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Studies on the sterile-male technique as a means of control of Adoxophyes orana (Lepidoptera, Tortricidae) 4. Technical and economic aspects of mass-rearing

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Abstract

Adoxophyes orana could be mass-reared on a wheat germ medium with agar as a gelating agent or with agar replaced by lucerne meal. On these media, production reached 131 and 111 moths per rearing container, respectively. Good sanitary measures and well chosen rearing conditions were important.

The rearing system was analysed and modelled by a computer programme written in Fortran IV, which allowed calculation of the optimum rearing method. The minimum cost per moth was calculated at *f*0.015 – 0.03, depending on wages and size of culture. The calculations were based on preliminary estimates and need to be refined.

Introduction

The practicality of the sterile-male technique as a method of control depends largely on the cost of mass-rearing. The natural population of males has to be overwhelmed by sterile males and ratios of 40:1 or more are often used (Proverbs et al., 1975).

In our work with *Adoxophyes orana*, a laboratory method of rearing (Ankersmit, 1968) had to be altered to a mass-rearing method. Studies by Ankersmit and Van der Meer (1973) revealed the cannibalistic behaviour of the larvae when reared in groups. This makes mass-rearing difficult and the costs per moth high.

During development of the method, we encountered many interrelated effects: for instance, a higher temperature speeds up development, thereby reducing costs because of shorter use of climate cabinets, but lowers production per rearing unit. We attempted to analyse the rearing system and to evaluate its relationships. Some parameters were unknown and were estimated. The constructed model was useful in our effort to optimize mass-rearing. Our mass-rearing system is, however, still in the experimental phase. Definite steps towards large-scale breeding, as is necessary for extensieve field use, were not made, as this involves provisions like further automation and high costs for housing facilities. Because of the limited prospects of use of the sterile-male technique against *A. orana* (Ankersmit, 1975), this step was not taken.

In this paper, we describe techniques for rearing many thousands of moths per day and some of the results obtained from our calculations with the model. All prices and costs are those of 1973.

Materials and methods

Unless otherwise stated in the text, moths, eggs and larvae were always kept at 20 °C, 70% relative humidity and 16.5 h light per day.

Oviposition took place in plastic 2-litre jars, covered with a thin polythene sheet. Most eggs (80 to 90%) were laid on these sheets. Before use, the sheets were kept for at least one week in water. This was found to increase hatch. Sheets with eggs were collected daily. Each jar contained about 40 moths. Moisture was provided by a cotton pad, placed in a vial filled with water.

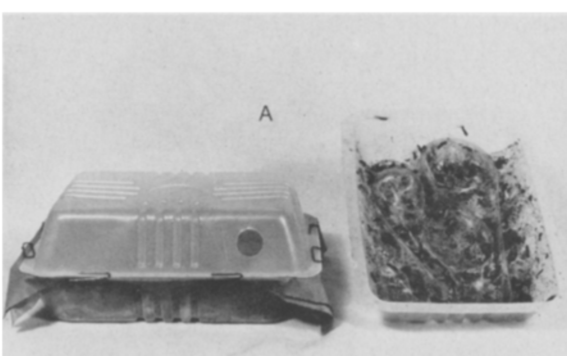
Egg development lasts 9 days. Then eggs were transferred to a refrigerator and stored for not more than 4 days until use. Larvae were reared on an artificial medium in plastic rearing containers (Fig. 1A). Attempts were also made to use larger containers (Fig. 1B). Plastic strips were added to reduce cannibalism (Ankersmit and Van der Meer, 1973). Before use, containers and strips were disinfected in plastic bags with formaldehyde vapour. The strips and covers of the containers were used again, the strips after cleaning in sodium hypochlorite solution to dissolve the silk spun by the larvae.

The medium was added to the containers in a well isolated room equipped with ultraviolet lamps to reduce contamination by fungi. Sheets with about 300 eggs were placed on a paper towel covering part of the open side of the bottom part of the container. Hatched larvae dropped from the paper onto the diet. Avoiding contact between polythene sheets, paper towels and diet reduced contamination with fungi.

The containers were then covered by two paper towels and closed by another empty container placed upside down and kept in place by paperclips.

After 35 days in a climate room (Fig. 2), when most larvae had pupated, the containers were opened and stacked in wooden emergence boxes (Fig. 3) kept in room

Fig. 1. Container used in rearing. A) Small type of container, rim size: 14.5 × 20.5 cm and 4 cm high. B) Large container used in trials to reduce labour costs, rim size: 34 × 44 cm and 9 cm high.



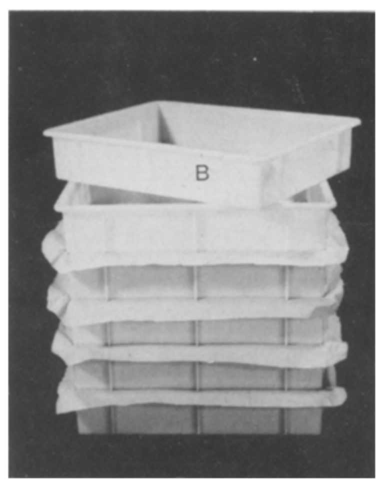


Fig. 1. Kweekbakjes die bij de massakweek werden gebruikt. A) Klein type bakje bovenrand 14.5 × 20.5 cm en 4 cm hoog. B) Groot type kweekbak dat in proeven om arbeidskosten te verminderen werd toegepast, bovenrand 34 × 44 cm en 9 cm hoog.

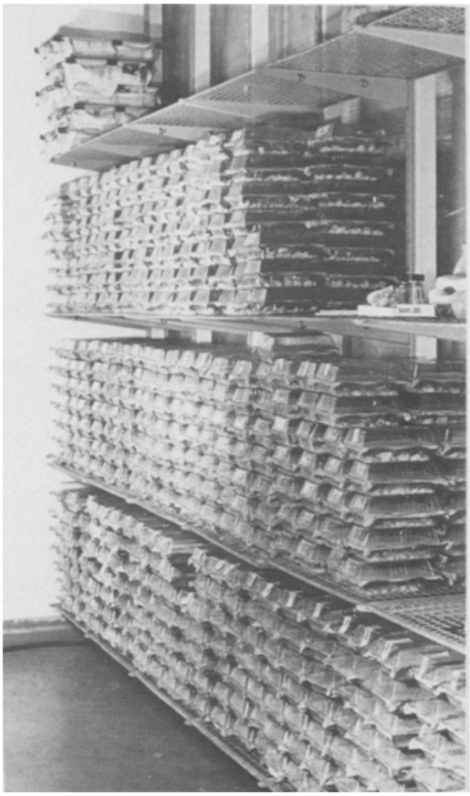


Fig. 2. Rearing containers stacked in climate room. Such a culture would produce 4000 moths per day.

Fig. 2. Opgestapelde kweekbakken in klimaatkamer. Deze kweek produceerde 4000 motten per dag.

Fig. 3. Emergence boxes for moths. Outer size 41 × 42 × 50 cm.

Fig. 3. Kisten waarin de motten uitkwamen. Buitenmaten 41 × 42 × 50 cm.

Table 1. Average weight per moth on different days calculated from four samples of 50–100 moths.

Day	Weight (mg) $\bar{x} \pm S(\bar{x})$	Day	Weight (mg) $\bar{x} \pm S(\bar{x})$
1	16.0 ± 0.8	6	15.1 ± 0.5
2	15.9 ± 1.1	7	15.0 ± 0.8
3	14.5 ± 0.7	8	15.4 ± 0.5
4	15.5 ± 0.7	9	15.2 ± 0.6
5	16.1 ± 0.5	10	14.5 ± 1.1

Tabel 1. Gemiddeld gewicht per mot op 10 verschillende dagen berekend uit vier monsters van elk 50–100 motten.

conditions for emergence of the moths. Pupae were present in the bottom part of the container and on part of the paper towels. Polythene bags were fitted with rubber bands over each of 3 plastic funnels in the 3 emergence holes (diameter 9 cm) in the wall of the emergence box. As the moths were attracted by light, they could be collected in these bags. The bags with the moths were removed daily and the moths col lected each day were bulked into one bag in a cold room (2–3 °C). They were then weighed and samples of about 100 were taken for determining the weight of individuals (Table 1) and the sex ratio. The sampling allowed calculation of the actual number of moths. As a check on the sampling method on several days all females were counted. The results showed that the calculated number was almost always a little higher than the counted one (Table 2). This was caused by a 5% loss of weight by moths when killed. Correcting for this percentage resulted in values close to the counted ones.

When the moths were to be used in release trials, they were distributed as soon as possible over some refrigerator containers and stored for not more than one day at 2–3 °C. Longer storage affected their viability (Table 3) as egg production and hatchability decreased. This effect seemed stronger at 4 °C than 8 °C. But even storing for 4 days at 12 °C strongly decreased hatchability of eggs.

Two types of medium were used. One had agar as gelating agent; in the other, agar was replaced by lucerne meal. One litre of agar-based medium was composed of (a) the nutritional components: caseine 35 g, wheat germ 30 g, sucrose 35 g, brewer's yeast 30 g, linseed oil 5 ml, choline chloride 4 g (dissolved in 20 ml water): (b) the inhibitors: sorbic acid 1.5 g, methyl-*p*-hydroxybenzoate 1.5 g, streptomycine sulphate 0.2 g; and (c) the gelating agents: carboxymethylcellulose (AKZO, Arnhem: CMC, Hz858) 5 g, and agar 20 g; (d) water 850 ml. The pH of the medium was about 4.7.

Table 2. Check on sampling method for number of females on different days.

Calculated	Counted	Corrected
753	729	715
2800	2554	2660
2132	2047	2025
2152	2045	2044
2156	2178	2048

Tabel 2. Controle op de bemonsteringsmethode voor het aantal wijfjes op verschillende dagen.

Table 3. Hatchability of eggs and egg production by moths at 20 °C when moths were stored at temperatures (t) of 4 or 8 °C. Experiments in five replicates with 5 females and 5 males.

Period of storage (days)	t = 4°C		t = 8°C	
	number of eggs	egg hatch (%)	number of eggs	egg hatch (%)
0	7385	81.5	8590	81.4
1	7522	78.7	8058	79.2
2	7034	62.6	6412	70.7
3	5912	52.2	5903	63.6
4	4537	41.0	6424	56.8

Tabel 3. Percentage uitgekomen eieren en eiproduktie van motten bij 20 °C na bewaring van de motten bij 4 of 8 °C. Proeven in vijf parallellen met 5 wijfjes en 5 mannetjes.

The medium was prepared as follows. The agar was dissolved at 95°C in water and the solution added to the other ingredients in a 3.8-litre Waring blender. After blending for 1 min at high speed (14000 min^{-1} in water) the mixture was dispended into trays, in layers of about 1 cm. After cooling in a paper bag at room temperature, the trays with medium were ready for use or stored for not more than a week in plastic bags in a refrigerator. Longer storage, however, seemed possible. Per container, 150–200 g of medium was given as small cubes (0.5–1 cm^3), providing additional protection against cannibalism. The moth emergence room where spores from many fungi from the old cultures are present, should be well separated from the medium preparation room to avoid contamination of the medium. Two holes in the covers of the containers provided ventilation to remove excess of moisture.

The composition of the lucerne meal medium was similar except that agar was replaced by 250 g lucerne meal per kg of medium, carboxymethylcellulose was omitted and 600 ml 0.1 M citric acid was used instead of water. This lowered the pH of the lucerne meal medium to about 4.5 and the sorbic acid would be dissociated enough to be effective. This mixture was blended in a bowl by an Inventum hand blender. It was not heated and 100 g per container sufficed. Ventilation of the containers by holes proved to be undesirable, as the medium then dried out too rapidly.

Results

Multiplication rate. Multiplication rate allows estimation of the size of the stock to be maintained before the actual mass-rearing period. As it takes about 50 days before the mass culture is in full production, its size has to be decided early and the availability of eggs at that moment will be the determining factor.

A culture of 40 containers per day required a parental rearing of three; a culture of 60 containers per day required a parental rearing of four containers per day.

Moth production. Table 4 presents weekly moth production from a culture of 40 containers, with agar diet, per working day (five per week) after emergence of the first moth. The gradual rise at the beginning showed that a high production was reached only in the third week while the decline at week 8 marked the end of the rearing. The weight per moth was rather constant throughout the period and males

Table 4. Moth production per week from 40 containers per working day.

Week	Weight (g)	Weight per moth (mg)	Number of moths (calc.)	Females (%)
1	72.35	15.4	4700	47.0
2	197.42	15.0	13000	49.9
3	569.51	14.9	38500	51.2
4	480.64	15.8	30200	49.5
5	514.12	15.4	33500	47.1
6	437.59	15.3	28400	46.0
7	495.37	15.3	32200	46.0
8	259.86	13.7	19100	49.6

Tabel 4. Motproduktie per week uit 40 kweekbakken per dag.

were slightly dominant. Emergence of most moths from containers started on the same day and took about 14 days (Table 5). These data illustrate the importance of choosing the moment of beginning and terminating the collecting period. Starting early means the trapping of a higher proportion of males but several larvae have not yet pupated, and crawl around in the emergence boxes. The threads they spin may block the funnels for the moths, or crawling larvae may enter the collecting bags and disturb moth collection. Collection must be terminated when production of moths is no longer profitable because of labour costs. Also their quality might be different as the weight gradually decreased. As the emergence boxes were kept at unregulated room temperature, a cold day caused a sudden drop in production on 16 October. For regular production, constant temperature is necessary. In the first mass culture, based on the agar diet, 1240 containers produced 212500 moths per container. Without the periods of low production that are of minor importance in

Table 5. Daily moth production of 41 containers started at the same day.

Date (month-day)	Weight (g)	Weight per moth (mg)		Number	
		♀	♂	♀	♂
10–12	5.47	24.2	10.5	84	294
10–13	14.81	25.2	10.5	294	511
10–14	18.33	23.5	10.0	497	620
10–15	16.28	23.3	9.8	479	493
10–16	8.91	24.0	10.2	244	286
10–17	12.01	24.8	9.0	356	271
10–18	8.72	20.7	8.6	307	225
10–19	4.56	22.2	9.4	151	124
10–20	3.88	20.9	9.0	146	89
10–21	3.31	20.3	8.6	123	79
10–22	3.23	20.6	8.6	121	66
10–23	2.08	19.6	8.3	81	54
10–24	1.63	19.2	8.7	67	30
Total	103.22			2950	3142

Tabel 5. Motproduktie per dag van 41 op één dag aangezette kweekbakken.

Fig. 4. Scheme of rearing system.

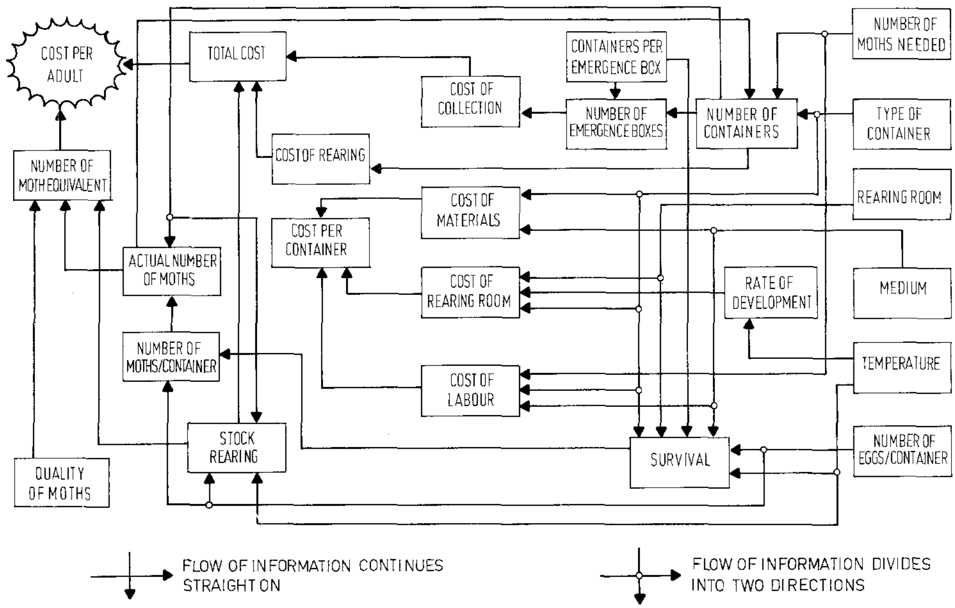


Fig. 4. Schema van het kweeksysteem.

release projects, at the beginning and end of collection, production can be estimated at 155 moths per container. In a second culture, 5500 containers produced 722000 moths or 131 moths per container. In a third, with the lucerne meal medium, an average of 111 moths per container was obtained. In a fourth culture, also with lucerne meal medium, production per container was 108 moths.

In all cultures, production was irregular. Months with productions of 160 moths per container alternated with months where production dropped to 80 moths per container. The causes were neglect of strict sanitary measures and excessive humidity in the rearing room because of poor ventilation when the containers were too closely packed.

Analysis of the rearing system. Fig. 4 shows the items and their relations used in calculations. A scheme of the program, with equations is given below. Coefficients could be estimated from small detailed trials and the results of mass rearing.

Cost per moth equivalent (output) = total cost number of moth equivalents

A moth equivalent is a hypothetical reared insect identical in mating competitiveness and other aspects of behaviour, and in lifespan with a moth developed under natural conditions.

Total cost = (cost per container) × (number of containers) + (cost of collection) + (cost of rearing parental stock)

The cost of stock rearing was added here as a total amount and not split up in labour, space and material.

Cost per container = (cost of materials) + (cost of rearing space) + (labour costs)

Cost of materials = (cost of container) + (cost of medium)

Here also depreciation of a blender could be included. However we found that even the purchase of a blender of *f* 1600 did not increase the costs of material to any extend. The cost of a large re-usable container (Fig. 1B) was estimated at *f* 0.30 included cleaning, that of a small disposable type (Fig.

1A) at f 0.07. Costs for the ingredients of the medium were f 0.12 for the lucerne meal diet and f 0.47 for the medium based upon agar when the small containers were used. In the large containers, we used seven times as much medium.

Cost of rearing space = (cost of shelving) × (duration of storage) × (factor for effect of type of climate room)

From the figures of the report of the 'Phytotron Committee' (Nationale Raad voor Landbouwkundig Onderzoek, 1973) we calculated that keeping a small container for one day in the climate room costs f 0.01 and a big container f 0.04. These amounts were multiplied with the number of days needed for full development (30 days at 25 °C and 35 days at 20 °C). A precisely regulated climate room would be more expensive than a simple one but production per container would then be less. A rough allowance was made for this assumption. We took the cost for the expensive room as unity and that of a less precisely regulated room as half the amount.

Cost of labour = (cost of handling of the containers) × (factor for type of medium) × (factor for the numbers of moths needed)

The costs of handling the containers, closing and cleaning them was estimated at f 2.50 for the large type and f 1.25 for the small type. These costs are directly affected by wages. They were calculated from our mass-rearing experience. The lucerne meal was easier to prepare. Therefore its labour costs were estimated at 0.75 × those of the agar medium. Labour costs depend upon the size of the culture. If it is small, the work can be done part time. A culture of 10000 moths per day does not take all time of one man. With a still bigger culture spare time and fixed costs like walking become less important and some of the work can be done by less qualified staff. We took the costs of the culture of 10000 moths as unity; that of a small one of 1000 moths was set 0.8 and of 50000 moths at 0.6 times the costs per container.

Cost of collection = (number of containers) × (cost of collection per container) × (factor for number of containers per emergence box)

The number of containers per emergence box was set at 20 or 30. In the last case collecting time was set at 0.8 because of fewer boxes. With more containers per box, many moths could not easily find the exit holes and died in the box. We introduced a coefficient of survival with 30 containers of 0.8 and 20 containers of 1.0. Labour costs for collecting per container were set at f0.06 with hourly f 20 wages, f 0.08 with wages f 25 and f 0.09 with wages f 30. With the big type of containers 1/6 of the numbers of containers were placed per box.

Numbers of containers needed = number of moths needed/moth production per container

The cost of collecting the moths was estimated at f 0.06 per container.

Cost of stock rearing = (costs per container for stock rearing) × (number of containers) × (initial number of eggs per container) × (size of container factor)/(daily egg production/female)

Daily egg production was 17.0 eggs at 20 °C and 23 eggs at 25 °C. However we could keep oviposition jars 5 days in good production at 20 °C and only 3 days at 25 °C.

Total costs = (cost per container) × (number of containers) + (costs of collection) + (costs of stock rearing)

Production of moths per container = (number of eggs per container) × (survival coefficient) × (size-of-container factor) × (medium factor) × (temperature factor) × (climate-room factor) × (factor for number of containers per emergence box)

With 200 eggs per container, we found a survival to adult of 0.75 and with 300–500 eggs of 0.6. Large containers produced thrice the amount of moths but required seven times the number of eggs and amount of medium as the small type. At 25 °C survival to adult was 0.8 times that at 20 °C. With mass rearing on lucerne meal medium, survival was 0.8 times that with agar medium. The less precisely regulated climate room was assumed to produce only 0.7 times the number of moths as a better controlled room.

Number of moth equivalent = (number of containers) × (number of moths per container) × (quality) – (number of stock reared/temperature factor)

The quality of our moths was assessed by Denlinger et al. (1973) at 0.6 times that of a wild moth. The number of moths needed for the stock rearing was divided by 5 for a rearing temperature of 20 °C as the moths were used for 5 days and by 3 for a rearing temperature of 25 °C as the moths were then used for 3 days.

As an example we give the following calculation:

Hourly wage costs f 25; 300 eggs/container (coefficient of survival 0.6); 10000 moths needed; Small type of container (coefficient of survival 1.0); Lucerne meal medium

(coefficient of survival 0.8); Rearing temperature 20 °C (coefficient of survival 1.0); Numbers of containers per collecting box 30 (coefficient of survival 0.8).
Number of moths produced per container = 300 × 0.6 × 1.0 × 0.8 × 1.0 × 1.0 × 0.8 = 115.2.
Number of containers needed = 10000:115.2 = 86.8.
Stock required for rearing = (number of containers) × 300/17.9 = 1454 (17.9 is egg production per female per day at 20 °C). These were kept 5 days for egg production.
Number of moth equivalents = 86.8 × 115.2 × 0.6 — 1454/5 = 5709.
Costs of stock rearing with 10000 moths needed per day is estimated at *f*18.75 requiring $\frac{3}{4}$ h per day with hourly wages of *f*25.
Cost of rearing room = *f*0.01 × 35 × 1.0 = *f*0.35.
Costs of material = *f*(0.07 + 0.12) × 1.0 = *f*0.19.
Costs of labour for preparing medium and container = *f*1.25 × 0.75 × 1.0 = *f*0.94.
Costs for collecting adults = *f*86.8 × 0.08 × 0.8 × 1.0 = *f*5.55
Costs per container = *f*(0.35 + 0.19 + 0.94) = *f*1.48
Total costs = *f*(86.8 × 1.48 + 5.56 + 18.75) = *f*152.77
Costs per moth equivalent = *f*152.77/5709 = *f*0.0267
Computer calculation gave *f*0.0269.

The following aspects of mass rearing were examined by computer calculations with a programme written in Fortran IV.
Number of eggs per container: 200 or 300
Size of culture: 1000, 10000 or 50000 moths per day
Type of container: small or large type
Medium: lucerne meal or agar.
Temperature: 20 or 25 °C.
Rearing room: better or poorer control of conditions.
Number of containers/box: 20 or 30 for small containers.
Labour costs: *f*20, *f*25 or *f*30 per h. (The different values allow for no complete employment during the remainder of the year).

The results (Table 6) indicated that cheapest conditions were 300 eggs per container, 50000 moths per day, the small type of container, lucerne meal diet, 20 °C, an expensive accurate rearing room, and 20 containers per emergence box.

Discussion

The figures (Table 6) show the effect of increasing the size of mass-rearing upon the costs at three levels of labour costs when all rearing conditions are optimum in cost. The figures show that most important are rearing temperature, number of containers per box and control of the rearing room. Of six factors studied, labour costs affected five strongly (Table 6). With a culture producing 10000 moths, it became cheaper to use large containers when wages rose above *f*25. For a culture of 50000 moths, we could find by extrapolation that this would be so with wages of about *f*45. The lower production per container is then compensated by the lower labour costs.

The total cost of rearing on an agar medium is not strongly affected by labour costs because of the higher production of moths per container on agar medium. Consequently, less containers are needed per number of moths required. As labour

Table 6. Minimum rearing costs per moth in guilders × 10^6 and difference from this minimum when one condition is not optimum.

Not optimum	Wages								
	f 20			*f* 25			*f* 30		
	number of moths needed			number of moths needed			number of moths needed		
	1000	10000	50000	1000	10000	50000	1000	10000	50000
Minimum rearing costs	22975	18712	15100	27141	21813	17367	31211	24817	19398
200 eggs/container	2654	3047	2329	3017	3508	2647	3362	3951	2920
Large container	2087	1209	2275	1496	397	1735	995	-323	1278
Agar medium	2223	2387	2177	2281	2473	2210	2349	2580	2265
25°C	4212	6308	4575	4732	7351	5171	5205	8348	5750
Cheap rearing room	3579	4292	2653	4525	5415	3368	5426	6495	4037
30 containers/box	4029	4442	3493	4637	5153	3967	5190	5809	4386

Tabel 6. Minimum kweekkosten per mot in guldens × 10^6 en verschil met dit minimum wanneer één omstandigheid niet optimaal is.

costs here affect mainly unfavourable preparation of the medium compared with the lucerne meal medium, it could be worthwhile to consider this aspect in more detail for improvement. The use of fewer eggs per container only increases costs as it directly reduces moth production. The resulting reduction in stock rearing is of minor importance. Rearing temperature seems most important. It directly results in a decrease in moth production per container. Consequently more containers are needed to obtain the desired number of moths. The smaller stock rearing and the shorter stay in the climate room do not sufficiently compensate the costs. We did not investigate whether rearing at a high temperature affected the quality of the insects.

The use of inexpensive rearing rooms with a lower production is not advisable. The figures used are estimates but any decrease in moth production per container will increase the size of the mass rearing. All our previous experience in rearing of *A. orana* indicated that poor control of humidity is always detrimental while poor control of temperature causes variations in daily production.

Placing only 20 containers per box does increase production per container sufficiently to overcompensate the increase in costs of collection.

The effect of the variables on cost is not additive but costs increase more when more variables are not optimum (Fig. 5). Non-optimum conditions increase production costs, decrease moth production or do both. When two or more coincide, the result will be multiplicative.

Butt (1974) surveyed the costs for rearing of the codling moth, *Laspeyresia pomonella*. This species seems to be more expensive and more difficult to rear than *A. orana*. Rearing costs were extremely variable, *f*0.04 – 0.20 per pupa against *f*0.015 – 0.03 per moth for *A. orana* in our cultures. This is probably attributable to the high production per kg diet, which is more than 1000 moths against 200 for codling moth. So production per container is high, an important factor in reducing the costs per moth.

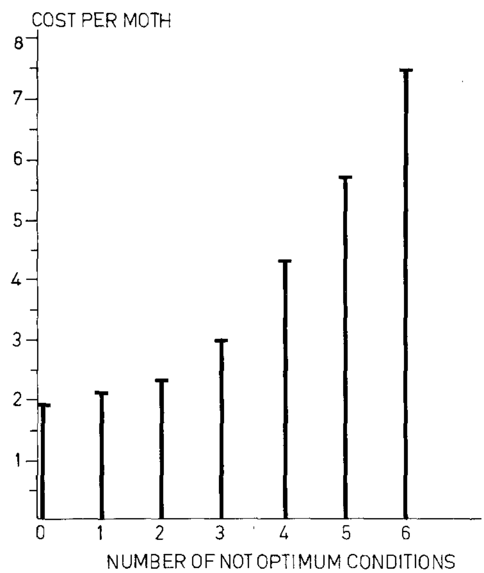


Fig. 5. Increase in rearing costs per moth in Dutch cents when an increasing number of factors becomes not optimal. Moths needed 10000; labour costs *f* 20/h. Selected sequence variables: 1) eggs; 2) type of container; 3) medium; 4) temperature; 5) climate room; 6) number of containers per emergence box.

Fig. 5. Toename in kweekkosten per mot in centen wanneer een toenemend aantal factoren niet optimaal wordt genomen. Aantal gewenste motten 10000; arbeidsloon f 20 per uur. Volgorde variabelen: 1) eieren; 2) type kweekbak; 3) medium; 4) temperatuur; 5) klimaatcel; 6) aantal kweekbakken per vangkist.

The best available figures on costs in mass rearing are probably those of the screw-worm, *Cochliomyia hominivorax*, programme in Mission (Texas). Here total costs in 1964 were estimated at $ 5 million for rearing, irradiating and releasing of nearly 5×10^9flies. This is about $ 0.001 each or at that time *f*0.004. The costs for rearing the onion fly seem even somewhat lower. They were estimated at *f*0.001 – 0.002 (K. J. de Vries, LEI, Landbouw-Economisch Instituut, The Hague, pers.commun.). Even if costs are difficult to compare because of differences in wages and inflation, it is clear that the rearing of *A. orana* is much more expensive than of the screw-worm and the onion fly. Moreover in the screw-worm programme, the number of insects released per ha was extremely low so that a release programme is quite cheap. About 40000 moths will be needed per generation for control of *A. orana* in one ha. We can therefore estimate the costs of the moths per ha at *f*800 compared with about *f*50 – *f*100 for insecticides. This means that, for practical control, further reduction in costs of rearing of *A. orana* is necessary. This can best be achieved by increasing moth production per container and by labour-saving methods.

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Samenvatting

Onderzoek over de steriele-mannetjestechniek als bestrijdingswijze van Adoxophyes orana (Lepidoptera, Tortricidae). 4. Technische en economische aspecten van de massakweek

Voor toepassing van de steriele-mannetjestechniek is een goede massakweekmethode een eerste vereiste. Het bleek mogelijk op kunstmatig dieet een produktie van vele duizenden motten per dag te krijgen (Tabel 4). Deze aantallen werden bepaald door bemonstering en weging (Tabel 1). Controle door telling (Tabel 2) gaf slechts een geringe afwijking aan. Een kunstmatig medium met agar als geleringsmiddel produceerde gemiddeld per seizoen 131 motten per kweekbakje. Een goedkoper en gemakkelijker te bereiden medium, waarbij agar was vervangen door luzernemeel, produceerde 111 motten per bak. Een probleem was de onregelmatige produktie waardoor langdurige perioden met produkties van 160 motten per bak werden afgewisseld door perioden waarin 80 motten per bak werden geproduceerd. Schimmel- en bacteriegroei op het medium waren hiervan de oorzaak.

Voor een goed inzicht in de problemen bij een massakweek was het nuttig een systeemanalyse te verrichten (Fig. 4). Hieruit bleek een netwerk van relaties. Na kwantificering van een aantal hiervan, vooral op grond van de uitkomsten der massakweek, kon door een computerprogramma in Fortran IV de optimale kweekmethode worden berekend. Daar nog veel relaties moeten worden geschat, is de waarde van de berekeningen toch nog beperkt.

Enkele resultaten van de berekeningen zijn gegeven in Tabel 6. De variabelen ble-

ken niet steeds een gelijk effect te hebben. De goedkoopste mot kostte 1.5 cent. Vergeleken met de 'screw-worm', een soort waartegen de steriele-mannetjestechniek met succes wordt toegepast, is *A. orana* duur in kweek, maar vergeleken met de fruitmot, een soort waarbij de methode in onderzoek is, goedkoop.

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