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# Growth and development of khapra beetle, *Trogoderma granarium* Everts (Col., Dermestidae) on pulses

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## Introduction

*Trogoderma granarium* Everts can develop on a variety of substances of animal and plant origin (Hinton, 1945; Noon, 1958), and its nutritional requirements have been the subject of many earlier investigations (Pant, 1957; Pant & Uberoi, 1958; Pant & Pant, 1962; Pant, Nayar & Gupta, 1958). Singh & Pant (1955) clearly established that, though *T. granarium* is primarily a pest of wheat, it can grow equally well on certain pulses, while on others it can barely exist. The present study has been conducted to determine by means of different culture media the probable causes of developmental incompatibility of some pulses for *T. granarium*.

## Materials and methods

A culture of *T. granarium* was maintained in glass jars containing sterilised whole wheat flour at 36°C and 70–75% r.h. The media tested included the basic artificial diet used by Pant, Nayar & Gupta, (1958) and nine pulses, namely *Phaseolus aureus* (green gram), *Cajanus cajan* (pigeon pea), *Lens esculenta* (lentil), *P. mungo* (black gram), *Cicer arietinum* (Bengal gram), *C. arietinum* (kabuli gram), *Vigna unguiculata* (cowpea), *Glycine max* (soybean) and *P. vulgaris* (French bean). All the grains were washed thoroughly under a constant flow of double-distilled water over a 30-mesh sieve, dried in the sun, disinfected by heating at 60°C for six hours (mainly to control Bruchids) and placed in separately labelled small muslin bags which were kept in desiccators at 70–75% r.h. The moisture content of the pulses was measured by the oven-dry method (Singh & Pant, 1955), and the pH by glass-electrode pH meter taking pulse and neutral water in 1:6 ratio. All commodities were offered to larvae as whole grains, ground flours and flours fortified with nutrients, the experimental diets being preconditioned for six days before use. Tests were carried out in $2 \times 1$-in. glass vials to which were added 25 recently hatched larvae and 2 g diet. The vials were closed with muslin tops held in position with a bored cork. The efficiency of a diet was assessed on the basis of (i) average duration of development (days) and (ii) percentage of adults emerged. Each treatment was replicated four times and the data were subjected to the analysis of variance (Snedecor, 1956). Data showing zero values were not considered for analysis.

## Results and discussion

### *Whole grains*

On whole wheat grains 52% of the larvae of *T. granarium* matured, but on whole grains of pulses larvae lived only for a few days (Table I). Differences in the moisture content of the pulses under test were unrelated to the developmental period of the larvae (Table II), in contrast to Chatterji's (1961) finding with *Corcyra cephalonica* (Stnt.) which was favoured by a higher moisture content. On whole grains of pulses, other species that have failed to develop include *Latheticus oryzae* Waterh. (Pant, Gupta &

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Nayar, 1958), *Stegobium paniceum* (L.) (Vilkhu, 1959), *Rhyzopertha dominica* (F.) (Kapoor, 1964) and *Tribolium castaneum* (Hbst.) (Pang & Dang, in press). Singh & Pant (1955) reported that a large proportion of *Trogoderma* larvae penetrated the seed coat of green gram and black gram. This result is not in agreement with the present findings in which larvae failed to penetrate through the seed coat of any pulses. This discrepancy may be explained in two ways. First, although Singh & Pant (1955) offered undamaged whole grains, they did not ensure that they were free from Bruchids which would provide a site for penetration. Secondly, in the earlier work the number of insects used was small, and resulted in higher standard errors.

*Flours*

The nutritive quality of pulse flours for larvae has been discussed mainly with respect to adult emergence and the developmental period (Table I).

TABLE I. *Growth and development of* T. granarium *on the commodities tested*

| Diet | No. of larvae becoming adult % | No. of larvae becoming adult angle* | Average developmental period (days) |
|---|---|---|---|
| Wheat grain | 52 | 46·3 | 40·2 |
| flour | 92 | 73·8 | 30·2 |
| flour (95 %) + brewer's yeast (5 %) | 93 | 75·1 | 30·3 |
| Green gram grain | 0 | — | — |
| flour | 91 | 74·9 | 29·7 |
| flour (95 %) + brewer's yeast (5 %) | 97 | 83·0 | 28·6 |
| Black gram grain | 0 | — | — |
| flour | 90 | 74·6 | 41·8 |
| flour (95 %) + brewer's yeast (5 %) | 98 | 84·2 | 39·9 |
| Pigeon pea grain | 0 | — | — |
| flour | 87 | 69·5 | 43·1 |
| flour (95 %) + brewer's yeast (5 %) | 86 | 68·6 | 45·7 |
| Bengal gram grain | 0 | — | — |
| flour | 87 | 69·7 | 31·9 |
| flour (95 %) + brewer's yeast (5 %) | 89 | 71·8 | 32·8 |
| Kabuli gram grain | 0 | — | — |
| flour | 90 | 71·8 | 32·8 |
| flour (95 %) + brewer's yeast (5 %) | 94 | 79·9 | 30·1 |
| Cowpea grain | 0 | — | — |
| flour | 87 | 69·3 | 33·6 |
| flour (95 %) + brewer's yeast (5 %) | 95 | 79·2 | 30·5 |
| Soybean grain | 0 | — | — |
| flour | 24 | 28·7 | 52·0 |
| flour (95 %) + brewer's yeast (5 %) | 59 | 50·7 | 47·0 |
| Lentil grain | 0 | — | — |
| flour | 5 | 12·8 | 58·5 |
| flour (95 %) + brewer's yeast (5 %) | 22 | 27·0 | 55·7 |
| French bean grain | 0 | — | — |
| flour | 0 | — | — |
| flour (95 %) + brewer's yeast (5 %) | 0 | — | — |
| Significant difference ($P$ = 0·05) | — | 11·8 | 2·4 |

*Angular transformation of percentages.

*Effect on adult emergence.*—The data on adult emergence clearly indicated that flours of the pulses tested fall into three categories. The first included flours of green gram, black gram, pigeon pea, Bengal gram, kabuli gram and cowpea. These were as nutritive as wheat flour, and addition of yeast (5%) did not show any improvement. The second category included flours of soybean and lentil. Addition of yeast (5%) to these significantly increased the adult population. According to Lipke *et al.* (1954) the growth of *Tribolium confusum* Duv. was poor on soybean flour but was improved on the addition of yeast (2%). For *Trogoderma granarium* and *Tribolium castaneum* a similar improvement in the dietary value was observed on the addition of brewer's yeast (5%)

to soybean and lentil (Singh & Pant, 1955; Pant & Dang, in press). The third category included French bean flour on which larvae failed to reach the adult stage.

*Effect on developmental period*.—Significant differences between the developmental periods on different diets indicated three categories of pulse flours (Table I). The first category included green gram and Bengal gram, on which the developmental period was the same as in wheat flour. The second category comprised black gram, pigeon pea, kabuli gram and cowpea in which larvae developed rather more slowly. Addition of yeast (5%) to these pulses shortened the developmental period in Kabuli gram and cowpea, but prolonged it in pigeon pea without, however, causing a higher larval mortality. The third category comprised soybean and lentil in which larvae developed more slowly, but the developmental period was shortened by supplementation with yeast (5%). Gray (1948) observed that the larval period of *T. confusum* was quickest in wheat flour and slower on soy products, cotton seed meal and patent flour. Soy products were also unfavourable for growth and development of *T. castaneum* and *T. confusum* (Lipke *et al.*, 1954), but supplementation with yeast greatly improved their food value (Lin & Richard, 1952; Sokoloff *et al.*, 1966). Pant & Dang (in press) also observed that addition of yeast (5%) to lentil, pigeon pea and soybean brought about significant improvement in the developmental period of *T. castaneum*. In the present studies *Trogoderma* larvae failed to develop on French bean flour, even when supplemented with yeast. Similarly, *Ephestia kuehniella* Zell., *Callosobruchus maculatus* (F.), *C. chinensis* (L.) and *R. dominica* also failed to grow and develop on French bean (Richardson, 1926; Srivastava & Bhatia, 1958; Kapoor, 1964; Singh, 1965). Clearly the flours of some commodities are more favourable than others to the larvae of *T. granarium*. The benefits from adding yeast suggest that the reason is a deficiency of one or more essential nutrients, and the anomalous result with yeast plus pigeon pea flour could be explained as due to nutrient imbalance. The hydrogen-ion concentration, being similar in all flours tested (Table II), cannot be a significant factor.

TABLE II. *Moisture content of the grain and hydrogen-ion concentration of the flours of the commodities tested*

| Commodities | Moisture content (%) | pH |
|---|---|---|
| Green gram | 14·2 | 6·5 |
| Lentil | 13·8 | 6·5 |
| Black gram | 9·4 | 6·3 |
| Pigeon pea | 13·6 | 6·3 |
| Bengal gram | 12·3 | 6·3 |
| Kabuli gram | 12·7 | 6·4 |
| Cowpea | 14·2 | 6·5 |
| Soybean | 10·3 | 6·4 |
| French bean | 13·0 | 6·4 |
| Wheat | 12·3 | 6·3 |
| Significant difference ($P = 0{\cdot}05$) | 0·54 | NS |

### *Artificial diets*

To investigate the nature of the deficiencies, experiments were conducted with a balanced artificial diet (Pant, Nayar & Gupta, 1958). Pulse powder in increasing amounts (0·25, 0·50, 1·00, 1·50 and 1·75 g) were compounded individually with decreasing amounts of artificial diets (1·75, 1·50, 1·00, 0·50 and 0·25 g).

*Trogoderma* larvae showed only little variation in developmental period and adult emergence on diets containing flours of green gram, black gram, pigeon pea, Bengal gram, kabuli gram and cowpea (Table III). The reason might be that these pulses themselves contained sufficient nutrients. On the other hand, soybean proved to be a poor food for *Trogoderma* larvae as it supported only 31% adult emergence. Addition of a minimum level (0·25 g/2 g of diet) of artificial diet to soybean supported 82% adult emergence and shortened the developmental period. This indicated that the

TABLE III. *Growth and development of* T. granarium *on wheat flour, artificial diet, pulses and mixtures of artificial diet and pulse*

| Diet (g) | No. of larvae becoming adult % | angle* | Average developmental period (days) |
|---|---|---|---|
| 2·00 wheat flour | 89 | 73·2 | 28·2 |
| 2·00 artificial diet (AD) | 78 | 66·2 | 37·8 |
| 1·75 AD + 0·25 green gram flour | 93 | 76·7 | 31·8 |
| 1·50 „ + 0·50 „ „ „ | 90 | 75·4 | 30·3 |
| 1·00 „ + 1·00 „ „ „ | 90 | 75·0 | 25·1 |
| 0·50 „ + 1·50 „ „ „ | 88 | 73·4 | 30·1 |
| 0·25 „ + 1·75 „ „ „ | 92 | 76·2 | 29·7 |
| 0·00 „ + 2·00 „ „ „ | 93 | 77·0 | 31·6 |
| 1.75 AD + 0·25 black gram flour | 70 | 57·5 | 38·6 |
| 1·50 „ + 0·50 „ „ „ | 79 | 63·9 | 35·8 |
| 1·00 „ + 1·00 „ „ „ | 77 | 61·6 | 37·2 |
| 0·50 „ + 1·50 „ „ „ | 69 | 56·8 | 39·0 |
| 0·25 „ + 1·75 „ „ „ | 74 | 59·5 | 39·9 |
| 0·00 „ + 2·00 „ „ „ | 87 | 71·7 | 36·7 |
| 1·75 AD + 0·25 pigeon pea flour | 89 | 73·4 | 39·4 |
| 1·50 „ + 0·50 „ „ „ | 79 | 63·9 | 37·4 |
| 1·00 „ + 1·00 „ „ „ | 89 | 70·7 | 39·5 |
| 0·50 „ + 1·50 „ „ „ | 75 | 60·5 | 39·3 |
| 0·25 „ + 1·75 „ „ „ | 71 | 57·5 | 40·4 |
| 0·00 „ + 2·00 „ „ „ | 66 | 54·3 | 40·7 |
| 1·75 AD + 0·25 Bengal gram flour | 91 | 74·8 | 31·2 |
| 1·50 „ + 0·50 „ „ „ | 91 | 73·3 | 32·0 |
| 1·00 „ + 1·00 „ „ „ | 89 | 73·9 | 32·7 |
| 0·50 „ + 1·50 „ „ „ | 85 | 71·3 | 31·2 |
| 0·25 „ + 1·75 „ „ „ | 89 | 70·7 | 33·9 |
| 0·00 „ + 2·00 „ „ „ | 83 | 66·6 | 33·3 |
| 1·75 AD + 0·25 kabuli gram flour | 98 | 85·9 | 26·4 |
| 1·50 „ + 0·50 „ „ „ | 97 | 83·0 | 28·1 |
| 1·00 „ + 1·00 „ „ „ | 93 | 76·7 | 26·9 |
| 0·50 „ + 1·50 „ „ „ | 91 | 74·9 | 28·7 |
| 0·25 „ + 1·75 „ „ „ | 93 | 77·6 | 29·7 |
| 0·00 „ + 2·00 „ „ „ | 85 | 73·4 | 30·1 |
| 1·75 AD + 0·25 cowpea flour | 85 | 67·3 | 31·1 |
| 1·50 „ + 0·50 „ „ | 87 | 69·0 | 31·9 |
| 1·00 „ + 1·00 „ „ | 91 | 73·3 | 33·1 |
| 0·50 „ + 1·50 „ „ | 85 | 67·3 | 29·8 |
| 0·25 „ + 1·75 „ „ | 90 | 65·6 | 30·0 |
| 0·00 „ + 2·00 „ „ | 82 | 69·3 | 32·0 |
| 1·75 AD + 0·25 soybean flour | 89 | 70·3 | 34·5 |
| 1·50 „ + 0·50 „ „ | 86 | 68·8 | 36·9 |
| 1·00 „ + 1·00 „ „ | 80 | 63·9 | 36·7 |
| 0·50 „ + 1·50 „ „ | 85 | 70·1 | 38·5 |
| 0·25 „ + 1·75 „ „ | 82 | 65·3 | 36·9 |
| 0·00 „ + 2·00 „ „ | 31 | 27·6 | 41·8 |
| 1·75 AD + 0·25 lentil flour | 46 | 42·6 | 42·8 |
| 1·50 „ + 0·50 „ „ | 8 | 15·9 | 44·7 |
| 1·00 „ + 1·00 „ „ | 7 | 14·6 | 42·0 |
| 0·50 „ + 1·50 „ „ | 0 | — | — |
| 0·25 „ + 1·75 „ „ | 0 | — | — |
| 0·00 „ + 2·00 „ „ | 0 | — | — |
| 1·75 AD + 0·25 French bean flour | 60 | 51·2 | 39·8 |
| 1·50 „ + 0·50 „ „ „ | 58 | 50·3 | 41·8 |
| 1·00 „ + 1·00 „ „ „ | 13 | 20·1 | 43·7 |
| 0·50 „ + 1·50 „ „ „ | 0 | — | — |
| 0·25 „ + 1·75 „ „ „ | 0 | — | — |
| 0·00 „ + 2·00 „ „ „ | 0 | — | — |
| Significant difference ($P$ = 0·05) | — | 14·5 | 2·9 |

*Angular transformation of percentages.

deficiency of one or more nutrients from soybean flour could be made good with artificial diet. Similarly, earlier workers recorded that addition of yeast to soybean increased its food value for *Tribolium* (Sweetman & Palmer, 1928; Sokoloff *et al.*, 1966).

The effects of adding artificial diet to lentil flour were more marked. No adults emerged when larvae were fed on diets containing little of the artificial diet. Development and emergence improved with a 1 : 1 mixture of artificial diet and lentil flour, and still more with a higher proportion of artificial diet (Table III). This clearly indicated that addition of a higher amount of nutrients to lentil flour increased its dietary value. The effects of several mixtures of artificial diet and French bean flour also resembled those of lentil flour. In these diets, inclusion of 0·25 and 0·50 g of French bean flour resulted in 60 and 58% of adult emergence, respectively, but only 13% with 1·00 g of French bean flour. Further increase in the proportion of French bean flour proved inadequate for adult emergence. In all the test mixtures cited above, there was a reduction in the adult populations in flours of French bean and lentil.

TABLE IV. *Growth and development of* T. granarium *on artificial diet and cellulose powder*

| Diet (g) | No. of larvae becoming adult | | Average developmental period (days) |
|---|---|---|---|
| | % | angle* | |
| 2·00 artificial diet (A.D.) | 78 | 66·2 | 37·8 |
| 1·75 AD + 0·25 cellulose | 48 | 43·9 | 40·8 |
| 1·50 „ + 0·50 „ | 41 | 39·6 | 40·9 |
| 1·00 „ + 1·00 „ | 25 | 30·0 | 39·4 |
| 0·50 „ + 1·50 „ | 15 | 21·5 | 40·8 |
| 0·25 „ + 1·75 „ | 7 | 14·6 | 43·5 |
| 0·00 „ + 2·00 „ | 0 | — | — |
| Significant difference ($P$ = 0·05) | — | 15·39 | NS |

*Angular transformation of percentages.

Addition of cellulose in increasing proportions to artificial diet resulted in a gradual decrease in the number of adults emerging (Table IV). Substitution of cellulose by either French bean or lentil flour caused much heavier mortality of larvae (Table III). The pulses cannot, like cellulose, be regarded as physiologically inert, so that it may be concluded that lentil and French bean flours are either nutritionally deficient and/or contain developmental inhibitors.


## Summary

Rearing experiments with *Trogoderma granarium* Everts were conducted to determine why the larvae fail to develop in certain pulses. The larvae were unable to penetrate whole grains of any of the nine pulses tested. In flour form, the pulses fell into three main groups. On flours of green, black, Bengal and kabuli grams, and cowpea and pigeon pea, development was as successful and rapid, or nearly so, as on wheat flour and showed little improvement from the addition of yeast. Development on flours of soybean and lentil was markedly slower, and showed marked improvement when yeast was added. By adding increased proportions of balanced diet, it was shown that the performance of larvae on soybean, lentil and even on French bean flours could be improved, but with the last two was not as good as with cellulose. It is concluded that lentils and French beans lack essential nutrients and may also contain a growth inhibitor.



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