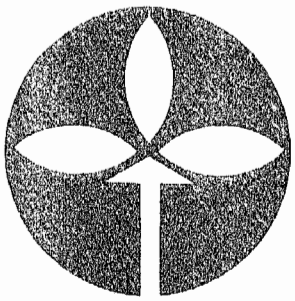

DEPARTMENT OF AGRICULTURE, SOUTH AUSTRALIA

# Agronomy Branch Report

## THE BIOLOGY OF DESIANTHA CAUDATA, PASC., (FAM. CURCULIONIDAE), THE CEREAL CURCULIO

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SUMMARY

Factors affecting the different stages of Desiantha caudata in the laboratory are discussed. An understanding of these factors resulted in techniques suitable for rearing D. caudata in the laboratory.

The life-cycle of D. caudata is described. This life cycle was developed from field and laboratory observations.

Adult survival through the summer months is necessary for oviposition and a study of factors affecting this survival has provided the basis for hypotheses explaining why D. caudata damage is neither found in cereal crops sown after fallows nor in successive crops in South Australia. A more detailed understanding of some of these factors, viz. the effect of rainfall distribution on adult survival, could provide the basis for forecasting seasons when D. caudata larvae could cause damage in susceptible crops in an area.

## 1. BACKGROUND

Desiantha caudata is a native weevil which has become a sporadic pest of germinating cereals during the last 15-20 years. D. caudata damage to cereals varies from year to year and district to district. A complete loss of an estimated 5,000 acres of cereals occurred in the Manoora-Mintaro area in 1962. In other years or other districts the damage may range from a thinning of a number of crops to the almost complete baring of one or two crops or to an absence of damage.

The larvae are soil dwelling insects which damage cereals by eating the swelling seeds soon after sowing, or by attacking young seedlings or tillers causing them to wither and die. Damage can result in bare patches throughout the crop, or, with a thinning of plants and tillers only, yields can be significantly reduced.

Damage is confined to crops sown after at least four or five years of pasture with the initial cultivations carried out with late summer or autumn rains (short term fallow). Damage following a late winter or spring prepared fallow (long term fallow) has not been reported. The pasture prior to D. caudata damage has usually reverted to a barley grass dominant pasture with the build up in fertility. The effect of the length of fallow was seen at Manoora in 1962 where D. caudata was seen in half of a paddock which had a short term fallow prior to the cereal crop, while the other half, which had a long term fallow, showed no damage. The length of fallow was the only difference that could be determined in the history of the two halves. Damage has not been reported in successive cereal crops in South Australia.

This pest has increased in importance with the reduction in the use of fallows. The proportion of wheat sown on fallowed land in County Stanley has decreased from 97% to 42% during the period 1940/41 to 1960/61. This same order of reduction has occurred in Counties Light, Victoria and Dalhousie, which together with County Stanley includes the main areas where cereal crops are damaged by D. caudata in South Australia (Appendix I). The reduction in fallowing has come about with increased mechanisation, enabling more rapid land preparation prior to sowing cereals, and the introduction of annual legumes and superphosphate, which have increased soil fertility and allowed a ley farming system to be developed.

At the commencement of this project the general biology of D. caudata was not understood and there were no satisfactory control measures. References on D. caudata referred only to taxonomic work (Pascoe 1870, Lea 1899) or to records of damage caused by this weevil (Anon 1947, Froggatt 1899, Swan 1937). Squires (1964) published the life cycle of D. caudata but, while the photographs were D. caudata, the text applied to another insect. (This mistake was confirmed by Squires, personal communication, 1965).

## 2. AIMS

2.1 To maintain D. caudata cultures in laboratory conditions.

2.2 To describe the life cycle of D. caudata.

2.3 To study factors influencing the life cycle of D. caudata and how these may be used to explain D. caudata infestations and to forecast D. caudata damage.

## 3. REARING AND OBSERVATIONS IN THE LABORATORY

### 3.1 Adults

The following are chronological notes on tests and observations which were made in developing optimum conditions for survival and oviposition by D. caudata adults in laboratory conditions.

3.11 The survival and behaviour of adults was first studied using recently emerged adults collected from the field at Manoora in December 1965. These adults were kept in crispers with moist sand on the bottom in an incubator at 15°C; they were either fed wireweed or wheat grains for three months and then all were fed wheat grains. Early survival was poor but several adults survived for six months. There was no difference in survival between adults first fed on wireweed and those fed continuously on wheat.

3.12 Adults were placed in pots containing cores of pasture $2\frac{1}{2}$" diameter x 2" deep cut from the field which were kept moist in laboratory conditions (24°C). The survival of adults was satisfactory but recovery of eggs and larvae from such cultures would be difficult and unpractical. Feeding on subterranean clover leaves was evident.

3.13 Other foods which were tested with adults collected from the field in December were barley grass foliage, since field infestations in cereal crops appeared to be closely related with barley grass patches of the previous season, and dry straw, since adults emerge in early summer and larvae are not found until the following winter. The barley grass deteriorated rapidly with prolific fungal growth and was not considered practical for further use. Most of the adults kept with dry straw died within six weeks.

3.14 <u>To determine the effects of temperature, day length, food and moisture on adult survival in a pilot trial</u>:

Adults were collected from Manoora on 23/2/66 and the experiment set up the next day. Conditions in the field had been sufficiently moist to support an extensive growth of summer annual weeds. There were two replicates per treatment and each replicate had two males and one female in a petri dish with a filter paper on the base.

Summary of adult survival and activity after 24 days -

| Treatment | | Survival (Tot. 2 reps) | Activity |
|---|---|---|---|
| 15°C, 10 hours light - | moisture, wireweed | 4 | + |
| | dry, wireweed | 3 | - |
| | dry, no food | 2 | - |
| 15°C, 12 hours light - | moisture, wirewed | 5 | + |
| | dry, wireweed | 4 | + |
| | dry, no food | 0 | - |
| 20°C, 0 hours light - | moisture, wireweed | 0 | - |
| | dry, wireweed | 0 | - |
| | dry, no food | 0 | - |
| 20°C, 10 hours light - | moisture, wireweed | 5 | + |
| | dry, wireweed | 0 | - |
| | dry, no food | 0 | - |
| 25°C, 10 hours light - | moisture, wireweed | 0 | - |
| | dry, wireweed | 0 | - |
| | dry, no food | 0 | - |
| 25°C, 16 hours light - | moisture, wireweed | 2 | + |
| | dry, wireweed | 0 | - |
| | dry, no food | 0 | - |

Comments -

There was a limited choice in daylengths since these were fixed in the incubators used at W.A.R.I.

The survival was best in the moist conditions with food at the lower temperatures.

The complete mortality of adults at 0 hours light showed the need for light in incubators when D. caudata adults were being reared.

The activity, assessed by signs of feeding and excretion, was most marked in moist conditions. With wireweed in dry conditions there was some activity in the first few days of the trial. Scuffing of filter paper was evident in the moist conditions at 15°C; this was found to be associated with oviposition.

Conclusion -

Adults from the field can be kept satisfactorily at 15-20°C with moisture, food and at least 10 hours light per day.

3.15 Light requirement of D. caudata adults

Another trial supporting the requirement of adult D. caudata for light was a trial determining the effect of light on fecundity.

Adults collected from the field in early March were placed in small crispers with 1" soil on the bottom and clods of soil on the surface to provide sheltered niches. There were ten females and ten males in each crisper and moist tissue pads were provided for oviposition (3.22). The adults were fed wheat grains

Summary of adult survival and number of eggs after 35 days -

| Treatment | Survival | No. Eggs |
|---|---|---|
| 15°C, 11¾ hours light | 2 females<br>4 males | 96 |
| 15°C, 0 hours light | 1 female<br>1 male | 26 |
| 20°C, 11¾ hours light | 4 females<br>4 males | 98 |
| 20°C, 0 hours light | Nil | 6 |

Comments -

Adult survival was poor with continuous dark conditions. At 15°C, 55% of the mortalities occurred within 7 days and at 20°C all the adults had died by 7 days. In the light treatments, the mortalities were more even over the 35 days.

The low number of eggs in the dark conditions would be related to the early mortality of the adults since 97% of the eggs in the light conditions were laid within the last 14 days of the trial.

Temperatures in the range of 15-20°C had no effect on the number of eggs laid.

Conclusion -

Laboratory cultures of adult D. caudata should not be kept in continuous dark conditions.

3.16 Summary

Pilot trials showed that the following conditions were suitable for good adult survival in the laboratory - closed containers, with soil or filter paper on the base, kept at 15-20°C with at least 10 hours light per day. The adults should be provided with moisture and food, either wireweed (Polygonum aviculare) or wheat grains. The containers should be checked regularly to minimise fungal growth at the warmer temperature.

3.2 Oviposition

In trials determining the factors affecting the survival of adults, very few eggs per female were laid. Weevils were also kept in large numbers (100-200) in crispers at 15-20°C with food for egg production. Soil was not placed on the bottom to facilitate the recovery of eggs. A few eggs were laid on the surface of the crisper but the numbers were very low which indicated that conditions were not suitable for oviposition. In the trial to determine factors affecting the survival of adults (3.14), the filter paper on the bottom of the petri dish in the moist conditions at 15°C were riddled with small holes; one replicate had an egg in each of three holes. This showed the females requirement for an oviposition site other than a hard, bare surface. Oviposition activity or eggs were only found in moist conditions compared to dry conditions.

3.21 To determine the effectiveness of filter paper for oviposition by D. caudata

Beetles from 3.14 were placed in petri dishes with three layers of moistened No. 1 filter paper on the bottom of the dish. Wireweed was provided as food and the dishes were kept at laboratory temperatures ($24^{o}C$).

Observations -

Within 7 days holes were drilled in the filter paper. The oviposition habits of a female were watched under a microscope. The female dug a hole in the filter paper with her mouthparts to the depth of the rostrum. The width of the hole was only a little larger than the rostrum and the antennae fitted into the grooves along the rostrum. When the hole was dug the female turned around and located the hole with her ovipositor and inserted an egg. When the single egg was laid she attempted to fill the hole by scratching the surface over with her legs. This suggested that eggs are laid singly in the soil and buried.

Conclusion -

Female D. caudata need specific sites for oviposition in the laboratory.

3.22 To determine the effectiveness of tissue paper pads without soil for oviposition by D. caudata:

Safe removal of eggs from the filter papers was tedious because of the rigid, coarse texture of the filter paper fibres and the thickness of the filter paper. Eggs could be firmly held in the filter paper even though the paper was thoroughly moistened.

Ten and eleven females with males were placed in two crispers, respectively, with moistened tissue paper folded into a pad (about 2" x $\frac{3}{4}$") and no soil. The adults were fed whole wheat grains and kept at laboratory temperatures ($24^{o}C$).

Two tubes (1" diameter x 2") had a moist tissue paper pad on the bottom with a female and male in each. These beetles were kept under the same conditions as those in the crispers.

The oviposition pads were checked for eggs and the adult deaths recorded.

Summary of female survival and the eggs laid after 14 and 30 days -

| | 14 days | | 30 days | | Eggs/female |
|---|---|---|---|---|---|
| | females | eggs | females | eggs | |
| Crisper 1 | 11 | 36 | 11 | 140 | 16.0 |
| Crisper 2 | 10 | 250 | 7 | 272 | 52.2 |
| Tube 1 | 1 | 17 | 1 | 22 | 39.0 |
| Tube 2 | 1 | 24 | 1 | 35 | 59.0 |

Comments -

Fungal growth developed rapidly in plastic tubes and the individual handling would be more tedious than having a number of adults in a crisper.

The wheat needed replacement every seven days in the crisper to avoid fungal growth and deterioration.

Conclusions -

Damp tissue paper pads provide a suitable oviposition site for females in laboratory cultures. The eggs are easily removed with a fine hair brush when the pad is unfolded and thoroughly moistened with water.

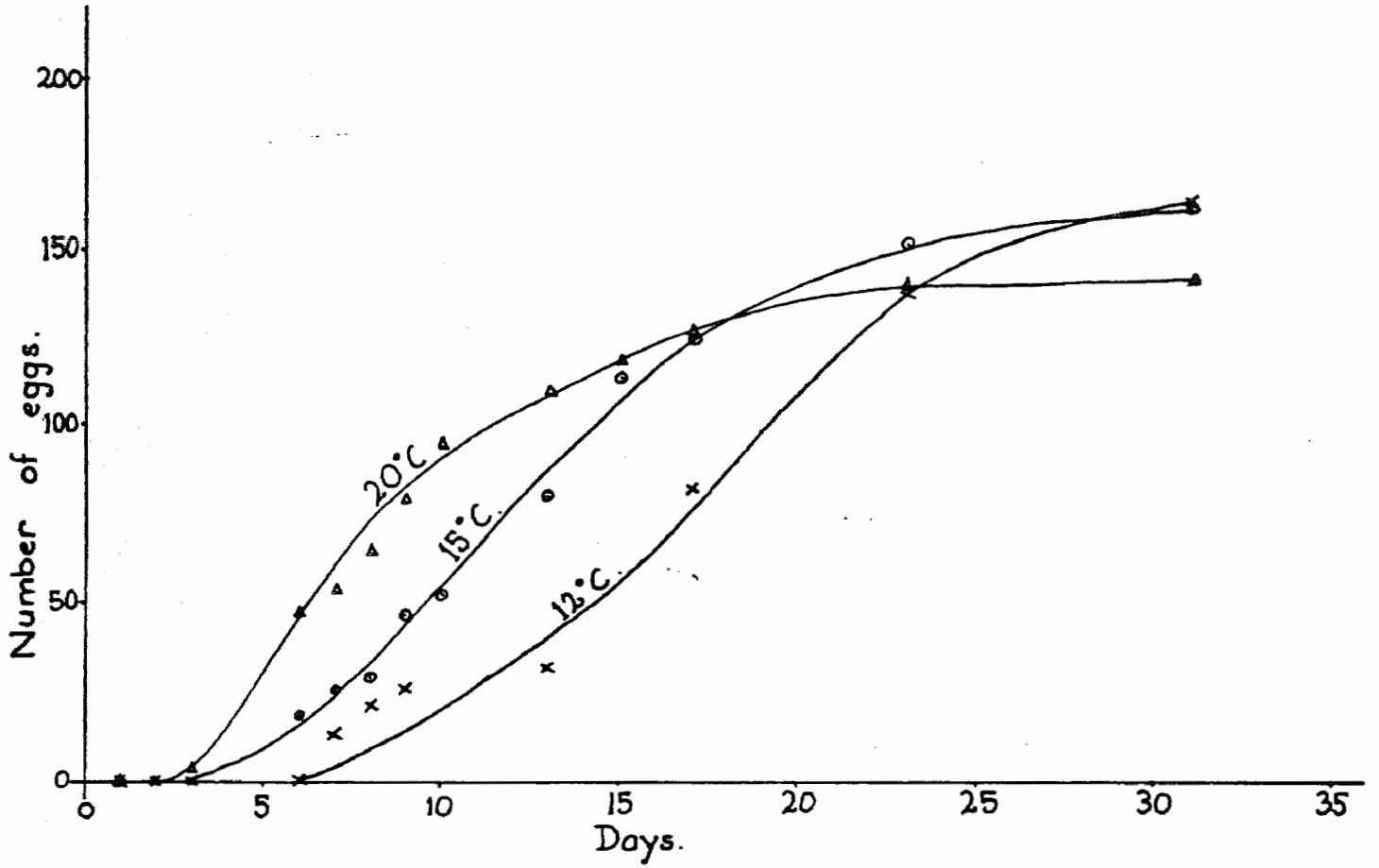
3.23 To determine the effect of daylength on fecundity:

See 3.15.

3.24 To determine the effect of temperature on fecundity:

Gravid females collected from the field in May were placed in petri dishes and kept at 12°C, 15°C and 20°C. There were three females and two males in each dish with a filter paper base and moist tissue paper pad for oviposition. The beetles were fed wheat grains. There were five replicates for each temperature.

I— THE EFFECT OF TEMPERATURE ON FECUNDITY OF ADULT D. caudata.



The pads were removed and inspected for eggs daily at the beginning of the experiment and as the rate of oviposition slowed down the pads were inspected at less frequent intervals.

Summary showing the progressive total of eggs produced in the five replicates for each temperature -

| Temperature | Days | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 6 | 7 | 8 | 9 | 10 | 13 | 15 | 17 | 23 | 31 |
| 12°C | 0 | 0 | 0 | 0 | 12 | 20 | 25 | - | 31 | - | 81 | 137 | 164 |
| 15°C | 0 | 0 | 0 | 18 | 25 | 29 | 46 | 52 | 80 | 113 | 124 | 152 | 162 |
| 20°C | 0 | 0 | 3 | 47 | 53 | 64 | 79 | 94 | 109 | 118 | 127 | 140 | 142 |

Graph I.

Comments -

The experiment was stopped after 31 days because of adult mortalities, probably due to age. The average number of eggs per female over the whole experiment was not very high since the females would have laid eggs prior to this period, but the trial showed that temperatures (12-20°C) did not affect the total number of eggs laid (also 3.15) but affected the rate of oviposition.

Conclusion -

Temperature in the range 12°C to 20°C does not influence the total number of eggs produced but affects the rate of oviposition.

3.25 To determine the effect of moisture on fecundity and selection of oviposition sites:

Trials studying the conditions which are suitable for adult survival and oviposition showed that females required moist conditions for oviposition. This was further substantiated in trials examining the effects of different conditions on the life cycle (5.1).

A shallow tray (11" x 6") had about $\frac{1}{2}$ inch of moist sand placed on the bottom. The tray was covered with celluloid and a small gap left at one end to allow the sand to dry out unevenly. When it was thought that there was a moisture gradient across the sand, three gravid females and two males were placed in the tray for 24 hours. After this time the beetles were removed and the tray was divided into 24 sections (6 sections along by 4 sections across). The moisture contents of half of the sections along the tray were calculated to find the moisture gradient along the tray while the other corresponding samples were examined for eggs.

The moisture content ranged from 19-23% and only one egg was recovered. To obtain more positive results on the effect of moisture on the selection of the oviposition site, the moist sand should be given more time to dry out and a higher density of gravid females should be used.

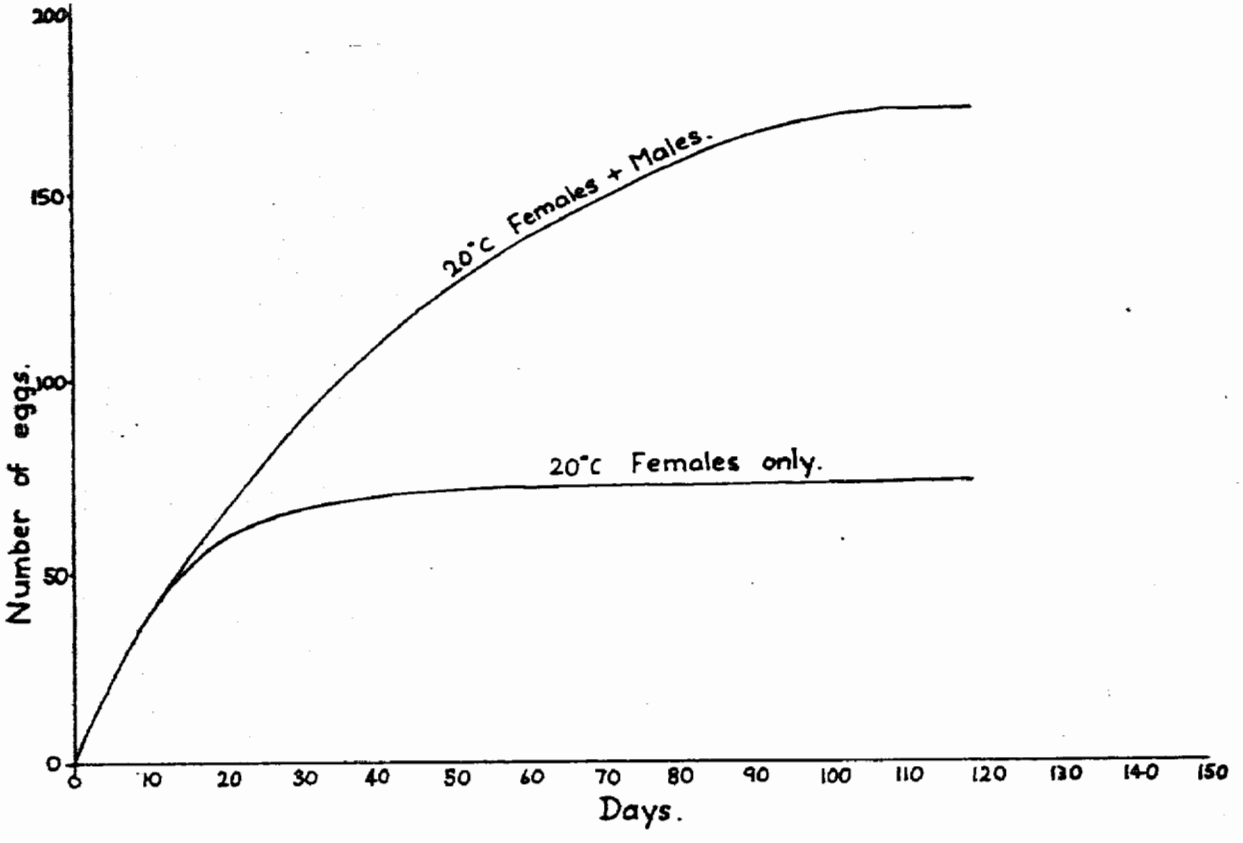
3.26 To determine the effect of males on fecundity -

Adults collected from the field in mid-December were separated into males and females and kept in containers with wireweed and moist tissue paper pads at 20°C for three months. Within this time the ovaries had matured and some egg-laying had occurred which suggested that either the females had mated in the field prior to collection and stored the sperm or parthenogenetic reproduction was occurring.

To test the effect of males on fecundity, two crispers with wireweed and moist tissue paper pads for oviposition were kept at 20°C with ten females and ten males in one and ten females only in the other.

The number of eggs laid were recorded every few days for 118 days.

11 — THE EFFECT OF MALES ON FECUNDITY OF ADULT D. caudata IN LABORATORY CULTURES.



Summary of the number of eggs laid for each treatment -

| | Days | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 5 | 8 | 11 | 15 | 19 | 21 | 26 | 27 | 29 | 33 | 34 | 36 | 38 | 40 | 42 | 45 |
| Females + Males | 0 | 25 | 47 | 54 | 65 | 67 | 67 | 67 | 86 | 87 | 92 | 93 | 93 | 94 | 102 | 105 | 108 |
| Females only | 0 | 25 | 35 | 50 | 56 | 62 | 62 | 63 | 63 | 63 | 63 | 65 | 68 | 71 | 72 | 72 | 72 |

| | Days | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 46 | 49 | 50 | 53 | 56 | 57 | 61 | 63 | 64 | 69 | 70 | 75 | 82 |
| Females + Males | 122 | 122 | 129 | 132 | 132 | 141 | 143 | 147 | 147 | 148 | 150 | 154 | 162 |
| Females only | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 73 | 74 | 74 | 74 | 75 |

| | Days | | | | |
|---|---|---|---|---|---|
| | 89 | 97 | 104 | 111 | 118 |
| Females + Males | 169 | 173 | 174 | 174 | 174 |
| Females only | 75 | 75 | 75 | 75 | 75 |

Graph II.

Comments -

All eggs laid by the females without males were fertile. Since the initial oviposition rate is constant for both treatments it is assumed that the females were fertilized soon after emergence for the first batch of eggs, but for further fertile egg production the females have to be refertilised.

Dissections of gravid females have shown that eggs are developed in batches which move into the lateral oviducts ready for oviposition. (The batches appear to range from about 7-12 eggs).

Conclusions -

For maximum egg production males should be included with females since one mating will not produce the full potential of fertile eggs from a female.

3.27 To determine the effect of crowding on fecundity:

When females only or males and females were kept in large numbers in crispers at 20°C with food, moisture and suitable oviposition sites, very few eggs per female were laid - usually about 0.5-1.0 egg for female.

Ten males and ten females were taken from a crisper containing about fifty females and fifty males. This crisper had been set up with suitable conditions for oviposition but very few eggs had been laid to this time. The beetles taken out were kept in pairs at 20°C in individual tubes with dry soil on the base, wireweed and a damp tissue paper pad for oviposition. The egglaying of the adults in the tubes and the crisper was compared.

Summary of the rate of oviposition -

| | | Rate | Eggs/female/day | Eggs/female |
|---|---|---|---|---|
| Crisper (40 females) | | 27 eggs in 54 days | 0.01 | 0.7 |
| Tubes (1 female) | 1. | 82 eggs in 59 days | 1.4 | 82 |
| | 2. | 19 eggs in 10 days | 1.9 | 19 |
| | 3. | 32 eggs in 19 days | 1.7 | 32 |
| | 4. | 13 eggs in 10 days | 1.3 | 13 |
| | 5. | 12 eggs in 10 days | 1.2 | 12 |

Comments -

In some replicates there was an early, unexplainable mortality of adults, while others were affected by fungus which resulted from very humid conditions in the small tubes. Two of the females did not lay eggs in these tubes after living for about a month.

Conclusions -

These observations showed that individuals are better kept individually in the laboratory than in bulk for oviposition studies.

The potential egg-laying capacity of female D. caudata is at least 80 eggs.

3.28 Summary

In laboratory cultures D. caudata females need to be provided with a site for oviposition. An easily prepared site, where recovery of eggs is relatively simple, is moist tissue paper folded into a tight pad. Females will lay eggs in moist soil, but they prefer damp tissue paper to dry soil for oviposition if soil is used in the container. For optimum laboratory conditions for egg-laying see 5.1.

3.3 Eggs

3.31 To determine the effect of temperature and moisture on the incubation period of D. caudata eggs:

Eggs which were collected daily from trial 3.24 were used. In the moist treatments the eggs were placed in petri dishes with the filter papers on the bottom marked into grids to keep an individual record of eggs; the moist filter paper held the eggs in place. In the dry treatments, the eggs were placed separately in the compartments of a cocktail ice cube tray.

Two replicates for each moisture regime were placed at 8°, 15° and 20°C. Each replicate contained 20 eggs.

Summary of the incubation period of D. caudata eggs -

| Treatment | | | Incubation Period (days) | Average incubation period (days) |
|---|---|---|---|---|
| Moist | 8°C | A | No hatching | |
| | | B | | |
| | 15°C | A | 25 24 24 24 | |
| | | B | 25 24 24 25 24 21 27 24 24 24 24 27 24 | 24.3 ± 1.2 |
| | 20°C | A | 20 19 20 20 20 20 19 | |
| | | B | 20 22 17 17 18 20 17 17 17 20 20 | 19.1 ± 1.4 |
| Dry | 8°C | A | No hatching | |
| | | B | | |
| | 15°C | A | No hatching | |
| | | B | | |
| | 20°C | A | No hatching | |
| | | B | | |

Comments -

The percentage of eggs hatching in the moist conditions at both 15° and 20°C was low (45%). Part of this was due to fungal growth around the eggs but the main reason was not understood. In all treatments the eggs changed from white to grey which showed that some development occurred.

After a month the eggs in the dry conditions were inspected under the microscope. At 15° and 20°C the eggs were shrivelled but fully developed larvae could be seen inside. No larval development could be seen in the eggs kept at 8°C, both in dry and moist conditions.

After 30 days the following results were obtained when the eggs from the respective treatments were transferred to 20°C, moist -

a. Most eggs from 8°C, moist hatched after 18 days

b. Some eggs from 8°C, dry hatched after 15 days

c. Eggs from 15°C, dry immediately hatched

d. Eggs from 20°C, dry immediately hatched.

Eggs which were kept under dry conditions at 8°C for three months did not hatch when they were changed to 20°C, moist.

Transferring eggs from 8°C to warmer conditions with moisture shows that little development occurs at 8°C regardless of moist or dry conditions. At the warmer temperatures the rate of development depends on the temperature, but hatching will only occur in moist conditions.

Conclusions -

D. caudata eggs only hatch under moist conditions. In dry conditions fully developed larvae can remain in the chorion without hatching until the eggs are placed in moist conditions.

At 8°C little larval development takes place but normal development will occur once the eggs are placed in warmer conditions.

Application -

If newly hatched larvae are not required in the laboratory 2-3 weeks after oviposition, eggs can be stored in moist conditions at 8°C for 2-3 months without seriously reducing the viability.

3.32 To determine the effect of magnesium sulphate on the viability of D. caudata eggs:

In trials where soil is used for oviposition, eggs can be recovered from the soil by floating them off with the organic matter using magnesium sulphate solution (S.G.= 1.1). The viability of the eggs in contact with the magnesium sulphate was tested.

29 eggs were removed from soil by flotation with magnesium sulphate; the contact with the magnesium sulphate was 10 minutes.

29 eggs were immersed in the magnesium sulphate solution for 20 minutes.

29 eggs were untreated.

All the eggs were incubated in moist conditions at 20°C.

Summary of the percentage hatching -

| Treatment | Per cent hatching |
|---|---|
| No contact with magnesium sulphate | 45 |
| 10 minutes contact with magnesium sulphate | 27 |
| 20 minutes contact with magnesium sulphate | 21 |

Comments -

There was no explanation for the low percentage hatching with the control treatment. All eggs turned from white to grey showing that they were fertile.

Conclusions -

Immersion in magnesium sulphate (S.G. = 1.1) affects the viability of D. caudata eggs. In trials where egg recovery and viability of eggs is important, folded pads of damp tissue paper should be used for oviposition rather than damp soil.

3.33 Summary -

Eggs need to be kept in moist conditions to hatch and when they are kept at 15°C and 20°C they hatch in about 19 and 24 days, respectively.

Eggs can be stored at 8°C in moist conditions for two to three months without seriously reducing the viability.

The viability of eggs is reduced if the eggs are separated from the soil by floating them off with magnesium sulphate (S.G. = 1.1).

3.4 Larvae -

The two main food sources of D. caudata larvae in the field are cereals and barley grass. The larvae feed on the swelling seeds of cereals, bore into the underground stems of cereal seedlings, and bore into the tillers of barley grass and tillers. A suitable technique for rearing larvae in the laboratory had to be developed to study the growth and food requirements of larvae and to rear larvae for insecticidal screening trials.

The behaviour of newly hatched larvae was observed in both petri dishes with moist filter paper on the bottom and in containers with soil. The larvae were strongly photo-negative in the petri dishes and this taxis was further shown when the larvae placed on the soil immediately burrowed into the soil.

Two pieces of glass were set up parallel to each other with enough space between them to slide in a softened wheat seed. The seed was placed about 1½" from the top and the spaced filled with soil. A larva was placed on the surface and the container was kept in the dark. The path of the larva in the soil was watched to see if the larva was attracted to the grain. The larva tunnelled a little way into the soil and stopped; the trial did not offer any information on the attraction of food, probably due to the unnatural conditions for burrowing.

3.41 To determine the effectiveness of bulk rearing D. caudata larvae in crispers with soil and wheat in the laboratory:

Larvae, mainly second instar, collected from the field were placed in plastic crispers (12" x 8" x 4") in about $2\frac{1}{2}$ inches of moist soil with whole wheat. Sixty larvae were put in each crisper and when the trays were sampled after a week there were drastic reductions in larval numbers. This technique was tried with a number of crispers and does not offer a reliable method to rear D. caudata larvae in the laboratory.

3.42 To determine the effectiveness of bulk rearing newly hatched D. caudata and D. maculata larvae in trays with soil and wheat in the laboratory:

Newly hatched D. caudata and D. maculata larvae were placed in aluminium trays (10" x 15" x $1\frac{1}{2}$") with whole wheat and soil. The contents of the trays were either dry, moist, or very moist and all trays were kept at 15°C. After 10 days the trays were sampled for larvae.

Summary of the recovery of larvae from the trays after 10 days -

| Moisture level | Species | Recovery |
|---|---|---|
| Dry | D. caudata | 25/60 = 42% |
| Dry | D. maculata | 11/70 = 16% |
| Moist | D. caudata | 1/100 = 1% |
| Moist | D. maculata | 8/100 = 8% |
| Very moist | D. caudata | 7/100 = 7% |

Comments -

Fungal growth developed on the soil surface and mould developed around the wheat grains, especially in the wetter treatments. Vitamised wheat was put in soil in other trays with D. caudata larvae to reduce the fungus but the fungus was still a problem and the recovery low (0/100 and 22/100 after 20 days at 24°C).

Conclusions -

Open trays with soil and wheat are unsuitable for the bulk rearing of Desiantha larvae in the laboratory.

3.43 To determine the effectiveness of rearing D. caudata in an environment of 100% food:

Oatmeal "porridge" of varying consistencies were placed in five test-tubes and a flask. Ten larvae were put in each test-tube and forty in the flask and kept at 24°C.

Comments -

Many larvae drowned in the more liquid mixtures and after three days the fungus reached a level where it was impossible to find the larvae in the test-tubes. In the flask 25% of the larvae were recovered after 3 days; the fungus was not as severe throughout the medium and the "porridge" was stiff textured.

Conclusions -

Oatmeal "porridge" was not a suitable medium for rearing D. caudata larvae in the laboratory.

3.44 To determine the effectivness of rearing D. caudata larvae in individual plastic tubes in the laboratory:

Cannibalism occurred amongst early instar larvae kept under high densities in petri dishes and soil. This cannibalism explained part of the poor larval recovery experienced in 3.41 and 3.42. This trial was to test survival without cannibalism.

Larvae were placed separately in plastic tubes (1" x 2" deep) with a wheat grain and about 1" of soil. The soil was moistened and the tubes left open to reduce fungal growth.

After one week the recovery was 90%, but during the second week the soil dried out and the larvae died.

Conclusions -

Larvae placed in individual tubes reduced losses due to cannibalism. This technique was more tedious than bulk rearing but should be tested further because of the better recoveries.

Since there was a small quantity of soil per larva, the soil dried out quickly and the moisture level should have been watched more closely.

3.45 To determine the effectiveness of cocktail ice cube trays for rearing D. caudata larvae in the laboratory:

The trays contained 90 cubes, each $1\frac{1}{2}$ cm. x $1\frac{1}{2}$ cm. x 1 cm. deep. A larva was placed in each cube with a wheat grain and covered with moist soil. The soil rapidly dried out and the technique appeared impractical unless evaporation could be controlled.

Trays, set up as above, were placed in plastic bags and sealed with sellotape to control evaporation. The evaporation was reduced but some cubes were flooded by moisture dripping from the condensate inside the top of the bags. There was also a rapid build up of fungus at 15°C, 20°C and 24°C.

Moistened blotting paper, cut to the same size as the ice cube tray, was placed in the plastic bag on top of the tray to maintain even moisture in all the cubes. There was condensation in the bag, but when this dripped on to the blotting paper it was dispersed more evenly and avoided over wetting of some cubes. Suitable moisture levels could be maintained for at least two weeks by this method but in this time food was limiting and fungus became a problem. With the blotting paper on the surface there was some intercrossing of cubes by the more mature larvae.

Conclusions -

Early instar D. caudata larvae were successfully reared in cocktail ice cube trays where the larvae were separated to minimise cannibalism. The cubes contained a grain of wheat and moist soil and the moisture level across the tray was kept constant by moistened blotting paper placed on the tray and the tray kept in a sealed plastic bag.

Larval cultures kept by this method required changed soil and fresh food weekly.

3.46 To determine the effectiveness of sterilized soil to reduce the fungal problem when rearing D. caudata larvae in the laboratory:

The use of cocktail ice cube trays had overcome some of the problems in rearing D. caudata larvae but fungal contamination which appeared to be soil borne was still a problem.

Soil was autoclaved in glass jars sealed with brown paper for 1 hour at 30 p.s.i. and set up in the ice cube trays with larvae and wheat at 20°C.

Comments -

Development of surface fungi was delayed but growth began after a week. Even though the soil was sterilized there was early development of mould around the wheat.

90% of the older larvae and 60% of the first and second instar larvae were recovered.

Conclusions -

Sterilized soil reduced the fungal problem in larval cultures and provided good recovery of older larvae but the recovery of younger larvae was poor.

Mould developed on the food.

3.47 To determine the effectiveness of sterilized wheat used with sterilized soil to reduce the fungal problem when rearing D. caudata in the laboratory:

The soil and wheat were autoclaved in glass jars sealed with brown paper for 1 hour at 30 p.s.i. 150 larvae were set up in two ice cube trays with these materials.

After a week there was no fungus and the recovery of larvae was nil. Sterilization by autoclaving had caramelised the wheat which appeared to be toxic to the larvae.

3.48 To determine the effectiveness of fungal suppressants to reduce the fungal growth when rearing D. caudata larvae in the laboratory:

Potassium sorbate (Sorbistat K) was sprayed until saturation on the surface of petri dishes with unsterilised soil and wheat - concentrations of spray used were 0.025%, 0.035%, 0.05%, 0.1% and nil potassium sorbate.

After 7 days the nil treatment had substantial fungal growth, after 10 days the sorbistat K treatments showed some fungal growth, and after 14 days the fungal growth with all treatments was similar. Sorbistat K retarded the initial growth of fungi but did not give a practical control of the fungus at the rates tested for rearing D. caudata larvae.

Sorbic acid sprays or dust and sodium hypochlorite sprays have been used to reduce fungus in laboratory cultures of Lepidopterous larvae being reared on wheat germ media (Chawla et al, 1967).

The following treatments were set up in ice cube trays sealed in plastic bags without blotting paper and kept at laboratory temperatures (24°C). The treatments included two food sources (wheat germ and whole wheat), three soil conditions (sterilized soil (3.46), unsterilized soil, no soil) and three fungal suppressant conditions (1% sorbic acid dust, 1% sodium hypochlorite solution and nil suppressant). The soil was moistened before the suppressants were added. The sorbic acid was sprinkled lightly on the surface and the sodium hypochlorite was sprayed on the surface.

The trays were checked for fungal infection. Each tray was scored on a percentage basis $\left\{\frac{\text{number of squares with fungal growth}}{\text{Total number of squares (90)}} \times 100\right\}$. The growth was estimated as heavy (1), medium (2), or light (3).

Summary of percentage infested and the level of fungal growth after 7 and 13 days for each treatment -

| Treatment | | | 7 days | | 13 days | |
|---|---|---|---|---|---|---|
| Suppressant | Soil | Food | % Infected | Growth | % Infected | Growth |
| Sorbic acid | Sterilized | Wheat germ | 0 | - | 3 | (1) |
| | | Wheat | 10 | (1) | 60 | (1) |
| | Unsterilized | Wheat germ | 96 | (1) | 96 | (1) |
| | | Wheat | 83 | (1) | 83 | (1) |
| | Nil | Wheat germ | 9 | (1) | 10 | (1) |
| | | Wheat | 10 | (2) | 79 | (3) |
| Sodium hypochlorite | Sterilized | Wheat germ | 100 | (3) | 100 | (3) |
| | | Wheat | 100 | (2) | 100 | (2) |
| | Unsterilized | Wheat germ | 94 | (1) | 95 | (1) |
| | | Wheat | 100 | (1) | 100 | (1) |
| | Nil | Wheat germ | 32 | (2) | 32 | (2) |
| | | Wheat | 91 | (2) | 95 | (2) |
| Nil | Sterilized | Wheat germ | 100 | (3) | 100 | (3) |
| | | Wheat | 94 | (2) | 100 | (3) |
| | Unsterilized | Wheat germ | 100 | (2) | 100 | (2) |
| | | Wheat | 91 | (1) | 100 | (2) |
| | Nil | Wheat germ | 2 | (2) | 30 | (2) |
| | | Wheat | 100 | (3) | 100 | (3) |

Comments -

Wheat germ generally supported less fungal growth than whole wheat. The use of wheat germ has not been fully tested as a suitable food for the larvae.

Sorbic acid gave better overall control of fungus than sodium hypochlorite.

With sterilized soil and wheat the fungus was kept to a low level after 7 days but it spread rapidly during the next week.

Sodium hypochlorite prevented the germination of whole wheat without soil.

Conclusions -

Sorbic acid (1%) dusted on the soil surface will suppress fungal growth for at least 7 days when sterilized soil and wheat is used as a medium for rearing D. caudata larvae.

3.49 To determine the toxic effect of sorbic acid and sodium hypochlorite on D. caudata larvae:

Ice cube trays were set up with whole wheat and sterilized soil and kept in sealed plastic bags at 20°C. In one treatment the surface was dusted with sorbic acid (1%) and in another the wheat was first soaked in 20% sodium hypochlorite solution for 20 minutes and the surface dusted with sorbic acid. Newly hatched larvae were used in all treatments.

In the treatments with fungal suppressants the trays remained practically fungus free for 30 days and the trays were assessed for larvae after 44 days.

Summary of the number of larvae recovered after 44 days -

| Treatment | Recovery |
|---|---|
| 1. Whole wheat, sterilized soil, no suppressant | 11/30 = 37% |
| 2. Whole wheat, sterilized soil, sorbic acid | 14/30 = 47% |
| 3. Whole wheat (sodium hypochlorite treated), sterilized soil, sorbic acid | 13/30 = 42% |

Comments -

The first treatment had considerable fungus after 30 days while the other two were lightly infested.

The sorbic acid and sodium hypochlorite did not affect the larvae compared to the no suppressant treatment. Larval recovery from all treatments was low and the effect of sterilized soil on first instar larvae should be checked.

3.410 To determine the effect of sterilized soil on newly hatched D. caudata larvae:

In 3.46 there was a better recovery of older larvae in sterilized soil compared to early instar larvae and in 3.49 there was a poor recovery of newly hatched larvae put in sterilized soil.

Ice cube trays were set up with moist sterilized and unsterilized soil and newly hatched and more mature larvae. All were given whole wheat for food and the trays were sealed in plastic bags and kept at 20°C. The number of larvae surviving after 10 days was assessed for each treatment.

Summary of the larvae recovered after 10 days -

| Treatment | Recovery |
|---|---|
| First instar larvae, sterilized soil | 8/30 = 27% |
| First instar larvae, unsterilized soil | 24/30 = 80% |
| Mature larvae, sterilized soil | 25/30 = 83% |
| Mature larvae, unsterilized soil | 23/30 = 77% |

Conclusions -

Sterilized soil is toxic to a high proportion of first instar larvae, but does not affect more mature larvae. This could be due to an initial requirement of the larvae for organic matter since the organic matter was broken down when the soil was sterilized by autoclaving.

3.411 To determine whether newly hatched D. caudata larvae feed on organic matter in the soil:

Newly hatched larvae reared in autoclaved soil suffered high mortalities which could have been caused by a breakdown in the organic matter (3.410).

Newly hatched larvae were placed in the following treatments in ice cube trays covered with blotting paper in a plastic bag and kept at 20°C. The treatments were -

1. Moist soil + wheat
2. Moist soil + barley grass tillers
3. Moist soil
4. Moist organic matter.

The organic matter was floated off with $MgSO_4$ (SG = 1.1) from soil which was collected from an area where D. caudata damage occurs. The organic matter was rinsed with water before use.

The trays were checked weekly for survival.

Summary of the survival of larvae at weekly intervals -

| Treatment No. | Days | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 |
| 1. (10 reps) | 61 | 58 | 54 | 50 | 48 | 46 | 42 | 32$^p$ | 18 | 4 | 3 |
| 2. (10 reps) | 61 | 48 | 37 | 21 | 19 | 16 | 15 | 8 | 6 | 6$^p$ | 3 |
| 3. (9 reps) | 57 | 44 | 22 | 5 | 2 | 0 | | | | | |
| 4. (9 reps) | 57 | 43 | 19 | 12 | 4 | 1 | 1 | 0 | | | |

p = time of first pupation

Comments -

With the moist soil and wheat about 75% reached fifth instar but then there were very high mortalities due to Beauvaria bassiana, a cosmopolitan fungal disease of a wide range of insects.

This disease became established in laboratory cultures and affected the whole experiment.

About 30% reached fifth instar with moist soil and barley grass tillers. In this treatment the tillers decayed quickly and various fungal infestations, including B. bassiana, contaminated the cultures. The use of tillers for food is not a practical method to rear D. caudata larvae in the laboratory.

The survival of larvae in soil only was poor and no larvae reached second instar. The soil was sieved through a 0.5 m.m. sieve and contained fine particles of organic matter only.

In moist organic matter the survival was a little better than with the soil and some larvae reached second instar. The larvae were found feeding on the larger bits of organic matter.

Conclusions -

The results of this trial were affected by B. bassiana but it was shown that some growth of D. caudata larvae occurs with organic matter only. Further work should be done to see if the larvae are selective in the size of organic matter on which they feed.

The combination of moist soil and wheat gave the best survival and growth rate.

3.412 To determine whether newly hatched D. caudata larvae are selective in the particle size of organic matter which they feed:

This trial resulted from 3.411. The treatments were

1. Moist soil and wheat
2. Moist coarse organic matter (particle size between 0.5 m.m. and 4 m.m.)
3. Moist fine organic matter (particle size less than 0.5 m.m.)
4. No food

Treatments 1, 2 and 3 were set up in ice cube trays as in 3.411. The organic matter was obtained as in 3.411 and sieved to give the required particle sizes. Larvae in treatment 4 were placed in petri dishes with moist filter paper to prevent dehydration. The petri dishes were covered with "glad wrap" to prevent larval escape.

All treatments were kept at 20°C and checked weekly; in addition, treatments 2 and 3 were checked mid-weekly to reduce fungal contamination.

Summary of the survival of larvae at weekly intervals -

| Treatment No. | Days | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 |
| 1. (8 reps) | 59 | 56 | 38 | 26 | 18 | 12 | 7 | 6[p] | 1 | 0 | | |
| 2. (8 reps) | 57 | 32 | 14 | 10 | 6 | 4 | 4 | 3 | 2 | 2 | 2 | 2[p] |
| 3. (8 reps) | 57 | 26 | 9 | 2 | 0 | | | | | | | |
| 4. (8 reps) | 59 | 36 | 18 | 2 | 0 | | | | | | | |

p - time of first pupation

Comments -

This trial was seriously affected by B. bassiana, especially with the moist soil and wheat treatment. This disease does not appear to cause the death of larvae until they are in the fifth instar. Some larvae kept in coarse organic matter reached fourth instar while one pupated. The larvae fed on both organic matter and seeds present in this treatment. Pupation occurred about a month after those fed on germinating wheat indicating a slower rate of development.

The growth and death rate of the larvae in the fine organic matter was similar to the growth and death rate of those with no food, except that one larva did reach second instar in the fine organic matter.

Conclusions -

D. caudata larvae can survive for about two weeks without food.

D. caudata larvae can survive and mature to the pupal stage when they are fed on organic matter with particle sizes greater than 0.5 m.m.; organic matter with particle sizes less than 0.5 m.m. does not support the larvae.

Application -

Since larger particles of organic matter can support D. caudata larvae, this material probably provides the food for a population in the field between initial cultivation of a pasture and sowing of cereals.

3.413 To determine whether cannibalism occurs amongst late instar larvae when reared in the laboratory:

Newly hatched and second instar larvae have to be reared separately in the laboratory to overcome reductions in numbers due to cannibalism. This method is tedious compared to rearing the larvae in bulk containers. This trial was to find whether fourth and fifth instar larvae can be bulked together for easier handling.

104 fourth and fifth instar larvae were put into a large crisper with moist soil and whole wheat and kept at 20°C. After 7 days there was a 97% recovery which suggested that cannibalism was not a problem with bulk rearing late instar larvae.

3.414 To determine the effectiveness of light sandy soil for rearing D. caudata larvae in the laboratory:

Red brown earth soils have been used for rearing larvae in previous trials. The clay content of R.B.E. can sometimes make it difficult to recover larvae without damaging them.

Desiantha spp. damage in the field has been found in a wide range of soil types and sand was tested because of the easier handling of larvae with an understanding that soil type was not very critical.

52 larvae were placed in moist grey sandy soil from Kangaroo Island in an ice cube tray with moist blotting paper on the surface and sealed in a plastic bag. The larvae were older than third instar and fed on wheat at 20°C.

After 11 days there was a 42% recovery. The survivors were placed in a moist red sandy soil from Moorook under the same conditions and after 14 days there was a 5% recovery.

The unsuitability of sandy soils for rearing D. caudata larvae in ice cube trays in the laboratory could be due to the low water holding capacity of sands. The small quantity of sand in each cube became saturated with only small variations in the amount of moisture within the sealed bags. The use of blotting paper with sand was not as effective as its use with red brown earths.

Conclusions -

Light sandy soils were not suitable for rearing D. caudata larvae in ice cube trays in the laboratory.

3.415 To determine the number of larval instars of D. caudata and the head capsule widths of these instars:

(1) Measurements of head capsule widths were made on a number of larvae in field and laboratory populations to give an estimate of the head capsule widths for the different instars and confirm the number of instars. The calculation was based on Taylor's modification of Dyer's method for determining instars (Drooz, 1965).

Results -

| Instar | No. Specimens | Range m.m. | Mean head width m.m. | Ratio between Instars | Calc. head widths m.m. |
|---|---|---|---|---|---|
| 1 | 370 | 0.35-0.38 | 0.38 | | 0.38 |
| | | | | 1.52 | |
| 2 | 64 | 0.55-0.58 | 0.57 | | 0.53 |
| | | | | 1.31 | |
| 3 | 204 | 0.73-0.78 | 0.75 | | 0.73 |
| | | | | 1.33 | |
| 4 | 319 | 0.95-1.05 | 1.00 | | 0.98 |
| | | | | 1.34 | |
| 5 | 10 | 1.33-1.35 | 1.34 | | 1.38 |

Average 1.38

Comments -

This method confirmed that there were five larval instars.

(2) Larvae were reared individually to check on head capsule measurements and the number of instars. The following measurements were made on some of the individuals (many individuals died before completion of their development partly due to B. bassiana and also an incubator thermostat stuck and the temperature was lowered to 0.5°C).

Summary of head capsule widths (m.m.) for the different instars for individual larvae -

| Individual | Instar 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | 0.38 | 0.53 | 0.75 | 1.15 | 1.35 |
| 2 | 0.35 | 0.50 | 0.78 | - | 1.32 |
| 3 | 0.35 | 0.55 | 0.78 | 1.10 | 1.32 |
| 4 | 0.38 | 0.55 | 0.78 | 1.10 | 1.35 |
| 5 | 0.38 | 0.53 | 0.80 | - | - |
| 6 | 0.38 | 0.55 | 0.75 | - | - |
| 7 | 0.38 | 0.55 | 0.83 | 1.18 | - |
| 8 | 0.38 | 0.55 | 0.83 | - | - |
| 9 | 0.38 | 0.50 | 0.75 | 1.13 | - |
| 10 | 0.38 | 0.55 | 0.80 | 1.20 | - |
| 11 | 0.38 | 0.53 | 0.80 | 1.13 | - |
| 12 | 0.38 | - | 0.78 | 1.10 | - |
| 13 | 0.38 | 0.55 | 0.80 | - | - |
| Average | 0.38±0.01 | 0.54±0.02 | 0.79±0.03 | 1.14±0.04 | 1.34±0.02 |

Comments -

Individuals 7-12 did not reach fifth instar because of B. bassiana infection.

In field populations the above range of head capsule widths for the different instars are prominent but there are also individuals with head capsules between these sizes. This would probably be due to nutritional factors and the inclusion of Desiantha maculata larvae in field populations.

Conclusions -

D. caudata larvae pass through five instars. The head capsule widths are recorded in the above tables.

3.416 To determine the rate of growth of D. caudata larvae in laboratory cultures:

(1) The following summary of the rate of growth of larvae at 10°, 15° and 20°C has been collected from a number of trials where these estimates could be extracted. The 20°C figures have the most meaning since they come from a trial where the trays were checked every 3-4 days. In all cases the larvae were reared in ice-cube trays with moist soil and wheat.

Time (days) after hatching to reach the following instars:

| Temp. | 2nd | 3rd | 4th | 5th | Pupation |
|---|---|---|---|---|---|
| 10°C | - | - | - | 105 | 157 |
| 15°C | 16 | 45 | 67 | 81 | 109 |
| 20°C | 10.5±3.5 | 19.6±2.8 | 27.0±4.5 | 31.5±4.7 | 57.0±8.7 |

These results show the expected increase in rate of growth with an increase in temperature.

(2) The rate of growth of larvae in moist soil at 20°C fed on barley grass tillers and wheat, respectively, were compared (3.411).

| Food | Time (days) after hatching to reach 5th instar | Pupation |
|---|---|---|
| Wheat | 31.5 | 57 |
| Barley grass tillers | 38.5 | 63 |

There appeared to be little difference in growth rates, but the recovery of larvae from the barley grass tillers was not as consistent since the tillers decayed rapidly.

(3) In 3.416, the time taken for the first three moults at 20°C was recorded but the time taken to reach the fifth instar and pupation was not valid since the incubator broke down.

Time (days) after hatching to reach

| 2nd instar | 3rd instar | 4th instar |
|---|---|---|
| 11.7±2.9 | 20.2±2.9 | 28.0 |

These time intervals compared closely with those extracted from previous experiments for larvae reared at 20°C.

3.417 Useful techniques when rearing D. caudata larvae in ice-cube trays:

The following factors have helped to give suitable conditions for rearing larvae in ice cube trays:

(1) The best recoveries were made in cultures using wheat and moist soil in ice cube trays when sieved R.B.E. soil was used. The screenings from a 0.5 m.m. sieve gave the best results.

(2) The most suitable moisture content for the soil ranged from 12.0% w/w with the heavier soils to 9.0% w/w with the lighter soils. At these percentages there was sufficient moisture to protect the larvae from dehydration and to germinate the wheat but the soil was not damp enough to encourage extensive fungal growth, rot the wheat, nor adversely effect larval development.

(3) Before wheat was used in the trays it was swelled on damp tissue paper for 2-3 days to provide an immediate food source for the larvae.

3.418 Summary

(1) The following method gave the most satisfactory rearing technique for D. caudata larvae in the laboratory:

The larvae were individually placed in the cubes ($1\frac{1}{2}$ cm x $1\frac{1}{2}$ cm x 1 cm deep) of cocktail ice cube trays with a whole wheat grain. The cube was filled with sieved (0.5 m.m. sieve) R.B.E. soil which had 9-12% moisture content. The tray was covered with moist blotting paper and sealed in a plastic bag to maintain even moisture and prevent the cubes from drying out between checks.

If fungus is a problem this can be checked by sprinkling sorbic acid (1%) dust on the surface of the soil under the blotting paper. This method of application of sorbic acid is not toxic to larvae.

The trays were best kept at 15-20°C. The lower will help to reduce fungal problems while the rate of growth of larvae will be faster with the higher. Newly hatched larvae have pupated after 7 weeks at 20°C. Usually fungus was too much of a problem at temperatures higher than 20°C, even with sorbic acid.

Trays should be checked every 7 to 10 days to replace the soil and provide new food. At each check new blotting paper and a clean plastic bag should be used. This reduced fungal problems and helped to reduce the spread of disease.

(2) First, second, and early third instar larvae should be reared as above to prevent cannibalism, but older instar larvae may be bulk reared in crispers with moist soil and germinating wheat. Bulk rearing was not as tedious and time consuming as the ice cube trays.

(3) Soil sterilized by autoclaving should not be used to rear first instar larvae. Such soil had the organic matter broken down and was toxic to these larvae.

(4) Wheat sterilized by autoclaving was caramelized and toxic to larvae.

(5) Light sandy soil was unsatisfactory in the ice cube trays because of its low water holding capacity - it was difficult to maintain a suitable moisture level.

## 4. LIFE CYCLE OF D. CAUDATA

The life cycle of D. caudata was established from field experience and laboratory observations and trials.

The adults emerge in early November and spend the summer protected under stones, clods of soil, or any material lying on the soil surface. The females are sexually immature when they emerge; the ovaries are fully developed with eggs ready to lay by March and there is active mating and oviposition with the autumn rains. Eggs are laid singly in the soil only under moist conditions. The eggs hatch after two and a half to three and a half weeks, but the eggs can withstand dry periods where the larvae become fully developed within the chorion but eclosion does not occur. Females can lay over 80 eggs in a period of about four months. With this extended oviposition period and a difference in the rate of growth between larvae, there is a wide range of larval instars found in the field during winter.

Larvae are strongly photonegative and spend their entire life in the soil. The larvae pass through five instars and can develop on coarse organic matter but prefer living plant tissue. In fields other than cereal crops they are closely related with barley grass. Barley grass can support very high densities of larvae (greater than 50 larvae per square foot) without showing a significant reduction in growth.

Pupae can be found as early as September, though most are found during late October-November. The larvae pupate in earthern cells 4-6" deep and the adults emerge after 2-3 weeks.

## 5. FACTORS AFFECTING THE LIFE CYCLE OF D. CAUDATA

The effects of various factors on adult survival and oviposition were studied to understand the variation in the intensity and distribution of D. caudata damage to cereals from year to year.

In 1966/67 a trial was carried out to find the effect of temperature (15°, 20°C), moisture, and food (wireweed and wheat grains) at 12¼ hours light on the survival and egg-laying of recently emerged D. caudata adults (collected from Hilltown during the first week of December). Each replicate was set up in a petri dish with folded tissue paper for the oviposition site. The trial was biased by dense fungal growth with the moist treatments and early adult mortalities, but it was evident that females required moist conditions for oviposition. Females kept at 20°C in moist conditions with wireweed were the most suitable conditions for oviposition.

5.1 To determine the effect of temperature, moisture, and food on survival, ovary development, and oviposition of newly emerged D. caudata adults in the laboratory and to compare their survival and ovary development with adults in the field:

The beetles were collected at Tarlee on 9/11/67 from a paddock where a wheat crop was damaged by D. caudata in the previous winter. The adults had emerged during the previous two weeks. They were kept under the same conditions as the field (dry, no food) for four days to preclude damaged beetles from the trial.

The adults for each treatment were placed in plastic containers (7" x 5" x $2\frac{1}{2}$") which had about $1\frac{1}{2}$" of soil on the base with clods of soil scattered on the surface. These clods simulated sheltering niches which were preferred by the beetles in the field for protection. A folded wad of tissue paper was included in each container for oviposition.

There was one container for each treatment with twenty females and sixteen males. The treatments were:

1. 20°C, dry, food (20 DF)
2. 20°C, dry, no food (20 D)
3. 20°C, moist, food (20 MF)
4. 25°C, dry, food (25 DF)
5. 25°C, moist, food (25 MF)

The food was wireweed, a summer annual weed found in areas that have reported D. caudata damage. Moisture was applied to the folded tissue paper only and not to all the soil in the moist treatments. This helped to reduce the fungal problem which occurred in previous trials, and since females required moisture for oviposition, most of the eggs would be laid in the tissue paper and not in the soil, thus making it easier to assess egg numbers. The day length for all treatments was 12 hours.

Each container was inspected every two or three days for as long as adults survived. With each inspection

(1) the number of dead adults was recorded

(2) the wireweed was replaced in the treatments with food

(3) the pad of tissue paper was checked for eggs and either put back or changed depending on the number of eggs present, and the extent of fungal growth in the moist conditions.

A female from each treatment was dissected to study ovary development at 0, 23, 52, 72 and 97 days. Ovary development in females collected from the field (Tarlee) at regular intervals through summer were recorded. The development of ovaries was recorded as five separate stages. Adult survival in the field was also estimated.

The rainfall pattern and conditions of the area where the beetles were collected was recorded.

Treatment 2. (20°C, dry, no food) suffered very high adult mortalities after 70 days and the remaining adults were evenly divided and placed with the following conditions

(a) 20°C, dry, food

(b) 20°C, moist, food

There were not sufficient adults to have a no food treatment.

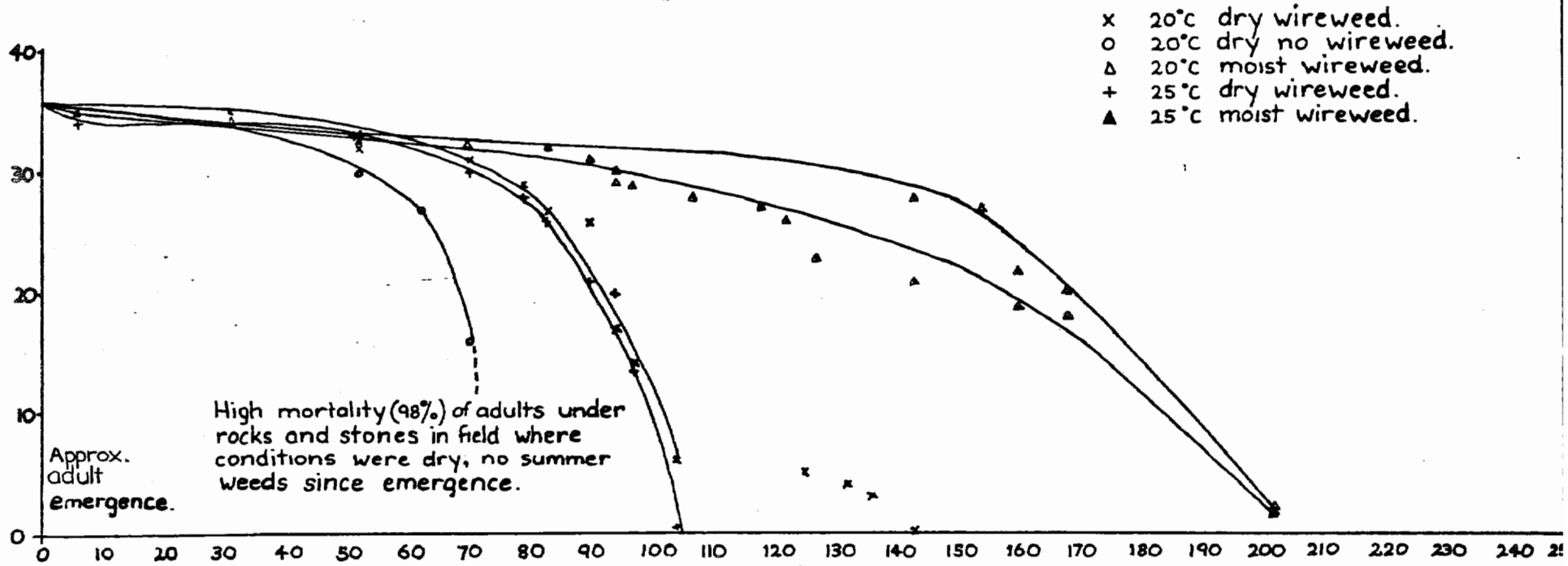
Results:

1. Adult survival -

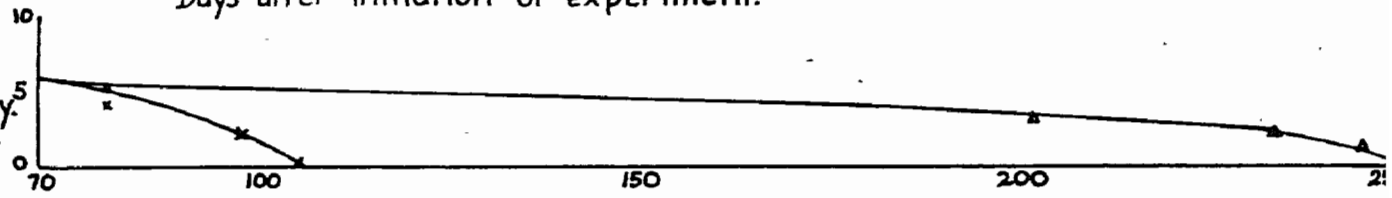
Table 1: The accumulative total of the number of adults dead for each treatment in the laboratory. (This table only includes days where there was a change in adult numbers in any of the treatments and not those inspection days where no deaths had occurred).

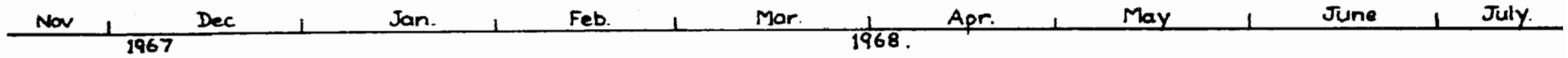
| Treatments | Days 3 | 30 | 31 | 52 | 62 | 70 | | 79 | 83 | 90 | 94 | 97 | 104 | 107 | 118 | 122 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 DF | 0 | 0 | 1 | 4 | 4 | 5 | | 7 | 9 | 10 | 19 | 22 | 30 | 30 | 30 | 30 |
| 20 D | 0 | 0 | 0 | 6 | 9 | 20 | (a) | 2 | 2 | 2 | 2 | 4 | 6 | All dead | | |
| | | | | | | | (b) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 20 MF | 0 | 2 | 2 | 3 | 3 | 4 | | 4 | 4 | 4 | 7 | 7 | 7 | 7 | 7 | 7 |
| 25 DF | 2 | 2 | 2 | 3 | 3 | 6 | | 8 | 10 | 15 | 16 | 22 | 36 | All dead | | |
| 25 MF | 1 | 1 | 1 | 3 | 3 | 3 | | 3 | 4 | 5 | 6 | 7 | 7 | 8 | 9 | 10 |

111 — THE EFFECT OF TEMPERATURE, FOOD AND MOISTURE ON THE SURVIVAL OF ADULT D. caudata.




Number of adults taken from 20°C dry, no wireweed and put into 20°C moist wireweed and 20°C dry wireweed respectively. (5♀, 1♂ in each). After 70 days.



| Treatments | Days | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 125 | 127 | 132 | 136 | 143 | 146 | 160 | 168 | 202 | 232 | 234 | 237 | 246 | 251 |
| 20 DF | 31 | 32 | 33 | 33 | 36 | All dead | | | | | | | | |
| 20 D (b) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 4 | 4 | 5 | 6 All dead |
| 20 MF | 7 | 7 | 7 | 8 | 8 | 9 | 14 | 14 | 34 | 36 | All dead | | | |
| 25 DF | All dead | | | | | | | | | | | | | |
| 25 MF | 13 | 13 | 13 | 15 | 15 | 15 | 17 | 18 | 34 | 34 | 34 | 36 | All dead | |

See Graph III

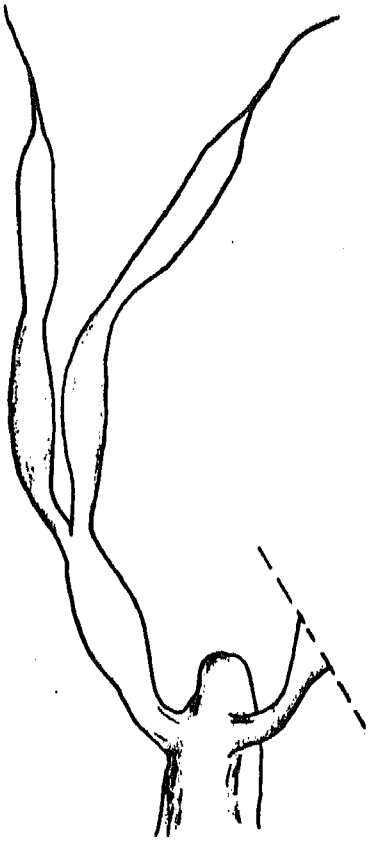
Table 2: The number of dead and alive adult D. caudata found under stones and clods of soil on the surface in the field (Tarlee) 65 days after the approximate adult emergence.

| | Alive | Dead | % Mortality |
|---|---|---|---|
| Females | 8 | 334 | 97.7 |
| Males | 6 | 254 | 97.7 |
| Total | 14 | 588 | 97.7 |

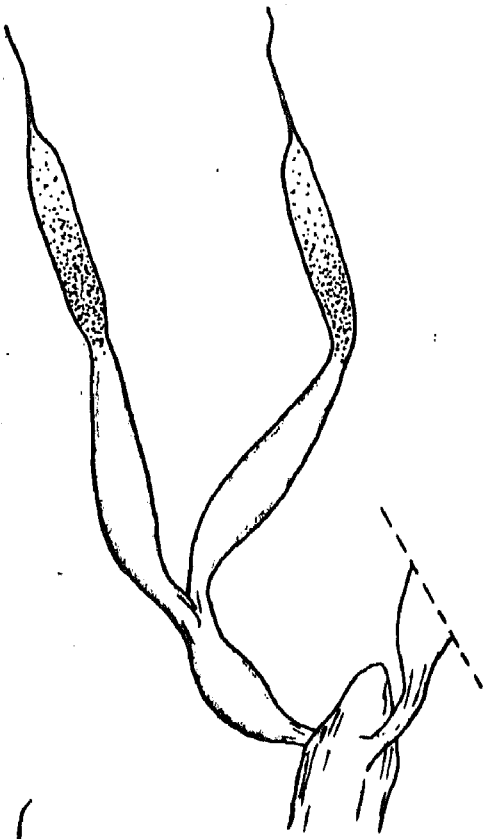
2. Ovary Development -

The development of ovaries was classified into five stages (see diagrams).

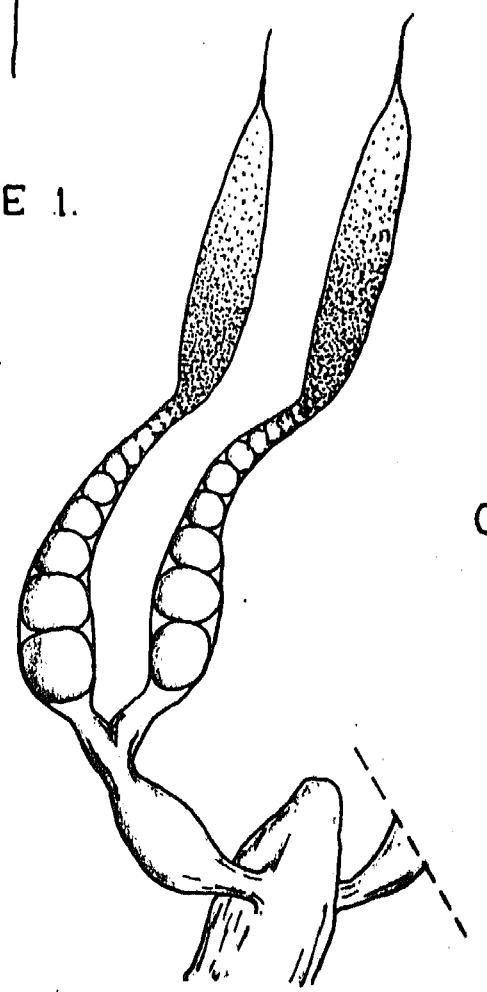
Stage 1 - very small, transparent
Stage 2 - Opaque
Stage 3 - Opaque, material separating into eggs
Stage 4 - Fully developed eggs, but not in lateral oviduct
Stage 5 - Fully developed eggs in lateral oviduct ready to be laid.



STAGE 1.

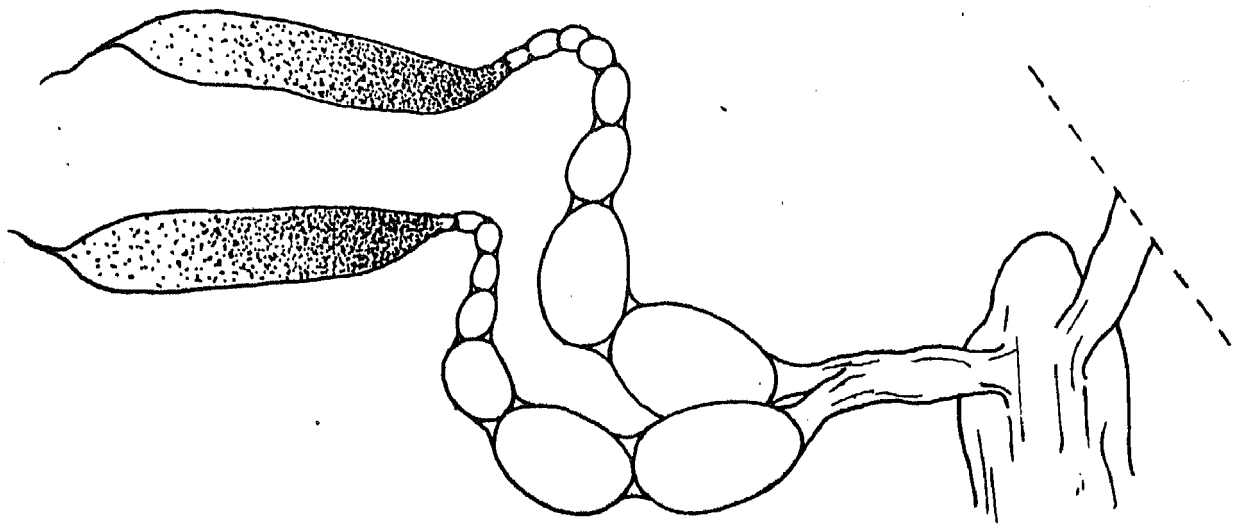


STAGE 2.



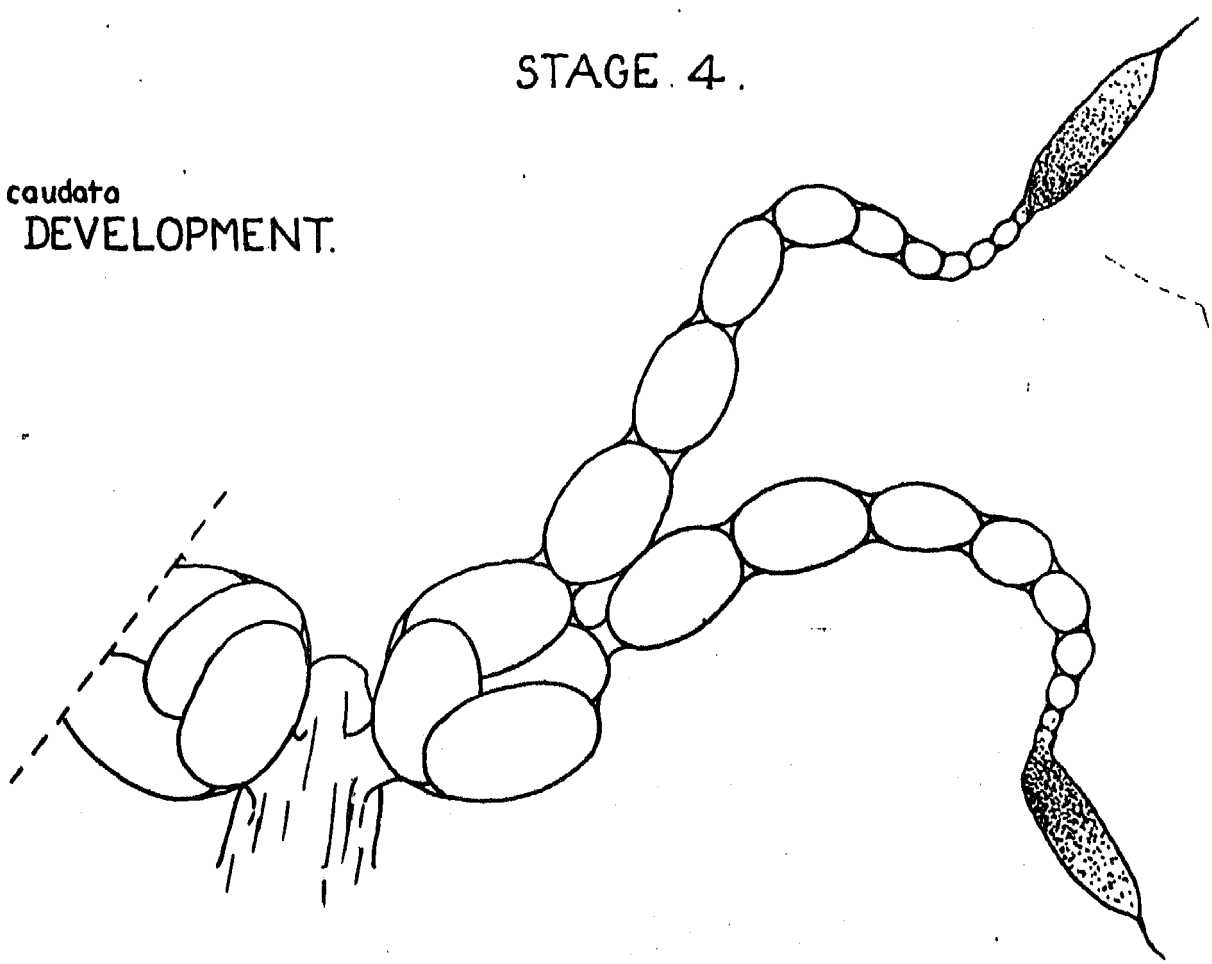
STAGE 3.

D. caudata
OVARY DEVELOPMENT.



STAGE. 4.

D. caudata
OVARY DEVELOPMENT.



STAGE 5.

Table 3: The stage of ovary development in females from each treatment in the laboratory:

| Treatment | Days 0 | 23 | 52 | 72 | 97 |
|---|---|---|---|---|---|
| 1. 20 DF | 1 | 2 | 2 | 2 | 2 |
| 2. 20 D | 1 | 2 | 2(a) | 2 | – |
| | | | (b) | 2 | 4 |
| 3. 20 MF | 1 | 2 | 2 | 2 | 4 |
| 4. 25 DF | 1 | 1 | 1 | 2 | – |
| 5. 25 MF | 1 | 1 | 1 | 2 | 4 |

Table 4: The stage of ovary development at different times of the year for females in the field (Tarlee).

| Date of Collection from field | Days after initiation of trial in laboratory | Stage of development |
|---|---|---|
| 9/11/67 | -5 | 1 |
| 21/11/67 | 7 | 2 |
| 4/12/67 | 20 | 2 |
| 18/12/67 | 34 | 2 |
| 18/1/68 | 65 | 2 |
| 9/2/68 | 87 | 3 |
| 15/2/68 | 93 | 3 |
| 1/3/68 | 108 | 3 |
| 15/3/68 | 122 | 4 |
| 2/4/68 | 144 | 5 |

IV — RAINFALL AT TARLEE — 1967/68 SUMMER.

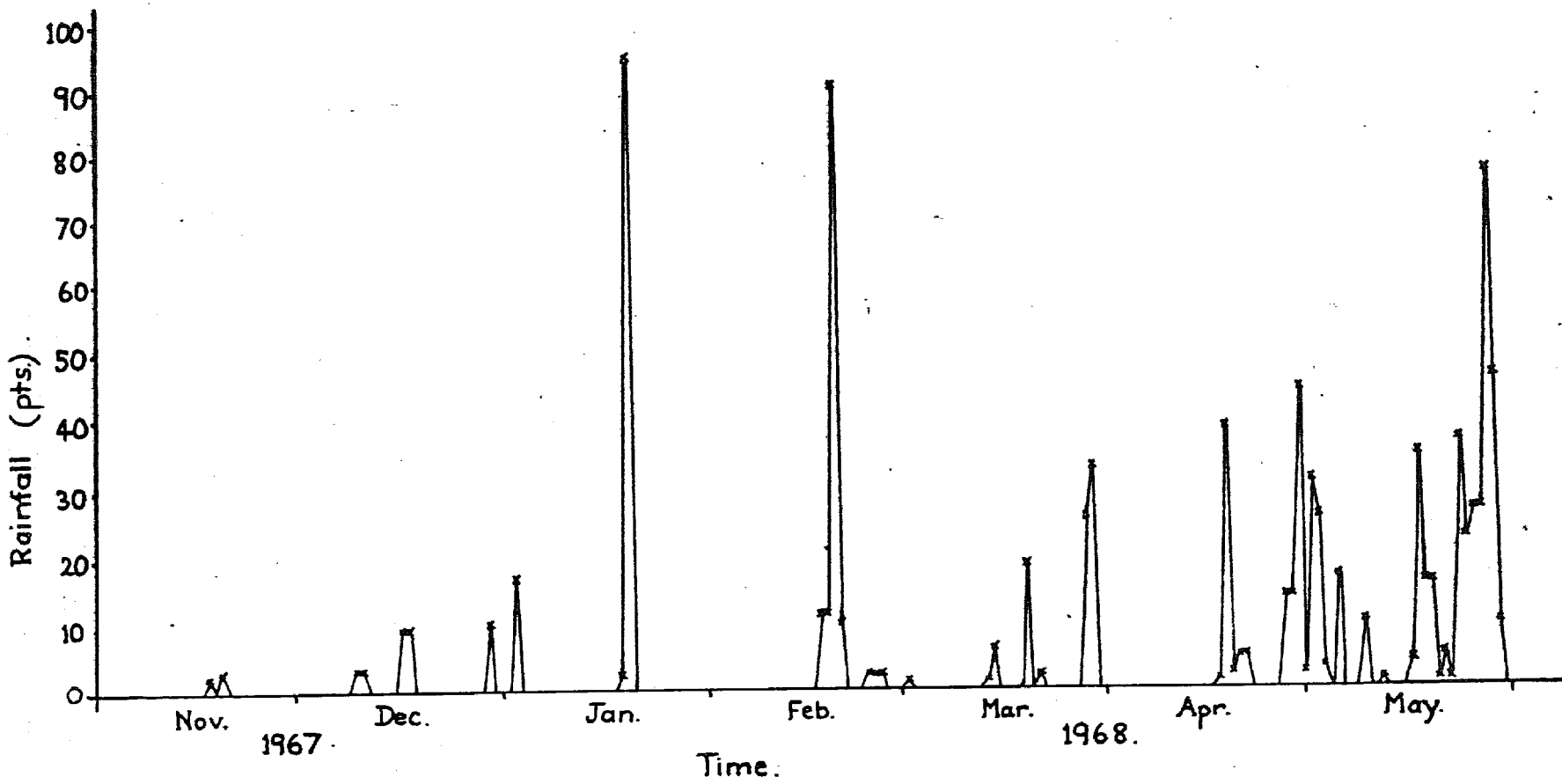


Table 5: A comparison of the rate of ovary development in females in the laboratory with the development in females in the field.

| | Nov. | | | | Dec. | | | | Jan. | | | | Feb. | | | | Mar. | | | | Apr. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WEEKS | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 |
| 20 DF | 1 | | | | 2 | | | | 2 | | | 2 | | | 2 | 2 | - | | | | | |
| 20 D | 1 | | | | 2 | | | | 2 | | (a) | 2 | | | - | | | | | | | |
| | | | | | | | | | | | (b) | 2 | | | 4 | * | | | | | | |
| 20 MF | 1 | | | | 2 | | | | 2 | | | 2 | | | 4 | | | | | | * | |
| 25 DF | 1 | | | | | | | | 1 | | | 2 | | | - | | | | | | | |
| 25 MF | 1 | | | | | | | | 1 | | | 2 | | | 4 | | | | | | * | |
| FIELD | 1 | | 2 | | 2 | | 2 | | | | 2 | | | 3 | 3 | | 3 | | 4 | | 5 | |

* - first eggs.

3. Conditions at Tarlee for 1967/68 summer:

   a. Rainfall - see Graph IV.

   b. Field Conditions - The adults were collected from a paddock which had a cereal crop damaged by D. caudata larvae in the previous winter. The crop was very thin because of both grub damage and the drought conditions. When the adults first came to the surface in November there was sparse wireweed present but this dried off and during the summer, even after the January and February rains, there were no annual summer weeds. The crop stubble was grazed by sheep leaving the surface bare.

Comments -

The adults used in this trial emerged within two weeks prior to the commencement of the trial; many of the adults used were not fully hardened from emergence. Dissections of a series of females showed that the ovaries were immature with no sign of development and there had been limited feeding only on green material, probably wireweed which was present in small amounts amongst the stubble.

Adult survival -

The adult survival was independent of temperature for the range 20-25°C and the treatments for the two temperatures acted as replicates for the food and moisture treatments. This indifference to temperature was probably due to the small range tested.

The best adult survival was found when both moisture and wireweed were present from emergence. Over 50% of these adults survived until the end of April and a few were still living up to June. The survival of adults till June corresponded with field observations where adults had been found in June in cereal crops damaged by D. caudata larvae at Hilltown (1966) and Tarlee (1967).

Adults in dry conditions with food suffered an 80% mortality by the end of February and a few adults (7%) survived until the end of March. This reduction in survival showed that adults needed moisture as well as food.

The absence of food and moisture caused high mortalities during January; 50% died within two weeks of emergence. In the field at Tarlee there was a very high mortality (98%) of adults sheltering under rocks, clods of soil, etc., on the soil surface during January. The conditions in the field were similar to the dry, no food conditions in the laboratory since there had only been a scattered 57 points of rain (Graph IV) since adult emergence and all the wireweed had died. The mortalities in the laboratory and field showed that D. caudata adults kept under dry conditions without food died within two to three months of emergence.

The survival of the adults which were transferred from the dry, no food treatment to the dry with food and moist with food treatments, respectively, closely followed the trend seen with similar treatments in the main part of the experiment (eve: though the number of adults were low). The presence of food only extended the survival to the end of February and with food and moisture most of the adults remained alive into July. This demonstrated that initial adverse conditions were not carried over in the population if the conditions were improved within ten weeks.

Moisture and food gave better survival in this trial compared to food only, but a further trial will have to be carried out to test the effect of moisture only to see whether a combination of both is critical or whether moisture only is necessary. In the field moisture would be the most critical since good summer rains usually produce summer annual weed growth in the areas affected by D. caudata larvae.

Ovary and Egg Development -

The female ovaries were small and transparent at adult emergence; within two weeks the material in them became opaque and the ovaries developed in size. After this, the growth of the ovaries was independent of external conditions, but the development of eggs within the ovaries was dependent on moisture.

Adults kept in dry conditions did not develop eggs even though food was present in some treatments. The ovaries grew in size but remained opaque up to the death of all the beetles by the end of February. Females kept in moist conditions since emergence contained fully developed eggs in mid-February and began ovipositing at the end of March. This occurred at both 20°C and 25°C. The adult's requirement for moisture for egg development was further shown with those females taken from the dry, no food treatment and placed in dry, with food and moist, with food conditions, respectively. Those females in the dry conditions did not develop eggs while those in the moist conditions did. Fully developed eggs were found in these females by mid-February which was similar to the time when fully developed eggs were found in females kept in moist conditions since emergence.

In the field, females with fully developed eggs were first detected in mid-March, indicating that there was a period of nearly four months necessary for egg development before oviposition could occur in 1967 Keeping females in continuous moist conditions since emergence only reduced this time by about a month which meant that a three month period was necessary for full egg development even under the apparent optimum conditions.

Oviposition -

Previous trials showed that gravid D. caudata females do not oviposit in dry conditions. In this trial eggs were not laid in dry conditions because the ovaries did not become fully developed with eggs ready to lay.

In all treatments with moisture the females laid eggs. An assessment of the number of eggs per female for each treatment could not be made since the females were dying during the oviposition period.

Females in moist conditions at both 20°C and 25°C began laying eggs at the end of March and oviposition continued for a period of about two months.

Neither active oviposition nor eggs had been seen in the field, but dissections of females from the field showed that eggs were first ready to be laid by the end of March.

Observations on egg development and oviposition habits of D. caudata females indicated that oviposition coincides with the autumn rains.

Summary -

1. The survival of D. caudata adults through the summer and autumn months was necessary for maximum egg production. Conditions adverse to this survival decreased the potential larval numbers in the next generation.

   The survival was necessary since:

   a. There was a delayed period required for ovary maturation and egg development in female D. caudata. The shortest time for full development was about three months when females were kept in continuous moist conditions since emergence and this was delayed to four months in the field.

   b. Females required moist conditions for oviposition and copulation had not been seen in the field prior to mid-March; this suggested that oviposition occurred during the autumn months.

   c. Females oviposited for a period of about two months and did not lay all their eggs in one batch.

2. Adult survival was dependent on moisture and food. Under dry conditions without food very high mortalities occurred within two and a half months from emergence. Survival was improved by providing food but the best survival was found with food and moisture.

3. Complete ovary development and egg formation only occurred when females were kept in moist conditions.

Application -

The results from this trial have been used to form a hypothesis explaining the absence of D. caudata damage in cereal crops sown after fallows or in successive cereal crops in South Australia, and to help forecast years when D. caudata damage could occur in susceptible crops.

In South Australia, fallows are usually kept weed free throughout the summer months and the resulting dry conditions without food are adverse conditions for the survival of the adults sheltering on the surface. This reduction of adults over summer before oviposition occurs, together with the understanding that there are not mass migrations of adults from one paddock to another which prevents reinfestation, can explain why damage does not occur in crops following fallows. Examples supporting this hypothesis were seen in two situations found in the field. At Rutherglen, Victoria, a pasture was ploughed in November (1966), but only half of the area was kept as a "clean" fallow throughout the summer. The whole paddock was sown to wheat in the next year and only that crop sown on the area which was not kept "clean" was damaged by D. caudata larvae. A similar observation was made at Tarlee in 1966/67 where a paddock was ploughed in November and allowed to become over-run with summer annual weeds; the cereal crop sown in the next season was severely damaged by D. caudata larvae. In both these situations poor fallow management had resulted in suitable conditions for adult survival through the summer months.

The absence of damage in successive cereal crops in S.A. is probably a similar situation to fallows since most stubble paddocks are heavily grazed early in the summer and remain relatively bare for the rest of the summer. Some adults survive in stubbles but the larval densities in the next generation have not been great enough to cause significant damage. In Victoria, damage has occurred in successive crops and this could be due to annual summer weeds in the stubble.

Food was necessary within two and a half months from adult emergence for adult survival to the end of February and then moisture was necessary to ensure that this survival extended over the full egg laying period. Since widespread annual summer weeds in the field are associated with good summer rains, moisture would probably be the more important factor when adult survival in the field is studied in relation to the frequency of larval damage. If the influence of the rainfall distribution on adult survival is understood, it could be used as an aid to forecast years when D. caudata larvae are likely to be a problem in susceptible cereal crops in an area.

In 1968 there were no reports of D. caudata damage to cereals and only very low grub densities were found at Auburn and Saddleworth. This absence of damage was expected since there was a high adult mortality in the field during the 1967/68 summer because of the lack of moisture and summer annual weeds for the first two months after adult emergence.

5.2 To determine the effect of food on survival, ovary development and oviposition of D. caudata adults kept in moist conditions at 20°C:

The previous trial (5.1) showed the necessity of moisture for good adult survival and full ovary development in the presence of food. Adults kept in dry conditions with food survived longer than adults kept in dry conditions without food, but the full effect of food on survival and ovary development could not be assessed.

Newly emerged adults (9 females, 10 males) were placed in a plastic container (7" x 5" x $2\frac{1}{2}$") with about 1" of soil on the bottom and a moist pad of tissue paper for oviposition and to supply moisture. The container was kept at 20°C. This was the only treatment which was set up at this time because of the scarcity of adults.

Twenty nine days later fully emerged adults were collected in the field at Auburn and kept in large containers with moisture and food. In the field these adults were in moist conditions with food since there was above average rainfall in the area during November and December. These beetles were used as a check on the survival of adults (see 5.1). After three months, during which time there were very few deaths, 10 females and 10 males were placed in a smaller crisper with food and moisture to keep a closer check on mortalities.

Twenty males and twenty females of these fully emerged adults were also placed in moist conditions without food knowing that they had already been in moist conditions with food in the field for about a month. After 174 days the adults in this treatment suffered high mortalities and there were no signs of oviposition. The remaining five females were transferred to crisper (3) and individual tubes (2) with moisture and food at 20°C. Males from the laboratory were provided in each container.

This trial was sampled and checked as in 5.1 except that dissections to assess ovary development were made only on newly emerged females and females surviving after 81 days in moisture without food from emergence.

Results:

Table 1: The accumulative total of the number of adults dead for each treatment at 20°C.

a. Moisture, no food

| *Days | 0 | 4 | 5 | 8 | 12 | 15 | 18 | 22 | 25 | 29 | 32 | 35 | 39 | 49 | 54 | 57 | 61 | 64 | 67 | 71 | 75 | 78 | 81 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Males | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 6 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 9 |
| Females | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 4 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 6 | 7 | 7 | 7 |
| Total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 | 9 | 11 | 11 | 12 | 13 | 13 | 13 | 14 | 14 | 15 | 15 | 16 | 16 | 16 |

No eggs laid

b. Moisture, food

| *Days | 92 | 97 | 100 | 103 | 107 | 111 | 113 | 118 | 121 | 125 | 128 | 132 | 138 | 141 | 145 | 149 | 153 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Males | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 3 | 4 | 4 | 6 | 7 | 7 | 7 | - |
| Females | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 5 | - |
| Total | 0 | 0/ | 0 | 0 | 1 | 1 | 3 | 5 | 5 | 6 | 7 | 8 | 10 | 12 | 12 | 12 | 14 |

| *Days | 156 | 161 | 167 | 174 | 181 | 189 | 196 | 203 | 210 |
|---|---|---|---|---|---|---|---|---|---|
| Males | - | 9 | 9 | 10 | 10 | 10 | 10 | 10 | 10 |
| Females | - | 6 | 6 | 6 | 6 | 7 | 8 | 8 | 10 |
| Total | 14 | 15 | 15 | 16 | 16 | 17 | 18 | 18 | 20 |

c. Moisture, no food - Adults collected from field approx. 29 days after emergence

| *Days | 29 | 34 | 37 | 41 | 51 | 56 | 59 | 63 | 66 | 69 | 73 | 77 | 80 | 83 | 87 | 91 | 94 | 97 | 101 | 104 | 108 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Males | 0 | 2 | 2 | 2 | 2 | 3 | 5 | 6 | 6 | 7 | 7 | 7 | 7 | 8 | 9 | 13 | 13 | 13 | 13 | 14 | 14 |
| Females | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 4 | 4 | 4 | 5 | 5 | 5 |
| Total | 0 | 2 | 3 | 3 | 3 | 4 | 7 | 8 | 8 | 9 | 9 | 9 | 9 | 10 | 11 | 17 | 17 | 17 | 18 | 19 | 19 |

*Approximate number of days after initial emergence of adults
/First eggs

c. Moisture, no food etc. (Cont'd)

| *Days | 112 | 115 | 119 | 122 | 126 | 129 | 132 | 136 | 140 | 142 | 147 | 150 | 154 | 157 | 161 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Males | 14 | 15 | 15 | 15 | 15 | 16 | 16 | 17 | 17 | 18 | 18 | 19 | 19 | 19 | 19 |
| Females | 7 | 8 | 9 | 9 | 9 | 9 | 9 | 11 | 11 | 12 | 13 | 13 | 13 | 14 | 14 |
| Total | 21 | 23 | 24 | 24 | 24 | 25 | 25 | 28 | 28 | 30 | 31 | 32 | 32 | 33 | 33 |

| *Days | 167 | 170 | 174 |
|---|---|---|---|
| Males | 19 | 19 | 20 |
| Females | 15 | 15 | 15 |
| Total | 34 | 34 | 35 |

No eggs laid

d. Females from C. placed into crisper (3) and individual tubes (2) with moisture and food after 174 days.

| | Crisper | | | | | | | | | | Tube 1. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Days | 174 | 182 | 190 | 196 | 203 | 210 | 218 | 225 | 232 | 239 | 174 | 182 | 190 |
| Males | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| Females | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 0 | 0 | 1 |
| Total | 0 | 2 | 2/ | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 0 | 0 | 2 |

| | Tube 2. | | | | |
|---|---|---|---|---|---|
| *Days | 174 | 182 | 190 | 196 | 203 |
| Males | 0 | 0 | 0 | 1 | 1 |
| Females | 0 | 0 | 0 | 0 | 1 |
| Total | 0 | 0 | 0/ | 1 | 2 |

*Approximate number of days after initial emergence of adults

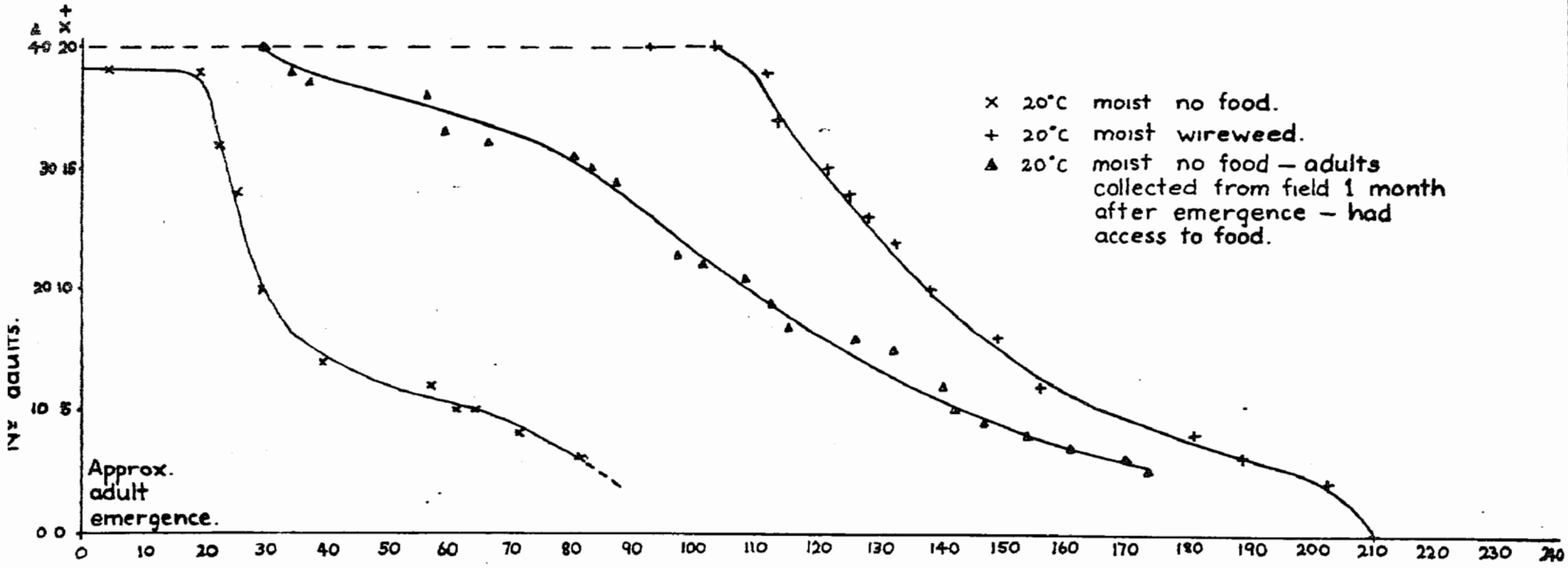
/First eggs

See Graph V.

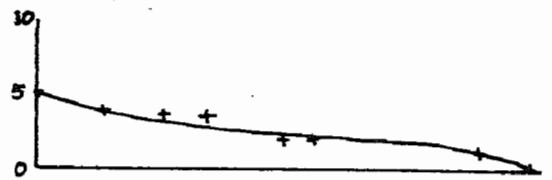
Comments -

Adults in the moist, no food treatment since emergence suffered high mortalities in a short period (50% in a month). When adults were left for a month in the field where food was available before being placed without food, the decline in numbers was more gradual, but 50% of the adults died after about three months without food. The initial feeding improved the survival of adults when they were placed without food compared to adults placed without food which had not fed, but there was still a high mortality within three months which indicated that adults need to feed periodically throughout the summer.

# V — THE EFFECT OF FOOD ON THE SURVIVAL OF ADULT D. caudata.




№ adults transferred from 20°C moist no food to 20°C moist wireweed after 174 days.



The survival of adults kept in moist conditions without food was comparable to the survival under the same conditions in 5.1 (c.f. Graph V with Graph III).

There was no egg development in females which had survived for 81 days in the moist, no food treatment since emergence. Females provided with moisture and food began oviposition 97 days after emergence but those females which had fed for a month and were then kept in moist conditions without food did not begin oviposition after 174 days. After 174 days the surviving females were given food and oviposition began after a further 16 days. These observations showed that food was necessary for egg development.

Conclusions -

The results of 5.1 and this trial showed that D. caudata adults required both food and moisture from emergence for good survival and egg development. Moisture was necessary for oviposition.

Initial feeding by adults increased their resistance to periods without food but there was still a high mortality within three months without food, hence adults need food throughout the summer for good survival within a population.

Application -

The necessity of food for adult survival and egg development does not alter the hypotheses described under Application in 5.1 since food (summer annual weeds) are dependent on rainfall (moisture) in the field.

Since adults need food throughout the summer for good survival within a population there could be a critical fallow period of at least three months which could reduce a population to an uneconomic level. This hypothesis could be tested in a trial measuring the change in population levels in areas with different lengths of fallow prior to sowing.

In laboratory cultures of adults, summer annual weeds should be provided as food. Experience has shown that wireweed (Polygonum aviculare) is convenient.

## 6. ACKNOWLEDGMENTS

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## 8. APPENDIX I

### Acreages of wheat grown for grain sown on fallowed and non-fallowed land

| County | Year | Fallowed (acres) | Non-fallowed (acres) | % sown on fallowed land |
|---|---|---|---|---|
| Light | 1940/41 | 64,130 | 1,387 | 98.0 |
| | 1951/52 | 42,744 | 2,798 | 94.0 |
| | 1960/61 | 28,771 | 24,804 | 54.0 |
| Stanley | 1940/41 | 192,354 | 6,135 | 97.0 |
| | 1951/52 | 127,064 | 9,069 | 93.0 |
| | 1960/61 | 62,886 | 87,983 | 42.0 |
| Victoria | 1940/41 | 155,509 | 10,024 | 94.0 |
| | 1951/52 | 72,926 | 13,118 | 85.0 |
| | 1960/61 | 38,206 | 88,257 | 30.0 |
| Dalhousie | 1940/41 | 67,171 | 5,368 | 93.0 |
| | 1951/52 | 25,800 | 3,085 | 89.0 |
| | 1960/61 | 11,293 | 30,373 | 27.0 |