 female weevils, 14 ($\pm$1) days old, were introduced into each test box in preliminary tests but later 6 males and 10 females were used. After an oviposition period of 7 days, all adults were removed. Thirty one-day-old eggs of the lesser grain borer and Angoumois grain moth were placed in each test box. The number of hatched eggs was determined by microscopic examination after ample time for hatching.

Collection of Progeny. The progeny of the weevils were collected by spreading the contents of each box on plain white paper and aspirating the adult progeny into a 25 mm x 100 mm plastic tube.

The moths were collected in a cage with a glass top and front and wooden sides with arm holes and cloth sleeves through which boxes, aspirator, etc. could be introduced without moths escaping. The top of each test box was removed and the moths aspirated into a plastic tube.

Lesser grain borer adults were more difficult to collect since they characteristically feed inside damaged kernels or particles. Due to the high number of larvae that failed to enter the cracked particles, it seemed advisable not to spread the contents on paper. Each box of this medium had to be inspected carefully and the infested kernels or pieces of kernels examined for exit holes which adults may have re-entered. The kernels usually had to be broken open and the adults forced out.

Weighing of Progeny. In selected treatments, depending on the insect and its ability to infest various sizes of bulgur and wheat particles, the first 10 males and first 10 females from the collective emergence of all replications for each treatment were weighed and sexed. The insects that could be sexed while alive, without damaging the genitalia, were sexed prior to weighing. Then they were frozen and mounted on points for later comparison of variations within and among treatments.

Those insects that could not be sexed without damage were weighed, sexed and discarded. Visual and weight comparisons within and among treatments were made at the time of collection.

RESULTS AND DISCUSSION

Equilibrium Moisture Content of Bulgur and Wheat

Solutions of sulfuric acid and potassium hydroxide were prepared in large plastic containers to give various relative humidities (Solomon, 1951). Specific gravity readings were taken to determine the concentrations of the solutions. This method of producing the desired constant relative humidity was satisfactory at the beginning but as time passed the solutions became diluted. This allowed the relative humidity and consequently the moisture content of the test media to rise. Since a constant relative humidity was desired, saturated salt solutions were used in later tests because they were easier to handle and adjust.

Initial air-oven method moisture tests revealed that bulgur would not reach an equilibrium moisture content as high as wheat of the same type in the same relative humidity. Bulgur that had been stored at room temperature and 40% RH for a long time contained 9.2% moisture. Wheat at that relative humidity is expected to have an average moisture content of about 10.5% depending on the type of wheat, year of harvest, length of storage, method of regulating relative humidity, temperature, method of maintaining relative humidity, and method of determining the moisture content (Davey and Elcoate, 1965). Other results indicated that at 70% RH bulgur reached moisture equilibrium at 1.0 - 1.5% lower than wheat (Plate III and Table 1).

EXPLANATION OF PLATE III

Percentage moisture of bulgur and wheat of different particle sizes equilibrated at 71%, 58%, and 43% relative humidities.

PLATE III

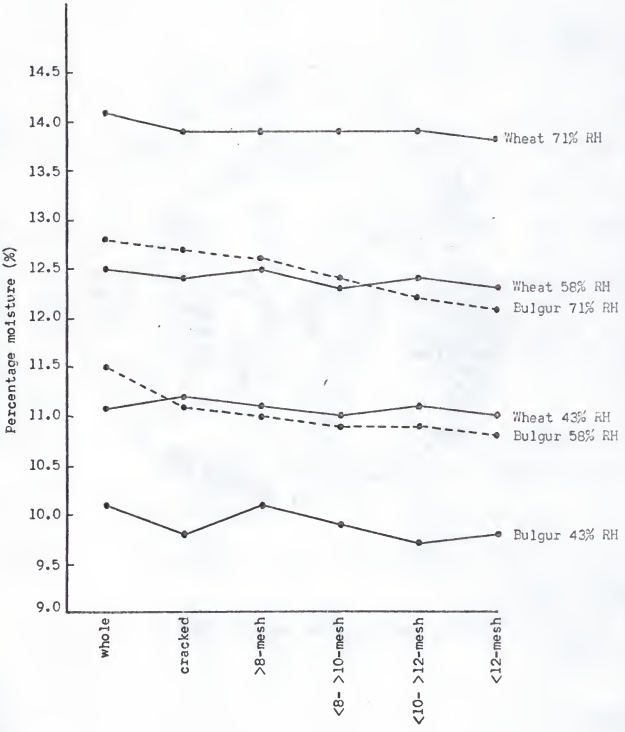

Percentage moisture (%)
14.5
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
Wheat 71% RH
Wheat 58% RH
Bulgur 71% RH
Wheat 43% RH
Bulgur 58% RH
Bulgur 43% RH
whole
cracked
>8-mesh
<8- >10-mesh
<10- >12-mesh
<12-mesh

Table 1. Percentage moisture of bulgur and wheat of various particle sizes equilibrated at 71%, 58%, and 43% relative humidities.

Medium	71% RH	58% RH	43% RH
Whole wheat	14.1%	12.5%	11.1%
Whole bulgur	12.8	11.5	10.1
Difference	1.3	1.0	1.0
Cracked wheat	13.9	12.4	11.2
Cracked bulgur	12.7	11.1	9.8
Difference	1.2	1.3	1.4
>8-mesh wheat	13.9	12.5	11.1
>8-mesh bulgur	12.6	11.0	10.1
Difference	1.3	1.5	1.0
<8- >10-mesh wheat	13.9	12.3	11.0
<8- >10-mesh bulgur	12.4	10.9	9.9
Difference	1.5	1.4	1.1
<10- >12-mesh wheat	13.9	12.4	11.1
<10- >12-mesh bulgur	12.2	10.9	9.7
Difference	1.7	1.5	1.4
<12-mesh wheat	13.8	12.3	11.0
<12-mesh bulgur	12.1	10.8	9.8
Difference	1.7	1.5	1.2

Many researchers have conducted moisture tests to determine the equilibration point of wheat at a given relative humidity but those results showed a wide range of variation depending on the several factors mentioned above. Information regarding the equilibration moisture content of bulgur and wheat of the same particle size at a constant relative humidity and temperature was desired and carried out along with the other tests.

The results of moisture tests of samples held at the 3 relative humidities in which media were tested are shown in Table 1 and Plate III. Regardless of the particle size, the equilibration moisture content of bulgur was more than 1.0% lower than wheat. In the same relative humidity the moisture contents of the samples generally decreased as the particle size decreased. Variation in moisture contents in all tests indicated a smaller degree of variation between the largest and smallest particles of wheat, 0.3%; and bulgur, 0.7%; at 70% RH. At 58% RH the variation was about the same as at 70% RH but at 43% RH the variation was negligible.

Preliminary tests on equilibration showed that bulgur molded when placed in an environment at or above 75% RH and room temperature. The range in time for molding to occur was from less than 30 days in 75% RH to less than one week in 100% RH. In a later test the different media were infested with larger rice weevils, as described previously, and placed in plastic test boxes without screen-covered holes in the lid. After 30 days the media in which the progeny were developing were covered with mold. At that time lids with holes covered with screens were placed on the boxes and progeny collected as usual. It wasn't

known whether that was done soon enough to prevent the mold from influencing the test. The mold did not seem to harm the weevils with regard to numbers developing, developmental periods, or weights. Due to molding of the media the test was repeated using lids with screened holes in them to allow for air movement. No mold appeared then on any media.

Ferrel et al. (1965) determined the equilibrium moisture content of bulgur at various relative humidities and temperatures with results similar to those in this experiment.

Preliminary Testing of Infestation by Three Species in the Rearing Room

Determination of Species Capable of Infesting Bulgur. The lesser rice weevil, Angoumois grain moth, granary weevil and lesser grain borer were tested to determine if they could infest bulgur under a standard rearing room temperature and relative humidity. Information gathered indicated that progeny or hatched larvae of the species mentioned could develop in whole and cracked bulgur at 70% RH and 27.7°C.

Lesser rice weevil adults were allowed to mate and the females oviposit for 7 days in each replicate. Results showed that the average developmental period in whole bulgur was about 4 days longer than in whole wheat and 2.5 days longer in cracked bulgur than in cracked wheat (Table 2). It was noted also that the length of the developmental period for whole and cracked media of the same type was about the same. Peak emergence days for the different media also indicated faster development in wheat than in bulgur.

The weights of the first 10 males and 10 females to emerge from any replicate within a treatment were recorded (Table 2). The variation of weights of the same sex and treatment was narrow; the average weight of progeny emerging from whole bulgur was slightly greater than from whole wheat. Females from whole kernels tended to weigh slightly heavier than males. The variation in the sizes of the particles in the cracked media influenced the weights of the progeny emerging from the various particles. A newly-emerged adult from a large particle of wheat or bulgur may have weighed 2-3 times more than a newly-emerged adult from a very small particle of the same medium. The variations in actual weights were large and a good comparison could not be made between the sexes or media due to the small number of progeny weighed.

Many immature rice weevils were observed in various stages of development outside the particles of both cracked wheat and bulgur. They eventually became adults. Several whole kernels served as a shelter and food source for two larvae at the same time, which is common with this species.

The granary weevil produced adult progeny in each of the 4 media but produced more in whole kernels of bulgur and wheat than in the cracked media and more from cracked wheat than from cracked bulgur (Table 2). The average developmental period of the granary weevil was 7-10 days longer than that of the lesser rice weevil in corresponding media. The total number of granary weevil progeny was considerably less than for the lesser rice weevil in all media. Fewer granary weevil larvae were observed developing outside the kernels in cracked wheat and bulgur than for the rice weevil.

Table 2. Developmental periods, progeny and weights of Sitophilus spp. reared in whole and cracked bulgur and wheat in the rearing room at 70 (±2)% RH and 27.7°C (6 males and 12 females were introduced into each of the 6 replicates of each medium and left for 7 days for oviposition).

	Medium	Avg. no. progeny/rep.	Developmental period ±3 days (oviposition to adult) Range	Avg.	Peak emergence ±3 days	Avg. wt. (mg) of 1st 10 Males	Females
Lesser rice weevil	Whole wheat	202.6	28 - 53	33.3	32	1.30	1.45
	Whole bulgur	209.2	29 - 53	37.1	35	1.40	1.55
	Cracked wheat	249.0	28 - 50	33.6	32	1.00	0.80
	Cracked bulgur	209.0	29 - 52	36.0	36	1.10	1.15
Granary weevil	Whole wheat	75.6	35 - 59	41.0	39	2.55	2.50
	Whole bulgur	41.0	40 - 66	44.2	46	2.20	2.15
	Cracked wheat	34.8	33 - 61	41.5	40	1.55	1.25
	Cracked bulgur	12.2	38 - 66	46.8	45	1.50	1.35

The granary weevil weighed almost twice as much as the lesser rice weevil at maturity; males were slightly heavier than females (Table 2). The average weights of the adults emerging in cracked wheat and bulgur were less than from whole particles and was probably due to the variation in the sizes of the particles.

Angoumois grain moth tests were started by placing 30 eggs in each replicate. This test was destroyed by psocids before data could be taken. One replicate of whole wheat yielded 17 adult moths but no other replicate of any media yielded adults. Other tests set up in 70% RH chambers using sulfuric acid and potassium hydroxide indicated that this moth could develop in bulgur but the data on developmental periods were not accurate.

About 70% of the lesser grain borer eggs hatched and a high percentage of larvae developed into adults (Table 3). The cracked wheat yielded adults with the shortest average developmental periods of 45.7 days; followed by whole bulgur, 51.3; whole wheat, 53.1; and cracked bulgur, 54.1 days. A high rate of survival was recorded in each medium also.

Table 3. Survival, developmental periods and weights of lesser grain borers reared in whole and cracked bulgur and wheat in the rearing room at 70 (±2)% RH and 27.7°C (30 eggs were introduced into each of the 6 replicates of each medium).

Medium	Avg. no. hatched larvae/rep.	Avg. no. adults per rep.	% Survival of hatched larvae	Avg. dev. period in days	Avg. wt. (mg) of 1st 10 Males	Females
Whole bulgur	16.4	13.4	81.5	51.3	1.00	1.00
Whole wheat	23.2	17.0	77.3	53.1	1.15	1.20
Cracked bulgur	22.4	16.6	74.6	54.1	0.90	1.00
Cracked wheat	24.6	19.8	82.0	45.7	1.25	1.15

Infestation of Bulgur and Wheat by Two Species at 71%, 58%, and 43% RH

The Larger Rice Weevil

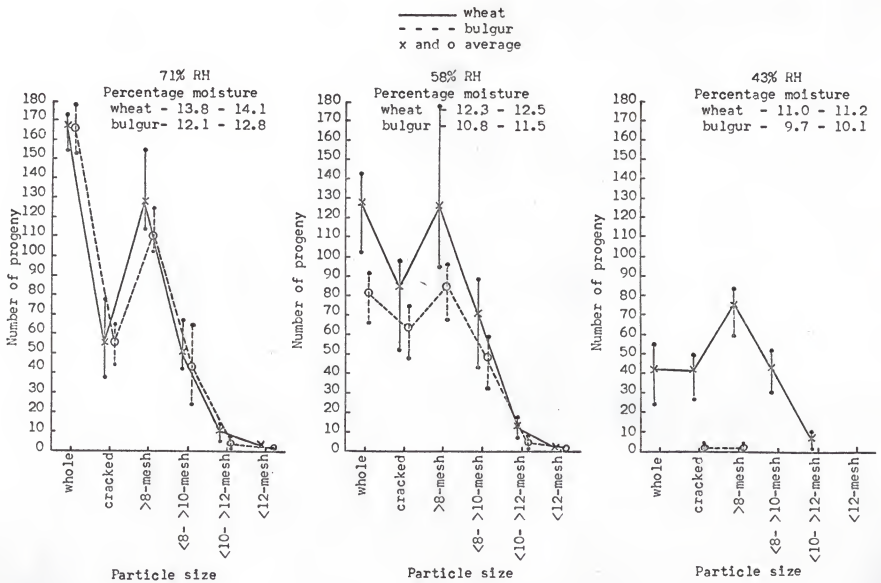
71% RH. The average numbers of progeny per test box produced in whole bulgur and wheat were 165.2 and 166.8; in cracked bulgur and wheat, 55.0 and 54.3; in >8-mesh, 109.6 and 127.7; in <8- >10-mesh, 41.7 and 49.0; in <10- >12-mesh, 2.2 and 9.2; and in <12-mesh, 0 and 1.0 (Plate IV, Appendix Table 6). Whole, cracked, >8-mesh and <8- >10-mesh bulgur yielded progeny 29 (±4) days after oviposition compared to whole, cracked, >8-mesh, <8- >10-mesh and <10- >12-mesh wheat which had progeny present 27 (±4) days from oviposition. No adults emerged from the <12-mesh bulgur medium and only 1 emerged from each replicate of <12-mesh wheat, the first occurring after 31 (±4) days. Bulgur and wheat of the same particle size produced about the same numbers of progeny and those numbers decreased as the particle size decreased.

Differences were evident in the developmental periods of the first adults to emerge and in the average developmental periods (Plate V). The average developmental periods of adults maturing in bulgur were longer in all cases than those in wheat and the first adults appeared later in bulgur than in wheat. Average developmental periods in whole bulgur and wheat were 35.7 and 32.9 (±4) days; in cracked bulgur and wheat, 37.2 and 33.1; in >8-mesh bulgur and wheat, 36.9 and 33.0; in <8- >10, 37.1 and 33.3; in <10 - >12, 37.9 and 34.4; and in <12-mesh wheat, 36.7. The developmental periods increased in both wheat and bulgur as the particle size decreased.

EXPLANATION OF PLATE IV

Range and average numbers of progeny produced by larger rice weevils in bulgur and wheat of different particle sizes at 71%, 58% and 43% RH (6 males and 10 females were introduced into each of the 6 replicates of each particle size for oviposition and removed after 7 days).

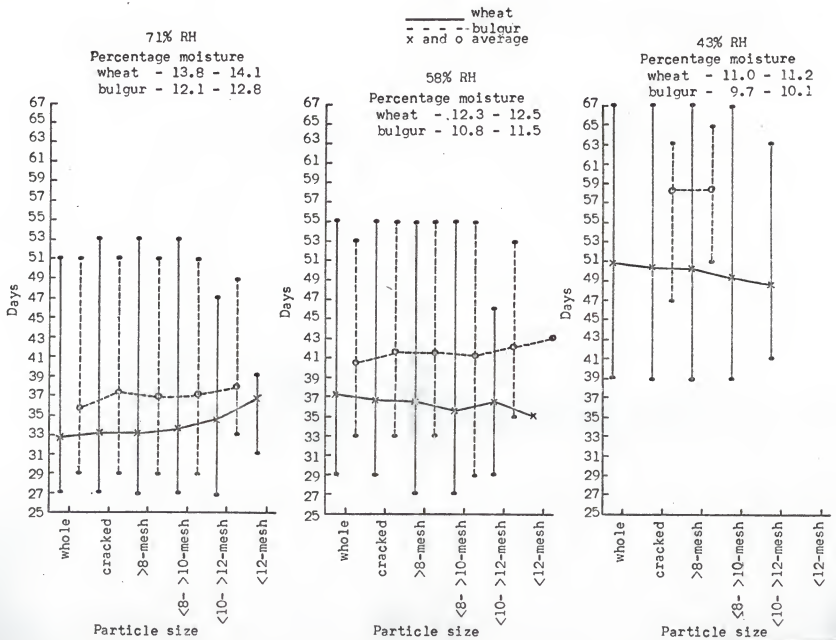
PLATE IV


wheat
bulgur
x and o average
71% RH
Percentage moisture
wheat - 13.8 - 14.1
bulgur- 12.1 - 12.8
58% RH
Percentage moisture
wheat - 12.3 - 12.5
bulgur - 10.8 - 11.5
43% RH
Percentage moisture
wheat - 11.0 - 11.2
bulgur - 9.7 - 10.1
Number of progeny
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
whole
cracked
>8-mesh
<8- >10-mesh
<10- >12-mesh
<12-mesh
Particle size

EXPLANATION OF PLATE V

Range and average length of developmental periods (±4 days) of larger rice weevils in bulgur and wheat of different particle sizes at 71%, 58%, and 43% RH (6 males and 10 females were introduced into each of the 6 replicates of each particle size for oviposition and removed after 7 days).

PLATE V


wheat
bulgur
x and o average
71% RH
Percentage moisture
wheat - 13.8 - 14.1
bulgur - 12.1 - 12.8
58% RH
Percentage moisture
wheat - 12.3 - 12.5
bulgur - 10.8 - 11.5
43% RH
Percentage moisture
wheat - 11.0 - 11.2
bulgur - 9.7 - 10.1
Days
Particle size
whole
cracked
>8-mesh
<8- >10-mesh
<10- >12-mesh
<12-mesh

The weights of the progeny reared in whole bulgur, in whole wheat, in <8- >10-mesh bulgur and in <8- >10-mesh wheat were similar; those that developed in the whole kernels of wheat and bulgur weighed twice as much as those that matured in the <8- >10-mesh media (Table 4). All adults from whole kernels averaged 2.6 mg and those from <8- >10-mesh media averaged 1.3 - 1.4 mg (Table 4).

58% RH. The number of progeny that developed in each replicate of whole bulgur and wheat averaged 80.7 and 127.8; in cracked bulgur and wheat, 62.8 and 82.8; in >8-mesh bulgur and wheat, 81.8 and 126.2; in <8- >10, 48.0 and 69.5; in <10 - >12, 4.7 and 12.7; and in <12-mesh, 0.0 and 1 developed in 1 of the 6 wheat replicates. The numbers of progeny were less than in corresponding media at 71% RH in each treatment except cracked bulgur and wheat and <8- >10-mesh bulgur and wheat (Plate IV, Appendix Table 7). In cracked bulgur and wheat at 71% RH there were 55.0 and 54.3 progeny per replicate compared to 62.8 and 82.8 at 53% RH. The <8- >10-mesh bulgur and wheat yielded 41.7 and 49.0 at 71% RH and 48.0 and 69.5 at 58%. In these cases the numbers of progeny from the 53% RH tests were not significantly higher (.05 level) than those from the 71 RH tests.

As was true at 71% RH, the developmental periods of progeny maturing in bulgur were longer than in their corresponding wheat media. The first adult progeny emerged 4 days later in whole bulgur than in whole wheat, 2 days later in cracked, >8, <8- >10-mesh bulgur and 6 days later in <10- >12-mesh bulgur. Average developmental periods in whole bulgur and wheat were 40.6 and 37.0; in cracked bulgur and wheat, 41.6 and 36.6; in

Table 4. Range and average weights (mg) of the first 10 male and 10 female larger rice weevils to emerge from bulgur and wheat media at 71%, 58%, and 43% RH.

Medium	Males		Females	
	Range	Avg.	Range	Avg.
71% RH				
Whole bulgur	2.40 - 2.85	2.64	2.40 - 2.85	2.65
Whole wheat	2.30 - 2.90	2.64	2.30 - 2.95	2.68
<8- >10-mesh bulgur	1.05 - 2.00	1.32	1.05 - 1.85	1.40
<8- >10-mesh wheat	1.15 - 1.85	1.43	1.00 - 1.75	1.26
58% RH				
Whole bulgur	2.40 - 3.00	2.77	2.40 - 3.10	2.73
Whole wheat	1.95 - 2.85	2.42	2.10 - 2.90	2.55
<8- >10-mesh bulgur	1.10 - 1.90	1.42	1.15 - 1.70	1.38
<8- >10-mesh wheat	1.00 - 1.60	1.31	1.00 - 1.50	1.24
43% RH				
Whole bulgur	---- ----	----	---- ----	----
Whole wheat	1.90 - 2.45	2.21	1.65 - 2.70	2.26
<8- >10-mesh bulgur	---- ----	----	---- ----	----
<8- >10-mesh wheat	0.95 - 1.75	1.27	1.00 - 1.45	1.24

>8-mesh bulgur and wheat, 41.4 and 36.4; in >8- >10, 41.4 and 35.6; and in <10 - >12, 42.1 and 36.4 (Plate V). The developmental periods fluctuated more in the wheat media than in the bulgur media and increased as the particle size decreased except for <8- >10-mesh bulgur. Average developmental periods tended to be more similar in both the bulgur and wheat media at 58% RH than at 71% RH.

Males and females that developed in whole and in <8- >10-mesh bulgur weighed a little more than those that developed in the wheat. The longer developmental periods may have accounted for this difference. The progeny from the whole kernels of both media, 2.4 - 2.8 mg, weighed about twice as much as those from <8- >10-mesh media, 1.3 - 1.4 mg (Table 4).

43% RH. The average numbers of progeny produced in whole bulgur and wheat were 0.0 and 40.8 per replicate; in cracked bulgur and wheat, 0.8 and 40.7; in >8-mesh bulgur and wheat, 2.5 and 74.7; in <8- >10-mesh, 0.0 and 43.0; in <10- >12-mesh, 0.0 and 6.7; and in <12-mesh, 0.0 and 0.0 (Plate IV, Appendix Table 8). The average numbers of progeny per replicate were much less in most treatments at 43% RH than in 71% and 58% RH. The parents introduced initially into the bulgur did not survive as well as those in the wheat. All adults were removed from all replicates at the end of the 7-day oviposition period. Nearly all of the 16 parents in the whole bulgur were dead; none were dead in wheat at the end of the ovipositional period. More progeny were collected from the 8-mesh wheat media than from any of the others, possibly because the adults could feed more easily on the broken kernels and had larger particles in which to oviposit. Fewer large particles were present in the cracked wheat.

The average developmental periods were 50.0 (±4) days in whole wheat; 50.2 days in cracked; 50.1 in >8-mesh; 49.1 in <8- >10-mesh; and 48.4 days in <10- >12-mesh (Plate V). The average developmental period in cracked bulgur was 58.2 (±4) days and in >8-mesh bulgur, 58.6 days. No progeny developed in the <12-mesh wheat or in whole bulgur, <8 - >10-mesh bulgur, <10- >12-mesh and <12-mesh bulgur. The average developmental periods were less in the wheat media as the particle size decreased as contrasted with other humidities, but the smaller numbers of progeny were probably inadequate for valid comparisons.

Males and females collected from the whole wheat averaged 2.21 mg and 2.26 mg. From the <8- >10-mesh wheat the males weighed 1.27 mg and the females 1.24 mg (Table 4). Since no adults developed in whole bulgur or <8- >10-mesh bulgur no weights could be taken (Table 4).

The Lesser Grain Borer

71% RH. The survival rates of hatched larvae in whole bulgur and wheat were 89.6 and 90.2%; in cracked bulgur and wheat, 87.9 and 90.3%; in >8-mesh bulgur and wheat, 87.4 and 89.8%; in <8- >10, 81.7 and 92.4%; in <10- >12, 69.9 and 80.4%; and in <12, 31.0 and 39.0% (Plate VI, Appendix Table 9).

$$\text{Survival rate} = \frac{\text{number of hatched larvae}}{\text{number of emerged adults}}$$

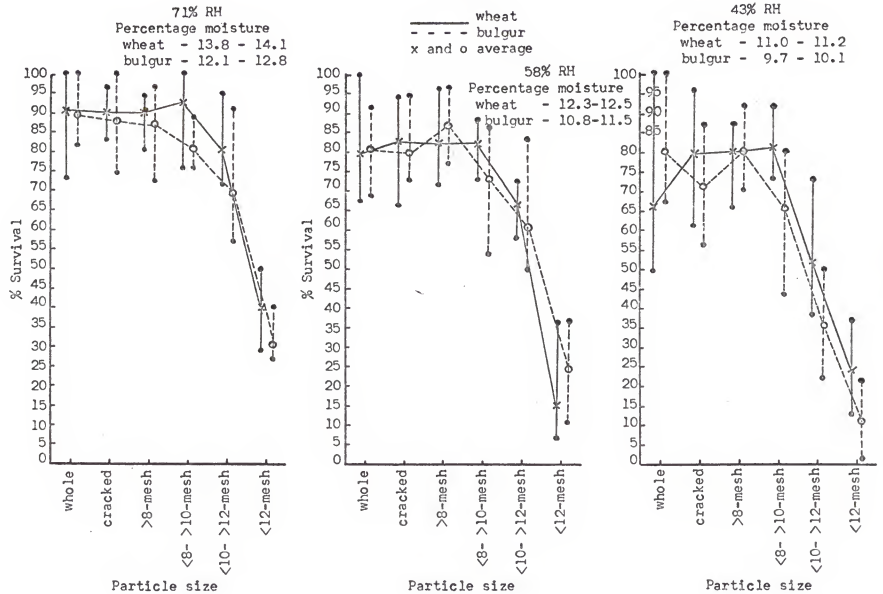
The survival rates decreased as the particle size decreased but remained high in all media except in both <12-mesh media.

The first adults appeared in whole bulgur and wheat 41.5 (±0.5) days and 37.5 (±0.5) days after the eggs were laid, in cracked bulgur and wheat, 43.5 and 37.5; in >8-mesh bulgur and wheat, 41.5 and 37.5; in <8- >10, 43.5

EXPLANATION OF PLATE VI

Range and average survival (% of hatched larvae) of lesser grain borers in bulgur and wheat of different particle sizes at 71%, 58%, and 43% RH (30 eggs were introduced into each of the replicates of each particle size).

PLATE VI


71% RH
Percentage moisture
wheat - 13.8 - 14.1
bulgur - 12.1 - 12.8
wheat
bulgur
x and o average
58% RH
Percentage moisture
wheat - 12.3-12.5
bulgur - 10.8-11.5
43% RH
Percentage moisture
wheat - 11.0 - 11.2
bulgur - 9.7 - 10.1
% Survival
whole
cracked
>8-mesh
<8- >10-mesh
<10- >12-mesh
<12-mesh
Particle size

and 37.5; in <10- >12, 41.5 and 37.5; and in <12, 43.5 and 39.5. There was a difference of 4 days between whole, >8 and <10- >12 and 6 days between cracked, <8- >10, and <12-mesh bulgur and its wheat equivalent. Developmental periods were distinctly longer in the bulgur than in wheat (Plate VII). The average in whole bulgur and wheat was 47.0 and 43.6 (±0.5) days; in cracked bulgur and wheat, 50.4 and 42.6; in >8-mesh bulgur and wheat, 50.2 and 43.6; in <8- >10, 50.8 and 42.6; in <10 - >12, 52.1 and 42.6; and in <12, 54.6 and 44.0. Average developmental period differences were from 3.4 days longer in whole bulgur to 7.8 days longer in cracked bulgur and 10.6 days longer in <12-mesh bulgur than in wheat of the same particle size. As the particle size decreased the developmental period increased greatly in bulgur but only slightly in wheat.

Average weights of the females in whole bulgur and wheat were slightly more than males but all averaged about 1.20 mg. In the <8- >10-mesh media, the males and females from the wheat were a little larger and weighed a little more than those from the bulgur. All adults from the wheat averaged about 1.2 mg and from the bulgur, 1.0 mg. All adults in both bulgur and wheat in the <12-mesh media averaged about 0.85 mg (Table 5).

58% RH. Survival rates were 80.8 and 79.6% in whole bulgur and wheat; 80.1 and 83.3% in cracked bulgur and wheat; 87.1 and 82.4% in >8-mesh; 73.6 and 81.6% in <8- >10; 60.9 and 65.6% in <10- >12; and 24.3 and 14.9% in <12. Those figures show a slightly lower survival rate in bulgur than in wheat in all media except whole and <12-mesh bulgur (Plate VI, Appendix Table 10). The first adults were found in whole bulgur and wheat 45.5 (±0.5) and 41.5 (±0.5) days after the eggs were

EXPLANATION OF PLATE VII

Range and average developmental periods (from oviposition) in days ±0.5 of lesser grain borers in bulgur and wheat of different particle sizes at 71%, 58%, and 43% RH (30 eggs were introduced into each of the 6 replicates of each particle size).

PLATE VII

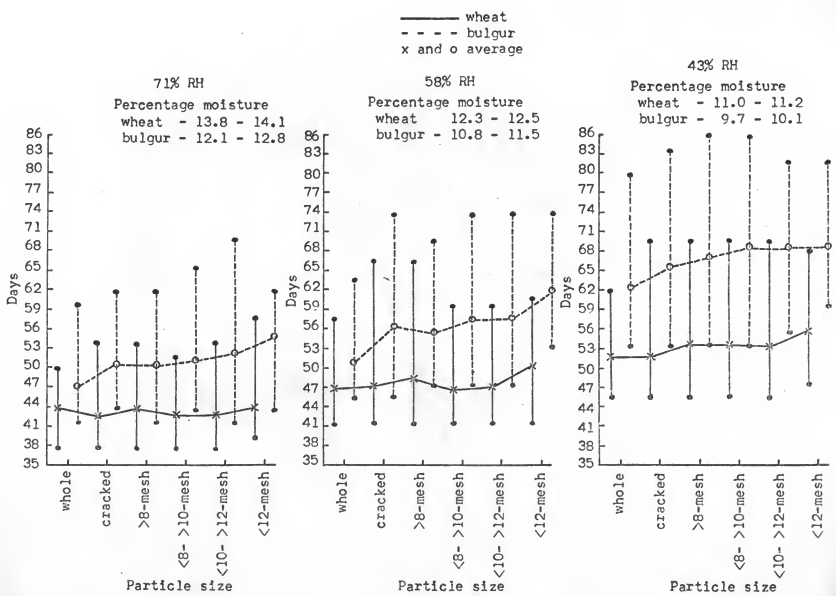

wheat
bulgur
x and o average
71% RH
Percentage moisture
wheat - 13.8 - 14.1
bulgur - 12.1 - 12.8
58% RH
Percentage moisture
wheat 12.3 - 12.5
bulgur - 10.8 - 11.5
43% RH
Percentage moisture
wheat - 11.0 - 11.2
bulgur - 9.7 - 10.1
Days
86 83 80 77 74 71 68 65 62 59 56 53 50 47 44 41 38 35
whole
cracked
>8-mesh
<8- >10-mesh
<10- >12-mesh
<12-mesh
Particle size

Table 5. Range and average weights (mg) of the first 10 male and 10 female lesser grain borers to become adults in bulgur and wheat media at 71%, 58%, and 43% RH.

Medium	Males		Females	
	Range	Avg.	Range	Avg.
71% RH				
Whole bulgur	1.05 - 1.45	1.18	1.05 - 1.45	1.23
Whole wheat	1.00 - 1.40	1.15	1.00 - 1.40	1.20
<8- >10-mesh bulgur	0.90 - 1.15	0.99	0.90 - 1.10	0.96
<8- >10-mesh wheat	1.00 - 1.40	1.15	1.00 - 1.40	1.20
<12-mesh bulgur	0.70 - 0.95	0.82	0.70 - 1.05	0.86
<12-mesh wheat	0.70 - 0.90	0.84	0.80 - 0.90	0.85
58% RH				
Whole bulgur	0.95 - 1.20	1.15	1.05 - 1.25	1.14
Whole wheat	1.20 - 1.40	1.33	1.10 - 1.45	1.27
<8- >10-mesh bulgur	0.75 - 1.00	0.91	0.80 - 0.95	0.89
<8- >10-mesh wheat	0.90 - 1.05	0.98	0.85 - 1.10	0.99
<12-mesh bulgur	0.70 - 0.90	0.77	0.60 - 0.90	0.78
<12-mesh wheat	0.75 - 0.95	0.86	0.70 - 0.95	0.80
43% RH				
Whole bulgur	0.95 - 1.15	1.04	1.00 - 1.25	1.07
Whole wheat	0.90 - 1.40	1.22	1.00 - 1.25	1.13
<8- >10-mesh bulgur	0.70 - 0.90	0.82	0.75 - 0.85	0.83
<8- >10-mesh wheat	0.80 - 1.00	0.86	0.85 - 1.00	0.92
<12-mesh bulgur	0.60 - 0.75	0.68	0.60 - 0.80	0.67
<12-mesh wheat	0.55 - 0.80	0.72	0.85 - 1.00	0.92

laid; in cracked bulgur and wheat, 45.5 and 41.5 days; in >8-mesh bulgur and wheat, 47.5 and 41.5; in <12, 53.5 and 41.5. The first adults were found in the wheat media at least 4 days before any were found in the whole and cracked bulgur and 6 days before any in the remaining bulgur media.

The average developmental periods increased in every media of both bulgur and wheat at 58% RH over 71% RH. Average developmental periods in whole bulgur and wheat were 50.8 (±0.5) and 46.8 (±0.5) days; in cracked bulgur and wheat, 56.3 and 47.1 days; in >8-mesh bulgur and wheat; 55.6 and 48.4; in <8- >10, 57.9 and 46.2; in <10 - >12, 57.6 and 46.9; and in <12, 61.6 and 50.5 (Plate VII). The average difference in the developmental period ranged from 4 days longer in whole bulgur to 11.1 and 11.7 days longer in <8 - >10 and <12-mesh bulgur than in the corresponding wheat media.

The weights of the adults from the bulgur media were slightly less than those from the wheat media but average weights of all adults from whole bulgur and wheat were about 1.15 and 1.30 mg; from <8 - >10-mesh, 0.90 and 1.00 mg; and from <12, 0.80 and 0.80 - 0.85 mg (Table 5).

43% RH. The survival rates in whole bulgur and wheat were 80.3 and 67.0%; in cracked bulgur and wheat, 71.9 and 19.7%; in >8-mesh bulgur and wheat, 80.7 and 80.2; in <8- >10, 65.6 and 81.6; in <10 - >12, 35.5 and 51.8; and in <12-mesh, 11.0 and 23.6. The percentage survival in the bulgur decreased as particle sizes decreased (Plate VI, Appendix Table 10). The first insects completed development in all the wheat media, except <12-mesh, at 45.5 (±0.5) days after oviposition (Plate VII); the first in the bulgur media at 53.5 (±0.5) days, or 8 days later than

in wheat, in all media except <10 - >12 and <12-mesh bulgur. The <12-mesh wheat yielded adults at 47.5 (±0.5) days, and the <10- >12 and <12-mesh bulgur at 55.5 and 59.5 (±0.5) days after egg laying.

The average developmental periods in whole bulgur and wheat were 62.5 days and 51.7 (±0.5) days after egg laying.

The average developmental periods in whole bulgur and wheat were 62.5 days and 51.7 (±0.5) days; in cracked bulgur and wheat, 65.2 and 51.8; in >8-mesh bulgur and wheat, 67.1 and 53.8; in <8 - >10, 68.7 and 53.3; for <10 - >12, 68.5 and 53.1; and in <12, 68.6 and 55.7.

The insects that developed in whole, <8 - >10 and <12-mesh wheat were all heavier than those reared in the comparable bulgur medium. All adults in whole bulgur and wheat averaged about 1.1 mg and 1.2 mg; in <8 - >10, 0.8 and 0.9 mg; and in <12, 0.7 and 0.7 - 0.9 mg (Table 5).

SUMMARY

The primary objectives of the study were to determine whether or not internally-feeding stored-product insects could develop in bulgur and if so, what effects the diet would have on their biology. Under "optimum" conditions of 70% RH and 27.7°C four species were tested and all were well adapted for survival. They either produced progeny or hatched larvae survived in bulgur. The larger rice weevil and the lesser grain borer were further tested in 6 bulgur and 6 wheat media at relative humidities of 71%, 58%, and 43% at 27.7°C.

Moisture content tests conducted on samples placed in constant humidity chambers revealed that bulgur would reach moisture equilibrium at 1.0 - 1.5% less than in wheat in the same relative humidity. The

larger particle samples tended to attain a slightly higher moisture content than the smaller particle samples, especially in the bulgur media.

The numbers of larger rice weevil progeny collected from the media generally decreased as the particle size decreased at a given relative humidity. They also decreased appreciably as the relative humidity decreased except in cracked bulgur and wheat in 58% RH. The percentage survival of hatched lesser grain borer larvae also decreased as the particle size decreased and as the relative humidity decreased.

The developmental periods of both the larger rice weevil and the lesser grain borer increased as the particle size decreased and as the relative humidity decreased except in the smaller particle size media and lower relative humidities where only a few progeny were collected or few larvae survived.

The weights of the males and females were very similar in all media of the same particle size checked. The weights of the larger rice weevils and lesser grain borers decreased as the particle size decreased but not necessarily as the relative humidity decreased.

Average developmental periods of the larger rice weevil and lesser grain borer were longer in bulgur media than in comparable wheat media at 71%, 58%, and 43% RH. There were exceptions but only when too few adults emerged for results to be valid.

The total numbers of progeny produced by the larger rice weevil were similar in comparable media at 71% RH but as the relative humidity decreased the differences became greater. This was also true of the

survival of lesser grain borer newly-hatched larvae. More adults were generally collected from the wheat media and at 43% RH the numbers were appreciably more than from the bulgur media. At 58% RH the differences were not as great but were greater than at 71% RH.

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APPENDIX

Table 6. Progeny and developmental period of the larger rice weevil in bulgur and wheat of various particle sizes at 71% RH (6 males and 10 females were left in each replicate for 7 days).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days		Day of peak emergence
			Range	Avg.	
Whole wheat 14.1	1	173	27 - 51	33.2	33
	2	155	27 - 49	32.9	31
	3	170	27 - 47	33.1	31
	4	173	27 - 47	32.8	33
	5	161	27 - 47	31.9	31
	6	169	27 - 47	33.5	33
	Avg.	166.8		32.9	
Whole bulgur 12.8	1	171	29 - 47	36.0	37
	2	178	31 - 47	36.0	35
	3	153	29 - 49	35.8	37
	4	168	29 - 51	36.2	35
	5	158	29 - 45	34.6	33
	6	163	29 - 49	35.4	35
	Avg.	165.2		35.7	
Cracked wheat 13.9	1	40	27 - 45	33.5	--*
	2	39	29 - 45	34.9	33
	3	47	27 - 53	33.3	27
	4	59	27 - 49	33.2	33
	5	77	27 - 45	31.8	27
	6	64	27 - 51	33.1	31
	Avg.	54.3		33.1	
Cracked bulgur 12.7	1	47	31 - 45	37.9	--
	2	45	31 - 51	37.5	39
	3	60	29 - 51	38.2	37
	4	60	29 - 47	36.6	35
	5	65	29 - 49	35.9	33
	6	53	29 - 47	37.2	37
	Avg.	55.0		37.2	

Table 6 (cont'd).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days		Day of peak emergence
			Range	Avg.	
>8-mesh wheat 13.9	1	125	27 - 49	33.0	31
	2	129	27 - 53	34.4	31
	3	118	27 - 47	33.1	31
	4	125	27 - 49	32.2	31
	5	153	27 - 47	31.9	29
	6	116	27 - 51	30.6	33
	Avg.	127.7		33.0	
>8-mesh bulgur 12.6	1	125	29 - 49	37.1	37
	2	116	31 - 51	37.9	37
	3	102	29 - 51	36.5	37
	4	106	29 - 45	37.1	35
	5	107	29 - 45	36.1	37
	6	102	29 - 49	36.7	37
	Avg.	109.6		36.9	
<8- >10-mesh wheat 13.9	1	42	27 - 49	33.1	31
	2	41	27 - 53	33.2	33
	3	43	27 - 49	35.8	31
	4	46	27 - 51	34.0	35
	5	67	27 - 49	32.0	31
	6	55	27 - 53	33.9	33
	Avg.	49.0		33.3	
<8- >10-mesh bulgur 12.4	1	37	31 - 45	37.2	39
	2	37	31 - 45	36.9	39
	3	50	29 - 49	36.2	37
	4	39	31 - 45	36.4	33
	5	63	31 - 51	37.4	37
	6	24	31 - 41	35.3	37
	Avg.	41.7		37.1	

Table 6 (concluded).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days		Day of peak emergence
			Range	Avg.	
	1	5	27 - 39	33.2	--
	2	6	29 - 41	36.7	39
<10- >12-mesh	3	11	29 - 45	34.6	35
wheat	4	11	27 - 47	35.0	--
13.9	5	13	27 - 45	33.6	--
	6	9	27 - 37	33.0	35
	Avg.	9.2		34.4	
	1	2	37 - 39	38.0	--
	2	1	---	35.0	35
<10- >12-mesh	3	2	---	49.0	49
bulgur	4	1	---	39.0	39
12.2	5	5	33 - 35	34.2	35
	6	2	---	37.0	37
	Avg.	2.2		37.9	
	1	1	---	35.0	35
	2	1	---	39.0	39
<12-mesh	3	1	---	37.0	37
wheat	4	1	---	39.0	39
13.8	5	1	---	31.0	31
	6	1	---	39.0	39
	Avg.	1.0		36.7	
	1	0	---	---	--
	2	0	---	---	--
<12-mesh	3	0	---	---	--
bulgur	4	0	---	---	--
12.1	5	0	---	---	--
	6	0	---	---	--
	Avg.	0.0		---	

* There was no day of peak emergence.

Table 7. Progeny and developmental period of the larger rice weevil in bulgur and wheat of various particle sizes at 58% RH (6 males and 10 females were left in each replicate for 7 days).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days		Day of peak emergence
			Range	Avg.	
Whole wheat 12.5	1	135	29 - 51	37.0	35
	2	141	31 - 53	37.0	35
	3	135	33 - 55	36.0	37
	4	124	29 - 47	36.6	37
	5	129	29 - 51	36.2	35
	6	103	29 - 53	37.1	35
	Avg.	127.8		37.0	
Whole bulgur 11.5	1	90	35 - 47	40.6	41
	2	80	33 - 51	40.5	39
	3	70	35 - 53	41.8	41
	4	91	35 - 51	40.2	39
	5	87	35 - 49	41.0	41
	6	67	33 - 47	39.4	39
	Avg.	80.7		40.6	
Cracked wheat 12.4	1	87	29 - 51	35.8	35
	2	82	29 - 51	36.6	37
	3	52	29 - 53	38.1	35
	4	97	29 - 55	36.6	37
	5	0	Adults escaped from this rep.		
	6	96	29 - 49	36.1	35
	Avg.	82.8		36.6	
Cracked bulgur 11.1	1	72	33 - 53	40.4	39
	2	61	35 - 55	43.8	43
	3	59	35 - 51	42.0	41
	4	70	33 - 53	41.1	39
	5	66	35 - 53	41.5	41
	6	49	35 - 51	41.5	39
	Avg.	62.8		41.6	

Table 7 (cont'd).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days Range	Avg.	Day of peak emergence
	1	177	27 - 51	36.4	35
	2	122	27 - 53	36.3	35
>8-mesh	3	96	29 - 55	37.1	33
wheat	4	135	29 - 53	35.9	33
12.5	5	116	29 - 55	36.0	35
	6	111	29 - 55	36.9	35
	Avg.	126.2		36.4	
	1	97	33 - 51	40.3	39
	2	68	35 - 51	42.1	41
>8-mesh	3	84	35 - 53	42.2	41
bulgur	4	87	35 - 55	42.4	43
11.0	5	69	33 - 55	41.3	41
	6	86	35 - 49	40.2	41
	Avg.	81.8		41.4	
	1	89	29 - 47	35.6	35
	2	66	29 - 51	35.9	35
<8- >10 mesh	3	42	29 - 51	37.1	35
wheat	4	63	29 - 47	35.6	33
12.3	5	78	27 - 53	35.2	35
	6	79	29 - 51	34.8	37
	Avg.	69.5		35.6	
	1	59	35 - 53	40.6	37
	2	46	33 - 47	42.4	41
<8- >10-mesh	3	33	37 - 55	42.6	39
bulgur	4	47	29 - 51	39.2	37
10.9	5	48	37 - 53	41.7	41
	6	55	33 - 51	41.1	39
	Avg.	48.0		41.1	

Table 7 (concluded).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days		Day of peak emergence
			Range	Avg.	
<10- >12-mesh wheat 12.4	1	15	29 - 39	35.5	35
	2	14	31 - 39	34.4	31
	3	8	33 - 47	40.0	--*
	4	14	31 - 45	35.9	31
	5	8	31 - 41	35.0	33
	6	17	33 - 47	37.8	35
	Avg.	12.7		36.4	
<10- >12-mesh bulgur 10.9	1	8	35 - 53	43.5	39
	2	2	43 - 45	44.0	--
	3	2	---	49.0	49
	4	5	35 - 45	41.4	43
	5	4	39 - 41	40.0	--
	6	7	39 - 41	39.8	39
	Avg.	4.7		42.1	
<12-mesh wheat 12.3	1	1	---	35.0	--
	2	0	---	--	--
	3	0	---	--	--
	4	0	---	--	--
	5	0	---	--	--
	6	0	---	--	--
	Avg.	0		35.0	
<12-mesh bulgur 10.8	1	0	---	44.0	--
	2	0	---	--	--
	3	0	---	--	--
	4	1	---	--	--
	5	0	---	--	--
	6	0	---	--	--
	Avg.	0		44.0	

* There was no day of peak emergence.

Table 8. Progeny and developmental period of the larger rice weevil in bulgur and wheat of various particle sizes at 43% RH (6 males and 10 females were left in each replicate for 7 days).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days		Day of peak emergence
			Range	Avg.	
Whole wheat 11.1	1	55	39 - 65	50.5	51
	2	48	41 - 67	50.1	49
	3	28	36 - 65	52.0	49
	4	43	43 - 67	52.5	47
	5	45	39 - 65	49.4	47
	6	26	43 - 63	51.5	49
	Avg.	40.8		50.9	
Whole bulgur 10.1	1	0	---	--	--
	2	0	---	--	--
	3	0	---	--	--
	4	0	---	--	--
	5	0	---	--	--
	6	0	---	--	--
	Avg.	0.0		--	
Cracked wheat 11.2	1	40	39 - 67	50.9	47
	2	28	43 - 61	50.0	49
	3	43	41 - 65	49.9	49
	4	45	41 - 67	50.4	47
	5	39	39 - 67	50.4	47
	6	49	39 - 63	49.9	45
	Avg.	40.7		50.2	
Cracked bulgur 9.8	1	2	47 - 63	55.0	--*
	2	0	---	--	--
	3	0	---	--	--
	4	0	---	--	--
	5	0	---	--	--
	6	3	53 - 65	60.3	--
	Avg.	0.8		58.2	

Table 8 (cont'd).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days Range	Avg.	Day of peak emergence
	1	77	41 - 67	50.7	47
	2	60	41 - 67	50.4	47
>8-mesh	3	82	41 - 67	49.5	49
wheat	4	64	39 - 67	49.8	47
11.1	5	83	39 - 67	49.8	45
	6	76	39 - 67	50.4	47
	Avg.	74.7		50.1	
	1	3	57 - 65	59.7	57
	2	4	53 - 65	57.5	--*
>8-mesh	3	3	57 - 63	60.3	--
bulgur	4	0	---	--	--
10.0	5	4	55 - 65	59.5	--
	6	1	---	51.0	51
	Avg.	2.5		58.6	
	1	43	39 - 63	47.2	47
	2	31	41 - 65	49.8	45
<8- >10-mesh	3	51	39 - 65	48.8	47
wheat	4	47	41 - 67	50.5	47
11.0	5	34	39 - 67	50.1	--
	6	52	39 - 63	48.5	47
	Avg.	43.0		49.1	
	1	0	---	--	--
	2	0	---	--	--
<8- >10-mesh	3	0	---	--	--
bulgur	4	0	---	--	--
9.9	5	0	---	--	--
	6	0	---	--	--
	Avg.	0.0		--	

Table 8 (concluded).

Medium and percentage moisture	Rep.	No. progeny	Developmental period days from oviposition ± 4 days		Day of peak emergence
			Range	Avg.	
	1	5	45 - 53	47.8	45
	2	9	45 - 59	49.4	49
<10- >12-mesh	3	4	45 - 55	49.0	45
wheat	4	3	41 - 53	46.3	--*
11.1	5	9	41 - 61	47.0	43
	6	10	43 - 63	49.4	47
	Avg.	6.7		48.4	
	1	0	---	--	--
	2	0	---	--	--
<10- >12-mesh	3	0	---	--	--
bulgur	4	0	---	--	--
9.7	5	0	---	--	--
	6	0	---	--	--
	Avg.	0.0		--	
	1	0	---	--	--
	2	0	---	--	--
<12-mesh	3	0	---	--	--
wheat	4	0	---	--	--
11.0	5	0	---	--	--
	6	0	---	--	--
	Avg.	0.0		--	
	1	0	---	--	--
	2	0	---	--	--
<12-mesh	3	0	---	--	--
bulgur	4	0	---	--	--
9.8	5	0	---	--	--
	6	0	---	--	--
	Avg.	0.0		--	

* There was no day of peak emergence.

Table 9. Survival and developmental periods of lesser grain borers reared in bulgur and wheat of various particle sizes at 71% RH (30 eggs were placed in each replicate).

Medium and percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day		Day of peak emergence 0.5 day +1
					Range	Avg.	
Whole wheat 14.1	1	21	18	85.7	39.5 - 51.5	43.6	41.5
	2	24	23	95.8	39.5 - 49.5	44.2	43.5
	3	23	17	73.9	39.5 - 47.5	41.7	41.5
	4	15	15	100.0	39.5 - 45.5	42.4	41.5
	5	19	18	94.7	37.5 - 51.5	42.7	43.5
	6	30	28	93.3	39.5 - 49.5	42.4	41.5
	Avg.	22.0	19.8	90.2		43.6	
Whole bulgur 12.8	1	23	19	82.6	43.5 - 55.5	38.1	49.5
	2	13	12	92.3	41.5 - 49.5	46.8	47.5
	3	20	20	100.0	41.5 - 59.5	47.1	49.5
	4	24	22	91.6	41.5 - 57.5	46.1	45.5
	5	23	21	91.3	41.5 - 55.5	46.9	----*
	6	22	18	81.8	41.5 - 53.5	47.3	----
	Avg.	20.8	18.6	89.6		47.0	
Cracked wheat 13.9	1	21	18	85.7	39.5 - 51.5	42.9	41.5
	2	16	14	87.5	37.5 - 45.5	42.6	----
	3	24	20	83.3	39.5 - 49.5	42.3	39.5
	4	17	16	94.1	39.5 - 43.5	43.6	----
	5	23	22	95.6	37.5 - 45.5	42.2	43.5
	6	23	22	95.6	37.5 - 49.5	42.8	41.5
	Avg.	20.7	18.7	90.3		42.6	
Cracked bulgur 12.7	1	28	24	85.7	43.5 - 57.5	49.4	49.5
	2	22	21	95.4	43.5 - 59.5	49.6	----
	3	15	14	93.3	43.5 - 59.5	51.2	49.5
	4	17	14	82.3	45.5 - 61.5	53.2	51.5
	5	14	14	100.0	43.5 - 53.5	48.6	47,5
	6	20	15	75.0	45.5 - 57.5	52.6	51.5
	Avg.	19.3	17.0	87.9		50.4	

Table 9 (cont'd).

Medium and percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day		Day of peak emergence ± 0.5 day
					Range	Avg.	
	1	18	17	94.4	39.5 - 49.5	43.3	43.5
	2	22	20	90.9	39.5 - 53.5	43.9	41.5
>8-mesh	3	21	17	80.9	37.5 - 51.5	43.7	43.5
wheat	4	20	18	90.0	39.5 - 47.5	42.6	39.5
13.9	5	24	22	91.6	39.5 - 49.5	44.3	43.5
	6	22	20	90.9	39.5 - 49.5	43.7	41.5
	Avg.	21.2	19.0	89.8		43.6	
	1	23	17	73.9	45.5 - 57.5	49.5	47.5
	2	17	15	88.2	45.5 - 51.5	48.0	47.5
>8-mesh	3	16	14	87.5	41.5 - 61.5	49.6	49.5
bulgur	4	23	21	91.3	45.5 - 61.5	49.6	47.5
12.6	5	22	21	95.4	45.5 - 57.5	51.0	----
	6	26	23	88.4	45.5 - 59.5	52.4	45.5
	Avg.	21.1	18.5	87.4		50.2	
	1	21	20	95.2	37.5 - 51.5	42.7	43.5
	2	16	15	93.7	39.5 - 47.5	43.1	41.5
<8- >10-mesh	3	17	13	76.4	39.5 - 45.5	42.0	41.5
wheat	4	19	19	100.0	39.5 - 47.5	42.2	41.5
13.9	5	21	19	90.4	39.5 - 45.5	42.7	41.5
	6	25	24	96.0	39.5 - 49.5	43.1	43.5
	Avg.	19.8	18.3	92.4		42.6	
	1	19	15	78.9	43.5 - 51.5	47.1	45.5
	2	21	16	76.1	43.5 - 65.5	50.9	51.5
<8- >10-mesh	3	13	11	84.6	45.5 - 55.5	50.4	49.5
bulgur	4	14	12	85.7	45.5 - 61.5	53.3	53.5
12.4	5	17	15	88.2	45.5 - 59.5	50.4	47.5
	6	25	20	80.0	45.5 - 65.5	52.7	----
	Avg.	18.2	14.8	81.7		50.8	

Table 9 (concluded).

Medium percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day		Day of peak emergence ± 0.5 day
					Range	Avg.	
	1	29	22	75.8	39.5 - 47.5	42.1	43.5
	2	22	19	86.3	39.5 - 51.5	42.4	41.5
<10- >12-mesh	3	25	18	72.0	37.5 - 53.5	42.4	41.5
wheat	4	24	19	79.1	39.5 - 47.5	43.4	43.5
13.9	5	18	14	77.7	39.5 - 49.5	43.2	41.5
	6	20	19	95.0	39.5 - 49.5	42.3	41.5
	Avg.	23.0	18.5	80.4		42.6	
	1	27	19	70.3	43.5 - 63.5	53.3	49.5
	2	25	18	72.0	47.5 - 59.5	51.4	49.5
<10- >12 mesh	3	19	11	57.8	43.5 - 69.5	50.6	49.5
bulgur	4	11	10	90.9	43.5 - 59.5	49.5	49.5
12.2	5	24	14	58.3	45.5 - 63.5	51.5	49.5
	6	30	23	76.6	41.5 - 69.5	53.8	49.5
	Avg.	22.7	15.8	69.9		52.1	
	1	18	9	50.0	39.5 - 49.5	44.2	41.5
	2	17	5	29.4	39.5 - 43.5	42.3	43.5
<12-mesh	3	24	10	41.6	41.5 - 47.5	43.9	43.5
wheat	4	17	5	29.4	39.5 - 49.5	44.3	43.5
13.8	5	21	9	42.8	39.5 - 49.5	43.1	41.5
	6	21	8	38.0	39.5 - 57.5	46.0	41.5
	Avg.	19.7	7.7	39.0		44.0	
	1	25	7	28.0	43.5 - 59.5	52.9	----
	2	12	4	33.3	51.5 - 61.5	55.0	53.5
<12-mesh	3	30	9	30.0	49.5 - 63.5	55.9	53.5
bulgur	4	18	5	27.7	49.5 - 53.5	51.5	----
12.1	5	25	8	32.0	45.5 - 61.5	55.8	61.5
	6	15	6	40.0	49.5 - 61.5	55.2	49.5
	Avg.	21	6.5	31.0		54.6	

* There was no day of peak emergence.

Table 10. Survival and developmental periods of lesser grain borers reared in bulgur and wheat of various particle sizes at 58% RH (30 eggs were placed in each replicate).

Medium percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day		Day of peak emergence ±0.5 day
					Range	Avg.	
Whole wheat 12.5	1	18	14	77.7	43.5 - 53.5	47.6	45.5
	2	24	17	70.8	43.5 - 53.5	46.3	----*
	3	26	19	73.0	41.5 - 53.5	47.5	45.5
	4	28	19	67.8	43.5 - 51.5	46.3	45.5
	5	25	25	100.0	41.5 - 57.5	45.7	----
	6	26	23	88.4	43.5 - 57.5	47.6	45.5
	Avg.	24.5	19.5	79.6		46.8	
Whole bulgur 11.5	1	22	20	90.9	47.5 - 55.5	50.8	51.5
	2	22	15	68.1	45.5 - 63.5	52.6	51.5
	3	26	23	88.4	47.5 - 57.5	50.8	----
	4	26	20	76.9	47.5 - 57.5	50.7	49.5
	5	26	23	88.4	45.5 - 61.5	49.9	47.5
	6	30	25	83.3	35.5 - 61.5	53.1	51.5
	Avg.	25.3	21.0	80.8		50.8	
Cracked wheat 12.4	1	17	16	94.1	41.5 - 51.5	46.8	47.5
	2	22	18	81.8	41.5 - 67.5	48.2	49.5
	3	26	23	86.7	41.5 - 67.5	46.7	43.5
	4	30	26	87.5	41.5 - 53.5	46.6	45.5
	5	26	22	84.6	41.5 - 61.5	48.9	45.5
	6	27	18	66.6	41.5 - 53.5	45.6	45.5
	Avg.	25.0	20.8	23.3		47.1	
Cracked bulgur 11.1	1	23	17	73.9	49.5 - 69.5	56.0	51.5
	2	18	17	94.4	45.5 - 73.5	56.1	53.5
	3	27	20	74.0	49.5 - 67.5	56.5	51.5
	4	30	27	90.0	47.5 - 73.5	57.4	53.5
	5	27	20	74.0	47.5 - 63.5	55.7	55.5
	6	26	20	76.9	47.5 - 69.5	55.6	53.5
	Avg.	21.8	20.2	80.1		56.3	

Table 10 (cont'd).

Medium percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day		Day of peak emergence ± 0.5 day
					Range	Avg.	
	1	23	17	73.9	45.5 - 51.5	48.2	----
	2	30	25	83.3	41.5 - 55.5	47.2	43.5
>8-mesh	3	28	27	96.4	41.5 - 57.5	47.8	47.5
wheat	4	27	24	88.8	43.5 - 67.5	48.7	45.5
12.5	5	22	17	77.2	47.5 - 67.5	51.4	47.5
	6	25	18	72.0	43.5 - 53.5	48.3	49.5
	Avg.	25.8	21.3	82.4		48.4	
	1	27	26	96.2	49.5 - 67.5	56.1	53.5
	2	20	19	95.0	47.5 - 63.5	55.5	51.5
>8-mesh	3	20	19	95.0	49.5 - 67.5	54.6	51.5
bulgur	4	22	17	77.2	49.5 - 69.5	55.4	53.5
11.0	5	28	22	78.5	47.5 - 65.5	54.6	53.5
	6	23	19	82.6	47.5 - 69.5	55.4	55.5
	Avg.	23.3	20.3	87.1		55.6	
	1	23	17	73.9	43.5 - 59.5	48.1	43.5
	2	24	19	79.1	41.5 - 55.5	46.1	45.5
<8- >10-mesh	3	20	17	85.0	41.5 - 51.5	47.0	45.5
wheat	4	26	22	84.6	41.5 - 49.5	45.0	45.5
12.3	5	28	22	78.5	41.5 - 51.5	45.6	43.5
	6	27	24	88.8	41.5 - 49.5	45.8	----
	Avg.	24.7	20.2	81.6		46.2	
	1	21	15	71.4	47.5 - 73.5	57.6	59.5
	2	26	18	69.2	47.5 - 71.5	54.	----
<8- >10-mesh	3	22	12	54.5	49.5 - 69.5	59.0	55.5
bulgur	4	11	8	72.7	51.5 - 69.5	59.3	----
10.9	5	25	21	84.0	49.5 - 63.5	56.9	55.5
	6	28	24	85.7	49.5 - 65.5	58.4	55.5
	Avg.	22.2	16.3	73.6		57.9	

Table 10 (concluded).

Medium percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day		Day of peak emergence ± 0.5 day
					Range	Avg.	
	1	20	14	70.0	42.5 - 53.3	46.4	47.5
	2	27	17	62.9	41.5 - 51.5	46.4	45.5
<10- >12-mesh	3	26	17	65.3	41.5 - 51.5	45.6	45.5
wheat	4	25	18	72.0	43.5 - 55.5	48.4	45.5
12.4	5	29	17	58.6	43.5 - 59.5	48.2	----
	6	27	18	66.6	41.5 - 43.5	46.2	45.5
	Avg.	25.7	16.8	65.6		46.9	
	1	20	13	65.0	51.5 - 67.5	57.7	53.5
	2	20	10	50.0	49.5 - 69.5	59.3	61.5
<10- >12-mesh	3	26	15	57.6	51.5 - 67.5	58.3	----
bulgur	4	24	13	54.1	49.5 - 65.5	56.2	----
10.9	5	24	13	54.1	49.5 - 65.5	58.1	61.5
	6	24	20	83.3	47.5 - 73.5	56.6	----
	Avg.	23.0	14.0	60.9		57.6	
	1	30	3	10.0	41.5 - 57.5	48.5	----
	2	20	3	15.0	43.5 - 67.5	54.2	----
<12-mesh	3	19	2	10.5	45.5 - 59.5	52.5	----
wheat	4	25	9	36.0	41.5 - 61.5	49.7	47.5
12.3	5	25	3	12.0	47.5 - 59.5	52.2	----
	6	29	2	6.8	41.5 - 51.5	46.5	----
	Avg.	24.7	3.7	14.9		50.5	
	1	19	2	10.5	53.5 - 55.5	54.5	----
	2	25	9	36.0	53.5 - 73.5	60.8	53.5
<12-mesh	3	19	4	21.0	53.5 - 73.5	64.0	----
bulgur	4	19	5	26.3	55.5 - 67.5	63.9	61.5
10.8	5	13	4	30.7	53.5 - 73.5	62.0	----
	6	28	6	21.4	53.5 - 73.5	61.5	57.5
	Avg.	20.5	5.5	24.3		61.6	

* There was no day of peak emergence.

Table 11. Survival and developmental periods of lesser grain borers reared in bulgur and wheat of various particle sizes at 43% RH (30 eggs were placed in each replicate).

Medium percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day		Day of peak emergence ± 0.5 day
					Range	Avg.	
Whole wheat 11.1	1	17	11	64.7	49.5 - 59.5	51.5	49.5
	2	14	9	64.2	47.5 - 59.5	51.7	49.5
	3	20	10	50.0	49.5 - 57.5	52.7	49.5
	4	8	8	100.0	47.5 - 51.5	49.5	----*
	5	29	19	65.5	47.5 - 59.5	51.9	49.5
	6	30	22	73.3	45.5 - 61.5	51.8	47.5
	Avg.	19.7	13.2	67.0		51.7	
Whole bulgur 10.1	1	16	16	100.0	55.5 - 73.5	63.5	61.5
	2	25	17	68.0	53.5 - 73.5	62.4	63.5
	3	26	18	69.2	55.5 - 79.5	64.2	----
	4	15	13	86.7	53.5 - 75.5	62.1	55.5
	5	23	19	82.6	53.5 - 71.5	60.1	61.5
	6	22	19	85.4	53.5 - 77.5	61.9	----
	Avg.	21.2	17.0	80.3		62.5	
Cracked wheat 11.2	1	22	18	81.8	45.5 - 59.5	52.1	49.5
	2	14	13	92.8	47.5 - 59.5	51.8	----
	3	30	23	76.6	47.5 - 61.5	51.8	49.5
	4	29	18	62.0	47.5 - 69.5	54.6	49.5
	5	23	22	95.6	45.5 - 57.5	50.8	53.5
	6	25	20	80.0	47.5 - 59.5	51.7	49.5
	Avg.	23.8	19.0	79.7		51.8	
Cracked bulgur 9.8	1	23	20	87.0	55.5 - 81.5	67.9	----
	2	18	12	66.7	57.5 - 73.5	64.0	57.5
	3	22	15	68.2	59.5 - 77.5	65.8	63.5
	4	20	17	85.0	53.5 - 69.5	61.7	59.5
	5	26	19	73.1	57.5 - 79.5	67.5	----
	6	30	17	56.7	57.5 - 83.5	66.3	----
	Avg.	23.2	16.7	71.9		65.2	

Table 11 (cont'd).

Medium percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day Range	Developmental period days from oviposition ± 0.5 day Avg.	Day of peak emergence ±1 0.5 day
	1	22	17	77.2	45.5 - 65.5	51.5	45.5
	2	24	21	87.5	45.5 - 59.5	51.5	53.5
>8-mesh	3	22	18	81.8	49.5 - 67.5	56.4	53.5
wheat	4	17	14	82.3	47.5 - 67.5	54.8	----
11.1	5	20	17	85.0	45.5 - 61.5	54.4	59.5
	6	21	14	66.0	49.5 - 69.5	58.4	53.5
	Avg.	21.0	16.8	80.2		55.3	
	1	20	14	70.0	55.5 - 81.5	71.2	----
	2	24	18	75.0	53.5 - 85.5	67.5	65.5
>8-mesh	3	19	15	78.9	59.5 - 75.5	65.8	----
bulgur	4	27	25	92.6	55.5 - 81.5	67.4	----
10.0	5	25	20	80.0	55.5 - 79.5	63.9	59.5
	6	30	25	83.3	57.5 - 81.5	67.7	----
	Avg.	24.2	19.5	80.7		67.1	
	1	21	16	76.1	45.5 - 57.5	52.6	53.5
	2	23	21	91.3	45.5 - 63.5	53.8	57.5
<8- >10-mesh	3	24	20	83.3	47.5 - 65.5	55.1	53.5
wheat	4	15	11	73.3	49.5 - 67.5	55.9	59.5
11.0	5	25	21	84.0	47.5 - 69.5	52.3	47.5
	6	23	18	78.2	45.5 - 59.5	51.3	45.5
	Avg.	21.8	17.8	81.6		53.5	
	1	23	15	65.2	59.5 - 85.5	70.2	----
	2	27	12	44.4	53.5 - 77.5	65.8	67.5
<8- >10-mesh	3	26	16	61.5	59.5 - 79.5	68.8	----
bulgur	4	23	18	78.3	53.5 - 83.5	68.5	----
9.9	5	30	20	66.7	57.5 - 83.5	70.0	69.5
	6	25	20	80.0	57.5 - 80.5	68.5	----
	Avg.	24.0	16.8	65.6		68.7	

Table 11 (concluded).

Medium percentage moisture	Rep.	No. eggs hatched	No. adults emerged	% Survival of hatched larvae	Developmental period days from oviposition ± 0.5 day		Day of peak emergence ±1 day
					Range	Avg.	
	1	15	8	53.3	47.5 - 69.5	53.5	----
	2	11	8	72.7	45.5 - 67.5	54.3	51.5
<10- >12-mesh	3	26	10	38.4	45.5 - 61.5	55.5	----
wheat	4	19	11	57.8	47.5 - 59.5	52.0	47.5
11.1	5	20	12	60.0	45.5 - 61.5	53.0	53.5
	6	19	8	42.1	49.5 - 69.5	55.0	53.5
	Avg.	18.3	9.5	51.8		53.1	
	1	12	6	50.0	65.5 - 73.5	68.8	----
	2	24	8	33.3	55.5 - 77.5	66.5	----
<10- >12-mesh	3	22	5	22.7	65.5 - 77.5	71.1	----
bulgur	4	20	8	40.0	65.5 - 75.5	70.5	----
9.7	5	23	9	39.1	57.5 - 81.5	67.7	67.5
	6	23	8	34.8	61.5 - 79.5	69.3	----
	Avg.	20.7	7.3	35.5		68.5	
	1	28	6	21.4	47.5 - 67.5	57.2	----
	2	22	8	36.3	51.5 - 67.5	55.8	51.5
<12-mesh	3	15	4	26.6	51.5 - 59.5	55.0	51.5
wheat	4	13	2	15.3	47.5 - 51.5	49.5	----
11.0	5	22	3	13.6	49.5 - 59.5	56.2	59.5
	6	23	6	26.0	47.5 - 61.5	56.5	59.5
	Avg.	20.5	4.8	23.6		55.7	
	1	17	1	5.9	----------	73.5	----
	2	23	5	21.7	59.5 - 77.5	69.1	----
<12-mesh	3	27	0	0.0	----------	----	----
bulgur	4	22	3	13.6	61.5 - 63.5	62.5	61.5
9.8	5	22	2	9.1	69.5 - 81.5	75.5	----
	6	25	4	16.0	61.5 - 75.5	69.0	----
	Avg.	22.7	2.5	11.0		68.6	

* There was no day of peak emergence.

SUSCEPTIBILITY OF BULGUR TO INFESTATION OF FIVE INTERNALLY-FEEDING STORED-GRAIN INSECTS AT THREE RELATIVE HUMIDITIES

by

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AN ABSTRACT OF A MASTER'S THESIS

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Preliminary tests at 70% RH showed that the smaller rice weevil, Sitophilus oryzae (L.) and the granary weevil, Sitophilus granarius (L.) produced a subsequent generation in whole and cracked bulgur; and hatched larvae of the lesser grain borer, Rhyzopertha dominica (F.) and the Angoumois grain moth, Sitotroga cerealella (Olivier) developed into adults.

Tests were conducted at relative humidities of 71%, 58%, and 43% using the larger rice weevil, Sitophilus zeamais Motschulsky and R. dominica. Six male and 10 female adults were introduced into each of 6 replicates of 6 different bulgur and 6 different wheat media based on sizes of particles. The parent weevils were allowed to oviposit for 7 days at which time they were removed. Thirty lesser grain borer eggs were placed in each replicate of the bulgur and wheat media. After normal hatching time, the number of hatched eggs was determined for use in determining survival rates.

The larger rice weevils produced adult progeny and a high percentage of lesser grain borer larvae developed into adults in whole kernels of bulgur and wheat and in the larger particles of bulgur and wheat. The numbers of progeny produced and numbers of larvae surviving decreased as the particle size decreased in a specific relative humidity and as the relative humidity decreased for a specific particle size.

The developmental periods of the larger rice weevil progeny and the lesser grain borer larvae increased as the particle size decreased and as the relative humidity decreased, except in certain media which yielded only a few progeny or adults from the larvae. The resulting data were probably not conclusive from these certain media.

Males and females collected and weighed from both bulgur and wheat media of various particle sizes tended to weigh the same within a particle size but decreased in weight as the particle size decreased.