EXPLORATION OF THE FEASIBILITY OF DEVELOPING RACES OF *TRICHOGRAMMA AUSTRALICUM* GIRAULT (TRICHOGRAMMATIDAE, HYMENOPTERA) SUITABLE FOR DIFFERENT ENVIRONMENTS

By

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A thesis submitted to the Faculty of the Post-graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfilment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY IN ENTOMOLOGY

NEW DELHI

1970

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CERTIFICATE

This is to certify that the thesis entitled "Exploration of the feasibility of developing races of *Trichogramma australicum* Girault (Trichogrammatidae, Hymenoptera) suitable for different environments" submitted by C.C. Abraham, in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Entomology, is based on *bona fide* research work carried out under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma. I further certify that such help or information as has been availed of in this thesis is duly acknowledged.

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ACKNOWLEDGEMENTS

The author wishes to record his deep sense of gratitude to Dr. S. Pradhan, Head of the Division of Entomology, for suggesting this problem, for the invaluable guidance and constant encouragement offered during the course of these investigations and for the preparation of the thesis.

The author also avails this opportunity to place on record his grateful thanks to Dr. S.K. Bhatia, Dr. A.K. Sharma, Shri S.S. Rajan and Dr. S.K. Prasad, members of the Advisory Committee, for the keen interest, invaluable suggestions offered at every stage of this study and for critically going through the manuscript.

Sincere thanks are due to Dr. M.G. Ramdas Menon and Shri S.I. Farooqi, for the valuable help rendered in identifying the parasites obtained from different regions.

Grateful thanks are due to the Head of the Division of Genetics, for the facilities made available for getting the material irradiated.

The help received from Shri I.C. Sethi, Institute of Agricultural Research Statistics, in the statistical analysis of the data, is gratefully acknowledged.

The help rendered by the Director, Indian Institute of Sugarcane Research, Lucknow; the Head of the Division of Zoology-

Entomology, Punjab Agricultural University, Ludhiana, the Parasitologist, Division of Entomology, Indian Agricultural Research Institute, New Delhi; the Assistant Entomologist, Parasite Breeding Station, Ambajipet; the Sugarcane Specialist, Sugarcane Research Station, Cuddalore and the Assistant Entomologist, Parasite Breeding Station, Mandya; by supplying parasite cultures and offering necessary facilities in the field collections, have been invaluable for which the author thanks them with all sincerity.

The author is very much indebted to Smt. B. Sarala Devi, Shri Samarjit Rai and Shri J.D. Saxena of the Section of Insect Genetics, Division of Entomology for their ungrudging help and co-operation.

I owe my sincere thanks to Shri S.M. Rao of the Syndicate Bank, for the timely and opportune financial assistance rendered, but for which it would not have been possible to complete the studies.

Sincere thanks are due to all my friends and colleagues for their kind help at various stages.

Thanks are also due to the Government of Kerala for granting me a deputation to undertake the Ph.D. programme at the Indian Agricultural Research Institute.

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Contents

I INTRODUCTION

There has been of late a marked revival of interest in the biological method of pest control arising from a growing realisation that supplements and alternatives are needed to overcome the faults and weaknesses, now widely recognised as inherent in the chemical method of pest control. The concept of controlling insects by augmentation or acceleration of the destructive action of the natural enemies of insects (vertebrate predators; invertebrate predators and parasites; and disease causing microbes) is the basis of biological method of insect control. Some of the spectacular successes achieved in the biological control of insect pests utilizing entomophagous insects suggest the potentialities of this method in subjugating pest populations.

The control of the cotton cushiony scale Icerya purchasi (Maskell) by the Australian lady bird beetle Rodolia cardinalis (Mulsant) is a classical example of successful biological control. Other outstanding examples are that of the woolly apple aphid Eriosoma lanigerum (Hausman) by Aphelinus mali (Haldeman), of the coconut moth Levuana irridescens Bethune-Baker by Ptychomia remota Aldrich, of the white peach scale Pseudaulacaspis pentagona (Targioni-Tozetti) by Prospaltella berlesei (Howard), of the citrus black fly Aleurocanthus woglumi Ashby by Eretmocerus serius Silvestri and of the sugarcane hopper Perkinsiella saccharacida Kirkaldy by a predaceous bug Cyrtorhinus mundulus (Breddin).

Of the many parasites that are utilised in biological control of insect pests, the chalcid wasp Trichogramma spp. have received widest attention. These parasites have been widely employed for the control of so large a number of lepidopterous crop pests, chiefly the codling moth Cydia pomonella (Linnaeus), the oriental fruit moth Grapholitha molesta (Busck), European corn borer Pyrausta nubilalis (Hubner), army worm Heliothis armigera (Hubner) and various species of sugarcane moth borers, particularly Diatraea saccharalis (Fabricius

In India work with the indigenous species of Trichogramma was initiated as early as 1930 in the Mysore State for the control of the early shoot borer Chilo infuscatellus (Snellen). Since then extensive trials all over the country have been carried out on the utilisation of this parasite for the control of other sugarcane borers viz., Proceras indicus Kapoor, Emmalocera depressella (Zeller), Chilo tumidicostalis Hampson, Scirpophaga nivella Fabricius, Bissetia steniellus Hampson, Rhanhimetopus ablutella Zeller and Sesamia spp. as well. It was, however, found that the parasite was successful only in certain areas while in other regions the results were inconsistent.

A sub-committee was constituted to critically review the work done on Trichogramma liberations in different parts of the Country. It was concluded that control of borers by periodic mass liberation of Trichogramma could not be an economic proposition in all parts of the Country. The parasite was particularly found ineffective in the northern sub-tropical belt during the

hot months of April to June when extremes of high temperatures and low humidity were experienced (Gupta, 1951, 1953).

A few workers have attempted to improve the efficiency of the indigenous species of Trichogramma as a biological control agent. Das (1959) and Sastry (1962) investigated the feasibility of improving the biotic potential of the parasite at near optimum condition of temperature and humidity. Sharma (1968) while trying to improve the efficiency of this parasite, carried out an experiment which indicated the feasibility of improving tolerance to low humidity-high temperature conditions by a suitable rearing technique. The above indications formed the basis for the present studies. These studies were directed towards exploring the possibilities for developing parasite strains suitable for different temperature-humidity conditions in different agro-climatic regions in the Country, with particular emphasis on evolving races which are tolerant to high temperature-low humidity conditions which are reported to be the principal factors responsible for the failure of the parasite in north Indian conditions.

A perusal of the results obtained in the present investigatio will indicate that it has been possible to evolve strains suited to high temperature-low humidity conditions, which may prove of great value in the control of sugarcane borers in northern and central regions, where Trichogramma liberations were earlier reported to be unsuccessful on account of poor adaptability of the parasite to these adverse conditions. It has also been

possible to identify some strains which are suitable for medium temperatures and for highly humid conditions.

II REVIEW OF LITERATURE

The importance of the egg parasites of the genus Trichogramma as biological control agents has long been recognised. After the first attempts in Guyana in 1921 (Cleare, 1928) biological control projects utilizing Trichogramma spp. have been in operation in different parts of the world. Probably, there is no agriculturally developed country where attempts have not been made to control one or the other insect pest by Trichogramma liberations. The results of mass liberations of the parasite, obtained in different countries have been reviewed by various workers. Metcalfe and VanMervin (1967) have presented a critical review of work done in Barbados on the utility of T. minutum Riley for controlling Diatraea spp. infesting sugarcane An account of the attempts made for the biological control of sugarcane moth borers in the Old World utilising Trichogramma spp. is furnished by Rao (1969). A detailed review on the use of Trichogramma spp. in the biological control of sugarcane moth borers is given by Metcalfe and Breniere (1969).

Work done in India on the utilisation of Trichogramma spp. in biological control projects.

In India extensive trials involving Trichogramma parasites were conducted mainly for controlling the sugarcane borers, Chilo infuscatellus, Proceras indicus, Emmalocera depressella, Rhaphimetopus ablutella, Chilo tumidicostalis, Scirpophaga nivella and Biasotia steniellus. These parasites have also been used for

control of other moth borers of graminaceous crops and cotton boll worms.

The earliest record of Trichogramma in India is that by Fletcher (1917) who noted an unidentified species on cereal borers in Pusa. Husain and Mathur (1934) recorded a species under the name T. evanescens Westwood, as parasitising cotton boll worms Earias spp. in the Punjab. Ghosin (1928) reported that it was successfully introduced on eggs of Earias cupreoviridis while Chopra (1928) recorded that it parasitised eggs of Diatraea auriciliz Dudgeon and Chilo simplex Butler.

The Indian species had been referred to as T. evanescens, T. minutum Riley or T. evanescens minutum Riley. Recently, Nagarkatti and Nagaraja (1968) reported that the indigenous species is actually T. australicum Girault, which has been mis-identified and referred to by other names. Work with this indigenous species was initiated in the Mysore State by Kunhikannan as early as 1930 for the control of Chilo infuscatellus. Narayanan (1933) suggested extensive liberations in cane growing areas at the time of borer outbreaks.

Subramanian (1935, '36, '37, '41) continued Kunhikannan's work and reported successful large scale release of T. minutum against C. infuscatellus. It was found that periodic releases in one acre plots for 2 to 3 months increased parasitisation by 2 to 50 and 10 to 92.4 per cent in particular instances. Substantial reduction in the number of dead-hearts and corresponding increase in yield upto 8 tonnes per acre were also reported.

Cherian and Margabandhu (1943) reporting the results of trials conducted at Coimbatore utilizing T. minutum for controllir Earias fabia Boisduval and Pectinophora gossypiella (Saunders) on cotton, stated that progressive reduction in the percentage infestation was obtained.

Issac (1948) gave results of releases against sugarcane borers made in Bengal (Sitabganj), Orissa (Cuttack) and Bhopal (Sehora). At Sitabganj, there was no initial parasitism of eggs of the root or stem borers. The percentage parasitism of Emmalocera depressella in the release plots were 21.85 in August and 28.68 in October as compared to 5.5 and 0.0 respectively in the control plots. The corresponding figures for the stem borers were 21.63 and 36.38 in the release plots and 1.6 and 27.7 in the control plots. The increase in yield in the release plots was 33 per cent over that in the control plots. In Bihar (Motihari), the percentage parasitism of stem borer eggs in August was 57.3 and 16.5 in the release and control plots respectively. At Bhopal (Sehora), the percentage parasitism of the stem borer eggs was 9.68, 10.75 and 5.00 in the release plots in July, September and December, respectively and the corresponding figures for the control plots were 19.76, 3.87 and zero.

In Madras, Trichogramma liberations were made at the rate of 16,000 adults/acre/week for a period of 12 weeks following germination of cane setts. Parasitism averaged 31.7 and 11.3 per cent in colonised and control plots and was observed to be erratic. Yield increases from 2.78 to 10.35 tonnes per acre were detected (Ramachandra Iyer et al., 1951).

Gupta (1951) reported that the parasite was ineffective in Uttar Pradesh since the high temperature and low humidity in summer had an adverse effect on parasite development. The results of trials conducted in different parts of the country upto the year 1950 were summarised by Gupta (1953). At first, these trials were conducted at eight selected centres. These were Sitabganj (Bengal), Cuttack (Orissa), Sehora (Bhopal), Lyallpur (now in Pakistan), Muzaffarnagar (U.P.), Walchandnagar (Bombay), Nellikkupam (Madras) and Motihari (Bihar). It was concluded that the trend of results was in favour of Trichogramma only at four centres viz., Walchandnagar, Cuttack, Nellikkupam and Motihari. The trials were, therefore, continued at these places during the period 1946-50. At Cuttack, parasitism was fairly satisfactory in the first year but in the succeeding two years it declined. Reduction in host larval population or increase in yield consequent on parasite liberations were found to be insignificant at Nellikkupam and Walchandnagar. Motihari was the only place where the releases proved to be effective.

Kapur (1957) referred to parasitisation of eggs of Biosotia stenielius in the Punjab by T. minutum and stated that artificial mass liberation of laboratory reared material proved ineffective.

Puttarudriah and Usman (1957) attempted to utilise T. evanescens minutum for the control of Chilo zonellus (Swinhoe) in Mysore State. The parasites were liberated at the rate of 24,000 adults per week for 12 weeks during the period from November to February in the year 1954-55, 1955-56 and 1956-57.

The percentage parasitism ranged from 18.1 to 100.0 for the three months but subsequently a decline was noticed.

Katiyar (1962) observed that the percentage of Chilo zonellus eggs parasitised by Trichogramma were 38.0 and 93.1 (1957), 29.0 and 85.1 (1958) in the control and treated plots respectively.

Rao (1966) indicated that in Madras, a strain of T. australicum was most effective, giving over 70 per cent control of Proceras indicus. Based on the encouraging results thus obtained, the parasite was later released in Plassey (W. Bengal) against C. infuscatellus. The results of this have, however, not been reported.

Recently, there has been a renewed interest in the utilisation of Trichogramma spp. With a view to studying the performance of some of the exotic species, these were introduced into India from different countries. The introduced species were: T. japonicum Ashmead from Philippines, T. australicum from Taiwan and T. fasciatu Perkins from Florida and Barbados. Rao (1969) reported that the Taiwan strain of T. australicum was quite successful in the control of Proceras indicus in Pugalur area of Madras State.

Reported reasons for the failure of Trichogramma spp. in India

The above review of the work done on the utilisation of Trichogramma spp. in India for the control of sugarcane moth borers will indicate that in most of the cases the results were either unsatisfactory or have been inconsistent.

Gupta (1951) gave a resume of trials conducted during 1941-44 with T. evanescens minutum for the control of Chilo infuscatellus and the root borer Emmalocera depressella in Uttar Pradesh and analysed the factors responsible for the failure of the parasite in north Indian sugarcane belt. These were: (1) low density of host eggs during the release period, (2) unfavourable atmospheric conditions for survival and multiplication of parasites, (3) incapacity of the parasites to readily parasitise host eggs. The ineffectiveness of the parasite was particularly evident in the hot weather season when high temperature (43°to 45°C) and low humidity (7 to 11 per cent) extremes were experienced. On this basis, it was concluded that the lack of adaptation of the parasite to climatic extremes was chiefly responsible for its failure.

A critical study of the performance of the parasite in different parts of the country was made by a special committee and it was concluded that control of borers by periodic mass liberation of Trichogramma had not been an economic proposition in all parts of the Country. Firstly, because the parasite did not flourish equally well in all these areas and secondly since its population had to be built up every year, they stated that its use could not be recommended for the whole of India (Gupta, 1953).

An assessment of the effect of Trichogramma liberations carried out for a period of over 20 years in the Country was made by Narayanan and Mookherjee (1953). The inconsistent results

obtained in different centres were attributed to the following reasons: (1) superparasitism in mass rearing of the parasite, resulting in weak, or no progeny, (2) lack of host abundance in the field and (3) the loss of adaptability of this parasite due to rearing under more or less constant laboratory conditions.

Narayanan and Chacko (1957) stated that the most important factor which contributed to the failures in the field colonization of Trichogramma spp. was the occurrence of superparasitism in laboratory breeding, leading to production of progeny with impaired vitality, fecundity and longevity.

The decline in parasitisation of Chilo zonellus eggs by T. evanescens minutum in Mysore State has been reported to be caused by a low host density (Puttarudriah and Usman, 1957).

Factors affecting the efficiency of Trichogramma spp.

Much of the controversy relating to the utility of Trichogramma liberations, is due to incomplete knowledge of their biology and ecology. Very few efforts have been made to improve the biological and ecological efficiency of Trichogramma spp. The present studies were, therefore, undertaken to meet this desideratum. A brief review of some of the biological, climatic and genetic factors affecting efficiency of the parasite is given in the following pages. These are dealt with separately for the purpose of review only, recognising their close interaction in nature.

(1) Biological Factors

(a) Mating, mode of reproduction

In Trichogramma, as indeed in all other parasitic Hymenoptera, mating is not obligatory, facultative parthenogenesis or arrhenotoky being general in T. australicum, T. evanescens, T. japonicum and T. minutum. T. fasciatum may be arrhenotokous or thelytokous (Peterson, 1930; Marchal 1936; Quednau 1960). Stern and Bowen (1968) reported the occurrence of a uniparental race of T. semifumatum Perkins in California which may also reproduce by deuterotokous parthenogenesis.

(b) Pre-oviposition period

The pre-oviposition period does not exceed 24 hours (Pradhan and Pesvani, 1954; Quednau 1960). In the absence of host eggs, the female can refrain from oviposition even until death (Salt 1936; Lund, 1938). The phenomenon of oviserption is not evident (Sharma, 1968).

(c) Host finding

Host finding is essentially a consequence of the exposed leaves of the host plant being the point where adult Trichogramma tend to congregate and pyralid borers prefer to oviposit. There is little or no attraction offered over a distance by the host, the parasite being drawn to the host environment rather than to the host itself (Laing, 1938; Stein, 1961).

Since a population of Trichogramma searches at random for the host eggs (Barber, 1936), an expanding searching environment must be a major factor affecting the parasitism that will occur during the crop growing season (Knipling and McGuire, 1968).

(d) Host specificity

Breniere (1963, 1965a) found that in Madagascar, the indigenous species T. australicum continuously reared on the laboratory host Corcyra cephalonica Stainton, for many generations would not parasitise eggs of Proceras saccharinhagus Bojer.

(e) Fecundity

The maximum number of eggs are laid on the first day of emergence and steep decline occurs thereafter (Lund, 1938; Chacko, 1961; Sharma, 1968). Fecundity varies between 20 and 186 eggs per female according to the species, the host and the longevity of the adult female (Peterson, 1930; Bowen, 1936; Subramaniam, 1937; Shread and Garman, 1938; Cherian and Margabandhu, 1944; Isaac, 1946; Venkataraman and Govil, 1952; Pradhan and Peswani, 1954; Narayanan and Mookherjee, 1956; Quendnau, 1956; Sastry, 1962; Breniere, 1965a; Sharma, 1968). Sweetman (1958) suggested that much of the contradictory reports on fecundity was, perhaps, due to a confusion of the species concerned and that the average was about 40 to 50 only. The fecundity of unmated females was reduced according to Moutia and Courtois (1952) in the case of T. australicum, but Peterson (1930) did not observe any such reduction. For T. evanescens, fecundity of unfertilized females was more than in mated ones (Lund, 1938).

(f) Progeny production

The information available on this is quite meagre. Lund (1938) reported that the average progeny produced at 25°C and 5 mm. saturation deficit for T. minutum was 66 ± 2.5. At 0 mm. saturation deficiency, the progeny production was 59.1 ± 2.5 and at 15 mm. saturation deficiency, the figure was 40.3 ± 2.0.

(g) Sex-ratio

In Trichogramma eggs may develop either parthenogenetically or zygogenetically, depending on whether fertilization is effected or not. Females are biparental and males are uniparental. The sex-ratio is highly variable. As reported by Peterson (1930) and Quednau (1956), the usual ratio is of the order of 2 females to 1 male.

(h) Adult longevity

In the case of T. evanescens, mated and fed females lived for 6.3 ± 0.3 days at 25°C while the life-span of males was 5.7 ± 0.2 days (Lund, 1938). Bowen (1936) gave the figure for female longevity as 5.17 ± 0.29 while Schulze (quoted by Lund, 1938) stated that the female life expectancy was about 13 days. Under laboratory conditions T. minutum adults lived for about 3 days (Subramaniam, 1937).

Venkataraman and Govil (1952) reported that in case of T. evanescens minutum the mated females and males lived for 36 and 26 hours respectively at a temperature of 25°C and 65 per cent R.H

A maximum longevity of 2 and 4 days respectively for males and females reared at 25°C and 75 per cent R.H. were reported by Pradhan and Pemmani (1954). With different sugars given as food, the unmated females or males lived for 9 to 10 days and 4 to 6 days, while the mated females and males lived for 11 to 14 days and 5 days respectively (Narayanan and Mookherjee, 1956).

(1) Superparasitism

According to Narayanan and Chacko (1957) superparasitism was an important factor responsible for the inefficiency of Trichogramma spp. Occurrence of superparasitism results in the production of progeny with impaired vitality, fecundity and longevity. Similar observations were made by some of the early workers (Kowalewa, 1954). Iyatomi (1958) endorsed these observations and concluded that in the case of T. japonicum superparasitism resulted in: (1) reduction of mean body length of the emergent (2) steady decrease of the emergence rate, (3) decrease of the proportion of female progeny, (4) remarkable decrease of the average number of eggs laid by the female parasite and (5) reduction in vitality. Salt (1936) recorded selective faculty of the parasite to reject the host which is already parasitised. Under sub-tropical conditions the selective faculty is lost, particularly when there is an abundance of parasites. This results in superparasitism leading to competition among larvae and in extreme cases larval development is suppressed (Salt, 1936; Breniera, 1965a,b).

The number of eggs laid by Trichogramma in a single host egg increases with host size (Salt, 1934), being 1 in Sitotroga cerealella Olivier, 2 in Corcyra cephalonica, 2-3 in Diatraea saccharalis, 3-4 in Chilo sacchariphagus and 8 to 10 in Papilio demodocus Esp. (Metcalfe, 1939; Breniere, 1965). These numbers are very variable and in laboratory conditions superparasitism may occur (Lund, 1938; Breniere, 1965). Sharma (1968) concluded that superparasitism occurs due to certain factors such as long exposure periods and high parasite densities. The parasite is able to show a sense of restraint or discrimination between parasitised and non-parasitised eggs for a period of about 10 hours.

(j) Multiparasitism

The competition between Trichogramma and other egg parasites may be keen, nevertheless, they all contribute to total egg mortality. The Scelionidae especially Telenomus alecto (Crawford) in Barbados (Metcalfe and VanWhervin, 1967) and T. beneficiens in Java and Taiwan (Jepson, 1954) were reported to be important competitors of Trichogramma. The intrisic superiority of Trichogramma is revealed by its survival under conditions promoting multiparasitism. It can kill and replace Telenomus sp. (Jones, 193 Metcalfe and VanWhervin, 1967).

(k) Host size, stage and density relations of hosts and parasites

Klomp and Teerink (1962) observed that the females were capable of determining the host egg size by the help of antennae.

The parasites will oviposit or atleast drill through the chorion regardless of the stage of development of the host (Breniere, 1965; Quednau, 1960). Most species of Trichogramma are able to successfully oviposit in host eggs irrespective of its stage of development. T. evanescens is stated to prefer freshly laid eggs of the gypsy moth and the cabbage butterfly (Flanders, 1935).

Many workers including Barber (1936), Box (1932), (1951), and Wolcott and Martorell (1943) have observed that efficiency of Trichogramma as measured by the percentage parasitism is related to host abundance. Jaynes and Bynum (1941) detected a direct linear relationship between the population of Diatraea saccharalis and the percentage parasitism, and obtained a correlation coefficient of 0.59. Breniere (1963) and Metcalfe and VanWhervin (1967) have also reported similar results.

The relative inefficiency of Trichogramma at low host densities is, therefore, expected. Normally, whenever there is an abundance of host eggs, a high level of parasitism is rapidly attained by virtue of the short life-cycle and widespread occurrence of the parasite (Metcalfe and Breniere, 1969).

Knipling and McGuire (1968) presented results of extensive theoretical calculations in which hypothetic population models were used to identify and appraise the importance of major factors governing the density relations between Trichogramma and its lepidopterous hosts. According to them, the parasites can

increase to effective levels only when the number of host eggs reaches a level substantially above the economic threshold. In critical situations when the host egg populations is very low, the desired level of host egg density may be artificially created by sustained releases of a suitable alternative host population in the susceptible stage.

Trichogramma will be successful only when the number released is a significant proportion of the total host population and this can be assured by mass breeding and inundating the total host environment with sustained releases of the adult parasites (Knipling and McGuire, 1968). The importance of such inundative parasite releases was emphasised also by Pradhan (1967).

(1) Diapause?

So long as temperature and humidity conditions are favourable, Trichogramma are reported to breed without interruption. The hibernation habit has not been conclusively proved in any species, though it is quite certain that the adults overwinter. So far as is known there is no obligate diapause except as may be imposed by host, as in T. cacoeciae Marchal (Barber, 1936).

(2) Climatic Factors

That a hostile environment may adversely affect the efficiency of Trichogramma had been pointed out by several workers (Tucker, 1940; Gupta, 1951, '56; Kovalewa, 1954; Stein, 196

Charpentier, Mathes et al., 1967). Among the various climatic factors, temperature is by far the most important limiting factor for Trichogramma. Other factors such as humidity, light etc. cause only insignificant differences especially within the non-limiting range.

(a) Temperature

Schepetilnikova (1939) stated that the lower and upper limits of temperature for Trichogramma evanescens were 13.5°C and 32.1°C and that oviposition did not occur at 10°C and 35°C, these being extremes. Between the upper and lower limits, the rate of development increases with temperature but the exact response varies with the species (Quednau, 1967). At the lower limit some resistance to cold was reported, the threshold temperature being 15°C for T. minutum and 4°C for T. cacoeciae (Lund, 1934; Quednau, 1967). That 32°C is somewhat above the upper limit of normal development was reported by Lund (1934). The parasite reared at 32°C appeared to be weaker and less vigorous than those which develop at low temperature. Van Zwaluwenburg (1951) reports that above 35°C and below 13°C, T. evanescens did not breed. Bare (1935) also observed that oviposition was suppressed above 37.7°C.

The optimum temperature for T. cacoeciae and T. minutum was reported to be 25°C and 32°C respectively but the grey race of the latter developed more quickly than the yellow at high temperatures (Peterson, 1930; Lund, 1934; Marchal, 1936; Flanders, 1937; Quednau, 1957.)

The seasonal and regional temperatures effect the potential of Trichogramma, particularly by way of the annual number of generations. This ranges from 2 for T. cacoeciae in Europe to 50 in the tropics (Peterson, 1930; Kuwana, 1930; Marchal, 1936; Breniere, 1963).

Temperature affects the sex-ratio through adverse effects on the viability of the sperms. Shread and Garman (1933) noticed that an excess of males appeared in the progeny of Trichogramma kept for two weeks at 3° to 8°C. Bowen and Stern (1966) have reported that when T. semifumatum was reared at temperatures below 25.5°C, the progeny was almost entirely female. As the temperature was increased above 25.5°C, males were produced in higher proportion and at 32.2°C, the progeny consisted of 97 per cent sterile males and 3 per cent sexual mosaics.

Many investigators have pointed out that when bred at alternating temperatures, Trichogramma performs better, (Stark, 1944; Schepetilnikova, 1960; Stein and Franz, 1960; Stein, 1960). The poor effectiveness of Trichogramma in Russia was attributed to laboratory breeding at constant temperature conditions (Stark, 1944).

(b) Humidity

The humidity relations of immature stages of Trichogramma merely follow those of the host egg. Adult Trichogramma are very susceptible to desiccation and optimum humidity is between

80 and 100 per cent R.H., varying slightly for different species (Lund, 1934). The immature stages are affected only to the extent that the host eggs are, but the host eggs which having been laid on leaves are unaffected by humidity, provided that the plant tissue is transpiring normally (Peterson, 1930).

(c) Light

The adults of Trichogramma spp. show a distinct positive phototaxis and under natural conditions are found on most exposed parts of the plant. Their activity increases with light intensity (Quednau, 1958) and this reaction is important for host finding. Under laboratory conditions, Costas (1951) detected higher parasitism occurring in light than under shaded conditions. However, it is known that T. evanescens can distinguish the host and oviposit in complete darkness (Salt, 1937). Breniere (1965) found that diffused light caused a slight increase in oviposition. Quednau (1957) stated that light has no effect on the rate of development, mortality or fecundity.

(d) Wind velocity

In Trichogramma dispersal is largely passive. Hence the direction and velocity of wind are of much importance in parasite movement. Tucker (1951) relied on wind for uniform distribution of the released Trichogramma adults in Barbados. In Peru, Smyth (1939) observed that the parasites moved downwind from the release points at the rate of one mile per month and that lateral and upward movements were negligible. Experiments conducted in

Louisiana had shown that Trichogramma moved downwind only 500 feet from the release point in three weeks (Hinds and Osterberger, 1932).

Parsons and Ullyett (1936) found that the dispersal of Trichogramma is rapid extending from the centre to the outer part of five acre fields in about 24 hours.

The effect of wind on dispersal of T. semifumatum was investigated in Texas. Greater percentages of parasities were recovered downwind than in any other direction (Hendricks, 1967).

3 Genetic Factors

The occurrence of biological or physiological races in Trichogramma has long been known. The races differ in the manner of reproduction, colour pattern, flight habit, length of life-cycle, fecundity, binomics, biology and with regard to climate tolerance. Several workers have reported about these races (Howard and Fiske, 1911; Martin, 1926; Marchal, 1927; Tucker, 1928 Peterson, 1930; King, 1931; Dosier, 1932; Harland and Atteck, 193 Flanders, 1930, '31, '37; Bowen, 1936; Steen burgh, 1938; Meier, 1938, '40, '41; Urquijo, 1948, '51 and Breniere, 1965.)

The existence of such races is indicative of the vast genetic variability available in the genus Trichogramma. Mayer (1960) noticed that in dense populations new inheritable behaviour

patterns emerged as ecological adaptations. This could explain the existence of several ecotypes within the same habitat.

Some of the races have been reported to show variability with regard to climate tolerance. Flanders (1931) recorded atleast four races of T. minutum. Of these the yellow race from Massachusetts was less responsive to temperature of fluctuations Meier (1938) observed that some races of T. evanescens found in Russia showed variability with regard to temperature and humidity tolerance. Areas where the 'Central Asiatic' race, 'Asov Black Sea' race, 'Azerbaijan' race and 'Romnui' race can be used profitably, should have a mean monthly temperature of 25° to 30°C, 21° to 27°C and 20° to 27°C and under 22° C, respectively. The optimum relative humidity requirements for these were 73 to 75, 80 to 82, 73 to 75 and 80 to 82 per cent.

Meier (1940) reported that the 'Astrakhan' race is suitable for dry, hot conditions. According to Kamenkova's work quoted by Meier (1941) the 'Romnui' race of T. evanescens could not tolerate so wide a range of temperature and relative humidity as the 'Azerbaijan' race while the 'Astrakhan' race was most adaptable. Telenga (1959) observed that the 'pine' race of T. cacoeciae was more tolerant to low temperature, conditions, than the 'pallida' race.

Selective breeding to improve adaptations in insect parasites

For successful biological control, it is necessary that the agents introduced for the purpose should consist of a population

which is directly adaptable to the particular environment. DeBach (1958) stated "Parasitic insects usually exhibit a narrow range of adaptation to environmental conditions. Lack of adaptation among parasites includes among other things poor climate tolerance, lack of synchronization between host and parasite biologies, failure to recognise the host environments, and inability to survive on the host on certain host plants. Races or strains of parasites differing from one another in these characters are fairly common in nature and selective breeding for better adapted strains is as logical for insect parasites as for domestic animals and cultivated plants".

The concept of artificially developing improved races of parasites was apparently first suggested by Wilkes (1942). Selective breeding as a method of improving adaptations of entomophagous insects has been employed by many workers. The principles involved in this method have been elaborated by DeBach (1958), Simmonds (1963), DeBach and Hagen (1964), Wilson (1965) and Force (1967).

Selective breeding of parasites has already achieved some very interesting results and improvement in the following characteristics have been reported.

(1) By selection

a) For climatic tolerance

Wilkes (1942) was probably the first to investigate in laboratory, the changes produced by selective breeding in Dahlbominus fuliginosus (Nees) (D. fuscipennis Zetterstedt), a

eulophid parasite of the European saw fly Diprion hercyniae (Hartig). The objective of this study was to increase the effectiveness of this parasite in cooler field locations in Canada. The adult insects were released in a temperature gradient and the females which congregated between 6° to 10°C were selected. Selection of individuals congregating in the 6° to 10°C zone resulted within four generations, in the development of a strain in which over 50 per cent of the adults preferred temperature below 12.5°C. DeBach (1964) concluded that the rapidity of adaptation indicated a simple type of inheritance, especially since further selection did not appreciably lower temperature preferendum.

DeBach and Hagen (1964) reported the results obtained by DeBach et al. (1960), pertaining to improvement of Aphytis lingnanensis Compere by artificial selection. The improvement in the parasite was found necessary because the parental strains revealed lack of adaptation to climatic extremes in southern California. Selection for over 86 generations yielded three strains one adapted to survive under very low temperatures (2°C), the other to high temperatures (36°C) and a third to both the conditions. It is interesting to note that even when selection was made for cold adaptation or for heat adaptation only, increased tolerance was developed in both directions in the same strain.

b) For improvement of sex-ratio

Improvement of sex-ratios in the laboratory cultures of some parasitic insects, was obtained by Wilkes (1947) and Simmond (1947). Wilkes (1947) showed that in the case of Dahlbominus

fuliginosus, a continuous decrease in the number of sterile males from 35 to 2 per cent was brought about by selective breeding. It was shown that continued inbreeding in the laboratory stock was actually responsible for the prevalance of male sterility which resulted in the progressive reduction of female progeny in successive generations. By outbreeding and selection, the sterility factor could be reduced to the minimum.

Simmonds (1947) reported that in Mastrus carpocapsae Cushman, a larval parasite of codling moth Cydia pomonella, a progressive decline in the production of females could be checked by selective mating between males and females from high sex-ratio families. The percentage of females which had declined to 13.3 in F_4 from 54.5 per cent in the parent stock, was raised to 39.3 in F_7, by this technique.

c) For host preference adaptation

Through selective breeding, Allen (1964) achieved some significant results in the modification of host preference of an Ichneumonid parasite Horogenus molestae (Uchida), the natural host of which is the oriental fruit moth Grapholitha molesta.

After rearing the parasite for eleven generations on the potato tuber worm Gnorimoschema operculella (Zeller), it was found that the strain had become adapted to the foster host. Further selection for 39 generations resulted in the production of a strain which was many times more effectively reared on the potato tuber

worm than the original strain.

d) For increased oviposition and fecundity

By continued selection and outbreeding, the mean number of progeny per female could be improved in Dahlbominus fuliginosus from 34 to 68 (Wilkes, 1947). The selected strain also revealed improvements in oviposition and female longevity.

(11) Parasite improvement by hybridisation

Intraspecific and interspecific hybridisation as a means of improving the efficiency of parasites has been recommended by many workers (Sailer, 1954; DeBach, 1958; Simmonds, 1963). The occurrence of races or strains of entomophagous insects which differ in their potential value as agents of biological control, has been reported in many cases. (Thorpe, 1930; Smith, 1960; Simmonds, 1963; DeBach and Hagen, 1964). There is wide scope for detailed investigations of different field populations of parasites to determine if there are genetic differences reflected by differences in physiology and behaviour (Pradhan and Bhatia, 1968).

Box (1952, '56) reported a case in which the field effectiveness was improved in the tachinid parasite Paratheresia claripalpis Vander Wulp, parasiting the sugarcane borer Diatraea saccharalis. By crossing the 'Venezula' and 'Trinidad' races, a synthetic strain was evolved which showed better adaptability to Venezuelan condition

In an attempt to establish Lixophaga diatraea Townsend a parasite of D. saccharalis in Barbados, the progeny from crosses

between the different races were released in order to provide maximum genetic variability (Simmonds, 1963).

Work done on the improvement of Trichogramma

Tucker (1929) suggested that the local strain of Trichogramma in Barbados can be improved by cross breeding with another strain obtained from Louisiana. According to King (1934) better strains of the parasite could be obtained by bulk selection for improving fecundity, but the improvements thus attained may not be maintained in subsequent generations.

Urquijo (1945, '46, '51, '56) carried out investigations on the selection of better strains of T. minutum and T. pretiosum. Even after 4,000 generations, the increase in fecundity was found to be negligible, while ovotropism was significantly improved. Quednau (1960) observed that in the genus Trichogramma the physiological characters of an ecotype acquired through selection and adaptation are temporarily reversible or at least affected by new changes in the ecosystem.

Das (1959) conducted experiments to study the performance of three different cultures of T. evanescens minutum and their hybrids with regard to fecundity, longevity and sex-ratio. A marked improvement in fecundity and sex-ratio was obtained in the F_1 progeny of a cross between 'I.A.R.I.' female and 'Karnal' male.

Sastry (1962) carried out investigations to ascertain the scope for improving T. evanescens minutum strains by hybridisation. It was concluded that the scope for evolving a race with improved fecundity, sex-ratio, and longevity is limited in view of the fact that additive gene effects were not pronounced.

With the objective of increasing the efficiency of T. evanescens minutum, Sharma (1968) has conducted investigations utilising five indigenous cultures. A significant improvement in fecundity was attained in the F_1 progeny of a randomly mating population of the strains studied. This improvement was maintained for the subsequent generations upto F_6. It was also noted that low humidity tolerance in the parasite could be increased by successive breeding of the parasite at 30°C for 50 generations at progressively adverse humidity levels from 75 to 15 per cent R.H. It was also reported that increased tolerance to a combination of low humidity and high temperature (15 per cent R.H. and 35°C) could be brought about by rearing the parasite in the manner detailed above or by rearing under fluctuating conditions of temperature and humidity.

III MATERIALS AND METHODS

1 Source of *Trichogramma* cultures

For the present investigations, the parasites were collected from different regions in the country both from field collected parasitised egg masses of its common host, *Chilo infuscatellus* and from laboratory stocks maintained in Parasite Breeding Laboratories functioning in these regions as detailed below:

Cultures collected	Source
Ambajipet	Parasite Breeding Station, Ambajipet (E. Godavari District, Andhra Pradesh)
Cuddalore	Sugarcane Research Station, Cuddalore; Parasite Laboratory, Eastern India Sugars and Chemicals Ltd., Nellikkuppa (S. Arcot District, Tamil Nadu).
Delhi	Division of Entomology, Indian Agricultural Research Institute, New Delhi.
Lucknow	Indian Institute of Sugarcane Research Lucknow (Uttar Pradesh).
Ludhiana	Division of Zoology - Entomology, Punjab Agricultural University, Ludhiana (Punjab).
Mandya	Parasite Breeding Laboratory, Mandya (Mysore)

A part of the laboratory stock obtained from a particular source was mixed with field collected material from the same area and the cultures thus obtained were maintained individually. The original cultures are named after the places from where these have been obtained and referred to by the first letters of the place-name

e.g., A, C, D, L_1, L_2 and M.

2 Taxonomic identities of the cultures obtained from different regions

In order to establish the taxonomic identities of the six cultures utilized in the present studies, the male genitalia were studied from microscopic slide preparations from 10 to 20 males from each culture. (Figures 1 to 6).

The general morphological characters like shape and thickness of adeagus, size of the chelate structures and its relative distance from the tip of gonoforceps, relative projection of the basal lobes of gonobase, were examined. It was found that in respect of these characters all the six cultures were alike and these fully agreed with the description and figures of T. australicum Girault given by Nagarkatti and Nagaraja (1968). The male genitalia in the three cultures selected from the Ludhiana Delhi and Ambajipet stocks were also similarly studied (Figures 7 to 9). While the photographs appear to show slight differences, these could very well be differences in the slide mounts or individual variations.

It may, therefore, be concluded with a reasonable degree of certainty that the material used in these studies, all belong to the same species that is T. australicum.

3 Laboratory rearing of parasite stock cultures

The parasite cultures were maintained in the laboratory using eggs of Corcyra cephalonica Stainton, as the laboratory host.

Photomicrographs of male genitalia of adults from different cultures.

Fig. 1 : Ambajipet

Fig. 2 : Cuddalore

Fig. 3 : Delhi

Fig. 1

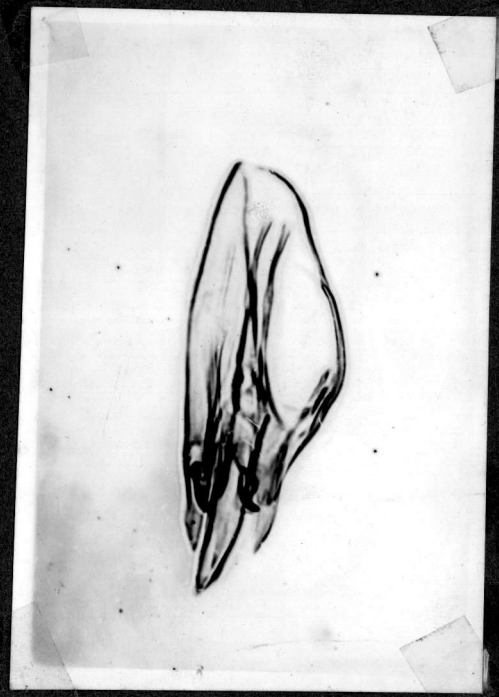


Fig. 2

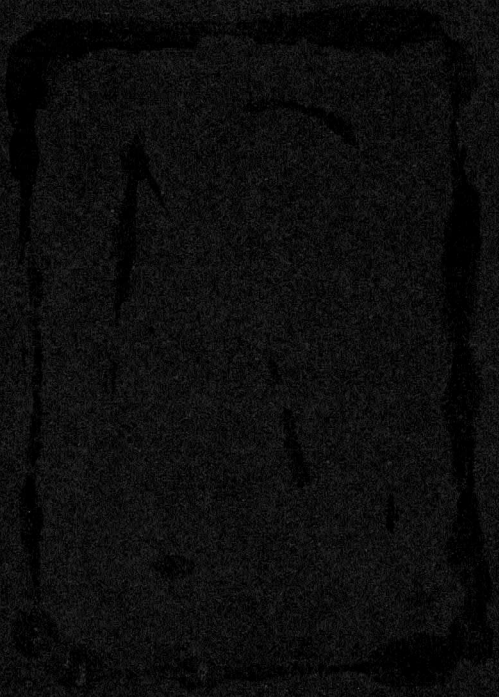


Fig. 3

Photomicrographs of male genitalia
of adults from different cultures

Fig. 4 : Lucknow

Fig. 5 : Ludhiana

Fig. 6 : Mandya

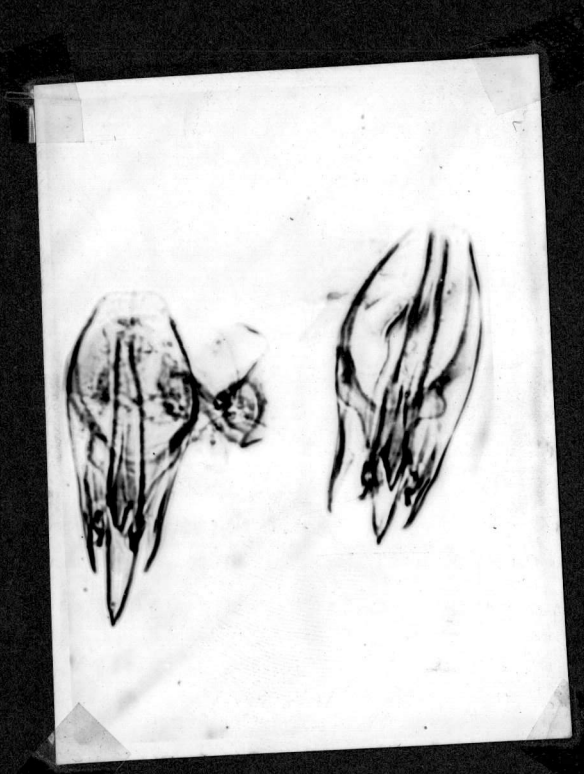


Fig. 4

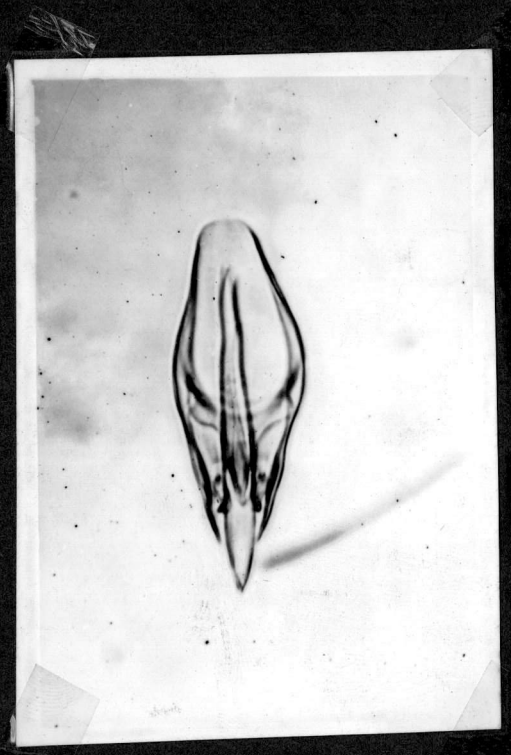


Fig. 5

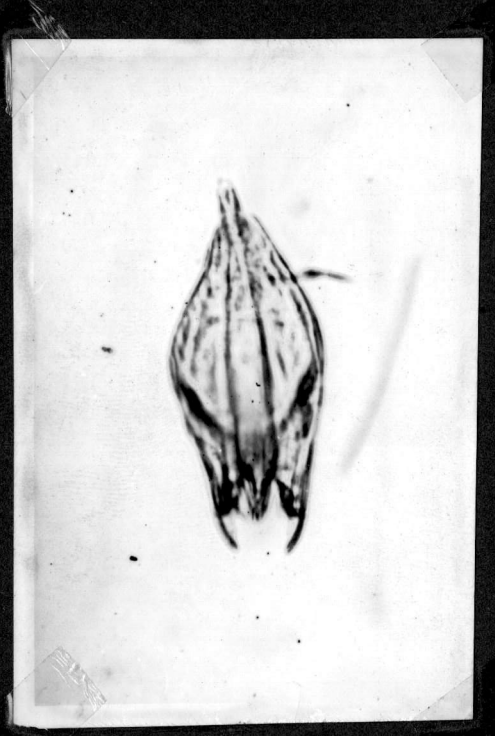


Fig. 6

Photomicrographs of male genitalia of adults from different cultures

Fig. 7 : Selected from the Ludhiana stock

Fig. 8 : Selected from the Delhi stock

Fig. 9 : Selected from the Ambajipet stock.

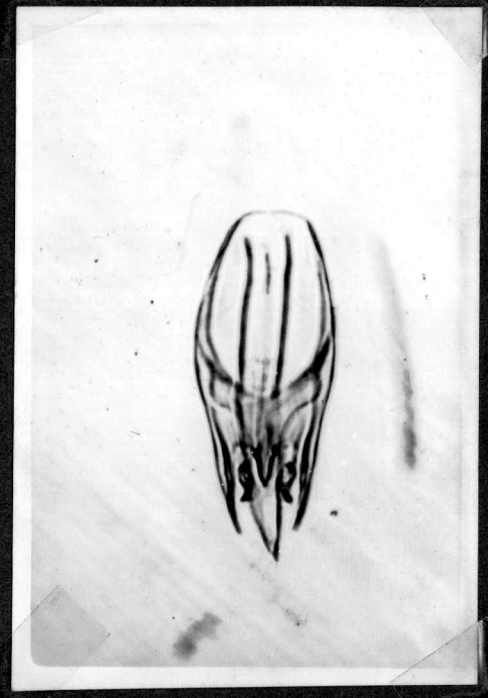


Fig. 7

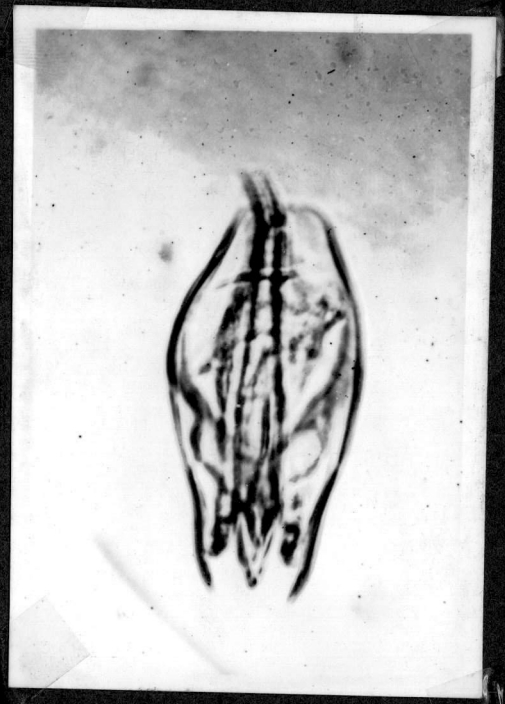


Fig. 8

Fig. 9

The adult parasites were provided with fresh Corcyra eggs for further parasitisation. For this, the host eggs were mounted on a piece of card-board of suitable size, after uniformly smearing a thin layer of 2 per cent solution of gum arabic in distilled water (w/v). A single layer of Corcyra eggs were evenly distributed on the card with the help of a coarse camel hair brush. After proper drying, the egg card was introduced into specimen tubes in which the parasites had emerged from a previous generation. The tubes were then closed with cotton plugs to ensure adequate aeration. The adult parasites of the succeeding generation emerge in 7 to 8 days.

In order to reduce superparasitism to the minimum possible extent, particular care was taken to provide adequate number of host eggs for parasitisation. As a further precaution, the egg cards were exposed to parasitisation only for a period of 12 hours after which these were promptly removed.

The cultures obtained from the different regions were separately maintained throughout the course of the experiments. The bulk rearings were carried out at $26^{\circ} \pm 1.5^{\circ}C$ in desiccators maintaining 75 per cent relative humidity. Equal volumes of a 10 per cent solution of pure crystalline sugar and honey were mixed together and this was used for feeding the adult parasites. The feed was provided on each egg card in the form of fine droplets by means of a bamboo 'pick' with pointed ends.

4 Obtaining inbred lines from the different cultures

Inbred lines of the different cultures were established by successive breeding from healthy mating pairs drawn out from the general collections. For this, mating pairs were collected by means of a camel hair brush having 2-3 long fine bristles. The bristles were slightly wetted with distilled water so as to enable easy collection of the parasite pairs. The mating pairs were transferred to glass vials 5 cm. x 1 cm. and about 100 healthy host eggs provided. The adults emerging out from these eggs were further multiplied as before and in this way four inbred lines in each culture were developed. These were kept at 26° ± 1.5°C and 75 per cent R.H.

5 Maintenance of stock culture of Corcyra cephalonica and cold treatment of eggs

Corcyra cephalonica was regularly bred throughout the course of these investigations. The moths were reared in cylindrical glass jars 6" x 4", using crushed 'jowar' (Sorghum vulgare Pers. as the food medium. About 0.2 cc. of freshly laid Corcyra eggs containing about 3600 eggs were sprinkled over crushed jowar (about 400 g.) kept in jars and these were gently mixed. The contents of the jar was taken out after a period of 3 weeks and this was sieved to eliminate excreta. To the remaining material fresh 'jowar' was added and the original culture was sub-divided into two. The moths emerging from these cultures were collected every day and were confined in oviposition cages.

Fresh eggs were collected from these cages and thoroughly cleaned. Only normal healthy eggs were used for experimental purposes.

In order to kill Corcyra embryos so as to suppress larval emergence from unparasitised eggs, the host eggs were exposed in paired petridishes to -4°C obtaining in the freezer chamber of a refrigerator for a period of 24 hours. This technique was found useful in avoiding damage to parasitised eggs caused by Corcyra larva emerging from unparasitised eggs.

6 Studying the physiological compatibility of different cultures of Trichogramma

The physiological compatibility of the cultures was ascertained by a series of cross breeding studies. These were carried out in two sets, the crosses AxC, AxD, AxL_1, AxL_2, AxM, CxD, CxL_1, CxL_2, CxM, DxL_1, DxL_2, DxM, L_1xL_2, L_1xM and L_2xM being done in the first set. Their reciprocal crosses were done in the second set. For effecting the crosses, parasitised eggs cards were taken from inbred lines of different cultures and these were gently brushed by means of a camel hair brush to dislodge some of the loosely adhering eggs. From among those eggs which were thus collected, healthy parasitised ones were selected and these were transferred to small glass vials at the rate of one in each. The vials were kept closed with cotton plugs of suitable size. On emergence the adults were taken out by moistened bristles of a camel hair brush and immediately observed under a binocular

microscope for sexing. The required cross was effected by confining virgin females from one culture with unmated male of the other. When mating was observed, about 100 Corcyra eggs were provided and the vials transferred to desiccators maintaining 75 per cent R.H.

On emergence of the F_1 generation, fresh egg cards were provided and a subsequent generation also bred. When all the F_1 adults died, these were counted and sexed. Since arrhenotoky is expected in Trichogramma spp., the production of females in the F_1 progeny would suggest the physiological compatibility of the parental cultures.

7 Pooling of different cultures at the F_2 stage

For this, Corcyra eggs parasitised by the F_1 adults from crosses AxC, AxD, AxL_1, AxL_2, AxM, CxD, CxL_1, CxL_2, CxM, DxL_1, DxL_2, DxM, L_1xL_2, L_1xM and L_2xM (details as in 6) were put together and the F_2 adults allowed to emerge. These were multiplied for a generation and the F_3 adults were utilised for screening for temperature tolerance. This pooled population is referred to as 'P_1'.

8 Radiation experiments

A part of the pooled population 'P_1' was irradiated by exposing them to gamma radiation in the pupal stage from ^{60}Co sour This was done to try whether temperature tolerance could be

increased through irradiation. The M_2 progeny from this line (referred to as 'P_2 pool) was utilised for selection purposes. The different cultures were separately irradiated and the progeny derived from these were also subjected to selection.

The r dose at which a fairly good culture population could be maintained was determined by trying various doses ranging from 500 to 10,000 r. These trials were conducted with inbred lines of the Ludhiana culture. For this experiment, 500 Corcyra eggs, blackened after successful parasitisation (pupal stage of the parasite) were exposed to gamma radiation. After irradiation, the specimen tubes (3" x 1") containing the parasitised host eggs were transferred to desiccators maintaining 75 per cent R.H. and these were incubated at 27°C.

The percentage adult emergence, fecundity, sex-ratio, and progeny production were determined for all the replicates. Irradiation was accomplished in the "Gamma Cell" maintained in the Division of Genetics, Indian Agricultural Research Institute, New Delhi.

9 High temperature tolerance of the pooled population

The population pool 'P_1 was exposed to 33°C for a period of four generations and the resulting population was subsequently transferred to 35°C and reared for as many generations as possible. The performance of the resulting population at 33°C and 35°C was compared with that of the Delhi culture which was maintained as control.

10 High temperature tolerance of progeny from irradiated cultures

The M_2 progeny derived from the different irradiated cultures were exposed to 33°C separately and reared for as many generations as possible to try whether the resulting population showed increased temperature tolerance.

11 The performance of the cultures under different combinations of temperature and humidity

These were studied by exposing freshly emerging adults obtained from inbred lines of the cultures (kept at 26° ± 1.5°C and 75 per cent R.H.) to the temperature-humidity combinations noted below:

	Temperature °C	Relative humidity
a)	27	75
b)	30	90
c)	30	75
d)	30	10
e)	32	90
f)	32	75
g)	32	10
h)	33	90
i)	33	75
j)	33	10
k)	35	90
l)	35	75
m)	35	10

The duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production of the different cultures in these conditions were studied. Of these, the progeny production and sex-ratio were observed from the F_2 emergents and other characteristics from the F_1 populations.

12 Selection of the cultures for high temperature-low humidity tolerance

For this, some of the relatively better performing cultures were reared at progressively adverse temperature-humidity conditions in sequence as shown below:

	R.H.	Temp°C	No. of generations
a)	60	30	4
b)	40	30	4
c)	30	30	4
d)	20	30	4
e)	10	30	4
f)	10	32	4
g)	10	33	10

A part of the culture which had been reared at 33°C and 10 per cent R.H. for ten generations was exposed to 35°C and 75 per cent R.H. and its performance studied. The remaining culture was reared in the same conditions (33°C and 10 per cent R.H.) for a few generations and the consistency of its performance verified.

Observations were made on adult emergence, adult longevity, total reproductive period in females, fecundity, progeny production and sex-ratio, for the cultures at successive stages of rearing. Controls were maintained at all the stages by directly exposing the original cultures taken from 26° ± 1.5°C and 75 per cent R.H.

The required temperatures for these experiments were maintained in electric thermostat incubators, while constant humidities were obtained in suitably sized desiccators by keeping calculated quantities of pure potassium hydroxide dissolved in

distilled water according to Buxton (1931).

13 Study of the various characteristics of the different cultures

The various characteristics were studied from ten mating pairs collected from each replicate as outlined below:

a) Adult longevity

To determine the longevity of adult parasites, the period elapsing between the time of their emergence and the time of death was considered separately for both the sexes. This was accomplished by periodical observations of the pairs confined for oviposition.

b) Fecundity

Fecundity was studied by taking counts of Corcyra eggs turning black as a result of parasite development. Not less than 100 Corcyra eggs were provided for each female parasite and these were replaced by fresh ones at periodic intervals of 5 to 10 hours. From the total number of eggs obtained from all the ten replicates, the mean fecundity was calculated.

c) Total reproductive period in females

The total period during which the females laid eggs, was recorded as the total reproductive period of females. This was observed from egg cards removed at periodic intervals ranging from 5 to 10 hours.

d) Progeny production

The egg cards removed from each vial at periodic intervals of 5 to 10 hours were put together and the total number of progeny emerging out of these were counted. The mean value for the ten replicates was recorded as progeny production per female.

e) Sex-ratio

While counting the progeny produced from a single female, these were also sexed (under a binocular microscope) and the ratio of the total number of females to the total number of males, worked out in each case. The mean values were expressed as sex-ratios.

The other characteristics of the parasites were determined as below.

Percentage adult emergence and duration of development

The duration of development was found out by calculating the weighted mean of the number of days taken by all the emerging parasites belonging to both sexes. For this, the parasites emerging on a particular day were isolated by removal of the egg cards and these were counted after death. On the basis of the total number of eggs parasitised (indicated by blackened eggs) and the total number of parasites emerging out from them, the percentages were calculated.

14 Statistical tests

The performance of the different cultures under a particular temperature and humidity condition was compared by using the analysis of variance technique suggested as for the Randomised Block Design. The irradiation experiment was also analysed in the same way. In order to study the effect of varying levels of temperature and humidity on the different cultures, the data were analysed by employing the analysis of variance technique suggested for the Split Plot Design.

Appropriate 't' tests were applied to compare sample means of a particular characteristic, obtained under different situations.

IV EXPERIMENTAL FINDINGS

The results are presented in the following order:

A Physiological compatibility of the cultures obtained from different regions

B Screening of the pooled population for high temperature tolerance

C Performance of the different cultures at various temperature-humidity combinations

D Selection of the cultures for high temperature-low humidity tolerance

E Radiation experiments

F Temperature tolerance of progeny from irradiated cultures.

(A) Physiological compatibility of the cultures obtained from different regions

These experiments were conducted to ascertain the physiological compatibility of the different cultures utilised in the course of the present investigations and to ensure that the cultures are not reproductively isolated and to develop a gene pool from these for subsequent screening for temperature tolerance.

Altogether 30 crosses were made between adults emerging from six different cultures, as outlined in Chapter III. These were made in two sets of fifteen crosses each, the second set being the reciprocal crosses of the first set. The percentage of females in the F_1 population was estimated from 10 replicates of a particu

Table 1 : Physiological compatibility of the different cultures as shown by the percentage of females in the F_1 progeny from crosses

Sl. No.	Parents	Total F_1 population	No. of crosses	No. of females in the F_1 population	Percentage of females in the F_1 population	No. of cases in which all the progeny were males
1	AxC	21.80	10	13.70	59.52	-
2	CxA	23.10	"	13.30	56.60	2
3	AxD	22.10	"	13.90	64.62	-
4	DxA	23.70	"	15.90	66.82	-
5	AxL_1	15.10	"	9.90	65.33	-
6	L_1xA	19.50	"	11.30	53.91	1
7	AxL_2	22.80	"	16.40	70.12	-
8	L_2xA	24.50	"	13.80	58.29	1
9	AxM	18.90	"	12.20	64.64	-
10	MxA	16.10	"	8.90	54.75	2
11	CxD	16.80	"	11.50	67.22	-
12	DxC	21.90	"	13.10	61.33	-
13	CxL_1	23.70	"	15.30	66.13	-
14	L_1xC	21.90	"	12.10	53.13	2
15	CxL_2	22.00	"	14.30	64.83	-
16	L_2xC	24.40	"	16.00	62.20	-
17	CxM	21.20	"	13.80	65.46	-
18	MxC	20.00	"	11.00	51.31	1
19	L_1xD	19.10	"	12.50	64.88	-
20	DxL_1	18.20	"	11.20	62.15	-
21	L_2xD	23.20	"	15.20	65.92	-
22	DxL_2	20.60	"	13.10	63.88	-
23	DxM	19.10	"	11.60	61.06	1
24	MxD	16.80	"	9.50	61.56	-
25	L_1xL_2	21.80	"	13.40	63.42	-
26	L_2xL_1	18.30	"	10.20	58.13	-
27	L_1xM	18.70	"	9.40	49.11	2
28	MxL_1	15.80	"	8.80	57.68	-
29	L_2xM	19.60	"	11.40	58.98	-
30	MxL_2	17.50	"	9.20	54.28	-

kept at 27°C and 75 per cent R.H.

The data pertaining to these are given in Table 1 and the detailed data in Appendix Table I. The percentage of females in the F_1 progeny ranged from 49.11 per cent in the L_1xM cross to 70.12 per cent in the AxL_2 cross. All male progeny were obtained in a total of 12 cases in the crosses, CxA, L_1xA, L_2xA, MxA, L_1xC, MxC, DxM, and L_1xM.

(B) Screening of the pooled population for high temperature tolerance

The object of these studies was to explore the possibility of selecting genotypes with high temperature tolerance from a genetically heterogenous population developed by interbreeding from the six cultures utilized in these investigations. For developing a pooled population, the F_2 progeny from the crosses AxC, AxD, AxL_1, AxL_2, AxM, CxD, CxL_1, CxL_2, CxM, DxL_1, DxL_2, DxM, L_1xL_2, L_1xM and L_2xM were allowed to emerge and interbreed by keeping together all the egg cards parasitised by the F_1 females. The F_3 progeny from these were used for screening for temperature tolerance. This is referred to as population pool P_1.

Replicates from the P_1 pool were exposed to 33°C and 75 per cent R.H. and reared for four generations in succession. Thereafter, the resultant population was brought to 35°C and bred at 75 per cent R.H.

Table 2 : Performance of the pooled population (P_1) obtained from the different cultures at 33°C and 35°C (at 75% R.H.) as shown by the percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production

Generation No.	Conditions of rearing		Adult emergence (%)	Adult longevity (hours)		Sex-ratio (females/male)	Total reproductive period in females	Fecundity	Progeny production
	Temp.°C	R.H.%		Females	Males				
1	33	75	70.75	30.15	21.62	4.03	26.87	17.10	7.62
2	33	75	68.42	28.05	24.40	3.88	22.75	13.77	9.07
3	33	75	70.22	32.45	21.87	3.81	23.10	15.67	8.20
4	33	75	73.72	31.50	20.45	3.98	25.92	15.20	7.20
5	35	75	22.77	21.82	13.85	3.25	14.02	4.32	2.12

Table 3 : Tests of significance ('t' tests) for comparing the performance of the pooled population P_1 at different temperature-humidity combinations.

Conditions of rearing		Percentage adult emergence and 't' values for comparing the means			Fecundity and the 't' values for comparing the means			Progeny production and 't' values for comparing the means		
Temp.°C	R.H.%	x	y	't'	x	y	't'	x	y	't'
33+	75	73.72	65.95	1.114	15.20	19.92	1.537	7.20	10.87	1.678
35	75	22.27	40.12	8.176**	4.32	6.20	2.106	2.12	2.36	0.540

x Mean values for the pooled population 'P_1'

y Mean values for the Delhi culture (direct exposures)

\+ Tested at the 4th generation

** Significant at 1% level

Tabular value of 't' at 1% = 3.499

Mean values of the percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production recorded for the 'P_1' culture at 33°C and 35°C are furnished in Table 2 and the detailed data in Appendix Table II. Testing was done to detect whether variability between the performance of the resultant population and that of the Delhi culture which was directly exposed to these temperatures (from stocks kept at 26° ± 1.5°C and 75 per cent R.H.). The results of testing are given in Table 3.

There were no significant differences between the 'P_1' population and the directly exposed Delhi culture at 33°C. But a significant reduction in adult emergence was detected in the resultant 'P_1' population which was exposed to 35°C. Thus, in the 'P_1' culture, the percentage adult emergence was 22.27 as compared with 40.12 observed in the Delhi culture maintained as control. The 'P_1' population could not maintain itself for more than a generation at 35°C.

(C) Performance of the different cultures at various temperature-humidity combinations

The object of these experiments was to detect whether variability existed among the different cultures with regard to their tolerance to different temperature-humidity combinations.

For this, freshly emerged adults in different inbred lines (kept at 26° ± 1.5°C and 75 per cent R.H.) of the original cultures were exposed to various temperature-humidity combinations shown in

section 11 of Chapter III.

The developmental period, percentage adult emergence, adult longevity, total reproductive period in females, fecundity and the percentage of adults with structural malformations were observed from the first generation emerging from adults exposed to the particular condition (F_1 population), while the progeny production and sex-ratio were recorded from the number of second generation (F_2) adults emerging from Corcyra eggs, parasitised by the F_1 population.

Details of analysis of variance for the treatments (a) to (m) are given in the Appendix Table XXVI.

(a) Performance of the cultures at 27°C and 75 per cent R.H.

The results are furnished in Table 4 in the form of mean values and the detailed data in Appendix Table III.

i) Duration of development

The duration of development was found to be 8.61 and 8.01 days respectively for the Lucknow and Ludhiana cultures. In the remaining cultures the range was from 7.17 to 7.37 days. Significant variations was not detected.

ii) Percentage adult emergence

The analysis of variance indicated significant variation among the cultures studied. The mean values of the percentage

Table 4 : Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 27°C and 75% R.H.

Sl. No.	Characters studied	Mean values for the different cultures A	C	D	L_1	L_2	M	Significance	C.D.	Ranking
1	Developmental period (days)	7.17	7.24	7.32	8.61	8.09	7.37	N.S.	-	-
2	Percentage adult emergence (F_1)	76.15	84.42	78.02	70.62	78.67	73.40	*	10.802	$\underline{C, L_2, D, A, M, L_1}$
3	Adult longevity female (hours)	51.57	46.20	40.90	51.32	60.87	42.75	**	12.304	$\underline{L_2, A, L_1, C, M, D}$
4	Adult longevity Male (hours)	29.72	35.00	34.32	36.27	36.82	39.60	N.S.	-	-
5	Sex-ratio (females/ male).	5.81	5.17	3.51	3.54	4.04	4.13	**	1.202	$\underline{A, C, M}, \underline{L_2, L_1}, D$
6	Total reproductive period in females (hours)	42.77	38.12	34.87	31.67	41.07	34.82	N.S	-	-
7	Fecundity (number of eggs laid per female)	42.20	36.80	34.87	54.77	41.45	31.55	**	14.066	$\underline{L_1, A, L_2}, C, D, M$
8	Progeny production per female	30.15	26.60	25.15	36.40	27.90	23.00	**	12.560	$\underline{L_1, A, L_2, C, D, M}$
9	Percentage F_2 emergence (from 7,8)	71.25	72.29	72.16	64.63	67.30	72.90	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level
N.S. Non-Significant.

emergence varied from 70.62 in the Lucknow culture to 84.42 in the Cuddalore culture and the latter was found to show high adult emergence than Lucknow and Mandya cultures. The percentage of adult emergence in the F_2 generation ranged from 64.63 to 72.00.

iii) Adult longevity

The maximum longevity was observed in the Ludhiana females (60.87 hours), while the females from Delhi culture revealed a mean longevity of 40.90 hours only. No differences were evident among Ludhiana, Ambajipet and Lucknow cultures.

The mean values of male longevity ranged between 29.72 hours in the Ambajipet culture to 39.60 hours in the Mandya culture The analysis of variance did not reveal any significant variation.

iv) Sex-ratio

The sex-ratio (expressed as females/male) was observed to be highest in Ambajipet and the Cuddalore cultures being 5.87 and 5.17 respectively. In Lucknow and the Delhi cultures, the sex-ratios were found to be 3.54 and 3.51 respectively. These differences were significant.

v) Total reproductive period in females

The mean values of the total reproductive period in females emerging from different cultures ranged from 31.67 hours in the Lucknow culture to 42.77 hours observed in the Ambajipet culture. The variation was non-significant.

vi) Fecundity

The mean values for different cultures ranged from 31.65 in the Mandya culture to 64.77 observed in the case of the Lucknow culture. The cultures were found to be significantly different among themselves with regard to this character. The Lucknow culture appeared to be significantly better than the Cuddalore, Delhi and Mandya cultures.

vii) Progeny production per female

The variation was found to be significant. The progeny production was found to be maximum in Lucknow culture (36.40 per female) and the lowest value was recorded in the Mandya culture (23.00 per female). The lucknow culture was distinctly better than the Mandya culture in this respect.

(b) Performance of the different cultures at 30°C and 90 per cent R.H.

The mean values for the different characters are furnished in Table 5 and the detailed data are appended (Table IV).

i) Duration of development

The developmental period varied significantly from 7.16 days in the Mandya culture to 8.48 days in the Ludhiana culture. In L_1 and L_2 cultures, the developmental period was of longer duration than in Cuddalore and the Mandya cultures.

Table 5 : Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 30°C and 90% R.H.

Sl. No.	Characters studied	Mean values for the different cultures A	C	D	L_1	L_2	M	Signi-ficance	C.D.	Ranking
1	Developmental period (days)	7.50	7.38	7.46	8.07	8.48	7.16	*	0.828	L_2, L_1, A, D, C, M
2	Percentage adult emergence	67.82	71.30	53.67	41.30	47.35	28.52	**	14.393	C, A, D, L_2, L_1, M
3	Adult longevity female (hours)	36.75	36.97	32.97	47.12	36.20	28.94	**	10.635	L_1, C, A, L_2, D, M
4	Adult longevity male (hours)	24.02	36.25	24.02	30.12	28.60	32.47	*	7.409	C, M, L_1, L_2, A, D
5	Sex-ratio (females/male)	6.75	6.27	3.11	3.72	3.25	4.37	**	1.364	A, C, M, L_1, L_2, D
6	Total reproductive period in females (hours)	20.85	36.35	26.12	24.37	24.82	20.15	**	10.002	C, D, L_2, L_1, A, M
7	Fecundity (number of eggs per female)	35.57	21.95	24.67	15.42	13.30	11.70	**	11.902	A, D, C, L_1, L_2, M
8	Progeny production per female	23.00	14.15	12.20	4.30	6.57	3.30	**	9.062	A, C, D, L_2, L_1, M
9	Percentage F_2 emergence (from 7,8)	64.65	66.90	49.92	27.42	49.34	34.12	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level

ii) Percentage adult emergence

In Cuddalore and Ambajipet cultures maximum emergence was observed (71.80 and 67.82 per cent respectively), while in the Mandya culture only 28.62 per cent emergence was found. The variation was significant. The percentage F_2 emergence ranged from 27.42 to 66.90.

iii) Adult longevity

Females emerging out of the Lucknow culture showed maximum longevity of 47.12 hours, while those from the Mandya culture lived only for 28.84 hours. Intermediate values were obtained in other cultures.

Male longevity was also found to vary significantly in different cultures reared at 30°C and 90 per cent R.H. In the Cuddalore, Mandya and Lucknow cultures, the males were relatively long lived (36.26, 32.47 and 30.12 hours respectively), while the longevity in Ludhiana, Ambajipet and Delhi cultures was for periods ranging from 24.02 to 30.12 hours.

iv) Sex-ratio

Significant variability was detected in this character. In the Ambajipet culture the mean value was 6.75 and this differed from the Lucknow, Ludhiana and Delhi cultures.

v) Total reproductive period in females

The Cuddalore culture produced females with a significantly longer reproductive period (36.35 hours) than in those

emerging from the remaining cultures.

vi) Fecundity

The females derived from Ambajipet and the Delhi cultures showed mean fecundity values of 35.57 and 24.67 respectively and these cultures were found to be significantly better than the Lucknow, Ludhiana and Mandya cultures. The fecundity was observed to be lowest in Mandya culture (11.70).

vii) Progeny production per female

The Ambajipet and Cuddalore cultures produced the highest number of progeny (23.00 and 14.15 respectively), these being higher than the values obtained for Ludhiana, Lucknow and Mandya cultures. The Lucknow culture when reared under this condition was found to produce the least number of progeny (3.80).

(c) Performance of the different cultures at 30°C and 75 per cent R.H.

The results pertaining to these experiments are given in Table 6 and the detailed values are given in Appendix Table 6.

i) Duration of development

When reared at 30°C and 75 per cent R.H., the cultures showed significant variation in the developmental period, the range being from 7.20 days (Ambajipet culture) to 8.14 days (Lucknow culture). In Lucknow and Ludhiana cultures the duration of development was found to be significantly longer than in the Ambajipet culture.

Table 9. Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 30°C and 75% R.H.

Sl. No.	Characters studied	Mean values for the different cultures						Signi-ficance	C.D.	Ranking
		A	C	D	L_1	L_2	M			
1	Developmental period (days)	7.20	7.30	7.45	8.14	7.98	7.42	**	0.642	$\overline{L_1, L_2, D, M, C, A}$
2	Percentage adult emergence	72.45	80.20	78.65	71.20	75.70	70.45	N.S.	-	-
3	Adult longevity female (hours)	44.32	46.20	39.40	50.12	55.17	38.45	N.S.	-	-
4	Adult longevity male (hours)	28.67	37.37	36.95	34.20	25.27	35.60	*	8.615	$\overline{C, D, M, L_1}, \overline{A, L_2}$
5	Sex-ratio (females/male)	6.51	5.22	3.07	3.67	3.80	4.23	**	1.679	$\overline{A, C, M, L_2, L_1, D}$
6	Total reproductive period in females (hours)	37.05	35.25	32.55	28.55	40.40	28.22	N.S.	-	-
7	Fecundity (number of eggs per female	36.45	34.45	38.82	48.70	40.05	28.55	*	10.706	$\underline{L_1, L_2, D, A}, \overline{C, M}$
8	Progeny production per female	24.50	13.72	25.55	25.12	21.45	8.35	**	8.410	$\underline{D, L_1, A, L_2}, \overline{C, M}$
9	Percentage F_2 emergence (from 7,8)	67.20	39.80	65.81	51.60	53.10	28.94	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level
N.S. Non-significant

ii) Percentage adult emergence

In the Cuddalore culture the adult emergence was found to be 80.20 per cent while in the Mandya culture, it was only 70.45 per cent. This variability was non-significant. The percentage F_2 emergence ranged from 28.84 to 67.20.

iii) Adult longevity

Females emerging from different cultures did not show any significant variability with regard to this character, but the males showed significant differences. In this case, the mean values ranged between 25.27 to 37.37 hours in Ludhiana and Cuddalore cultures respectively.

iv) Sex-ratio

The mean values ranged between 6.51 in the Ambajipet culture and 3.07 in Delhi culture, the differences being significant.

v) Total reproductive period in females

The total reproductive period in female emergents were found to vary between 28.32 to 40.40 hours (in the Mandya and Ambajipet cultures respectively), the variation being non-significant.

vi) Fecundity

Significant differences were observed among the cultures studied. The maximum fecundity was detected in the Lucknow culture

and the least in the Mandya culture (48.70 and 28.56 respectively). The Lucknow females were more fecund than those in the Ambajipet, Cuddalore and Mandya cultures.

vii) Progeny production per female

This was observed to vary from 8.36 in the Mandya culture to 25.55 in the Delhi culture. The variability was significant and in Delhi culture progeny production was higher than in the Cuddalore and Mandya cultures.

(d) Performance of the different cultures at 30°C and 10 per cent R.H.

The data pertaining to these experiments are given in Table 7 and the detailed data are presented in Appendix Table VI.

i) Developmental period

Significant differences in the duration of development were not detected at this temperature-humidity condition.

ii) Percentage adult emergence

The percentage adult emergence in the cultures revealed significant variation. The range for this was from 61.20 in the Ambajipet culture to 43.06 in the Mandya culture. In the Mandya culture, adult emergence was lower than in Ambajipet, Ludhiana and the Delhi cultures. The percentage emergence in the F_2 generation ranged from 35.37 in Cuddalore culture to 54.93 in the Ambajipet culture.

Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 30°C and 10% R.H.

Sl. No.	Characters studied	Mean values for the different cultures A	C	D	L_1	L_2	M	Significance	C.D.	Ranking
1	Developmental period (days)	7.01	7.63	7.63	8.67	8.02	7.10	N.S.	-	-
2	Percentage adult emergence	61.21	48.77	54.62	50.10	57.07	43.05	**	9.128	$\underline{A, L_2, D, L_1, C, M}$
3	Adult longevity female (hours)	25.97	38.30	37.10	40.31	37.67	32.00	N.S.	-	-
4	Adult longevity male (hours)	21.80	34.12	23.52	24.77	27.12	20.65	N.S.	-	-
5	Sex-ratio (Females/male)	6.44	4.87	3.14	3.69	3.91	4.75	**	2.576	$\underline{A, C, M, L_2, L_1, D}$
6	Total reproductive period (in females (hours)	18.60	20.25	25.55	21.70	26.35	20.18	N.S.	-	-
7	Fecundity (number of eggs per female)	17.24	10.02	11.97	14.57	21.25	11.00	*	11.023	$\underline{L_2, A, L_1, D, M, C.}$
8	Progeny production per female	9.47	3.35	6.60	6.20	9.20	5.65	*	3.724	$\underline{A, L_2, D, L_1, M, C.}$
9	Percentage F_2 emergence (from 7,8)	54.93	35.37	41.27	42.55	43.29	51.30	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level
N.S. Non-significant.

iii) Adult longevity

The range in adult longevity was 25.97 to 40.31 hours for female emergents. Significant variability was not evident. Adult longevity for males varied from 21.80 to 34.12 hours and these differences were also insignificant.

iv) Sex-ratio

Significant variation was detected with regard to the proportion of females to males, the range being 3.14 in the Delhi culture to 6.44 in the Ambajipet culture. The Ambajipet culture differed from Lucknow and the Delhi cultures in this respect.

v) Total reproductive period

The range in total reproductive period of females was from 18.60 hours in Ambajipet culture to 26.35 hours in the Ludhiana culture but the differences were non-significant.

vi) Fecundity

At 30°C and 10 per cent R.H. the mean fecundity ranged from 10.02 to 21.25 in Mandya and the Ludhiana cultures respectively. In the Cuddalore culture fecundity was significantly lower than in the Ludhiana culture.

vii) Progeny production per female

This ranged from 3.35 in the Cuddalore culture to 9.47 in the Ambajipet culture and the variation was significant. In the Ambajipet culture progeny production was higher than in the Cuddalore and Mandya cultures.

(e) Performance of the cultures at 32°C and 90 per cent R.H.

Data relating to this are given in Table 8 and the detailed data are given in Appendix Table VII.

i) Developmental period

The differences in the duration of the development in the cultures studied were found to be non-significant.

ii) Percentage adult emergence

Significant variability was detected in regard to the percentage adult emergence. This was highest in the Cuddalore culture (66.42 per cent). The least number of adults emerged from Mandya and Lucknow cultures (30.72 and 26.52 per cent respectively). In the F_2 generation, the least percentage emergence was in the Lucknow culture (21.92), while in the Ambajipet and the Delhi cultures, these were 51.00 and 52.20.

iii) Adult longevity

At this temperature-humidity combination, there were no significant differences in regard to the longevity of male and female emergents. The female longevity varied from 32.22 hours in the Lucknow culture to 34.57 hours in the Ludhiana culture. The male longevity varied from 15.90 hours to 27.92 hours in the Lucknow and the Ludhiana cultures respectively.

Table 3 : Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 32°C and 90 per cent R.H.

Sl. No.	Characters studied	Mean values for the different cultures						Signi-ficance	C.D.	Ranking
		A	C	D	L_1	L_2	M			
1	Developmental period (days)	7.10	8.02	7.33	7.78	8.17	7.24	N.S.	-	-
2	Percentage adult emergence	63.17	66.42	50.35	26.52	36.12	30.72	**	10.648	C,A,D,L_2,M,L_1
3	Adult longevity female (hours)	33.77	25.32	24.32	22.22	34.57	19.87	N.S.	-	-
4	Adult longevity male (hours)	24.02	21.25	19.07	15.90	27.92	16.80	N.S.	-	-
5	Sex-ratio (Females/male)	5.67	5.93	3.05	2.97	3.62	4.83	*	2.168	C,A,M,L_2,D,L_1
6	Total reproductive period in females (hours)	16.80	22.40	16.02	14.45	16.07	15.57	N.S.	-	-
7	Fecundity (number of eggs per female)	26.37	19.52	13.50	9.35	9.55	12.47	**	7.426	A,C,D,M,L_2,L_1
8	Progeny production per female	13.45	7.35	7.05	2.05	4.72	5.75	**	5.184	A,C,D,M,L_2,L_1
9	Percentage F_2 emergence (from 7,8)	51.00	37.65	52.20	21.92	49.42	46.11	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level
N.S. Not-significant.

iv) Sex-ratio

Significant differences were detected in the cultures at 32°C and 90 per cent R.H. The range was from 2.97 in the Lucknow culture to 5.93 in the Cuddalore culture.

v) Total reproductive period in females

These were not significantly different in the cultures studied, the range being from 14.45 hours in the Lucknow culture to 22.40 hours in the Cuddalore culture.

vi) Fecundity

Highly significant variability was detected in regard to the number of eggs laid by females in different cultures, the range being from 9.35 in the Lucknow culture to 26.37 in the Ambajipet culture. In the Ambajipet culture fecundity was significantly higher than in the Delhi, Mandya, Ludhiana, Lucknow cultures.

vii) Progeny production per female

The range for this character was from 4.72 in the Ludhiana culture to 13.45 in the Ambajipet culture, the variabilit being significant. The Cuddalore, Delhi, Mandya and Ludhiana cultures showed intermediate values.

(f) Performance of the cultures at 32°C and 75 per cent R.H.

Data pertaining to these are given in Table 9 and the detailed data in Appendix Table VIII.

Table 9 : Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 32°C and 75% R.H.

Sl. No.	Characters studied	Mean values for the different cultures						Signi-ficance	C.D.	Ranking
		A	C	D	L_1	L_2	M			
1	Developmental period (days)	7.20	7.09	7.34	8.34	7.59	7.62	*	0.724	L_1, M, L_2, D, A, C
2	Percentage adult emergence	72.05	61.50	72.30	64.32	67.95	64.90	*	7.237	D, A, L_2, M, L_1, C
3	Adult longevity female (hours)	38.37	40.72	40.12	40.15	41.40	35.15	N.S.	-	-
4	Adult longevity male (hours)	27.22	34.20	25.60	28.00	21.27	24.75	**	8.378	C, L_1, A, D, M, L_2
5	Sex-ratio (Females/male)	4.89	5.84	3.46	3.44	4.97	4.47	**	1.196	C, L_2, A, M, D, L_1
6	Total reproductive period in female (hours)	31.03	31.42	28.42	20.50	30.70	27.47	N.S.	-	-
7	Fecundity (number of eggs per female)	23.82	25.85	29.47	21.50	33.17	24.02	**	7.114	L_2, D, C, M, A, L_1
8	Progeny production per female	13.02	9.60	16.75	10.10	14.72	7.02	**	6.595	D, L_2, A, L_1, C, M
9	Percentage F_2 emergence (from 7,8)	54.65	37.13	56.83	46.88	43.05	29.21	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level
N.S. Not-significant.

i) Duration of development

The mean values of developmental period of different cultures when reared under this condition were found to vary significantly. In the Lucknow culture, the developmental period was 8.34 days, and the Cuddalore culture completed development in 7.09 days. In Ludhiana, Delhi and Ambajipet cultures the duratic of development was not found to be different.

ii) Percentage adult emergence

Variation in the percentage adult emergence in different cultures was found to be from 72.30 to 61.50 (in the Delhi and the Cuddalore cultures respectively.) The cultures from Delhi and Ambajipet were significantly different from the Lucknow and Cuddalore cultures which showed 64.32 and 61.50 per cent emergence respectively. The percentage F_2 emergence ranged from 29.21 to 56.33.

iii) Adult longevity

Longevity of adult females was not found to vary significantly. The mean female longevity in the Mandya culture was 35.15 hours. In the Ludhiana culture, it was found to be the highest (41.40 hours).

Significant variation was detected among the cultures with regard to male longevity. In the Cuddalore culture, male longevit was 34.20 hours. Males were relatively short lived in the Mandya culture (24.75 hours).

iv) Sex-ratio

The sex-ratio was observed to vary from 5.84 to 3.44 in the Cuddalore and Lucknow cultures respectively and the variation was significant. The highest proportions of females to males was observed in the Cuddalore culture and in this respect this differed from both the Delhi and Lucknow cultures.

v) Total reproductive period in females

The reproductive period was found to be higher in the Cuddalore and Ambajipet cultures (31.42 and 31.03 hours). But the differences were non-significant.

vi) Fecundity

The mean values for fecundity ranged from 21.50 in the Lucknow culture to a maximum of 33.17 observed in the Ludhiana culture. The fecundity in Ludhiana culture (33.17) was higher than in the Ambajipet and the Lucknow cultures (23.82 and 21.50 respectively).

vii) Progeny production per female

Highly significant variation was detected in this respect. The Delhi culture showed the maximum progeny production of 16.75 and this was higher than in the Lucknow, Cuddalore and Mandya cultures(10.10, 9.60 and 7.02 respectively). The Ludhiana and the Delhi cultures did not show significant differences.

(g) Performance of the different cultures at 32°C and 10 per cent R.H.

The mean values for the different characters studied at this temperature-humidity combination are furnished in Table 10 and the detailed data are presented in Appendix Table IX.

i) Developmental period

Significant differences were not detected with regard to the developmental period in the different cultures.

ii) Percentage adult emergence

The adult emergence was found to vary between 38.05 and 60.07 per cent in the Mandya and the Ambajipet cultures. In the Mandya culture, the emergence was the lowest (38.05 per cent) and this was significantly different from the Ambajipet and the Ludhiana cultures. (60.07 and 53.82 per cent). In the second generation, the percentage emergence of adults was found to be 61.14 and 44.60 in the Delhi and Ambajipet cultures respectively.

iii) Adult longevity

The life-span of adult females was not found to be significantly different in the cultures studied, but the variability in male longevity was significant. The duration of adult life of males ranged from 16.67 hours in the Mandya culture to 29.50 hours in the Cuddalore culture. In the Cuddalore culture males lived for significantly longer duration (29.50 hours) than those in the rest of the cultures.

Table 10 : Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 32°C and 10 per cent R.H.

Sl. No.	Characters studied	Mean values for the different cultures						Signi-ficance	C.D.	Ranking
		A	C	D	L_1	L_2	M			
1	Developmental period (days)	7.02	7.12	7.23	7.60	7.63	7.41	N.S.	-	-
2	Percentage adult emergence	60.07	44.27	52.30	46.45	53.82	38.05	**	10.642	$\underline{A, L_2, D, L_1, C, M}$
3	Adult longevity female (hours)	27.40	24.17	34.05	32.67	32.15	27.77	N.S.	-	-
4	Adult longevity male (hours)	19.87	29.50	20.10	22.05	22.85	16.57	**	5.846	$C, \underline{L_2, L_1, D, A, M}$
5	Sex-ratio (Females/male)	7.84	5.36	3.34	2.89	3.04	4.75	**	3.627	$\underline{A, C, M}, D, \underline{L_2, L_1}$
6	Total reproductive period in females (hours)	16.82	19.12	26.37	19.10	23.40	18.67	N.S.	-	-
7	Fecundity (number of eggs per female)	17.45	9.67	10.30	10.07	19.30	9.75	**	2.938	$\underline{L_2, A, D, L_1, M}, C$
8	Progeny production per female	7.82	4.90	6.07	4.80	8.77	4.65	*	3.781	$\underline{L_2, A, D}, C, \underline{L_1, M}$
9	Percentage F_2 emergence (from 7,8)	44.80	48.12	61.14	48.12	45.44	47.68	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level
N.S. Non-significant

iv) Sex-ratio

The proportion of females to males ranged from 7.84 in the Ambajipet culture to 3.04 in the Ludhiana culture, the differences being significant. In the Ambajipet culture, the sex-ratio was higher than in the Ludhiana and Lucknow cultures.

v) Total reproductive period in females

The differences with regard to this character were non-significant in the cultures studied. The total reproductive period in females ranged from 16.82 hours in the Ambajipet culture to 26.37 hours in the Delhi culture.

vi) Fecundity

The mean number of eggs laid per female varied from 9.67 in the Cuddalore culture to 19.30 in the Ambajipet culture and these differences were significant. In the Ludhiana and Ambajipet cultures, the females were more fecund (19.30 and 17.45 respectively) than in the rest of the cultures.

vii) Progeny production per female

Significant differences were detected in regard to this characteristic, in the different cultures. The range in progeny production was from 4.65 per female in the Mandya culture to 8.77 observed in the Ludhiana culture. Progeny production in the Ludhiana culture was found to be higher than in the Cuddalore,

Lucknow and Mandya cultures.

(h) Performance of the different cultures at 23°C and 90 per cent R.H.

The mean values for the different characters are furnished in Table 11 and the detailed data are furnished in Appendix Table X.

i) Duration of development

In the Lucknow and Ludhiana cultures, the duration of development was 7.95 and 8.66 days respectively and these were significantly different from the Ambajipet, Delhi and Mandya cultures.

ii) Percentage adult emergence

Significant variability was detected in this character The Cuddalore and Ambajipet cultures showed higher adult emergence (65.55 and 60.75 per cent respectively), and the cultures, Lucknow and Mandya showed the lower values (28.37 and 28.16 per cent respectively). The Delhi and Ludhiana cultures showed intermediat values. The adult emergence in the second generation was found to range from 12.34 to 48.11 per cent.

iii) Adult longevity

The longevity of female emergents from different cultures showed significant variation. In the Ludhiana culture, the female longevity was 33.16 hours, while those from the Mandya culture were relatively very short lived (18.40 hours). The

Table 11 : Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 33°C and 90% R.H.

Sl. No.	Characters studied	Mean values for the different cultures						Signi-ficance	C.D.	Ranking
		A	C	D	L_1	L_2	M			
1	Developmental period (days)	7.14	7.58	7.06	7.95	8.56	7.06	**	1.220	L_2, L_1, C, A, D, M
2	Percentage adult emergence	60.75	65.55	47.12	28.37	35.55	28.15	**	11.861	C, A, D, L_2, L_1, M
3	Adult longevity female (hours)	32.32	26.40	24.67	24.02	33.15	18.40	**	9.062	L_2, A, C, D, L_1, M
4	Adult longevity male (hours)	22.62	20.57	18.30	13.90	30.32	14.32	**	10.70	L_2, A, C, D, M, L_1
5	Sex-ratio (females/male)	5.21	6.35	2.81	2.83	3.81	4.54	**	1.435	C, A, M, L_2, L_1, D.
6	Total reproductive period in females (hours)	17.67	21.77	14.92	12.57	13.32	16.57	**	7.289	C, M, A, D, L_2, L_1
7	Fecundity (number of eggs per female)	25.45	18.17	14.35	9.72	8.27	10.20	**	7.487	A, C, D, M, L_1, L_2
8	Progeny production per female	11.90	6.32	6.90	1.20	3.05	4.42	**	4.317	A, D, C, M, L_2, L_1
9	Percentage F_2 emergence (from 7,8)	46.75	34.18	48.11	12.34	36.88	43.33	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level

cultures from Ludhiana, Ambajipet and Cuddalore, did not show any differences among themselves.

Longevity of male emergents was found to differ significantly and the range in mean values was from 13.00 hours in the Lucknow culture to 30.02 hours in the Ludhiana culture. The longevity of males emerging from the Ludhiana and Ambajipet and Cuddalore cultures did not show any differences.

iv) Sex-ratio

The sex-ratio was observed to be 6.35 in the Cuddalore culture and 2.81 in the Delhi culture with remaining cultures showing intermediate values. The variation was found to be significant.

v) Total reproductive period in females

When reared at 33°C and 90 per cent R.H., the total reproductive period in female emergents were found to vary significantly from 12.57 hours in the Lucknow culture to 21.77 hours in the Cuddalore culture.

vi) Fecundity

Highly significant differences were detected in respect of this characteristic and the variability was from 8.27 in the Ludhiana culture to 25.45 in the Ambajipet culture. In the Ambajipet culture, the fecundity was significantly higher than in the Mandya, Lucknow and Ludhiana cultures.

vii) Progeny production per female

In the Ambajipet culture the mean value of progeny produced per female was found to be 11.80 and this was significantly higher than in all the other cultures. The Delhi and Cuddalore cultures showed intermediate values (6.90 and 6.32 respectively) and the Lucknow culture produced the least number of progeny (1.20).

(i) Performance of the different cultures at 33°C and 75 per cent R.H.

The data relating to this are summarised in Table 12 and the detailed data are appended in Table XI.

i) Developmental period

The duration of development was maximum in the Lucknow culture (8.45 days) and the least in Cuddalore culture (6.68 days) the variability being significant.

ii) Percentage adult emergence

In respect of this character, the cultures revealed significant variation. In the Delhi culture, the percentage emergence was found to be the highest (65.95). Minimum adult emergence (50.17 per cent) was recorded from the Lucknow culture.

iii) Adult longevity

When the cultures were reared at 33°C and at 75 per cent R.H., the longevity of female emergents was found to vary

Table 12 : Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 33°C and 75% R.H.

Sl. No.	Characters studied	Mean values for the different cultures						Signi-ficance	C.D.	Ranking
		A	C	D	L_1	L_2	M			
1	Developmental period (days)	6.99	6.68	7.23	8.45	7.02	7.12	**	0.907	L_1,D,M,L_2,A,
2	Percentage adult emergence	65.57	53.80	65.95	50.17	62.77	59.02	**	11.048	D,A,L_2,M,C,L
3	Adult longevity female (hours)	31.07	30.60	38.17	23.20	35.25	30.05	*	8.127	D,L_2,A,C,M,L
4	Adult longevity male (hours)	22.02	24.57	20.17	20.87	21.27	20.70	N.S.	-	-
5	Sex-ratio (Females/male)	4.98	6.07	3.12	3.40	2.89	4.52	**	1.358	C,A,M,L_1,D,L_2
6	Total reproductive period in females (hours)	29.75	21.05	25.85	18.17	24.02	24.22	*	6.459	A,D,M,L_2,C,L
7	Fecundity (number of eggs per female)	26.95	17.65	19.92	13.72	22.77	13.02	**	8.160	A,L_2,D,C,L_1,
8	Progeny production per female	13.97	7.32	10.87	3.87	11.27	5.92	**	5.107	A,L_2,D,C,M,L
9	Percentage F_2 emergence (from 7,8)	51.83	41.46	54.56	28.20	50.60	45.46	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level
N.S. Non-significant.

significantly. The females from the Delhi culture lived for an average of 38.17 hours, while in the Lucknow culture females survived for relatively a short period (23.20 hours). The variability in male longevity was not significant.

iv) Sex-ratio

The Cuddalore and Ambajipet cultures produced a significantly higher proportion of females to males, the sex-ratio being 6.07 and 4.98 respectively. These were distinctly different from the Delhi and Lucknow cultures.

v) Total reproductive period in females

In the Ambajipet culture, this was 29.75 hours as compared with 18.17 hours observed for females emerging from the Lucknow culture. The variability was significant.

vi) Fecundity

The mean fecundity of females was found to differ significantly, the range being from 13.72 in the Mandya culture to 26.95 in the Ambajipet culture. The Ambajipet and Ludhiana cultures were found to be significantly different from both the Lucknow and Mandya cultures.

vii) Progeny production

The mean value of the number of progeny produced per female was found to be the highest in the Ambajipet culture (13.97). In the Lucknow culture, this was lower (3.87) than in the Ambajipet, Ludhiana and Delhi cultures. These differences

were significant.

(j) Performance of the cultures at 33°C and 10 per cent R.H.

The mean values for the various characters are summarised in Table 13 and the detailed data are presented in Appendix Table XII.

i) Duration of Development

The cultures did not show any significant variability with regard to this character.

ii) Percentage adult emergence

The percentage adult emergence ranged from 35.22 in the Mandya culture to 62.47 in the Ambajipet culture. The percentage emergence in the second generation in the Delhi and Ludhiana cultures were 6.23 and 64.20 respectively. In the Mandya and Lucknow cultures, these were 35.42 and 42.55 per cent respectively.

iii) Adult longevity

Significant differences were observed in respect of adult longevity in both the sexes. The females emerging from the Mandya culture were found to be relatively short lived (18.32 hours) than those in the Cuddalore and Delhi cultures.

Longevity of male emergents also were significantly different in the cultures studied. The longevity of males in

adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage F_2 emergence in different cultures when reared at 33°C and 10% R.H.

Sl. No.	Characters studied	Mean values for the different cultures A	C	D	L_1	L_2	M	Significance	C.D.	Ranking
1	Developmental period (days)	7.48	7.08	7.33	7.58	7.41	6.97	N.S.	-	-
2	Percentage adult emergence	62.47	42.60	50.10	45.15	52.27	35.22	**	7.643	A, L_2, D, L_1, C, M
3	Adult longevity female (hours)	25.45	28.90	34.12	28.07	28.07	18.32	**	10.543	D, C, L_1, L_2, A, M
4	Adult longevity male (hours)	21.27	24.12	16.07	19.42	18.72	14.72	*	7.413	C, A, L_1, L_2, D, M
5	Sex-ratio (Females/male)	7.49	6.13	2.94	2.79	3.27	5.12	**	2.437	A, C, M, L_2, D, L_1
6	Total reproductive period in females (hours)	16.22	15.35	23.32	15.60	17.75	14.64	**	9.437	D, L_2, A, C, L_1, M
7	Fecundity (number of eggs per female)	10.80	7.90	10.67	7.52	16.42	7.50	*	8.543	L_2, A, D, C, L_1, M
8	Progeny production per female	5.22	3.67	6.90	3.20	10.52	2.75	*	6.137	L_2, D, A, C, L_1, M
9	Percentage F_2 emergence (from 7,8)	48.33	46.00	61.23	42.55	64.20	35.42	-	-	-

* Significant at 5 per cent level ** Significant at 1 per cent level
N.S. Non-significant.

the Cuddalore culture was maximum (24.12 hours) and those in the Mandya culture were relatively short lived (14.72 hours).

iv) Sex-ratio

The proportion of females to males in the different cultures was significantly different, the range being from 2.79 in the Lucknow culture to 7.49 in the Ambajipet culture.

v) Total reproductive period in females

The variation in the total reproductive period in females was found to be significant in the different cultures reared at 33°C and 10 per cent R.H. This was the longest in the Delhi culture (23.32 hours) and the shortest in the Mandya culture (14.64 hours).

vi) Fecundity

The mean number of eggs produced per female varied from 7.50 in the Mandya culture to 16.43 in the Ludhiana culture, and the variability was significant.

vii) Progeny production per female

The mean number of progeny produced per female ranged from 2.73 in Mandya culture to 10.62 in the Delhi culture and the variability was significant. The Cuddalore and Lucknow cultures showed lower values for this character (3.67 and 3.20 respectively.)

(k) Performance of the cultures at 35°C and 90 per cent R.H

The data relating to these are given in Table 14 and the detailed data are furnished in Appendix Table XIII.

i) Duration of development

The variability was significant in respect of this character. In the Lucknow culture the duration of the development was the longest (7.67 days) while in the Ludhiana and Cuddalore cultures, this was relatively shorter (6.74 and 6.56 days respectively).

ii) Percentage adult emergence

The maximum percentage adult emergence was observed in the Ambajipet culture (40.15) and the emergence was very poor in the Lucknow culture (21.47). The variation was significant. The adult emergence in the second generation ranged from 21.56 to 56.45 per cent in the Ambajipet and Delhi cultures respectivel

iii) Adult longevity

In Ambajipet, Delhi and the Ludhiana cultures, the females lived for 32.77 hours, 30.60 hours and 28.52 hours respectively. Female longevity in Lucknow culture was the shortest (17.20 hours). In the Mandya culture, the males were relatively short-lived (10.42 hours) while in Ludhiana and the Ambajipet cultures, the mean values for male longevity were 20.95 and 22.67 respectively.

production, percentage F_2 emergence, Percentage adults with malformed wings in different cultures when reared at 35°C and 90% R.H.

Sl No.	Characters studied	Mean values for the different cultures A	C	D	L_1	L_2	H	Signi-ficance	C.D.	Ranking
1	Developmental period (days)	6.54	6.56	7.06	7.67	6.74	6.84	*	0.784	L_1,D,H,L_2,C,
2	Percentage adult emergence	40.15	36.65	35.17	21.47	31.32	26.32	**	9.648	A,C,D,L_2,H,L
3	Adult longevity female (hours)	32.77	20.02	30.60	17.20	23.52	19.82	**	9.952	A,D,L_2,C,H,L
4	Adult longevity male (hours)	22.67	16.70	18.12	12.67	20.95	10.42	**	7.199	A,L_2,D,C,L_1,
5	Sex-ratio (females/male) +	8.54	7.02	2.95	2.45	2.89	4.40	**	1.452	A,C,H,D,L_2,L
6	Total reproductive period in females (hours)	14.95	18.37	10.32	11.05	13.80	10.12	*	5.208	C,A,L_2,L_1,D,
7	Fecundity (number of eggs per female)	7.65	1.30	6.20	0.40	5.33	3.52	**	3.389	A,D,L_2,H,C,L_1
8	Progeny production per female	1.65	0.55	3.50	0.00	0.82	1.20	N.S.	-	-
9	Percentage F_2 emergence (from 7,8)	21.56	42.30	56.45	-	15.38	34.07	-	-	-
10	Percentage adults with malformed wings (females)	63.07	61.77	56.35	61.00	70.10	62.48	N.S.	-	-
11	Percentage adults malformed (Males)	38.30	43.47	50.30	46.82	47.90	46.85	N.S.	-	-

+ Estimated from the F_1 population * Significant at 5 per cent level

N.S. Non-significant. ** Significant at 1 per cent level.

iv) Sex-ratio

The sex-ratio recorded from the first generation emergents was found to be very high in the Ambajipet culture (8.64) reared at 35°C and 90 per cent R.H. In the Lucknow culture, the proportion of females to males was relatively very low (Sex-ratio 2.45). There were no differences among the cultures, Delhi, Ludhiana and Lucknow in this respect.

v) Total reproductive period in females

This was found to be the longest in the Cuddalore cult (18.37 hours). This culture differed significantly from cultures Lucknow, Delhi and Mandya which showed values ranging from 10.12 to 11.05 hours.

vi) Fecundity

Fecundity was observed to be highly variable in the different cultures. The mean number of eggs laid per female respectively 7.65, 6.20 and 5.35 for cultures Ambajipet, Delhi and Ludhiana. In the Cuddalore and Lucknow cultures, egg laying was found to be very poor (1.50 and 0.40 respectively).

vii) Progeny production

Complete suppression of progeny production was noticed in the Lucknow culture. The mean values for this in the remaining cultures were found to vary from 0.55 in the Cuddalore cultur to 3.60 in the Delhi culture. The variability was, however, non-significant.

viii) Percentage adults with malformed wings

The percentage of adults showing wing malformation (stumpy or partly unfolded wings) was found to vary from 56.35 in the Delhi culture to 70.10 in the Ludhiana culture(in the case of females). The variation was non-significant. The corresponding percentages for male emergence ranged from 38.30 to 60.30 in the Ambajipet and Delhi cultures respectively. These differences were also non-significant.

(1) Performance of different cultures at 35°C and 75 per cent R.H.

The data in the form of mean values are given in Table 15 and the detailed data are furnished in Appendix Table XIV.

i) Duration of development

Significant variability was not detected among the different cultures with regard to the mean developmental period.

ii) Percentage adult emergence

The maximum emergence was observed in the Ambajipet culture (46.37 per cent) and in the Lucknow culture the emergence was only 11.55 per cent. The adult emergence in Ambajipet, Ludhiana and Delhi cultures were found to be significantly higher than in rest of the cultures.

Table 15 : Mean values of the duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production, percentage F_2 emergence, percentage adults with malformed wings in different cultures when reared at 35°C and 75% R.H.

Sl. No.	Characters studied	Mean values for the different cultures						Signi-ficance	C.D.	Ranking
		A	C	D	L_1	L_2	M			
1	Developmental period (days)	6.94	6.78	7.04	7.19	6.99	6.89	N.S.	-	-
2	Percentage adult emergence	45.37	24.32	37.62	11.50	41.50	25.32	**	10.338	A, L_2, D, M, C, L_1
3	Adult longevity female (hours)	27.77	24.50	29.52	15.75	25.55	21.40	**	9.960	D, A, L_2, C, M, L_1
4	Adult longevity male (hours)	18.07	19.35	14.65	10.10	15.47	12.05	**	6.008	C, A, L_2, D, M, L_1
5	Sex-ratio (females/male)+	11.05	6.92	2.87	3.10	2.65	4.76	**	2.319	A, C, M, L_1, D, L_2
6	Total reproductive period in females (hours)	10.62	15.82	15.02	10.72	10.35	15.08	*	4.505	C, M, D, L_1, A, L_2
7	Fecundity (number of eggs per female)	4.95	0.77	6.20	0.52	5.72	1.40	**	4.019	D, L_2, A, M, C, L_1
8	Progeny production per female	1.35	0.25	2.35	0.00	2.47	0.52	**	1.308	L_2, D, A, M, C, L_1
9	Percentage F_2 emergence (from 7,8)	27.05	32.40	37.90	-	43.18	37.14	-	-	-
10	Percentage adults with malformed wings (females)	67.12	59.92	58.97	62.52	72.05	65.65	*	7.686	L_2, A, M, L_1, C, D
11	Percentage adults with malformed wings (males)	34.87	46.22	48.07	37.85	53.87	56.87	**	17.284	M, L_2, D, C, L_1, A

\+ Estimated from the F_1 population
N.S. Non-significant
* Significant at 5 per cent level
** Significant at 1 per cent level.

iii) Adult longevity

The female longevity was found to vary among the cultures and the variability was significant. The females emerging out from the Delhi, Ambajipet and Ludhiana cultures lived for mean durations of 29.62, 27.77 and 25.56 hours respectively. In Lucknow culture, the females were relatively short lived (15.75 hours).

Male longevity was observed to vary from 19.35 hours in the Cuddalore culture to 10.10 hours in the Lucknow culture.

iv) Sex-ratio

The sex-ratio recorded from the first generation emergents was found to be unusually high (11.05) in the Ambajipet culture. In the Lucknow, Delhi and Ludhiana cultures the values were 3.10, 2.87 and 2.65 respectively. The variabilit was highly significant.

v) Total reproductive period in females

In the Cuddalore, Mandya and Delhi cultures, the duration of reproductive life in females was 15.82, 15.08 and 15.02 hours respectively and these did not show any significant differences among themselves. In the Ludhiana culture, this was found to be 10.35 hours.

vi) Fecundity

The variability in the number of eggs laid by females was significant. The maximum value was obtained in the Delhi

culture (6.20) while in the Lucknow culture fecundity was the least being only 0.52.

vii) Progeny production per female

The progeny production was found to be the highest in the Ludhiana culture (2.47). In the Ludhiana, Delhi and Ambajipet cultures, progeny production was not significantly different. In Mandya culture, progeny production was distinctly lower (0.52) while in the Lucknow culture, there was no progeny production at all.

viii) Percentage adults with malformed wings

Significant variability among the cultures was detected in respect of this characteristic. The percentage of females having wing abnormalities, ranged from 58.97 to 72.05 in the Delhi and Ludhiana cultures respectively. Significant variation was detected among male emergents as well. In the Ambajipet culture, the percentage adult males with wing malformations was 34.87 while the corresponding figure for the Mandya culture was 56.87.

(m) Performance of the different cultures at 35°C and 10 per cent R.H.

The data in the form of mean values are furnished in Table 16. The detailed data are given in Appendix Table XV.

production, percentage F_2 emergence, percentage adults with malformed wings in different cultures when reared at 35°C and 10% R.H.

Sl. No.	Characters studied	Mean values for different cultures						Signi-ficance	C.D.	Ranking
		A	C	D	L_1	L_2	M			
1	Developmental period (days)	7.47	6.92	7.12	7.38	6.63	7.34	N.S.	-	-
2	Percentage adult emergence	36.60	18.25	40.67	14.72	42.20	20.12	**	9.144	L_2,D,A,M,C,
3	Adult longevity female (hours)	22.87	20.07	30.15	14.05	25.35	13.95	**	8.201	D,L_2,A,C,L_1
4	Adult longevity male (hours)	14.82	14.30	16.35	12.10	18.35	11.70	**	6.205	L_2,D,A,C,L_1
5	Sex-ratio (females/male)+	9.44	7.20	2.76	2.70	3.14	5.48	**	1.146	A,C,M,L_2,D,
6	Total reproductive period in females (hours)	11.27	10.35	22.80	8.07	14.42	8.62	**	6.539	D,L_2,A,C,M,
7	Fecundity (number of eggs per female)	4.22	0.50	5.42	0.30	6.80	2.30	**	3.618	L_2,D,A,M,C,
8	Progeny production per female	0.77	0.00	2.65	0.00	2.02	0.27	**	1.685	D,L_2,A,M,L_1
9	Percentage F_2 emergence (from 7,8)	18.24	-	48.80	-	29.68	11.07	-	-	-
10	Percentage adults with malformed wings (females)	74.37	74.25	69.22	75.47	69.85	68.25	N.S.	-	-
11	Percentage adults with malformed wings (males)	36.77	70.12	58.10	66.15	47.75	74.75	**	11.800	M,C,L_1,D,L

+ Estimated from the F_1 population ** Significant at 1 per cent level
N.S. Non-significant.

i) Duration of development

The developmental period of the different cultures ranged from 6.64 to 7.47 days in the Ludhiana and Ambajipet cultures, but the variation was not significant.

ii) Percentage adult emergence

The variability in the cultures was found to be significant in regard to this characteristic. More number of adults emerged from the Ludhiana, Delhi and Ambajipet cultures (42.20, 40.67 and 36.60 per cent respectively). These were higher than in the rest of the cultures. The adult emergence in the second generation ranged from 11.70 to 48.80 per cent.

iii) Adult longevity

The females emerging out from the Mandya culture were very short lived (13.95 hours) while those from the Delhi culture lived for 30.15 hours. The differences were significant.

Among males, variability in adult longevity was found to be significant and the mean values varied from 11.70 hours in the Mandya culture to 18.36 hours in the Ludhiana culture.

iv) Sex-ratio

In the Ambajipet culture, the sex-ratio was found to be very high (0.44), this being significantly different from all the other cultures. In the Ludhiana, Delhi and Lucknow cultures the sex-ratios were 3.14, 2.76 and 2.70 respectively.

v) Total reproductive period in females

This was observed to be 22.80 hours in the Delhi culture. In all the remaining cultures, females showed significantly lower values ranging from 8.07 hours in the Lucknow culture to 14.42 hours in the Ludhiana culture.

vi) Fecundity

The variability was found to be significant. The mean fecundity was observed to be 6.80 in the Ludhiana culture, while the lowest value was recorded in the Lucknow culture (0.30).

vii) Progeny production per female

The F_1 progeny produced by the Delhi and Ludhiana cultures were distinctly higher (2.65 and 3.02 per female) than in the remaining cultures. The progeny production was suppresse in the Lucknow and Cuddalore cultures.

viii) Percentage adults with malformed wings

The female emergents did not show significant differences, the range being from 68.25 per cent in the Mandya culture to 75.47 per cent in the Lucknow culture.

Significant variability was detected among males emerging from different cultures. Maximum number of malformed

adults were observed in the Mandya culture (74.75 per cent) and in Ludhiana and Ambajipet cultures, these were 47.75 and 36.77 per cent respectively.

(D) Selection of the cultures for high temperature - low humidity tolerance

These experiments were conducted to ascertain whether rearing under progressively adverse temperature-humidity conditions could increase the temperature tolerance, which appeared to exist in the Ludhiana, Delhi and Ambajipet cultures. For these experiments, the cultures were reared at gradually decreasing humidity levels (60 to 10 per cent R.H.) and at progressively increasing temperatures (30° to 33°C). The sequence of rearing was as below:

No. of generations reared	Conditions of rearing	
	R.H.	Temperature °C
4	60	30
4	40	30
4	30	30
4	20	30
4	10	30
4	10	32
10	10	33

Details of rearing are shown in Figure 10. A part of the culture reared at 10 per cent R.H. and 33°C was maintained for four subsequent generations at the same condition to test

Significant differences in fecundity were detected at 35°C and 75 per cent R.H. between the 'P' and 'Q' cultures. Thus, in the first generation of exposure to 35°C, the fecundity in the 'P' culture was 11.22 as compared with 5.72 observed for the corresponding 'Q' culture. In the 'P' culture, the fecundity decreased from 11.22 to 7.07 in the second generation of rearing at 35°C and 75 per cent R.H.

iii) Progeny production

In the Ludhiana 'P' culture the decline in the progeny production as a result of decrease in relative humidity from 60 to 10 per cent and increase in temperature from 30° to 33°C was from 15.72 to 13.70. The corresponding reduction in progeny production observed in the 'Q' culture was from 16.72 to 10.52. The differences between these two cultures were significant at 33°C and 10 per cent R.H. When the 'P' culture was exposed to 35°C and 75 per cent R.H., the progeny production was found to be 6.25 as compared with 2.47 observed in the 'Q' culture. This difference in the two cultures was significant. The progeny production in the 'P' culture decreased from 6.25 to 2.87 in the subsequent generation reared at 35°C and 75 per cent R.H.

iv) Adult longevity, sex-ratio and the total reproductive period in females

In the 'P' Ludhiana culture when temperature was increased from 30°C to 33°C and when relative humidity was decreased from 60 to 10 per cent, adult longevity showed a reduction from

54.75 to 30.50 hours in the case of females and from 36.65 to 24.00 hours in males(Table 17). There were no marked variations in sex-ratio in the 'P' culture reared in the manner prescribed above. The total reproductive period showed reduction from 38.17 to 22.15 hours in the 'P' culture.

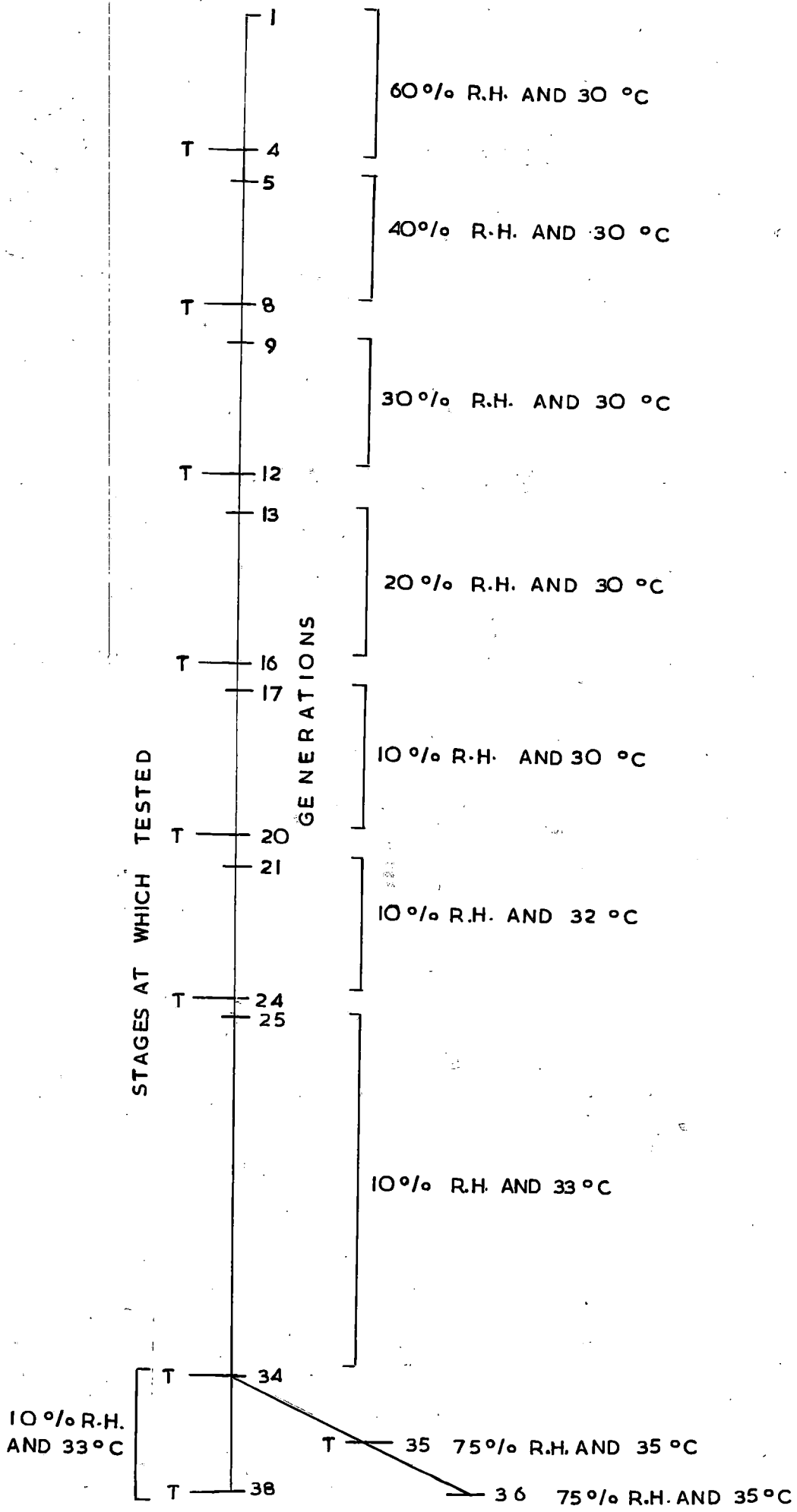
General performance of the culture selected from the Ludhiana stock

The 'P' culture selected from the Ludhia stock could be maintained at 33°C and 10 per cent R.H., while the 'Q' culture could not be maintained in the same condition for more than three generations. Though the 'P' culture showed improvement in adult emergence, fecundity and progeny production in the first generation of exposure to 35°C and 75 per cent R.H., a considerable decline in these characteristics was observed in the second generation and this culture could not be maintained beyond three generations. The corresponding 'Q' culture at 35°C could not be maintained beyond two generations and in the second generation, the adult emergence was found to be quite low.

(b) Selection from the Delhi culture for high temperature - low humidity tolerance

The Delhi culture reared at increasing temperature from 30° to 33°C and at decreasing humidity levels (60 to 10 per cent R.H.) is referred to as the 'P' culture and the corresponding control (Delhi culture from 26° ± 1.5°C, exposed directly), as the 'Q' culture. The data on adult emergence, adult longevity,

Fig. 10 : Sequence of rearing of the Ludhiana, Delhi and Ambajipet cultures at progressively adverse temperature-humidity conditions.


1
60 °/o R.H. AND 30 °C
T 4
5
40°/o R.H. AND 30 °C
T 8
9
30 °/o R.H. AND 30 °C
T 12
13
20 °/o R.H. AND 30 °C
T 16
17
10 °/o R.H. AND 30 °C
T 20
21
10 °/o R.H. AND 32 °C
T 24
25
10 °/o R.H. AND 33 °C
T 34
10 °/o R.H. AND 33 °C
T 35 75 °/o R.H. AND 35 °C
T 38
36 75 °/o R.H. AND 35 °C
GENERATIONS
STAGES AT WHICH TESTED

for consistency in the performance. The rest of the culture was exposed to 35°C and 75 per cent R.H. and their performance studied under these conditions.

(a) Selection from the Ludhiana culture for high temperature-low humidity tolerance

The mean values of adult longevity, adult emergence, sex-ratio, total reproductive period in females, fecundity and progeny production of the Ludhiana culture at different stages of rearing are shown in Table 17. The tests of significance to detect variations between the culture reared at progressively adverse temperature-humidity conditions and the controls (cultures maintained at 26° ± 1.5°C and 75 per cent R.H. and directly exposed to particular temperature-humidity condition), were applied and the results of these are given in Table 18.

The culture reared at progressively adverse conditions would henceforth be referred to as the 'P' culture and the corresponding control culture as 'Q'. Graphical representation of the data on adult emergence, fecundity and progeny production in the 'P' and 'Q', is given in Figure 11. The detailed data relating to these are given in Appendix Table XVI, and XVII.

1) Adult emergence

With progressive increase in temperature from 30° to 33°C and with reduction in relative humidity from 60 to 10 per cent the 'P' culture showed a decline in mean adult emergence from 74.72

Table 17 : Performance of the Ludhiana culture at increasing temperatures from 30° to 35°C and at decreasing relative humidity levels from 60% to 10%, as shown by adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production.

Generation No.	Conditions of rearing		Percentage adult emergence	Adult longevity (hours)		Sex-ratio (females/male)	Total reproductive period in females (hours)	Fecundity (no. of eggs laid per female)	Progeny production per female
	Temp °C	R.H.%		Female	Male				
4	30	60	74.72	54.75	35.65	4.05	38.17	39.97	15.72
8	30	40	74.95	52.42	31.37	3.74	36.40	34.65	15.12
12	30	30	70.82	47.65	28.65	3.92	32.60	30.75	14.72
16	30	20	62.20	43.12	26.12	3.51	28.47	30.97	12.75
20	30	10	64.60	40.57	26.30	3.85	28.97	26.10	12.32
24	32	10	60.72	35.62	25.01	3.40	26.30	23.72	11.35
34	33	10 (a)	61.82	33.45	22.17	4.08	23.65	22.25	13.50
38	33	10 (b)	63.40	30.50	24.00	4.10	22.15	23.02	13.70
35*	35	75 (a)	58.37	30.62	20.10	3.81	15.40	11.22	6.25
36	35	75 (b)	59.95	26.97	16.45	4.06	12.25	7.07	2.87

* Part of the culture from 34th generation.

Table 18 : Tests of significance ('t' tests) for the performance of the Ludhiana culture reared at progressively adverse temperature-humidity conditions as compared with the corresponding controls.

Stage at which tested (generations)	Conditions of rearing		Mean adult emergence %			Mean fecundity			Progeny production		
	Temp °C	R.H.%	'Q'	'p'	't'	'Q'	'p'	't'	'Q'	'p'	't'
1	2	3	4	5	6	7	8	9	10	11	12
4	30	60	73.19	74.72	0.1001	38.52	39.97	0.4130	16.72	15.72	0.8960
8	30	40	69.87	74.95	2.1890	31.10	34.65	0.5620	12.62	15.12	0.0919
12	30	30	64.52	70.82	1.6535	26.70	30.75	0.2236	10.07	14.72	2.2028
16	30	20	60.10	62.80	0.4465	24.05	30.97	0.4430	8.75	12.75	2.0048
20	30	10	57.07	64.80	0.1671	21.25	26.10	1.5933	9.20	12.32	0.2274
24	32	10	53.82	60.72	0.1388	19.30	23.72	0.3502	8.77	11.35	0.5947
34	33	10 (a)	52.27	61.82	1.9470	16.42	22.25	2.5552*	10.52	13.50	0.3047
38	33	10 (b)	52.27++	63.40	2.0176	16.42++	23.02	3.1114*	10.52++	13.70	0.3027
35+	35	75 (a)	41.50	58.37	4.4603**	5.72	11.22	2.8280*	2.47	6.25	2.8930*
36	35	75 (b)	41.50++	50.85	1.3371	5.72++	7.07	0.4297	2.47++	2.87	0.0160

\+ Part of the culture from 34th generation

'Q' Mean values for the control cultures (for direct exposure to the particular conditions)

'p' Mean values for the cultures reared at progressively adverse conditions

* Significant at 5% level

** Significant at 1% level

Tabular value of 't' at 5% = 2.3650

Tabular value of 't' at 1% = 3.4990

++ Mean values for the control 'Q' culture in the first generation at the particular temperature-humidity condition.

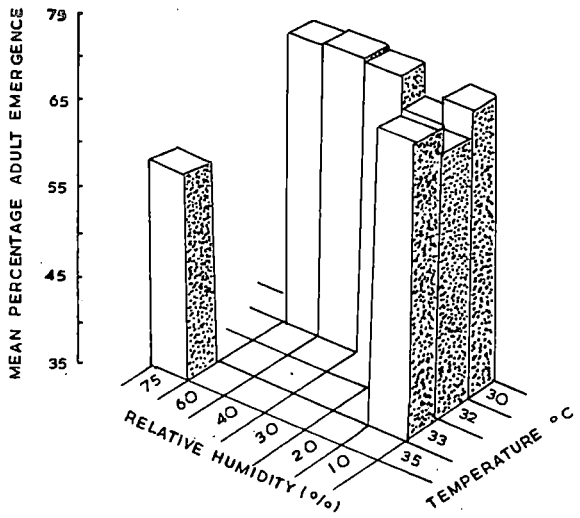
Fig. 11 : Percentage adult emergence, fecundity and progeny production in the Ludhiana 'P'* and 'Q'** cultures at different temperature-humidity combinations.

* Ludhiana culture reared at progressively adverse temperature-humidity conditions namely, increasing temperatures from 30° to 33°C and at decreasing relative humidities from 60 to 10 per cent and exposed to 35°C and 75 per cent R.H.

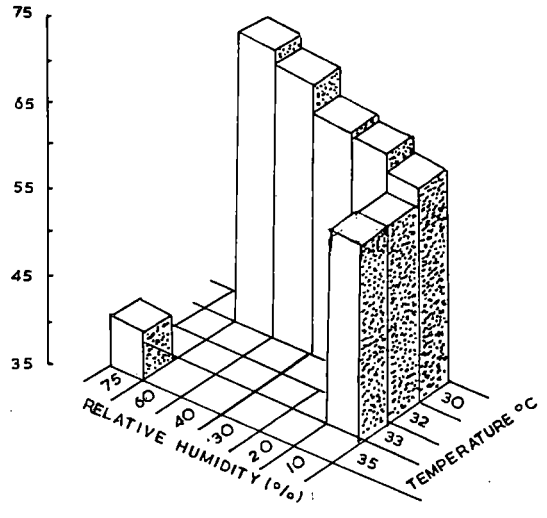
** Ludhiana culture directly exposed to the particular temperature-humidity combinations from stocks kept at 26° ± 1.5°C and at 75 per cent R.H.

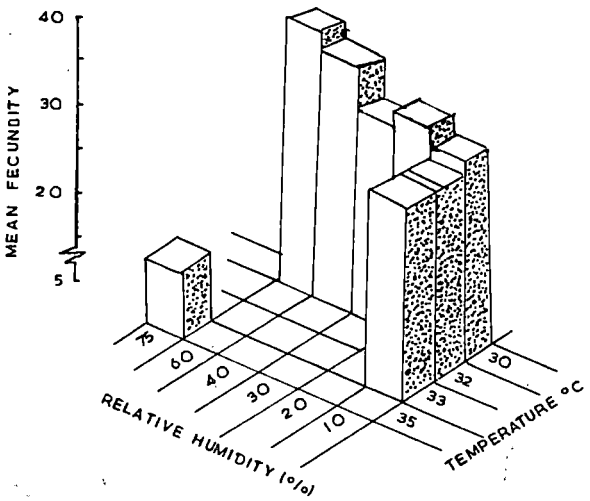
Fig . 11.

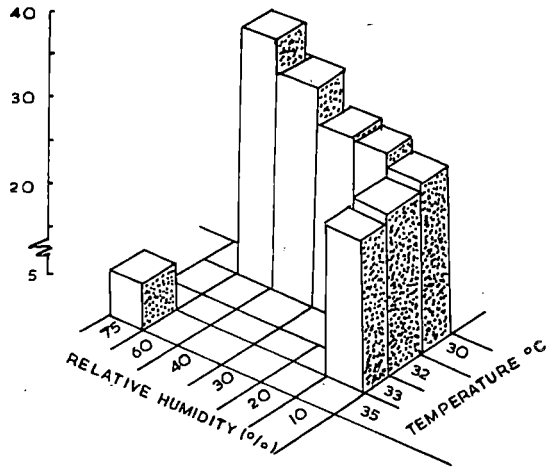
LUDHIANA 'P' CULTURE

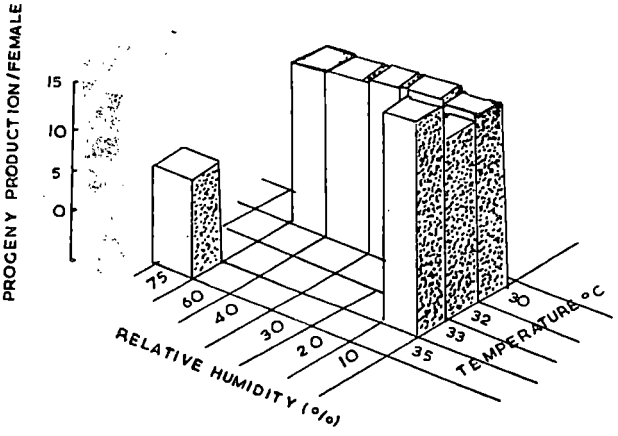


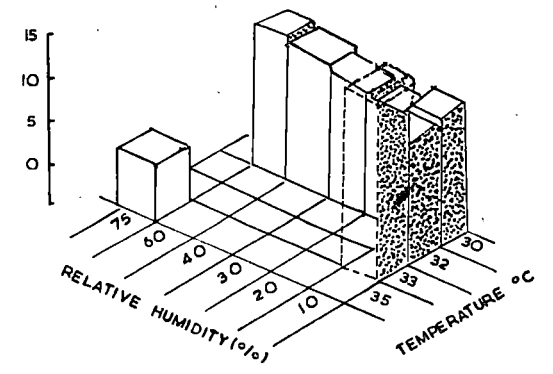
LUDHIANA 'Q' CULTURE











to 63.40 per cent (Table 18). The corresponding reduction observed in the 'Q' culture was from 73.19 to 52.27 per cent. These differences were not significant. But at all stages of rearing the adult emergence in the 'P' culture was higher than in the corresponding 'Q' culture.

At 35°C and 75 per cent R.H. the 'P' culture showed significant differences from the 'Q' culture in the first generation. Thus, in the Ludhiana 'P' culture which was exposed to 35°C, adult emergence was 58.37 per cent as compared with 41.50 per cent in the 'Q' culture. But in the second generation, the 'P' culture showed decrease in adult emergence from 58.37 to 50.95 per cent.

ii) Fecundity

The mean fecundity values for the 'P' and 'Q' cultures of the Ludhiana culture are furnished in columns 7 and 8 of Table 18. As the temperature was increased from 30° to 33°C and with a progressive reduction in humidity from 60 to 10 per cent, the 'P' culture showed a reduction in fecundity from 38.97 to 23.02. The corresponding decline in fecundity, in the 'Q' culture was 38.52 to 18.43. These differences between the 'P' and 'Q' cultures were significant at 33°C and 10 per cent R.H. The consistency in improvement of fecundity was maintained in the 'P' culture at 33°C and 10 per cent R.H., for the subsequent four generations. The 'P' culture could be maintained in this condition even in subsequent generations while the 'Q' culture tended to die out beyond three generations.

sex-ratio, total reproductive period in females, fecundity, progeny production of the 'P' culture are furnished in Table 19. Tests of significance were applied to detect variability in the 'P' and 'Q' cultures in respect of adult emergence, fecundity and progeny production. The results of these are given in Table 20 Graphical representation of the data relating to adult emergence, fecundity and progeny production in the 'P' and 'Q' cultures is given in Figure 12 and the detailed data pertaining to these are given in Appendix Table XVIII and XIX.

1) Percentage adult emergence

When temperature was increased from 30° to 33°C and when humidity was progressively reduced from 60 to 10 per cent, a decline in adult emergence in the 'P' culture was from 75.82 to 58.02 per cent. The corresponding decrease in the 'Q' culture was from 78.12 to 60.10 per cent (columns 4 and 5 of Table 20). At all levels of temperature and humidity combinations, the adult emergence in the 'P' culture showed increase over the correspondin 'Q' culture. These differences were significant at 33°C and 10 per cent R.H., being 57.80 and 50.10 per cent in the 'P' and 'Q' cultures respectively. This improvement was found to be consisten when reared for four subsequent generations.

At 35°C and 75 per cent R.H. also, there was increase in adult emergence in the 'P' culture, the mean value being 50.25 per cent as compared with 37.62 per cent observed in the 'Q' cultur

Table 19 : Performance of the Delhi culture at increasing temperatures from 30° to 35°C and at decreasing relative humidity levels from 60% to 10%, as shown by adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production.

Generation No.	Conditions of rearing		Percentage adult emergence	Adult longevity (hours)		Sex-ratio (females/male)	Total reproductive period in females (hours)	Fecundity (no. of eggs laid per female)	Progeny production per female
	Temp °C	R.H.%		Female	Male				
4	30	60	75.82	37.90	28.20	4.08	30.22	30.60	16.67
8	30	40	73.45	35.32	29.90	3.63	33.42	28.12	17.05
12	30	30	72.40	36.22	25.80	3.52	29.37	26.30	15.60
16	30	20	63.52	38.02	26.60	3.47	28.50	18.45	9.50
20	30	10	59.45	37.00	24.32	3.46	27.67	14.67	12.10
24	32	10	58.10	35.55	23.07	3.36	27.67	12.32	10.10
34	33	10 (a)	57.80	33.82	21.42	3.16	24.07	13.07	9.45
38	33	10 (b)	58.02	30.25	22.00	3.40	21.92	14.00	10.07
35*	35	75 (a)	50.25	32.35	16.42	3.61	19.70	9.95	5.47
36	35	75 (b)	40.85	24.20	14.52	4.15	15.82	5.76	2.37

* Part of the culture from 34th generation.

Table 20 : Tests of significance ('t' tests) for the performance of the Delhi culture reared at progressively adverse temperature-humidity conditions as compared with the corresponding controls.

Stage at which tested (generations)	Conditions of rearing		Mean adult emergence%			Mean fecundity			Progeny production		
	Temp °C	R.H.%	'q'	'p'	't'	'q'	'p'	't'	'q'	'p'	't'
1	2	3	4	5	6	7	8	9	10	11	12
4	30	60	78.12	75.62	0.2074	29.02	30.60	0.7330	15.15	16.67	0.0364
8	30	40	71.80	73.45	0.0137	26.10	28.12	0.1757	15.85	17.05	0.7100
12	30	30	68.22	72.40	0.4731	23.80	26.30	0.4317	10.40	15.60	0.8816
16	30	20	56.80	63.52	0.9100	16.90	18.45	0.1992	10.02	9.50	0.5608
20	30	10	54.62	59.45	0.6111	11.97	14.67	0.3093	9.60	12.10	0.4960
24	32	10	52.30	58.10	0.1472	10.30	12.32	1.0118	8.07	10.10	0.4138
34	33	10 (a)	50.10	57.30	2.3933*	10.67	13.07	0.4669	7.90	9.45	2.1500
38	33	10 (b)	50.10++	58.02	2.3962*	10.67++	14.00	0.3998	7.90++	10.07	1.3116
35+	35	75 (a)	37.62	50.25	2.7366*	6.20	9.95	3.0864*	2.35	5.47	2.7462*
36	35	75 (b)	37.62++	40.85	1.4095	6.20++	5.76	0.1509	2.36++	2.37	0.0191

\+ Part of the culture from 34th generation
'q' Mean values for the control cultures (for direct exposures to the particular conditions)
'p' Mean values for the cultures reared at progressively adverse conditions
* Significant at 5% level
Tabular value of 't' at 5% level = 2.3650

++ Mean values for the control 'q' culture in the first generation at the particular temperature-humidity condition.

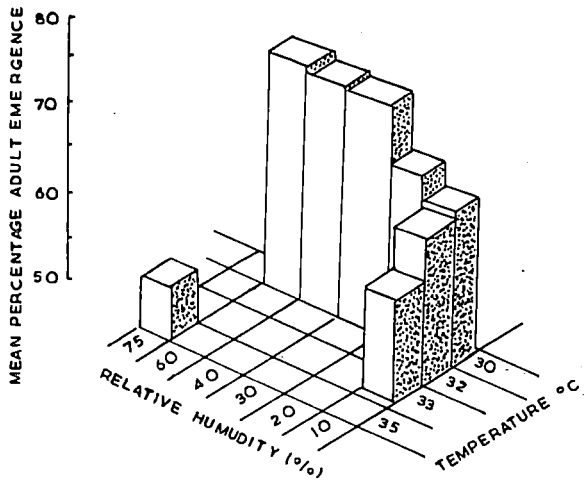
Fig. 12 : Percentage adult emergence, fecundity and progeny production in the Delhi 'P'* and 'Q'** cultures at different temperature-humidity combinations.

* Delhi culture reared at progressively adverse temperature-humidity conditions namely, increasing temperatures from 30° to 33°C and at decreasing relative humidities from 60 to 10 per cent and exposed to 35°C and 75 per cent R.H.

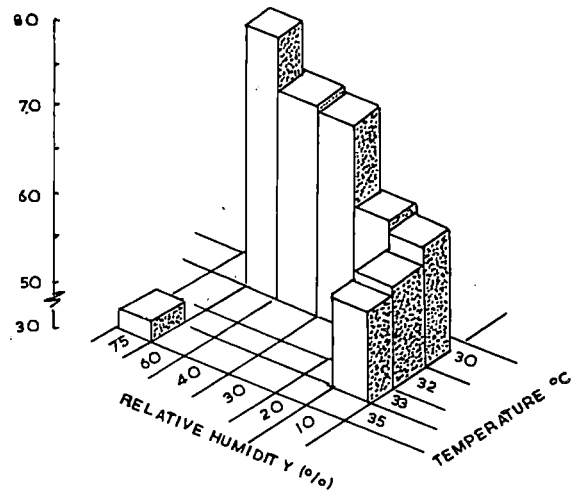
** Delhi culture directly exposed to the particular temperature-humidity combinations from stocks kept at 26° ± 1.5°C and at 75 per cent R.H.

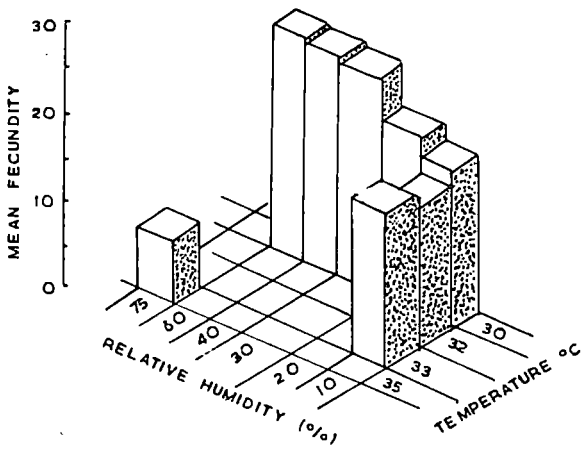
Fig. 12.

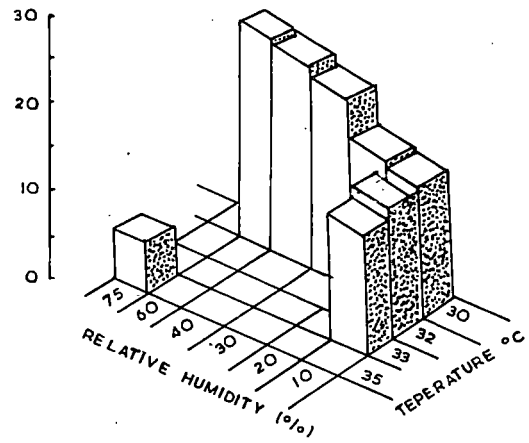
DELHI 'P' CULTURE

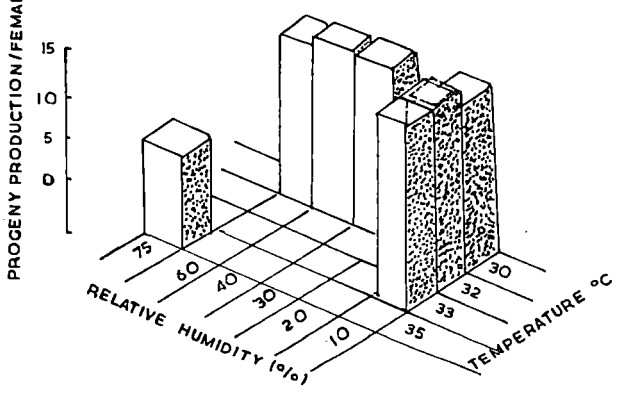


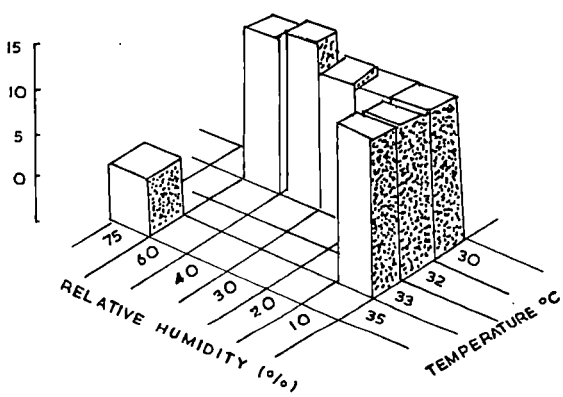
DELHI 'Q' CULTURE











In the subsequent generation at the same condition and adult emergence showed reduction from 60.25 to 40.85 per cent.

ii) Fecundity

The mean values of fecundity in the 'P' and 'Q' cultures of the Delhi stock are furnished in columns 7 and 8 of Table 20. With progressive reduction in humidity from 60 to 10 per cent R.H. and with increase in temperature from 30° to 33°C, the fecundity decreased in the 'P' culture from 30.60 to 14.00 while the reduction in 'Q' culture was from 29.02 to 10.67. These differences were not significant in the 'P' and 'Q' cultures. But at all levels of temperature and humidity conditions, fecundity was relatively high in the 'P' culture.

When the 'P' culture was exposed to 35°C and 75 per cent R.H., there was a significant improvement in fecundity over the 'Q' culture (9.95 and 6.20 respectively). But in a second generation, fecundity in the 'P' culture showed a decline from 9.95 to 5.76.

iii) Progeny production

Data pertaining to this are furnished in columns 10 and 11 of Table 20. With increase in temperature from 30°C to 33°C and with decrease in humidity from 60 to 10 per cent R.H., the progeny production in the 'P' culture showed a reduction of 16.67 per female to 10.07 while the corresponding reduction in the 'Q' culture was fr 15.15 to 7.90. At all stages, the progeny production in the

'P' culture was higher than the corresponding values in the 'Q' cultures. These differences between the 'P' and 'Q' stocks were not, however, significant.

The progeny production at 36°C and 75 per cent R.H. showed significant increase (5.47) over the observed value in the 'Q' culture (2.35). But in the subsequent generation progeny production declined from 5.47 to 2.37 per female.

iv) Adult longevity, sex-ratio and total reproductive period in females

In the 'P' culture, with increase in temperature from 30° to 33°C and with decrease in relative humidity from 60 to 10 per cent, the reduction in female longevity was from 37.50 to 30.25 hours, while the corresponding reduction in male longevity was from 23.20 to 22.00 hours. The sex-ratio at different stages ranged from 3.16 to 4.08. The total reproductive period in females in the 'P' culture showed reduction from 30.22 to 21.25 when reared at progressively adverse conditions (Table 19).

General performance of the culture selected from the Delhi stock

The 'P' culture selected out from the Delhi stock could be maintained at 33°C and 10 per cent R.H. while the 'Q' culture tended to die out after the second generation. The 'P' culture when exposed to 36°C and 75 per cent R.H. showed improvement in adult emergence, fecundity and progeny production in the first generation, but in the subsequent generation, considerable

reduction was observed in respect of these characteristics and the culture could not be maintained beyond two generations. The corresponding 'Q' culture also could not be maintained at 35°C and 75 per cent R.H. for more than two generations.

(e) Selection from the Ambajipet culture for high temperature-low humidity tolerance

The Ambajipet culture reared at progressively adverse temperature-humidity conditions is referred to as the 'P' culture while the corresponding control culture (Ambajipet culture directly exposed from 25° ± 1.5°C), is referred to as the 'Q' culture. The mean values of percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production of the 'P' culture are given in Table 21. Tests of significance were applied to detect variability between the 'P' and 'Q' cultures in respect of adult emergence, fecundity and progeny production and the results of these are furnished in the Table 22. The data on adult emergence, fecundity and progeny production in the 'P' and 'Q' cultures are graphically depicted in Figure 13 and the detailed data are furnished in Appendix Table XX and XXI.

1) Adult emergence

The percentage adult emergence in the Ambajipet 'Q' culture declined from 76.15 to 62.47 when the temperature was increased from 30° to 33°C and when the relative humidity was reduced from

Table 21: Performance of the Ambajipet culture at increasing temperatures from 30° to 35°C and at decreasing relative humidity levels from 60% to 10%, as shown by adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production.

Generation No.	Conditions of rearing		Percentage adult emergence	Adult longevity (hours)		Sex-ratio (females/male)	Total reproductive period in females (hours)	Fecundity (no. of eggs laid per female)	Progeny product per fem
	Temp °C	R.H.%		Female	Male				
4	30	60	77.67	42.62	31.55	5.48	32.27	30.62	19.72
8	30	40	77.87	35.00	26.25	6.11	20.52	29.87	20.72
12	30	30	71.60	38.10	25.37	6.30	23.80	24.80	14.87
16	30	20	70.92	34.72	26.45	5.23	24.10	21.65	13.05
20	30	10	66.27	31.67	24.75	5.59	24.20	22.72	12.17
24	32	10	66.37	30.55	22.47	5.39	24.15	20.47	12.32
34	33	10 (a)	65.32	26.62	22.35	6.12	20.35	14.25	8.50
38	33	10 (b)	66.80	28.00	20.10	5.14	20.20	13.87	8.10
35*	35	75 (a)	53.05	25.75	22.25	6.97	16.05	6.77	4.25
36	35	75 (b)	43.95	22.82	16.85	7.46	12.87	3.27	1.28

* Part of the culture from 34th generation.

Table 22 : Tests of significance ('t' tests) for the performance of the Ambajipet culture reared at progressively adverse temperature humidity conditions as compared with the corresponding controls.

Stage at which tested (generations)	Conditions of rearing		Mean adult emergence%			Mean fecundity			Progeny production		
	Temp °C	R.H%	'Q'	'P'	't'	'Q'	'P'	't'	'Q'	'P'	't'
1	2	3	4	5	6	7	8	9	10	11	12
4	30	60	76.15	77.57	0.9352	34.77	30.62	0.1363	22.12	19.72	0.116
8	30	40	70.05	77.87	1.3050	24.00	29.87	1.6460	17.90	20.72	1.776
12	30	30	64.12	71.60	1.7569	21.90	24.80	0.2005	12.40	14.87	0.606
16	30	20	62.25	70.92	2.3180	18.27	21.65	1.1665	11.30	13.05	0.276
20	30	10	61.20	66.27	1.5630	17.20	22.72	0.3512	9.47	12.17	0.376
24	32	10	60.07	66.37	1.0800	17.46	20.47	0.1059	7.82	12.92	2.417
34	33	10 (a)	62.47	65.32	0.0340	10.80	14.25	2.0210	5.22	8.50	1.306
38	33	10 (b)	62.47++	66.80	1.0200	10.80++	13.87	2.0069	5.22++	8.10	1.042
35+	35	75 (a)	45.42	53.05	2.4925*	4.95	6.77	2.1043	1.35	4.25	2.871
36	35	75 (b)	45.42++	43.95	0.0200	4.95++	3.27	0.4207	1.35++	1.28	0.051

\+ Part of the culture from 34th generation
'Q' Mean values for the control cultures (for direct exposures to the particular conditions)
'P' Mean values for the cultures reared at progressively adverse conditions
* Significant at 5% level
Tabular value of 't' at 5% level = 2.3650

++ Mean values for the control 'Q' culture in the first generation at the particular temperature-humidity condition.

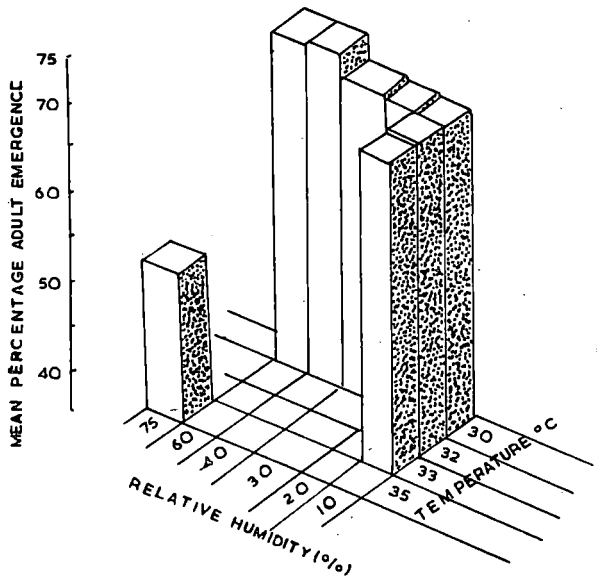
Fig. 13 : Percentage adult emergence, fecundity and progeny production in the Ambajipet 'P'* and 'Q'** cultures at different temperature-humidity combinations.

* Ambajipet culture reared at progressively adverse temperature-humidity conditions namely, increasing temperatures from 30° to 33°C and at decreasing relative humidities from 60 to 10 per cent and exposed to 35°C and 75 per cent R.H.

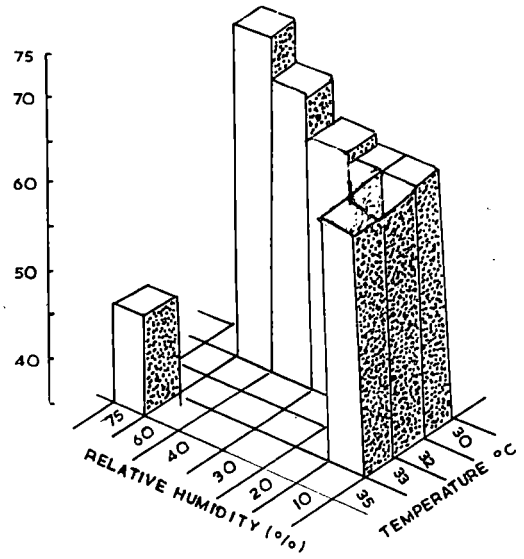
** Ambajipet culture directly exposed to the particular temperature-humidity combinations from stocks kept at 26° ± 1.5°C and at 75 per cent R.H.

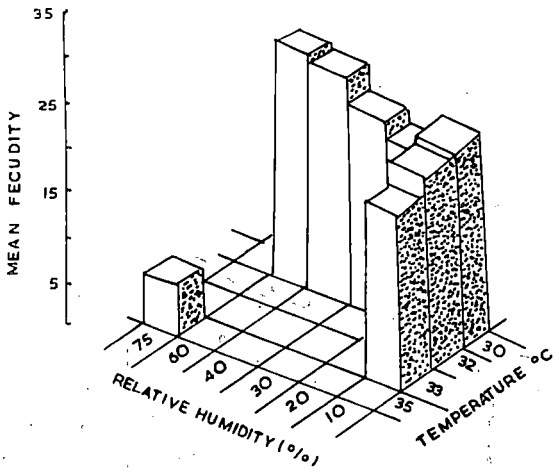
Fig. 13.

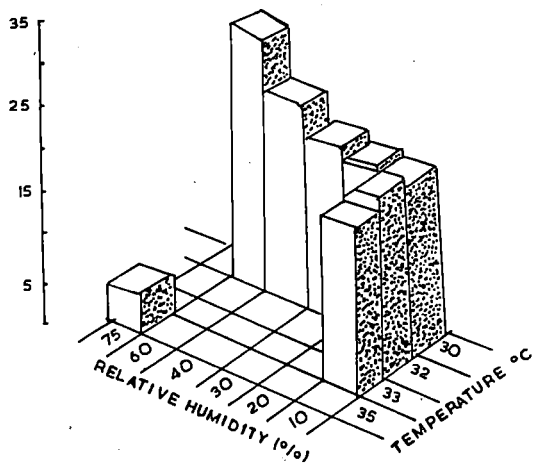
AMBAJI PET 'P' CULTURE

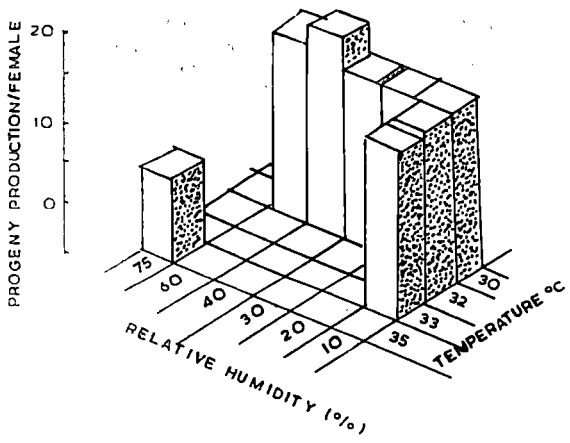


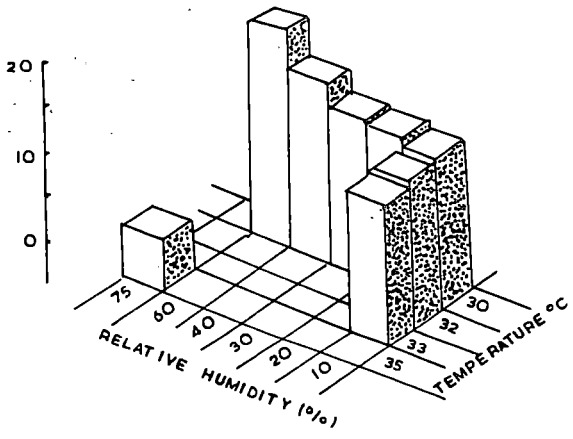
AMBAJI PET 'Q' CULTURE











60 to 10 per cent (columns 4 and 5 of Table 22). The corresponding reduction in the 'P' culture was from 77.57 to 66.80 per cent. At all temperature-humidity combinations, the 'P' culture showed higher adult emergence than the 'Q' stocks. However, these differences between the 'P' and 'Q' cultures were non-significant. But at 35°C and 75 per cent R.H. the 'P' culture showed significant improvement as compared to the 'Q' culture, the mean percentage values being 53.05 and 45.42 respectively. In the second generation, the adult emergence showed decline in the 'P' culture from 53.05 to 43.95.

ii) Fecundity

In the 'P' and 'Q' cultures of Ambajipet stock, significant differences were not observed at any of the temperature-humidity conditions tested, though the values in all cases were relatively higher in the 'P' culture than the corresponding controls. When the temperature was increased from 30° to 33°C and when relative humidity was decreased from 60 to 10 per cent, the 'P' culture showed a decline in fecundity from 30.62 to 13.87. The corresponding reduction in the 'Q' culture was from 34.77 to 10.80. When the 'P' culture was exposed to 35°C and 75 per cen R.H., this showed a mean fecundity of 8.77 as compared with 4.95 observed for the corresponding 'Q' culture. But this difference was not significant.

iii) Progeny production

The mean values of progeny production per female

relating to the 'P' and 'Q' cultures of the Ambajipet stock are given in columns 10 and 11 of Table 22. The decrease in the progeny production in the 'P' culture was from 19.72 to 8.10 when the temperature was increased from 30° to 33°C and when the relative humidity was reduced from 60 to 10 per cent. The corresponding decline in the 'Q' culture was from 22.12 to 5.22. In all cases the mean values of progeny production was higher in the 'P' culture than in the corresponding controls. The differences between the two cultures in respect of progeny production were significant at 32°C and 35°C. At 32°C, the mean values for 'P' and 'Q' cultures were respectively 12.32 and 7.82 while at 35°C the corresponding values were 4.25 and 1.35. In the 'P' culture, the progeny production decreased from 4.25 to 1.23 in the first to second generations of exposure to 35°C and 75 per cent R.H.

iv) Adult longevity, sex-ratio and total reproductive period in females

In the Ambajipet 'P' culture, with increase in temperature from 30° to 33°C and with decrease in relative humidity from 60 to 10 per cent, the reduction in female longevity was from 42.52 to 28.00 hours, while the corresponding reduction in male longevity was from 31.55 to 20.10 hours. The total reproductive period in females showed a decline from 32.27 to 20.20 hours. Sex-ratio did not show appreciable changes (Table 22).

General performance of the culture selected from the Ambajipet stock

The 'P' culture selected from the Ambajipet stock could be maintained at 33°C and 10 per cent R.H., while the corresponding 'Q' culture died out after three generations of rearing at the same condition. The 'P' culture when exposed to 35°C and 75 per cent R.H. showed significant improvement in adult emergence and progeny production in the first generation but there was decline in these values in the second generation and the culture could not be maintained beyond the second generation. The 'Q' culture also tended to die out beyond two generations and in the second generation adult emergence was found to be quite low in all the replicates.

(E) Radiation experiments

The object of these experiments was to find out a desirable dose of gamma rays from a ^{60}Co source at which a fairly good culture population could be maintained for subsequent screening for temperature tolerance.

Irradiation was accomplished as outlined in Chapter III. The inbred culture of Ludhiana stock was utilized for the experiments. The pupal stage of the parasite (observed by a blackening of the host egg as a result of parasitism) was irradiated at varying doses from 500 to 10,000 r.

The percentage of adults emerging from irradiated pupae,

Table 23: Effect of gamma radiation on the percentage of adult emergence, sex-ratio, fecundity and progeny production by adults emerging from irradiated pupae, in the Ludhiana culture.

Sl. No.	Dose	Percentage adult emergence	Fecundity (no. of host eggs blackened)	Progeny production by adults emerging from irradiated pupae	Sex-ratio (females/male)
1	500 r	76.62	36.37	24.90	4.34
2	1000 r	69.42	29.82	22.22	3.96
3	1500 r	67.70	31.02	20.70	4.29
4	2000 r	62.32	16.12	12.36	3.49
5	2500 r	55.95	16.84	14.42	3.54
6	3000 r	53.24	14.46	10.97	3.23
7	3500 r	46.97	15.80	12.35	3.12
8	4000 r	48.56	13.86	10.02	2.67
9	4500 r	44.45	11.90	6.40	2.60
10	5000 r	40.40	14.40	6.12	2.84
11	5500 r	42.12	9.02	3.40	2.85
12	6000 r	30.17	10.22	2.27	2.76
13	6500 r	28.62	6.17	3.85	2.36
14	7000 r	31.12	8.94	2.05	2.67
15	7500 r	27.90	4.77	1.10	2.29
16	8000 r	28.37	4.95	0.25	2.56
17	8500 r	18.05	4.30	0.27	2.38
18	9000 r	17.20	3.80	0.10	2.00
19	9500 r	15.47	4.20	0.20	2.00
20	10000 r	16.20	2.20	0.12	1.56
21	Control	78.82	41.45	27.90	4.04
	C.D. Values at 1% level	5.135	4.429	3.977	0.5762

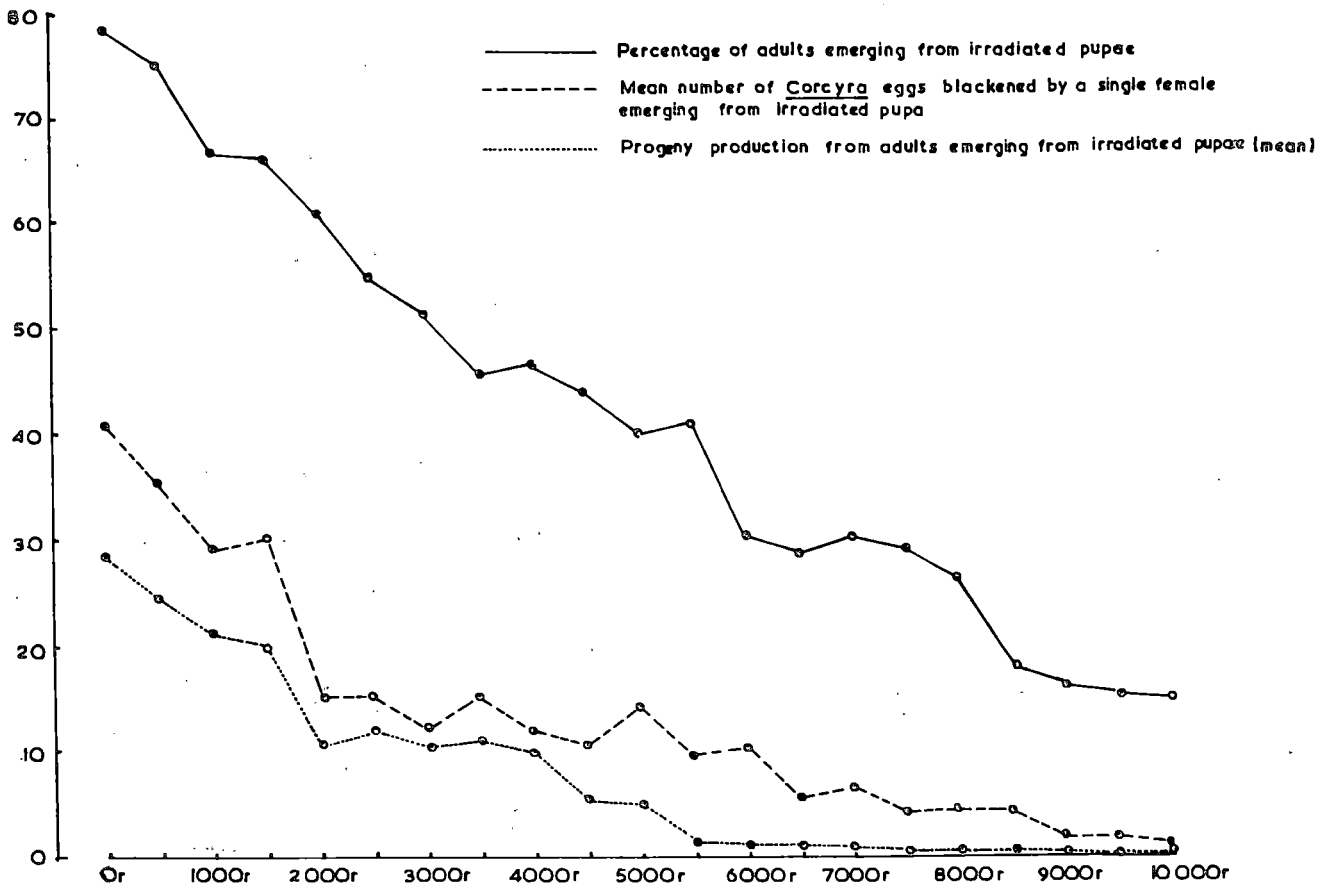
Fig. 14 : Effect of gamma radiations as shown by:

1) the percentage adult emergence from irradiated pupae,

2) Fecundity of adults emerging from irradiated pupae (recorded as the number of host eggs blackened by females emerging from irradiated pupae),

3) Progeny production by females emerging from irradiated pupae.

Fig . 14.


Percentage of adults emerging from irradiated pupae
Mean number of Corcyra eggs blackened by a single female emerging from irradiated pupa
Progeny production from adults emerging from irradiated pupae (mean)
80
70
60
50
40
30
20
10
0
0r
1000r
2000r
3000r
4000r
5000r
6000r
7000r
8000r
9000r
10000r

the fecundity of these adults (recorded from the number of Corcyra eggs blackened as a result of parasitism by a female), the number of progeny produced by adults emerging from irradiated pupae and the proportion of females in the progeny thus produced are furnished in Table 23 in the form of mean values and the detailed data are given in Appendix Table XXII. The data are graphically represented in Figure 14 and the analysis of variance is presented in Table XXVI.

i) Percentage adult emergence

Significant variation was detected in regard to this and a progressive reduction in adult emergence from 76.62 to 16.20 per cent was observed at doses 500 r to 10,000 r. At 1000 r the adult emergence was 68.42 per cent and this was significantly lower than in control (78.82 per cent). At increasing dosages from 6000 r to 8000 r, the adult emergence did not show any significant reduction. The adult emergence was quite low when doses 8500 r to 10,000 r were administered, the range in percentage values being 16.20 to 18.05.

ii) Fecundity

The mean number of Corcyra eggs turning black as a result of parasitism by a single female showed significant variability and the range was from 36.37 to 2.20 at doses 500 r and 10,000 r respectively. The mean fecundity of females emerging from pupae irradiated at 1000 r and 1500 r were respectively 29.82 and 31.02 and these were significantly lower than in control (41.45).

When doses from 7500 to 10,000 r were administered in the pupal stage, the female emergents showed a mean fecundity ranging from 2.20 to 4.77 and these were significantly lower than in the females emerging from pupae treated at 500 to 4000 r.

iii) Progeny Production

Significant variation was detected in the number of progeny produced by adults emerging from irradiated pupae, the range being 24.90 at 500 r to 0.12 at 10,000 r. At 1000 r, the progeny production was 22.23 per female and this was significantly lower than in control (27.80). At the doses 5,500 r to 10,000 r, the progeny production ranged from 3.40 to 0.12 but these differences were not statistically significant.

iv) Sex-ratio

A progressive reduction in the proportion of females was observed when the doses were increased from 3000 r. At 3000 r the proportion of females to males was 3.23 and this was significantly lower than the corresponding value of 4.04 observed in control. The proportion of females among the progeny produced by adults emerging from pupae irradiated 500 to 2500 r, was found to range from 3.54 to 4.34. These differences were not found to be significant.

(F) Temperature tolerance of progeny from irradiated cultures

The aim of these studies was to explore the feasibility of obtaining populations tolerant to high temperature, through

irradiation.

(a) Temperature tolerance of progeny from irradiated population pool

For these studies, the population pool 'P_1' (developed as explained in section B) was irradiated at 1500 r from a ^{60}Co source and the M_2 progeny from these (referred to as the population pool 'P_2') were reared successively for four generations at 33°C and 75 per cent R.H. The mean values of the percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production observed in the P_2 population are given in Table 24 and the detailed data pertaining to these are given in Appendix Table XXIII. The mean values of the percentage adult emergence, fecundity and progeny production in the 'P'_2 population in the fourth generation at 33°C and 75 per cent R.H. and the corresponding values for the Delhi culture (which was directly exposed from cultures maintained at 26° ± 1.5°C and 75 per cent R.H.), were compared. The results of these are given in Table 25.

There were no significant differences between the resultant 'P_2' population and the Delhi culture at 33°C and 75 per cent R.H., in respect of the characters tested. When a part of this 'P_2' population was exposed to 35°C and 75 per cent R.H., this also did not show any differences from the control culture.

Table 24: Performance of the pooled population (P_2) obtained from the different cultures at 33°C and 35°C (at 75% R.H.) as shown by the percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, and progeny production.

Generation No.	Conditions of rearing		Adult emergence (%)	Adult longevity (hours)		Sex-ratio (females/male)	Total reproductive period in females	Fecundity	Progeny production
	Temp.°C	R.H.%		Females	Males				
1	33	75	74.39	29.65	24.02	3.65	23.05	18.22	8.12
2	33	75	68.75	27.65	25.70	3.91	24.37	20.27	9.15
3	33	75	70.50	26.47	19.72	4.22	20.62	16.37	8.70
4	33	75	69.67	30.67	24.17	3.47	25.68	16.45	10.45
5	35	75	31.92	21.67	12.72	4.81	13.82	4.52	2.77

Table 25 : Tests of significance ('t' tests) for comparing the performance of the pooled population P_2 at different temperature-humidity combinations.

Conditions of rearing		Percentage adult emergence and 't' values for comparing the means			Fecundity and the 't' values for comparing the means			Progeny production and 't' values for comparing the means		
Temp.°C	R.H.%	x	y	't'	x	y	't'	x	y	't'
33+	75	69.87	65.95	0.844	16.45	15.92	0.138	10.45	10.87	0.226
35	75	31.92	40.12	0.545	4.52	6.20	1.353	2.77	2.35	1.044

x Mean values for the pooled population 'P_2'

y Mean values for the Delhi culture (direct exposures)

\+ Tested at the 4th generation

Tabular value of 't' at 5% = 2.365.

(b) Temperature tolerance of progeny from different irradiated cultures

In these experiments, the different cultures were seperately irradiated with gamma rays from a ^{60}Co source at 1500 r dose. Irradiation was done in the pupal stage of the parasite. The M_2 progeny from these were exposed to 33°C and 75 per cent R.H. to study the general performance of the different lines as compared with the irradiated stocks.

The mean values of adult emergence, fecundity, progeny production and sex-ratio in the different cultures derived from irradiated stocks are given in Table 26 and these are compared with the corresponding values for the parent cultures (Table 27). The detailed data are given in Appendix Table XXV.

Significant differences in the characters studied were not evident in the cultures derived from irradiated stocks and those in the parent cultures.

An attempt was made to mark out those females which showed highest fecundity in the M_2 generation in the different lines and to breed them further at 33°C and 75 per cent R.H. to ascertain whether the improvements noticed, were consistent. There was a general decline in all the lines derived from irradiated stocks beyond the M_3 generation. There was also a similar decline in the progeny arising from selected parents in all the lines other than those from the Mandya and Ambajipet cultures.

Table 26 : Performance of the M_2 progeny from culture irradiated at 1500 r in the pupal stage at 33°C and 75 per cent R.H., as shown by adult emergence, fecundity, progeny production and sex-ratio.

Sl. No.	Details of cultures	Adult emergence	Fecundity	Progeny production	Sex-ratio
1	Ir 'A'*	60.48	27.30	14.92	5.47
2	Ir 'C'*	55.40	15.45	6.55	5.80
3	Ir 'D'*	70.35	14.67	8.70	3.67
4	Ir 'L_1'*	46.20	14.27	3.60	3.34
5	Ir 'L_2'*	61.05	21.60	14.70	3.26
6	Ir 'M'*	56.12	14.00	7.50	4.20

* M_2 progeny from irradiated Ambajipet, Cuddalore, Delhi, Lucknow, Ludhiana and Mandya cultures.

Table 27 : Tests of significance ('t' tests) for comparing the performance of the M_2 progeny from irradiated cultures* at 33°C and 75% R.H. conditions.

Sl. No.	Details of cultures	Adult emergence x	Adult emergence y	Adult emergence t	Fecundity x	Fecundity y	Fecundity t	Progeny production x	Progeny production y	Progeny production t
1	Ir 'A'	60.45	65.57	1.1217	27.30	26.95	0.0426	14.92	13.97	0.0824
2	Ir 'C'	55.40	57.60	0.6137	15.45	17.65	0.8132	6.55	7.32	0.0631
3	Ir 'D'	70.35	62.12	1.3142	14.87	19.92	1.4687	8.70	10.87	0.6431
4	Ir 'L_1'	48.20	50.17	0.2173	14.27	13.72	0.0987	3.60	4.05	0.1234
5	Ir 'L_2'	61.05	62.77	0.0060	21.80	22.67	0.0060	14.70	11.27	1.1187
6	Ir 'M'	56.12	59.02	0.0047	14.00	13.02	0.3132	7.50	5.92	1.2172

x Mean values for the progeny from irradiated stocks

y Mean values for the parent cultures

Tabular value of 't' as 5% = 2.3650

* Irradiated at 1500 r from a ^{60}Co source

Table 28 : Performance of a selected culture from irradiated Mandya stock* at 33°C and 75% R.H. as shown by mean values of adult emergence, adult longevity, sex-ratio, total reproductive period, fecundity and progeny production.

Generation	Mean adult emergence (%)	Adult longevity (hrs.)		Sex ratio Females/male	Total reproductive period in females (hrs.)	Fecundity	Progeny production per female
		Female	Male				
M_2	62.50	26.65	23.10	3.56	18.14	21.50	12.47
M_3	58.90	25.57	21.82	3.10	15.60	20.40	13.02
M_4	65.42	26.32	18.60	4.02	21.02	22.35	12.60
M_5	61.77	27.60	24.27	3.87	14.00	21.82	14.50
M_6	64.30	26.42	20.80	4.10	17.80	23.12	14.05
M_{10}	64.00	25.00	21.55	3.22	21.32	21.80	13.72
Control+	59.02	30.05	20.70	4.32	24.22	13.02	5.92

* Mandya culture kept at 33°C and 75% R.H. corresponding to the M_2 generation

\+ Irradiated at 1500 r from a ^{60}Co source.

The progeny from the selected Ambajipet parents could be maintained only for three generations while those from the Mandya parents could be maintained successively upto M_{10} generation and beyond, at 33°C and 75 percent R.H. The performance of this selected culture at this temperature-humidity combination as shown by adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production is shown in Table 28. The mean percentage adult emergence in the selected culture ranged from 62.50 to 65.42 in generations M_2 to M_{10} as compared with a value of 59.02 obtained in the Mandya culture reared in the same condition (in the first generation). The parental Mandya culture could not be maintained beyond two generations at 33°C and 75 per cent R.H. The adult longevity (females) ranged from 25.00 to 28.32 hours when the selected culture was reared at 33°C and 75 per cent R.H. (Table 28). Fecundity in the selected culture ranged from 20.40 to 23.12 as compared with the mean value of 13.02 observed for the Mandya culture. The progeny production in the selected culture ranged from 12.47 to 14.05 as compared with the observed value of 5.92 for the Mandya culture. The detailed data pertaining to the performance of the selected culture from Mandya stock, are furnished in Appendix Table XXV.

V. DISCUSSION

The present studies were undertaken to explore the feasibility of developing strains of Trichogramma australicum Girault, suitable for different temperature-humidity conditions prevailing in different agro-climatic regions in the Country. For these studies, complex cultures (from laboratory stocks and from field collected populations) were obtained from different regions, viz., Ambajipet (East Godavari District, Andhra Pradesh), Cuddalore (South Arcot District, Tamil Nadu), Delhi, Lucknow (U.P. Ludhiana (Punjab), and Mandya (Mysore).

The results of these studies presented in Chapter IV are discussed in the following pages.

(A) Physiological compatibility of the cultures obtained from different regions

These studies were conducted to ascertain the physiological compatibility of the different cultures utilized in the course of these investigations and to ensure that no barriers for gene exchange existed among them.

Altogether, 30 crosses were made in two sets, the 15 reciprocal crosses being made in the second set. The percentage of females emerging in the F_1 population was recorded from ten

replicates in each cross. In all but 12 cases female emergence was observed in the F_1 generation and the percentage ranged from 48.11 percent among progeny derived from $L_1 x M$ cross to 70.22 per cent in the progeny from $A x L_2$ cross (Table 1).

The emergence of female progeny in a majority of the cases (96 per cent) indicated that the cultures were physiologically compatible and that it may be possible to combine the characters of the original cultures by interbreeding.

(B) Screening of the pooled population for high temperature tolerance

The object of these studies was to ascertain whether it is possible to select out a population with increased temperature tolerance, from a genetically heterogenous population developed by interbreeding from the different cultures. The F_2 generation from the different crosses was allowed to emerge together and interbreed. The F_3 adults emerging from these ('P_1' population pool) were exposed to 33°C and 75 per cent R.H. for four successive generations and the resultant population was then transferred to 35°C and 75 per cent R.H.

At the end of four generations of successive rearing at 33°C and 75 per cent R.H., the resultant population did not show any significant differences from the Delhi culture which was directly exposed to this condition (from stocks kept at 26° ± 1.5°C) in respect of the characters tested (Table 3). When part of the

resultant population was brought to 35°C and 75 per cent R.H., this showed a significant reduction in adult emergence as compared with the corresponding value obtained for the Delhi culture which was kept as control. At 35°C, the $'P_1'$ population could not maintain itself for more than one generation.

The results of these experiments showed that hybridisation was not effective in selecting out a population with increased temperature tolerance. It was further indicated that even the mean value of adult emergence for the resultant pooled population exposed to 35°C was less than that observed for the Delhi culture which was directly exposed to the same condition. The interpretation of these results was that some of the six cultures with which the pool was formulated, were much inferior in their performance than the Delhi culture which was used as control.

(C) Performance of the different cultures at various temperature-humidity combinations

The observation that the performance of a heterogenous population obtained by interbreeding from all the six cultures was much inferior to the Delhi culture, has led to a study of the relative performance of the cultures at different temperature-humidity conditions.

For these studies, freshly emerged adults were taken from the inbred lines of the original cultures (kept at 26° ± 1.5°C) and these were exposed to various temperature-humidity conditions

shown below:

	Temperature °C	R.H.
a)	27	75
b)	30	90
c)	30	75
d)	30	10
e)	32	90
f)	32	75
g)	32	10
h)	33	90
i)	33	75
j)	33	10
k)	35	90
l)	35	75
m)	35	10

These combinations were chosen to provide near optimum conditions in (a) and varying degrees of stress conditions in (b) to (m). The duration of development, percentage adult emergence, percentage adults with structural malformations, adult longevity, total reproductive period in females and fecundity were observed from the first generation emergents, while the progeny production and sex-ratio were recorded from the number of second generation adults emerging from Corcyra eggs parasitised by 10 mating pairs belonging to the first generation females. The results pertaining to these experiments are given in Tables 4 to 16.

Interactions between the different cultures on the one hand and the various combinations of temperature and humidity on the other were found to be significant in respect of the following characteristics for the range of 30° to 35°C (details of analysis of variance given in Appendix Table XXVI).

(1) Adult emergence

(2) Adult longevity

(3) Sex-ratio

(4) Total reproductive period in females

(5) Fecundity

The other characteristics studied in the course of these investigations viz., duration of development, progeny production per female and the percentage of adults with malformed wings are discussed separately.

(1) Adult emergence

Significant variation was detected in respect of adult emergence at 27°C and 75 per cent R.H., the range being 70.62 to 84.42 per cent (Table 4). The mean values for the range 30° to 35°C are summarised in Table 29.

Table 29: Mean values of adult emergence for the different cultures for temperatures, 30° to 35°C and at different relative humidity levels.

Conditions of rearing Temp°C	R.H.	A	C	D	L_1	L_2	M
30	90	67.82	71.80	53.67	41.30	47.35	27.52
30	75	72.46	80.20	78.65	71.20	75.70	70.45
30	10	61.20	48.77	54.62	50.10	57.07	43.05
32	90	69.17	66.42	50.35	26.52	36.12	30.72
32	75	72.05	61.50	72.30	64.32	67.95	64.90
32	10	60.07	44.27	52.30	46.46	53.82	38.05
33	90	60.75	65.55	47.12	28.37	35.55	28.15
33	75	65.57	53.80	65.95	50.17	62.77	59.02
33	10	62.47	42.60	50.10	45.15	52.27	36.22
35	90	40.15	36.65	35.17	21.47	31.32	26.32
35	75	45.37	24.32	37.62	11.55	41.50	25.32
35	10	36.60	18.25	40.62	14.72	42.20	20.12

C.D. 1% 10.43.

At 35°C and 10 per cent R.H. adult emergence in the Ludhiana, Delhi and Ambajipet cultures were relatively higher (42.20, 40.62 and 36.60 per cent respectively). The percentage adult emergence in these cultures at 35°C and 75 per cent R.H. was 41.50, 37.62 and 45.37 respectively and these were also relatively higher than in rest of the cultures. At 35°C, the Lucknow and Mandya cultures showed significantly lower adult emergence at all levels of humidity than the corresponding values in the Ambajipet and Delhi cultures.

The susceptibility of the Lucknow culture to high humidity condition (90 per cent R.H.) was pronounced for the range 30° to 33°C. For this range, extreme humidity conditions 90 and 10 per cent R.H., considerably affected adult emergence in all the cultures other than the Ambajipet stock. But at 35°C the effect of relative humidity was not quite pronounced. Lund (1934) observed striking differences in two races of T. minutum with regard to adult emergence for a temperature range of 22° to 32°C and a range of humidity from 30 to 100 per cent. It was concluded that the mortality of the parasites occuring in the immature stages decreased progressively with increase in humidity. In the present studies, a generalisation cannot be made since the different cultures showed differential response to the temperature-humidity combinations.

The percentage of adult emergence in the first and second generations showed variations (Tables 4 to 16). However, these variations were not pronounced at 27°C and 75 per cent R.H. The

variations observed in other temperature-humidity conditions may be explained on the basis of a selective elimination of individuals in the populations which are susceptible to the adverse effects of temperature-humidity conditions.

(2) Adult longevity

The life expectancy of females ranged from 40.90 hours to 60.87 hours at 27°C and 75 per cent R.H. (Table 4). The mean values for female longevity for the range of 30° to 35°C is summarised in Table 30.

Table 30: Mean values of adult longevity in females for temperatures of 30° to 35°C and at different relative humidity levels.

Conditions of rearing Temp°C	R.H.	A	C	D	L_1	L_2	M
30	90	36.75	36.97	32.97	47.12	36.20	28.94
30	75	44.32	46.20	39.40	50.12	55.17	38.45
30	10	25.97	38.30	37.10	40.31	37.57	32.00
32	90	33.77	25.32	24.32	22.22	34.57	19.87
32	75	38.37	40.72	40.12	40.15	41.40	35.15
32	10	27.40	34.17	34.05	32.67	32.15	27.77
33	90	32.32	26.40	24.67	24.01	33.15	18.40
33	75	31.07	30.60	38.17	23.20	35.25	30.05
33	10	25.45	28.90	34.12	28.07	26.07	18.32
35	90	32.77	20.02	30.60	17.20	28.52	19.82
35	75	27.77	24.50	29.52	15.75	25.55	21.40
35	10	22.87	20.07	30.15	14.05	25.35	13.95

C.D. 1% 10.93

At 90 per cent R.H, the females emerging from the Ambajipet culture

did not show a significant decline in longevity with increase in temperature from 30° to 35°C.

The females emerging from the Lucknow culture were found to be most affected and there was sharp reduction in longevity with increase in temperature from 30° to 35°C. At 30°C the females in the Ambajipet culture showed reduced longevity when the humidity was decreased from 75 to 10 per cent. With increase in temperature from 30° to 35°C, the Cuddalore and Mandya cultures showed a progressive reduction in female longevity.

The mean values for male longevity for the different cultures are summarised in Table 31.

Table 31: Mean values of adult longevity in males for temperatures of 30° to 35°C and at different relative humidity levels.

Conditions of rearing		A	C	D	L_1	L_2	M
Temp °C	R.H.						
30	90	24.02	36.25	24.02	30.12	29.22	32.47
30	75	23.67	37.37	36.95	34.20	25.27	35.60
30	10	21.80	34.12	23.52	24.77	27.12	20.65
32	90	24.02	21.25	19.07	15.90	27.92	15.80
32	75	27.22	34.20	25.60	28.00	21.27	24.75
32	10	19.87	28.50	20.10	22.05	22.85	16.57
33	90	22.62	20.57	18.30	13.90	30.02	14.32
33	75	22.02	24.57	20.17	20.87	21.27	20.70
33	10	23.45	24.12	16.07	19.42	18.72	14.72
35	90	22.67	16.70	18.12	12.67	20.95	10.42
35	75	18.07	19.35	14.65	10.10	15.47	12.05
35	10	14.82	14.30	16.35	12.10	18.35	11.70

C.D. at 1% 8.87

It will be seen that males emerging from the Ludhiana culture did not show any significant reduction in longevity when the rearing temperature was increased from 30 to 32°C, but those in the Lucknow and Mandya cultures were found to be much affected.

The mean values for adult longevity obtained in the present investigations agree with those reported by Schulze, 1926 (1 day for females at 32°C); Pradhan and Peswani, 1954 (1 day for both sexes at 30°C and 75 per cent R.H, 5 hours to 1 day for both sexes at 35°C and 75 per cent R.H.) and by Sharma, 1968 (1.5 days at 30°C and 15 per cent R.H.).

(3) Sex-ratio

The proportion of females to males in the different cultures ranged from 5.31 to 3.51 at 27°C and 75 per cent R.H. (Table 4) and these were relatively higher in the Ambajipet and Cuddalore cultures. The preponderance of females in these cultures was evident at other temperature-humidity combinations as well. The mean values for the sex-ratio observed in the different cultures for a range of 30° to 35°C are summarised in Table 32.

The Ambajipet culture at 35°C produced an unusually high proportion of females (11.05) per male at 75 per cent R.H. The rest of the cultures appeared to be unaffected by temperature-humidity fluctuations. It is probable that a high proportion of females in the Ambajipet culture may be due to mortality occurring in the immature stages of development of the males. In the Ambajipet culture reared at 35°C the adult emergence was quite low

(36.60 to 40.15 per cent) and a selective mortality of males occurring in the immature stages may, therefore, be responsible for the unusually high proportion of females in the population. Georgiana (1949) observed that the haploid males in Habrobracon juglandis Ashmead, were more vulnerable to environmental adversities. But in the present experiments since a selective mortality of males were not evident in all the cultures, a generalisation is not possible. However, Wilkes (1959) reported that in Dahlbominus fuliginosus, the percentage of the progeny that were females markedly decreased for exposures at temperatures of 27°C and above, falling from 86 per cent at 23°C to 16 per cent at 31°C.

Table 32 : Mean values of sex-ratio (females/male) for temperatures of 30° to 35°C and at different relative humidity levels.

Conditions of rearing		A	C	D	L_1	L_2	M
Temp °C	R.H.						
30	90	6.75	5.27	3.10	3.72	3.25	4.37
30	75	6.62	5.22	3.07	3.67	3.80	4.23
30	10	6.44	4.87	3.14	3.68	3.91	4.75
32	90	5.67	5.93	3.05	2.97	3.62	4.83
32	75	4.89	5.84	3.46	3.44	4.97	4.47
32	10	7.84	5.36	3.34	2.89	3.04	4.75
33	90	5.21	6.35	2.81	2.83	3.81	4.54
33	75	4.98	6.07	3.12	3.40	2.89	4.52
33	10	7.49	6.13	2.94	2.79	3.27	5.12
35	90	8.54	7.02	2.95	2.45	2.89	4.40
35	75	11.06	6.92	2.87	3.10	2.68	4.76
35	10	9.44	7.20	2.76	2.70	3.14	5.48

C.D. 1% 3.76

(4) Total reproductive period in females

The total period during which the females laid eggs was recorded as the total reproductive period of females. This was observed from egg-cards removed at periodic intervals of 5 to 10 hours. This period ranged from 31.67 to 42.77 hours at 27°C and 75 per cent R.H. (Table 4). The mean values for the range from 30° to 35°C are summarised in Table 3.

Table 33: Mean values of the total reproductive period in females for different cultures for temperatures 30° to 35°C and at different relative humidity levels

Conditions of rearing							
Temp °C	R.H.	A	C	D	L_1	L_2	M
30	90	20.85	36.35	26.12	24.37	24.82	20.15
30	75	37.05	35.25	32.55	28.55	40.40	28.22
30	10	18.60	20.25	25.55	21.70	26.35	20.18
32	90	16.80	22.40	16.02	14.45	16.07	15.57
32	75	31.02	31.42	28.42	20.50	30.70	27.47
32	10	16.82	19.12	26.37	19.10	23.40	18.67
33	90	17.87	21.77	14.92	12.57	13.32	13.57
33	75	29.75	21.05	25.85	18.17	24.02	24.22
33	10	16.22	15.35	23.32	15.60	17.75	14.64
35	90	14.95	18.37	10.32	11.05	13.80	10.12
35	75	10.62	15.82	15.02	10.72	10.35	15.08
35	10	11.27	10.35	22.80	8.07	14.42	8.62

C.D. 1% 8.77

The Lucknow and Mandya cultures showed a greater sensitivity to high temperature conditions. In the Lucknow culture, the total reproductive period declined from 31.67 to

8.07 hours when the temperature-humidity conditions were changed from near optimum (27°C and 75 per cent R.H.) to the near adverse (35°C and 10 per cent R.H.) conditions. The corresponding decline in the Mandya culture was from 34.82 to 8.62 hours. At 35°C and 10 per cent R.H., the Delhi culture showed the longest reproductive period of 22.85 hours.

Many workers have studied the egg distribution in Trichogramma spp., during the oviposition period. Since a characteristically high proportion of eggs is laid during the first few hours after emergence, (Peterson, 1930; Lund, 1938; Chacko, 1961; Sharma, 1968), the total duration of reproductive life seems to be of little importance in judging the efficiency of this species. However, the significantly longer reproductive period observed in the Delhi culture at 35°C and 10 per cent R.H. is indicative of its tolerance to such conditions.

(5) Fecundity

Fecundity was observed from the total number of Corcyra eggs turning black as a result of parasitism. At 27°C and 75 per cent R.H., the maximum fecundity was observed in the Lucknow culture (54.77) and in the Ambajipet and Ludhiana cultures, it was 42.20 and 41.45 respectively (Table 4). The mean values of fecundity for the temperature ranging from 30° to 35°C are summarized in Table 34.

For the temperature range from 30° to 33°C, most of the

cultures showed significant reduction at extreme humidity levels of 10 and 90 per cent. R.H. The Ambajipet culture showed pronounced tolerance to high humidity condition for this range of temperature. Pronounced tolerance to low humidity condition was not observed in any of the cultures for this range of temperature. At 35°C, the effect of relative humidity was not quite pronounced.

Table 34 : Mean values of fecundity for the different cultures for temperatures of 30°to 35°C and at different relative humidity levels.

Conditions of rearing		A	C	D	L_1	L_2	M
Temp °C	R.H.						
30	90	35.67	21.95	24.67	15.42	13.30	14.18
30	75	36.46	34.46	38.82	48.70	40.06	28.55
30	10	17.24	10.02	11.97	14.57	21.25	11.00
32	90	26.37	19.52	13.50	9.35	9.55	12.47
32	75	23.82	25.85	29.47	21.50	33.17	24.02
32	10	17.45	9.67	10.30	10.07	19.30	9.75
33	90	25.46	18.17	14.35	9.72	8.27	10.20
33	75	26.95	17.65	19.92	13.72	22.77	13.02
33	10	10.80	7.97	10.67	7.62	16.43	7.50
35	90	7.65	1.30	6.20	0.40	5.35	3.52
35	75	4.95	0.77	6.20	0.52	5.72	1.40
35	10	4.22	0.50	5.42	0.30	6.80	2.30

C.D. 1% 4.71

Pradhan and Peswani (1954) have reported that for T. evanescens minutum , the average fecundity at 35°C was 19 and 26 respectively when reared at 35°C and 75 per cent R.H. In the present investigations, the mean value of fecundity for the

Delhi culture reared at 35°C and 75 per cent R.H was found to be 6.20. The differences in fecundity may, perhaps, be due to genetic differences between the cultures used in the present investigations and those used by Pradhan and Peswani (1954). Schepetilnikova (1939) observed that for T. evanescens oviposition did not occur at 35°C. As far as the results Schepetilnikova are concerned, this may perhaps be explained on the basis of the fact that the area in which these experiments were conducted was of a colder climate and a temperature of 35°C was, therefore, extremely adverse to the indigenous Trichogramma population.

(6) Duration of development

With increase in temperature from 30° to 35°C and with changes in relative humidity, the duration of development did not show significant variation.

(7) Progeny production per female

The progeny production was observed from the total number of second generation adults emerging from Corcyra eggs parasitised by the females belonging to the F_1 generation. At 27°C and 75 per cent R.H., the progeny production ranged from 23.0 (in the Delhi culture) to 36.40 (in the Lucknow culture). At 35°C and 10 per cent R.H. considerable reduction in progeny production was evident in all the cultures and in Lucknow and Cuddalore cultures, it was completely suppressed (Table 16). Significantly higher number of progeny emerged in Ludhiana and the Delhi cultures (2.02 and 2.65 respectively), when reared

at this condition.

In the present studies, the maximum progeny production at 27°C and 75 per cent R.H. was observed to be 36.40 in the Lucknow culture.(Table 4). This is considerably lower than the figure reported by Lund (1934) for T. minutum (66.1 ± 2.6) at 25°C. The difference may be due to the differences in temperature and in the species used.

(8) Percentage adults with malformed wings

A certain percentage of adults emerging at 35°C invariably showed impaired mobility. These showed different degrees of wing malformations such as stumpy, partly unfolded or fused wings. The variation in respect of this characteristic was significant when the cultures were reared at 35°C and 10 per cent R.H. (Table 16). In these conditions, malformations were maximum in males emerging from the Mandya culture (74.75 per cent) and the minimum in the male emergents from the Ambajipet culture (36.77 per cent). In females, malformations were relatively high and the range was from 68.25 to 75.47 per cent.

Sharma (1968) reported that the percentage of malformed adults ('runts' as these were called by Salt, 1937) was more in females under conditions promoting superparasitism. In the present studies, since all precautions were taken to avoid this phenomenon, the appearance of 'runts' seems to be due to other aspects of adverse environment. Goldschmidt (1938) reported

that in Drosophila melanogaster Meigen, changes in the shape of wings occurred as a result of exposure to heat shock. In the present experiments also since 'runts' were found in increasing numbers at 35°C, it is probable that malformations occurred as a consequence of adverse temperature conditions.

Overall review of the different characteristics of the cultures at different temperature - humidity conditions

A study of the various characters of the different cultures for two generations under different temperature-humidity combinations leads to the following conclusions:

1 Distinct differences exist among the cultures in respect of the various characters studied under the different temperature-humidity combinations.

2 The performance of the Delhi, Ambajipet and Ludhiana cultures for two successive generations under different temperature-humidity conditions showed that these were relatively tolerant to a temperature range of 33° to 35°C.

The Ambajipet culture showed high tolerance to high humidity conditions (90 per cent R.H.) at 32°C and 33°C as shown by adult emergence, adult longevity and fecundity in these conditions. In this strain, there was a tendency for producing a very high proportion of females at 35°C.

The Cuddalore culture appeared to be unsuitable for high temperatures particularly at 35° to 35°C. But at 30°C and 32°C it showed relatively high tolerance to high humidity conditions.

The Lucknow culture showed high fecundity at 27°C and 75 per cent R.H., but it showed high sensitivity to temperatures beyond 33°C as revealed by a decline in the desirable characters with increasing temperatures.

These results indicate that the strains from Ludhiana, Delhi and Ambajipet are likely to be good performers in the northern and central regions in the Country, particularly in Uttar Pradesh, Punjab, Madhya Pradesh and Haryana where high temperature-low humidity conditions were earlier reported to be limiting factors for parasite efficiency.

For the humid coastal zone of Maharashtra, Mysore, Madras, Kerala, Andhra Pradesh and Orissa where relatively high humidity conditions (60 to 90 per cent R.H.) prevail during most parts of the year, the Ambajipet strain appears to be quite suitable since it revealed a high tolerance to high humidity condition (90 per cent R.H.) at temperatures 32° to 33°C.

For the southern zone consisting of the interior portions of Maharashtra, Mysore, Andhra Pradesh and Orissa having equitable temperature conditions (25° to 27°C), the Lucknow strain appears to be best suited.

3 That 35°C is well above the normal tolerable range for the parasite, is evidenced by the drastic reduction in adult emergence, shortening of adult life-span and the total reproductive period in females. The occurrence of structurally malformed adults with impaired mobility also indicated the unsuitability of this temperature.

It will be seen that the cultures obtained from Ludhiana and Delhi showed relatively high tolerance to high temperatures of 33° to 35°C. In these regions, extremes of high temperatures are experienced in the summer months of May to June and it is likely that natural selection operative on the population, resulted in increased tolerance to high temperatures. The absence of a similar temperature tolerance in the Lucknow culture, obtained from a region with similar climatic conditions appeared to be somewhat unexpected. It is understood that the Indian Institute of Sugarcane Research, Lucknow, have been obtaining cultures from elsewhere and releasing them in their environment. Obviously, the population has not undergone any appreciable natural selection for temperature tolerance.

It was found that when part of a resultant population pooled from all the six cultures was exposed to 35°C, there was a drastic reduction in adult emergence as compared with the Delhi culture which was kept as control (Section B, Chapter IV). The studies on the relative performance of the cultures at various temperature-humidity combinations have revealed that the Ludhiana

Ambajipet and Delhi cultures showed relatively high tolerance to high temperature conditions and the Luckmow and Cuddalore cultures showed relatively high susceptibility to high temperature conditions. It is likely that when all the six cultures were interbred and when the resultant population screened for temperature tolerance, the desirable genotypes for high temperature tolerance were progressively eliminated from the mixed population.

(D) Selection of the cultures for high temperature-low humidity tolerance

In view of the relatively better performance of the Ludhiana Delhi and Ambajipet cultures at high temperature conditions, efforts were made to improve their performance by selective breeding. Selective breeding was done by rearing these strains at increasing temperatures (from 30° to 33°C) and at decreasing humidity levels (60 to 10 per cent). A part of the culture thus reared was exposed to 35°C and a relative humidity of 75 per cent. The relative humidity at this temperature was kept at a near optimum level in order to prevent loss or extinction of the culture due to the high temperature-low humidity, stresses given simultaneously.

The sequence of breeding is furnished in Figure 10. The culture reared at progressively adverse conditions would be referred to henceforth as the 'P' culture and the corresponding control culture as 'Q' (directly exposed to the same conditions

from stocks kept at 26° ± 1.5°C).

The data on selective breeding of these strains are furnished in Tables 17 to 22 and these are graphically represented in Figures 11, 12, 13.

The performance of the three cultures viz., Ludhiana, Ambajipet and Delhi reared in the manner prescribed above was found to be more or less similar at progressively reduced humidity levels and at increasing temperature conditions. Thus, when the temperature was increased from 30° to 33°C and when the relative humidity was decreased from 60 to 10 per cent, all the 'P' stocks revealed decline in the characters studied, that is, adult emergence fecundity and progeny production. But the extent of decline of these characters in 'P' cultures was not as high as that observed for the corresponding control 'Q' cultures. At all stages of rearing under progressively adverse conditions, the 'P' cultures showed higher mean values for the characters tested (Tables 18, 20, 22).

The differences in the 'P' and 'Q' Ludhiana cultures were significant at 33°C and 10 per cent R.H. (34th generation) in respect of fecundity. This improvement in fecundity was maintained even in the 38th generation at the same set of conditions. This revealed consistency in the improvement attained as a result of selective breeding.

In the 'P' stock of Delhi strain, significant improvement

was observed in adult emergence at 33°C and 10 per cent R.H (34th generation) and this improvement was consistent for the succeeding four generations at the same conditions.

Significant differences between the 'P' and 'Q' cultures of Ambajipet strain were not evident in the first 34 generations reared at progressively adverse conditions.

Even when the 'P' cultures from Ludhiana, Delhi and Ambajipet stocks were subsequently exposed to 35°C and 75 per cent R.H., improvement in adult emergence, fecundity or progeny production was evident. Thus, the Ambajipet 'P' culture showed improvement in adult emergence and progeny production when reared at 35°C and 75 per cent R.H. The 'P' lines in the Delhi and Ludhiana stocks, showed improvements in fecundity and progeny production, and adult emergence when reared at 35°C and 75 per cent R.H. But the 'P' cultures in Ambajipet and Delhi stocks could not be maintained beyond two generations at 35°C and 75 per cent R.H. The Ludhiana culture could, however, be maintained for three generations. Obviously, the extinction of the selected cultures at 35°C, is due to the progressive deleterious effect of the very same adverse temperature condition.

The increase in tolerance to low humidity and high temperature conditions is explicable on the basis of elimination of susceptible genotypes and the selection of those which are more tolerant to these conditions.

It is evident that a significant improvement of a

particular character, namely adult emergence, fecundity and progeny production was brought about only after a period of 32 to 33 generations of rearing under progressively decreasing humidity levels and increasing temperatures.

DeBach and Hagen (1964) reported the results obtained by DeBach et al. (1960) that climate tolerant strains of Aphytis lingnanensis could be developed by selection only after 85 generations. In these studies, to develop heat or cold tolerant strains, DeBach and his co-workers used the criterion of adult survival at 1.6°C or 36.1°C. In the present studies, the selected lines and the corresponding controls were compared on the basis of the percentage adult emergence, fecundity and progeny production. Therefore, a comparison of the results obtained by DeBach et al. (1960) and those reported in the present investigations is not possible.

Wilkes (1942) developed cold tolerant strains of Dahlbominus fuliginosus by releasing the adults in a temperature gradient and by selection of those individuals which congregated in the 6° to 10°C zone. When selection was thus continued for four generations, a strain could be developed in which over 60 per cent of adults preferred temperatures below 12.5°C. In these studies, since the adults were released in a temperature gradient, selection of individuals with the required temperature preferendum could be directly made and this explains the rapidity with which cold tolerant strains could be developed.

In the present investigations the selection pressure (high temperature-low humidity conditions) was purposely kept low so as to avoid extinction of the cultures which might defeat the very purpose of selection. The relatively slow process of selection for high temperature-low humidity tolerance observed in the present studies was, perhaps, to be expected in view of the comparatively low slection pressure exercised.

Sharma (1968) reported that low humidity tolerance in T. evanescens minutum could be improved by rearing the parasites at 30°C for ten generations each at 75, 60, 45, 30 and 15 per cent R.H. In these experiments, the selection pressure was not rigorously applied and it is seen that the process of selection was relatively slow. However, a comparison of these results with those obtained in the present experiments is not possible since the selection pressures applied were quite different.

Periodical observations were made on adult longevity, sex-ratio, total reproductive period in females, in all the three strains reared at increasing temperatures and decreasing relative humidities. (Tables 17, 19, 21). In the Ludhiana culture when the temperature was increased from 30° to 33°C and when the relative humidity was decreased from 60 to 10 per cent R.H., the adult longevity declined from 54.75 hours to 33.45 hours in females and from 35.65 hours to 22.17 hours in the case of males. The sex-ratio remained more or less unaffected. The total reproductive period in females declined from 38.17 hours to 23.65

hours. These characters for the selected lines did not show any marked variations from those observed in the original cultures which were directly exposed (from 26° ± 1.5°C and 75 per cent R.H.) to the same condition (Table 14). In the Delhi and Ambajipet cultures also reared at progressively adverse conditions, a similar trend was observed. It is evident that selection for high temperature low-humidity tolerance has not adversely affected these characteristes.

The fecundity of females in the selected and control cultures was significantly different and among the selected cultures, the one from Ludhiana stock showed significantly higher fecundity than in both the Delhi and Ambajipet cultures. (details of analysis of variance in Appendix Table XXVI). The three strains, Ludhiana, Ambajipet and Delhi were found to show different degrees of improvement consequent on continuous rearing under progressively adverse conditions. Thus, in the Ludhiana 'P' culture, the mean fecundity was 23.02 as compared with 16.42 observed in the corresponding control maintained at 33°C and 10 per cent R.H. (Table 18). In the Delhi 'P' stock, the mean fecundity was 14.00 as compared with 10.67 observed for the 'Q' culture maintained at 33°C and 10 per cent R.H. (Table 20) After rearing in progressively adverse temperature-humidity conditions, the Ambajipet 'P' stock showed a mean fecundity of 13.87 as compared with 10.80 observed for the corresponding control culture maintained at 33°C and 10 per cent R.H. (Table 22)

The results indicate that in the Ludhiana, Delhi and Ambajipet strains which appeared to be relatively tolerant to high temperature-low humidity conditions, the biotic potential could be increased by rearing in progressively adverse temperature humidity combinations. The selections thus made from these strains are likely to be of better value in regions having high temperature low humidity conditions.

(E) Radiation experiments

The object of these experiments was to find out a desirable doze of gamma rays from a ^{60}Co source at which a fairly good culture population could be maintained so as to ensure availability of adequate population for screening for high temperature tolerance. In these studies inbred lines of the Ludhiana culture were irradiated in the pupal stage at varying doses of 500 to 10,000 r.

Data on the percentage adults emerging from irradiated pupae, fecundity of adults recorded from the number of Corcyra eggs blackened as a result of parasitism by females emerging from irradiated pupae (the number of pupal stages of the parasite), progeny production by adults emerging from irradiated pupae and the proportion of females among the resulting progeny, are furnished in Table 23 and these are graphically represented in Figure 14.

1) Adult emergence

A progressive decrease in adult emergence was observed at doses from 1000 r to 10,000 r (76.62 to 16.20 per cent). The adult emergence at 1000 r was 67.70 per cent and this was significantly lower than in control (78.82 per cent). The decline in adult emergence observed in these experiments is obviously due to a radiation induced mortality occurring in the treated pupae. Sharma (1968) reported a significant reduction in adult emergence at 500 and 1000 r doses administered at the pupal stage of the parasite. In the present studies, there was no significant reduction in adult emergence observed at 500 r dose. The variations in these results may possibly be due to differences in radio-sensitivity of the cultures utilized. The results reported here are for the Ludhiana culture and those reported by Sharma related to the Delhi culture.

2) Fecundity

The reduction in fecundity (recorded as the number of Corcyra eggs blackened as a result of parasitism by females) was significant at 1000 r (29.82) as compared with 41.45 in control and there was a progressive decline at dosages beyond 1000 r. This reduction can be due to the adverse effect of irradiation on the reproductive potential of the parasite. A reduction in the number of host eggs turning black as a result of parasitism by females emerging from pupae irradiated at doses 1000 r and above indicates a decrease in the number of parasites reaching the pupal stage.

3) Progeny production

The progeny production by females emerging from irradiated pupae showed reduction at doses 1000 r (22.22 per female as compared with 27.90 in control) and above. At 2000 r the decline in progeny production was 52.11 per cent (12.36 as compared with 27.90 in control). The decline in progeny production by adults emerging from irradiated pupae, suggests the persistent deleterious effect of irradiation.

4) Sex-ratio

A significant reduction in the proportion of efemales in the progeny produced by adults emerging from irradiated pupae was observed at 3000 r (3.23 females per male), as compared with control (4.04 females per male). A plausible explanation for this can be that as a result of irradiation, a higher proportion of sperms were inactivated or damaged, and this might have adversely affected the successful insemination of females. In as much as the females are derived from fertilized eggs and the males from the unfertilized eggs, the high proportion of males in the progeny produced by adults from irradiated pupae can be explained on the basis of unsuccessful fertilisation. DeBach and White (1962) have reported that in Aphytis lingnanensis, a paracite of the California red scale, the percentage of females in the progeny of X-ray irradiated females was drastically reduced at doses 2000 to 4000 r.

Another possible explanation for the occurrence of

increased number of male progeny can be the occurrence of androgenesis. Wilson (1925) defined androgensis as 'the activation of the egg by the sperm followed by development without participation of the egg nucleus". The emergence of a higher proportion of androgenetic males in the progeny from irradiated adults has been reported by Astaurow (1937) in the case of Bombyx mori Linnaeus, and by Whiting (1948) in Habrobracon juglandis, in both cases by X-ray treatment. If androgenesis is to be expected as the possible reason for increase in the proportion of males, the males might have emerged from untreated sperms which had fertilised the treated eggs of which the nucleus had been severely damaged, while the cytoplasmic injury was not so much as to preclude the successful functioning of the sperm nucleus. Thus, if androgenis is expected as a reason for the preponderance of males, it follows that haploid cells are relatively more resistant than diploid cells to irradiation. However, Clark (1959) has reported that in Habrobracon juglandis, the haploid males were more radio-sensitive (revealed by chromosomal abberrations) than diploid females in the larval and pupal stages.

At 1500 r dose, the adult emergence, fecundity and progeny production were significantly lower than in control, but the sex-ratio was not adversely affected. At 2000 r dose, the progeny production was 12.36 as compared with 27.90 (decline by 52.1 per cent) in control. DeBach (1958) has suggested that the r doses administered for the purpose of inducing additional genetic

variability in parasites may be so chosen that the progeny production is not reduced by more than 25 to 50 per cent. In the present studies since the progeny production was found to decline by 52.11 per cent at dose 2000 r, a dose of 1500 r was chosen for subsequent experiments.

(F) Temperature tolerance of progeny from irradiated cultures

The aim of these studies was to explore the possibility of obtaining populations tolerant to high temperature through irradiation.

When part of the population pool 'P_1' was irradiated at 1500 r and when the M_2 progeny from these were reared successively for four generations at 33°C and 75 per cent R.H., the resulting population did not show any significant variability from control (Delhi culture directly exposed), in respect of adult emergence, fecundity and progeny production (Table 25). When part of the resulting population from 33°C was exposed to 35°C and 75 per cent R.H., this also did not show any significant differences from the control culture.

The different cultures were seperately irradiated and the M_2 progeny from these also were exposed to 33°C and 75 per cent R.H. to study their overall performance in this condition and to isolate if possible, some individuals with increased temperature tolerance. The results of these experiments are

given in Tables 26 and 27. A comparison of the adult emergence fecundity and progeny production in the irradiated and non-irradiated cultures, revealed that there were no differences in the two populations exposed to 33°C and 75 per cent R.H. There was a decline of progeny production from the irradiated lines and these could not be maintained beyond the M_3 generation. A similar decline was also observed in the progeny from parents marked out for high fecundity at the M_2 generation. However, the progeny from a pair selected from irradiated Mandya stock could be maintained at 33°C and 75 per cent R.H. upto M_{10} generation and beyond. The performance of this, as shown by adult emergence, adult longevity, sex-ratio, total reproductive period, fecundity, and progeny production is furnished in Table 28. Fecundity in the selected line for generations M_2 to M_{10} ranged from 20.40 to 23.12 as compared with 13.02 in the parental Mandya culture. The progeny production also revealed consistent improvement (from 14.50 to 12.47 in M_2 to M_{10} generations) as compared with the parental value of 5.92. A comparison of the performance of the resultant population with the parental culture was not possible since the parental culture could not be maintaine at 33°C and 75 per cent R.H. for more than three generations.

The improvement in the selected culture might possibly be due to the specific combining ability in the parents for the desirable characters. The occurrence of a desirable mutation in the present case cannot be ruled out but it cannot be proved either.

The results of these experiments indicated that in general, irradiation as a means of inducing additional genetic variability for effecting selection for temperature tolerance, did not yield the desired results, at least at the dosage tried.

Chatterjee et al. (1961) in their experiments on the fecundity of Bracon gelechiae Ashmead reared on Corcyra cephalonica fed on 'jowar' mixed with radioactive ^{32}P, reported a marked increase in the fecundity of the M_3 generation. However, in the absence of statistical treatment of the data presented in these experiments, a comparison with the present findings is not possible.

On the other hand, Sharma (1968) observed that when pupae of T. evanescens minutum was irradiated at 1000 r with gamma rays from ^{60}Co source, there was a decrease in adult emergence, percentage of females and fecundity in the X_1 generation and beyond. This persistence of the adverse effects of radiation was reported to be due to a phenomenon of the nature of a dauermodifikation.

VI SUMMARY

Egg parasites of the genus Trichogramma have been extensively tried in India for the biological control of moth borer pests of sugarcane, particularly the early shoot borer Chilo infuscatellus. The parasite was successful in certain areas, while in other regions, it was either a failure or the results were inconclusive. Among the several factors responsible for the inefficiency of the parasite, poor climate tolerance, particularly the inability to withstand conditions of high temperature and low humidity is reported to be very important. In the present investigations, an attempt was made to explore the feasibility of developing strains of the parasite suitable for different temperature-humidity conditions prevailing in different agro-climatic regions in the Country.

1 For these studies, cultures were obtained from six different regions viz., Ambajipet (East Godavari District, Andhra Pradesh), Cuddalore (South Arcot District, Tamil Nadu), Delhi, Lucknow (Uttar Pradesh), Ludhiana (Punjab) and Mandya (Mysore).

The physiological compatibility of these cultures were ascertained by a series of cross-breeding experiments, in order to ensure whether a gene pool could be made for subsequent screenir for temperature tolerance. In a majority of cases (96 per cent) females were obtained in the F_1 population derived from these

crosses. This indicated that the cultures were physiologically compatible and that reporudctive isolation did not exist among the cultures used.

2 A heterogenous population obtained by interbreeding all the six cultures was successively reared at 33°C and 75 per cent R.H. for four generations and the resultant population brought to 35°C in order to ascertain whether it is possible to select a population with increased tolerance to these temperature conditions At 33°C, the population did not show any significant differences from the directly exposed Delhi culture in respect of adult emergence, fecundity and progeny production. When part of the resultin population at the end of four generations of successive rearing at 33°C was brought to 36°C, this showed a considerable decline in adult emergence as compared with that in the directly exposed Delhi culture.

These experiments showed that hybridisation between the cultures was not effective in selecting out a population with increased temperature tolerance.

3 The relative performance of the cultures utilised in these investigations at different temperature humidity combinations were studied to ascertain whether the cultures showed variability in respect of climate tolerance and to probe into the factors responsible for the poor performance of the pooled population derived from all the six cultures at high temperatures. These experiments yielded the following results.

1) The Ludhiana, Delhi and Ambajipet cultures were relativel

more tolerant to a temperature range of 33° to 35°C.

ii) The Ambajipet culture showed high tolerance to high humidity (90 per cent R.H.) at temperatures 30° to 33°C.

iii) The Lucknow culture showed highest fecundity at 27°C and 75 per cent R.H., but at temperatures above 33°C, it showed sharp reduction in adult emergence, fecundity and progeny production. At 35°C and 10 per cent R.H., progeny production in this culture was found to be suppressed.

iv) The Cuddalore culture revealed a relatively high tolerance to high humidity condition (90 per cent R.H.) at 30°C and 32°C but at higher temperatures the performance was quite unsatisfactory. At 35°C and 10 per cent R.H., there was no progeny production at all.

v) The performance of the Mandya culture at 27°C and 75 per cent R.H. was satisfactory, but temperatures above 32°C appeared to be quite unsuitable for this culture. At temperatures 30° to 33°C, this culture was susceptible to extremes of humidity conditions (90 and 10 per cent R.H.).

It will be seen that the cultures used in these studies showed considerable differences in their ability to tolerate various temperature-humidity conditions. The Ludhiana, Delhi and Ambajipet cultures showed relatively high tolerance to high temperature conditions, while those from Lucknow and Cuddalore showed high susceptibility. The poor performance of the populatio

pooled out from all the six cultures at 35°C is explicable on the basis of a progressive elimination of genotypes with relatively high tolerance to high temperature conditions, from the mixed population.

4 In view of the relatively better performance of the Ludhiana, Delhi and Ambajipet cultures at temperatures 32° to 36°C, efforts were made to further improve their performance by selective breeding. Selective breeding was done at progressively adverse temperature (increasing temperatures from 30° to 33°C) and humidity (decreasing from 60 to 10 per cent R.H.) conditions. The results obtained in these studies showed a continuous trend of improvement in adult emergence, fecundity and progeny production consequent on selective breeding. But the quantitative improvements attained statistical significance after rearing for 32-33 generations at progressively adverse conditions.

The selected cultures showed different degrees of improvements as a result of selective breeding. Thus, in the culture selected from Ludhiana stock, the mean fecundity at 33°C and 10 per cent R.H. was 23.2 as compared with the corresponding values of 14.00 and 13.55 obtained for the selections from Delhi and Ambajipet cultures. These differences were significant and in the selected Ludhiana culture, fecundity was significantly higher than in the remaining selected lines. These studies showed that the biotic potential of the cultures which were found to

possess relatively high tolerance to high temperatures, could further be improved by selective breeding at progressively adverse conditions.

5 In order to find out a desirable dose of gamma rays from a ^{60}Co source at which a fairly good culture population could be maintained so as to ensure availability of adequate population for subsequent screening for high temperature tolerance, inbred lines of the Ludhiana culture was irradiated at the pupal stage at varying doses from 500 to 10,000 r . These experiments yielded the following results.

i) At 500 r the adult emergence, fecundity, progeny production and sex-ratio were not adversely affected.

ii) A progressive decrease in the percentage adult emergence was detected at doses 1000 to 10,000 r.

iii) A reduction in fecundity of females emerging from irradiated pupae was detected at doses 1000 r and above. When the dose was increased from 1500 to 2000 r, the reduction in mean fecundity was from 31.02 to 16.12.

iv) A decline in the number of progeny produced by females emerging from irradiated pupae occurred at 1000 r and above. At 1500 r the reduction in progeny production was 29.39 per cent and a 2000 r, the corresponding reduction was 52.1 per cent.

v) A significant reduction in the proportion of females

in the progeny produced by females emerging from pupae irradiated at 3000 r (3.23 as compared with 4.04 in control) and above. Though the deleterious effects of radiation were observed at 1500 r, the decline in adult emergence, fecundity, progeny production was not so drastic as to lead to a quick decline of the culture population. At doses above 1500 r, the adverse effects of radiation was quite pronounced. In view of these, a dose of 1500 r was chosen for the subsequent experiments.

6 In order to explore the feasibility of improving the temperature tolerance of the parasite with the help of irradiation, a part of the pooled population (P_1) developed by interbreeding from all the cultures, was irradiated at 1500 r from a ^{60}Co source and the M_2 progeny screened for tolerance to 33°C and 35°C. When part of the resulting population at 33°C was exposed to 35°C, this did not show any significant differences from the Delhi culture which was directly exposed to this temperature.

The different cultures were seperately irradiated and the progeny from these were also screened for tolerance to 33°C. All the irradiated lines tended to die out beyond the M_3 generation. But the progeny from a selected pair marked out in the M_2 generation from the irradiated Mandya stock showed consistent improvement in fecundity and progeny production for generations M_2 to M_{10} as compared with the parent culture. The culture could be maintained at 33°C and 75 per cent R.H. even for subsequent generations.

The implications of the development of various improved cultures and their suitability to the different agro-climatic regions in the Country have been discussed.

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*Original not seen.

APPENDIX TABLES I - XXVI

Table I

Physiological compatibility of different cultures as shown by the percentage of females in the F_1 progeny from crosses.

Cross No.	Rep. No.	Parents	Total F_1 progeny	No. of females in the F_1 progeny	% females in the F_1 progeny
1		A x C			
	1	"	14	8	57.13
	2	"	25	16	64.00
	3	"	18	10	55.55
	4	"	19	13	68.42
	5	"	21	15	71.40
	6	"	29	9	31.61
	7	"	33	24	72.72
	8	"	20	12	60.00
	9	"	24	17	70.83
	10	"	15	6	40.00
2		C x A			
	1	"	21	13	61.90
	2	"	25	N11	N11
	3	"	26	20	76.42
	4	"	28	21	75.00
	5	"	14	11	78.57
	6	"	9	6	66.66
	7	"	19	N11	-
	8	"	23	17	60.70
	9	"	27	19	70.37
	10	"	34	26	76.40

Contd.

1	2	3	4	5	6
3		A x D			
	1		12	9	75.00
	2		25	18	72.00
	3		16	10	62.50
	4		39	29	74.30
	5		38	24	63.15
	6		31	8	25.80
	7		14	10	71.43
	8		9	6	66.66
	9		16	11	68.75
	10		21	14	66.70
4		D x A			
	1		21	12	57.14
	2		26	20	76.94
	3		22	15	67.17
	4		24	16	66.60
	5		17	13	76.47
	6		31	23	74.18
	7		24	12	50.00
	8		27	18	66.70
	9		21	16	76.19
	10		24	14	57.13
5		A x L_1			
	1		11	6	54.44
	2		19	12	63.15
	3		14	10	71.40
	4		16	10	62.50
	5		13	9	69.20
	6		18	14	77.70
	7		15	11	73.30
	8		12	8	66.66
	9		14	8	57.10
	10		19	11	57.89
6		L_1 x A			
	1		40	25	62.50
	2		11	7	63.63
	3		8	3	37.50
	4		21	10	47.61
	5		32	21	65.62
	6		16	9	56.25
	7		9	Nil	Nil
	8		14	12	85.71
	9		17	10	58.82
	10		27	16	59.27

Contd.

1	2	3	4	5	6
7		A x L_2			
	1		8	4	50.00
	2		14	10	71.43
	3		19	14	73.68
	4		19	12	63.15
	5		31	21	67.74
	6		42	31	73.81
	7		16	12	75.00
	8		19	14	73.68
	9		24	18	75.00
	10		36	28	77.77
8		L_2 x A			
	1		26	14	53.80
	2		29	19	65.50
	3		25	18	72.00
	4		27	20	74.70
	5		31	16	51.61
	6		20	10	50.00
	7		18	14	77.77
	8		30	N11	N11
	9		17	11	64.72
	10		22	16	72.72
9		A x M			
	1		15	9	60.00
	2		8	6	75.00
	3		21	15	71.40
	4		24	14	58.33
	5		16	10	62.50
	6		29	22	75.80
	7		35	21	60.00
	8		8	5	62.50
	9		17	11	64.70
	10		16	9	56.25
10		M x A			
	1		14	10	71.40
	2		16	11	68.75
	3		9	7	77.76
	4		21	N11	N11
	5		6	4	66.66
	6		18	12	66.60
	7		13	9	69.23
	8		38	28	73.66
	9		11	N11	N11
	10		15	8	53.33

Contd.

1	2	3	4	5	6
11		C x D			
	1		19	12	63.10
	2		15	12	80.00
	3		6	3	50.00
	4		16	10	62.50
	5		13	8	61.54
	6		17	14	82.30
	7		21	14	66.66
	8		14	10	71.42
	9		20	12	60.00
	10		27	20	74.74
12		D x C			
	1		11	8	72.72
	2		9	5	55.54
	3		21	14	66.60
	4		38	20	52.63
	5		41	26	63.41
	6		45	23	51.11
	7		13	9	69.22
	8		21	12	57.14
	9		16	12	75.00
	10		4	2	50.00
13		C x L_1			
	1		13	8	61.53
	2		18	13	72.22
	3		21	16	76.19
	4		27	10	37.03
	5		31	18	58.54
	6		21	14	66.66
	7		11	8	72.72
	8		19	15	78.94
	9		28	21	75.00
	10		48	30	62.50
14		L_1 x C			
	1		9	Nil	Nil
	2		14	8	57.14
	3		14	9	64.27
	4		38	22	57.89
	5		32	20	62.50
	6		12	9	75.00
	7		18	12	66.66
	8		31	21	67.74
	9		26	Nil	Nil
	10		25	20	80.00

Contd.

1	2	3	4	5	6
15		C x L_2			
	1		16	9	56.25
	2		28	13	46.42
	3		51	39	76.46
	4		12	9	75.00
	5		21	12	57.14
	6		31	20	64.51
	7		17	11	64.71
	8		14	10	71.42
	9		18	12	66.66
	10		12	8	66.66
16		L_2 x C			
	1		29	29	67.44
	2		38	21	55.26
	3		36	19	52.78
	4		21	10	47.61
	5		27	21	77.77
	6		22	14	63.64
	7		18	11	61.11
	8		29	14	48.27
	9		14	12	85.71
	10		16	9	62.50
17		C X M			
	1		31	17	54.83
	2		28	20	71.42
	3		20	14	70.00
	4		14	10	71.43
	5		24	18	75.00
	6		18	11	61.11
	7		26	16	61.53
	8		20	13	65.00
	9		17	9	52.94
	10		14	10	71.42
18		M x C			
	1		25	16	64.00
	2		18	10	55.55
	3		14	6	42.85
	4		17	8	47.07
	5		14	5	35.71
	6		20	14	70.00
	7		31	18	58.06
	8		14	N11	N11.
	9		19	13	68.42
	10		28	20	71.42

Contd.

1	2	3	4	5	6
19		L_1 x D			
	1		26	14	53.84
	2		19	13	68.42
	3		13	9	69.23
	4		21	14	66.66
	5		28	20	71.42
	6		8	6	75.00
	7		11	8	72.77
	8		16	8	50.00
	9		17	9	52.94
	10		32	22	68.75
20		D x L_1			
	1		14	10	71.42
	2		12	7	58.33
	3		18	12	66.66
	4		14	9	64.27
	5		21	11	52.37
	6		19	12	63.16
	7		17	12	70.58
	8		19	11	57.89
	9		31	18	58.06
	10		17	10	58.82
21		L_2 x D			
	1		12	7	58.33
	2		16	11	68.75
	3		23	18	78.26
	4		41	24	58.53
	5		28	15	53.57
	6		38	27	71.05
	7		21	15	71.42
	8		19	11	57.89
	9		14	10	71.42
	10		20	14	70.00
22		D x L_2			
	1		11	6	55.55
	2		16	9	56.25
	3		22	9	40.90
	4		26	21	80.76
	5		31	24	77.41
	6		16	11	68.75
	7		8	6	75.00
	8		19	14	73.68
	9		38	20	52.63
	10		19	11	57.89

Contd.

1	2	3	4	5	6
23		D x M			
	1		12	9	75.00
	2		18	12	66.66
	3		25	16	64.00
	4		20	14	70.00
	5		17	11	64.70
	6		31	20	64.51
	7		27	16	59.25
	8		9	7	77.70
	9		16	11	68.75
	10		16	Nil	Nil
24		M x D			
	1		6	4	66.66
	2		18	6	75.00
	3		14	9	64.28
	4		13	4	30.76
	5		9	6	66.66
	6		16	12	75.00
	7		21	11	52.38
	8		12	10	83.33
	9		40	28	70.00
	10		19	6	31.57
25		L_1 x L_2			
	1		15	11	73.33
	2		34	26	76.46
	3		23	12	52.17
	4		28	10	35.71
	5		26	17	65.38
	6		18	13	72.22
	7		20	12	60.00
	8		19	10	63.15
	9		23	14	60.86
	10		12	9	75.00
26	1	L_2 x L_1	21	15	71.42
	2		24	14	58.33
	3		18	4	22.22
	4		14	9	64.28
	5		9	6	66.66
	6		13	8	61.53
	7		24	16	66.60
	8		31	10	32.25
	9		14	10	71.42
	10		16	10	66.66

Contd.

1	2	3	4	5	6
27		L_1 x M			
	1		34	15	44.11
	2		21	13	61.90
	3		16	11	68.75
	4		14	8	57.14
	5		9	N11	N11
	6		16	10	62.31
	7		21	15	71.42
	8		24	16	66.60
	9		15	N11	N11
	10		17	6	58.82
28		M x L_1			
	1		15	7	53.32
	2		14	8	57.14
	3		16	12	75.00
	4		19	14	73.68
	5		16	6	37.50
	6		18	12	66.60
	7		9	5	55.55
	8		10	7	70.00
	9		24	10	41.66
	10		17	7	41.17
29		L_2 x M			
	1		24	17	70.83
	2		16	10	62.50
	3		15	9	60.00
	4		19	12	63.15
	5		14	9	64.28
	6		28	10	35.71
	7		17	11	64.70
	8		16	8	50.00
	9		26	16	61.53
	10		21	12	57.14
30		M x L_2			
	1		25	14	62.50
	2		11	6	54.55
	3		27	12	44.44
	4		15	9	60.00
	5		17	12	70.38
	6		14	6	42.85
	7		9	4	44.40
	8		26	12	46.15
	9		21	10	47.61
	10		10	7	70.00

Concluded.

Performance of the pooled population (P_1) at 33°C and 35°C (at 75 per cent R.H.)

Gen. No.	Rep. No.	Percentage adult emergence	Adult longevity		Sex-ratio (female/ male)	Total repr. period (hours)	Fecundity	Progeny production
			Female	male				
33°C and 75 per cent R.H.								
1	1	66.6	29.8	21.4	3.76	24.2	14.7	8.9
2	2	71.8	31.7	26.3	3.51	28.5	19.5	10.1
"	3	70.5	30.7	20.5	4.76	26.8	18.0	6.5
"	4	74.1	28.4	18.4	4.10	25.0	16.2	5.0
2	1	73.9	26.7	24.8	3.96	19.1	18.1	8.7
"	2	66.7	31.8	23.7	4.07	23.9	13.5	10.3
"	3	70.1	25.1	20.8	3.85	23.7	12.7	9.2
"	4	64.0	28.6	28.1	3.66	24.3	10.8	8.0
3	1	75.8	35.4	22.8	3.68	26.7	15.1	8.5
"	2	69.6	34.3	19.7	3.94	25.8	16.1	7.8
"	3	65.1	30.1	21.6	4.12	19.3	14.3	9.7
"	4	72.4	29.6	23.4	3.60	20.6	17.2	6.8
4	1	76.3	31.8	24.9	4.12	22.6	16.1	6.5
"	2	71.2	29.6	20.7	4.32	26.1	12.9	7.3
"	3	68.5	34.5	21.8	3.86	25.0	17.8	8.8
"	4	78.9	30.1	15.4	3.64	30.0	14.0	6.2
35°C and 75 per cent R.H.								
1	1	25.8	27.6	12.7	2.97	16.2	4.6	1.4
"	2	20.1	25.0	15.1	3.40	14.2	3.9	2.1
"	3	18.7	24.7	13.6	2.86	13.8	5.1	3.1
"	4	26.5	21.4	14.0	2.78	12.0	3.7	1.0

Duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production in different cultures when reared at 27°C and 75 percent RH.

Cultures	Rep.No.	Develop-mental period (days)	% adult emer-gence	Adult longevity		Sex-ratio Females/ male	Total rep-roductive period in females (hrs.)	Fecun-dity	Progeny productio per femal
				Female (hrs.)	Male (hrs.)				
A	1	7.31	70.5	49.1	37.7	6.10	40.3	35.6	30.2
	2	7.03	85.6	35.4	21.8	4.86	30.6	46.7	34.0
	3	7.14	86.0	62.1	27.1	5.71	52.1	50.1	39.7
	4	7.23	62.7	59.7	32.3	6.60	48.1	36.4	26.7
C	1	7.40	85.8	44.7	33.1	4.16	48.3	41.6	27.3
	2	7.30	80.5	51.0	34.3	5.97	36.2	38.4	28.4
	3	7.21	90.2	42.5	32.6	5.02	38.7	35.2	24.5
	4	7.06	81.2	46.6	40.0	5.52	35.8	34.0	26.2
D	1	7.32	74.1	45.1	40.3	3.61	38.5	31.3	27.4
	2	7.48	81.6	40.2	31.4	3.40	30.3	39.6	28.3
	3	6.56	76.5	42.3	35.5	3.00	36.7	25.5	20.4
	4	8.03	80.0	36.0	30.1	4.16	34.0	40.1	21.5
L_1	1	8.46	72.2	55.0	33.8	3.42	30.2	55.2	38.7
	2	7.48	70.1	45.7	36.4	3.60	32.7	51.0	39.0
	3	7.80	65.4	49.3	42.6	3.44	35.4	60.2	36.4
	4	8.70	74.8	55.3	32.3	3.70	28.4	62.3	32.5
L_2	1	8.64	89.6	63.3	40.0	3.62	56.4	23.5	20.1
	2	7.64	80.8	76.0	31.3	5.00	54.2	39.0	28.0
	3	9.10	74.2	55.2	27.6	2.81	13.6	51.1	34.6
	4	7.06	70.1	49.0	48.4	4.73	41.1	47.2	28.9
M	1	7.24	76.2	43.5	36.5	3.75	31.2	35.7	26.4
	2	7.32	72.3	42.2	38.0	4.12	36.2	29.1	20.0
	3	7.46	73.6	40.9	40.2	4.31	31.4	31.4	25.7
	4	7.47	71.5	44.9	43.7	4.36	34.5	30.0	19.1

Duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production in different cultures when reared at 30°C and 90 percent RH.

Cultures	Rep.No.	Develop-mental period (days)	% adult emergence	Adult longevity (hrs.) Female	Adult longevity (hrs.) Male	Sex-ratio Females/male	Total reproductive period in females (hrs.)	Fecundity	Progeny production per female
A	1	7.51	64.8	34.3	21.1	6.10	20.1	31.1	18.1
	2	7.32	80.2	40.4	19.1	7.48	15.4	28.2	17.7
	3	7.08	74.5	43.1	27.8	5.39	28.6	42.6	18.8
	4	8.10	51.8	29.2	28.1	8.06	19.3	40.4	37.4
C	1	7.10	73.5	35.0	31.2	5.47	41.5	26.7	16.1
	2	7.76	70.0	23.3	40.1	4.71	40.3	20.2	12.0
	3	7.20	68.4	30.6	32.5	4.82	30.4	18.2	12.9
	4	7.46	76.3	36.7	41.2	6.08	33.5	22.7	15.6
D	1	7.68	61.3	36.0	20.9	2.65	30.4	30.8	10.4
	2	7.14	52.1	31.1	23.2	3.05	24.0	25.6	6.5
	3	7.18	60.4	30.3	26.7	3.40	23.6	21.2	15.5
	4	7.84	60.9	34.5	25.3	3.34	26.5	20.8	16.4
L_1	1	8.45	40.0	47.8	34.8	3.29	21.7	14.6	3.4
	2	7.94	39.5	52.6	29.8	3.64	27.3	16.1	3.5
	3	7.69	42.6	46.1	31.4	4.10	26.5	13.2	5.8
	4	8.20	43.1	42.0	24.5	3.88	22.0	17.8	4.5
L_2	1	9.61	40.6	44.1	26.0	3.16	30.7	16.0	10.0
	2	8.90	45.3	32.0	29.8	2.81	26.6	14.4	5.1
	3	7.44	50.8	28.6	20.6	4.05	19.0	13.1	7.2
	4	8.00	52.7	40.1	38.0	3.00	23.0	9.7	4.0
M	1	6.60	30.4	35.0	32.1	3.57	14.5	10.9	2.0
	2	7.40	31.8	33.1	27.8	4.60	26.2	9.3	5.1
	3	7.81	28.8	26.4	30.7	4.00	18.7	10.0	4.5
	4	6.83	23.1	35.4	26.5	5.31	22.3	16.6	3.6

Duration of development, percentage adult emergence, adult longevity, sex-ration, total reproductive period in females, fecundity and progeny production in different cultures when reared at 30°C and 75% RH.

Cultures	Rep.No.	Develop-mental period (days)	% adult emergence	Adult longevity (hrs.) Female	Adult longevity (hrs.) Male	Sex-ratio Females/male	Total reproductive period in females (hrs.)	Fecundity	Progeny production per fema
A	1	7.10	70.1	45.0	21.0	6.10	38.0	30.7	20.1
	2	7.81	65.7	50.8	35.4	8.10	41.8	28.4	19.0
	3	6.90	80.1	39.2	26.1	5.37	32.1	41.1	27.7
	4	7.00	74.3	42.3	32.2	6.50	36.3	45.6	31.2
C	1	7.08	74.5	48.3	40.2	6.21	30.2	36.4	11.1
	2	7.57	76.8	47.0	36.5	5.50	40.0	32.6	15.7
	3	7.43	82.3	45.4	35.0	4.83	38.7	38.3	16.7
	4	7.12	87.2	40.1	37.8	4.20	32.1	30.5	11.4
D	1	7.16	84.2	35.9	40.1	2.86	30.8	36.5	25.1
	2	7.24	80.5	42.3	35.8	3.18	28.1	44.1	27.6
	3	7.50	75.6	40.4	30.2	2.78	35.3	33.9	21.5
	4	7.90	74.3	39.0	41.7	3.54	36.0	40.8	28.2
L_1	1	8.00	73.1	52.3	35.6	3.54	30.1	50.1	25.1
	2	8.10	72.0	49.7	28.2	3.55	26.6	46.0	23.1
	3	8.26	70.4	50.0	30.4	3.71	32.2	45.3	24.0
	4	8.20	69.3	48.5	32.6	3.38	25.3	53.4	28.3
L_2	1	7.83	76.6	64.1	28.6	3.64	61.0	44.1	12.5
	2	8.00	80.9	39.0	17.0	5.00	29.4	38.9	29.2
	3	8.64	69.6	36.4	36.1	4.36	35.2	41.0	26.1
	4	7.50	75.7	51.2	19.4	2.20	36.0	36.2	18.0
M	1	7.30	71.2	40.2	37.0	4.52	31.5	28.9	6.5
	2	7.40	77.0	37.5	38.3	4.06	23.0	28.0	8.3
	3	7.47	68.3	36.5	34.2	3.96	25.9	34.3	6.7
	4	7.51	65.3	39.6	32.9	4.38	32.5	31.0	9.8

Duration of development, percentage adult emergence, adult longevity sex-ratio, total reproductive period in females, fecundity and progeny production in different cultures when reared at 30°C and 10 percent R.H.

Cultures	Rep.No.	Develop-mental period (days)	% adult emergence	Adult longevity Female (hrs.)	Male	Sex-ratio Females/male	Total reproductive period in females (hrs.)	Fecundity	Progeny productio per femal
A	1	7.40	70.1	30.4	24.1	6.50	18.3	18.2	9.8
	2	6.53	60.4	26.3	20.0	6.07	20.1	11.4	6.1
	3	6.06	61.4	18.9	27.8	6.08	15.4	19.6	7.3
	4	6.07	52.0	28.3	15.3	7.14	20.6	20.5	14.7
C	1	7.78	50.4	40.0	26.7	4.93	16.0	14.7	3.2
	2	7.86	44.8	28.4	34.3	4.59	17.2	10.1	2.2
	3	7.41	44.7	22.2	36.8	4.36	25.1	8.0	2.7
	4	7.49	55.2	42.6	39.7	5.60	28.7	7.3	5.3
D	1	8.14	60.7	40.1	21.6	3.26	25.4	13.8	6.0
	2	7.50	53.2	33.7	25.3	3.04	22.0	10.3	7.4
	3	7.08	63.1	40.0	25.4	2.96	34.2	14.2	5.8
	4	7.80	62.5	34.6	21.8	3.30	20.7	9.6	7.2
L_1	1	8.48	44.4	42.4	26.0	3.50	25.0	16.5	4.5
	2	8.84	54.0	36.0	22.0	3.70	17.8	11.6	8.3
	3	8.61	51.4	38.5	27.4	3.78	21.8	13.5	6.2
	4	8.70	50.6	44.4	23.7	3.74	12.2	16.7	5.8
L_2	1	7.60	61.8	44.4	31.0	3.46	26.8	24.0	10.4
	2	8.14	55.7	33.0	24.1	3.03	28.0	19.6	8.6
	3	7.94	52.5	36.8	17.4	4.15	19.6	23.3	10.0
	4	8.53	58.3	39.1	36.0	5.00	31.0	18.1	7.8
M	1	6.49	41.8	33.1	15.3	4.10	22.0	10.1	3.7
	2	7.12	44.4	31.0	23.1	5.76	16.1	13.3	7.1
	3	7.55	39.4	28.6	21.5	5.21	24.6	8.6	6.5
	4	7.24	46.7	35.3	22.7	3.93	18.0	12.0	5.3

Duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production in different cultures when reared at:

Table VII (a) 32°C and 90 percent RH

Cultures	Rep.No.	Develop-mental period (days)	% adult emergence	Adult longevity Female (hrs.)	Adult longevity Male (hrs.)	Sex-ratio Females/male	Total reproductive period in females (hrs.)	Fecundity	Progeny production per female
A	1	7.14	62.3	34.6	24.8	6.40	16.9	28.4	11.4
	2	6.96	64.6	31.7	21.6	5.17	18.0	27.6	16.2
	3	7.03	68.7	36.8	27.5	5.63	15.3	23.2	14.0
	4	7.27	67.1	32.0	22.2	5.48	17.0	26.3	12.2
C	1	7.86	68.6	21.9	24.8	5.41	18.1	19.4	9.4
	2	8.31	63.1	30.1	17.4	6.80	27.2	17.0	7.9
	3	7.90	70.2	25.0	23.7	5.36	23.8	23.5	6.8
	4	8.04	63.8	24.3	19.1	6.18	20.5	18.2	5.3
D	1	7.48	51.8	25.7	21.2	3.16	18.1	15.6	9.1
	2	7.09	49.6	23.9	17.6	2.84	14.9	12.8	6.4
	3	7.11	53.7	27.1	20.7	2.45	16.3	12.7	5.1
	4	7.67	46.3	20.6	16.8	3.76	14.8	13.1	7.6
L_1	1	8.13	31.7	22.1	16.1	3.06	15.1	10.1	2.1
	2	7.81	24.9	27.4	12.9	2.94	16.2	9.0	1.0
	3	7.76	29.3	19.7	14.0	3.11	11.7	8.6	3.4
	4	7.45	30.2	20.6	20.6	2.78	13.8	9.7	1.7
L_2	1	8.63	33.6	32.1	29.8	3.36	17.1	9.4	3.9
	2	8.21	35.4	35.4	27.6	3.94	14.3	11.2	5.3
	3	7.69	34.6	29.8	33.5	3.78	19.2	10.7	4.7
	4	8.16	34.9	41.0	30.3	3.43	13.7	6.9	5.0
H	1	6.79	28.7	26.2	18.1	5.10	24.0	12.8	6.3
	2	7.53	30.0	14.8	15.0	4.86	12.8	12.1	4.2
	3	7.42	33.4	18.5	15.3	5.11	16.1	9.7	7.0
	4	7.26	30.8	20.0	14.8	4.28	17.4	15.3	5.5

Table VIII (b) 32°C and 75% R.H.

A	1	7.14	65.1	31.1	24.8	5.10	20.0	25.0	12.0
	2	7.61	72.6	41.6	19.7	4.78	35.4	31.7	17.4
	3	7.07	80.8	44.0	29.4	4.00	36.6	20.5	13.6
	4	7.00	70.5	36.8	34.0	5.70	32.2	18.1	9.1
C	1	6.40	77.5	40.1	36.8	5.90	34.1	27.6	8.1
	2	7.74	61.0	42.7	35.6	6.26	28.7	25.1	9.0
	3	7.12	50.0	41.6	30.4	5.08	29.4	27.4	10.2
	4	7.10	67.5	38.5	34.0	6.12	33.5	23.3	11.1
D	1	7.41	75.4	35.0	28.1	3.61	30.8	31.5	20.5
	2	7.06	70.6	42.7	24.0	3.34	28.0	34.7	14.2
	3	7.21	76.1	44.3	23.7	3.55	30.4	24.3	19.2
	4	7.68	67.1	38.5	26.6	3.34	24.5	27.4	13.1
L_1	1	8.21	70.6	30.0	26.8	3.37	23.1	24.0	12.6
	2	8.42	57.1	45.3	31.0	3.40	21.7	17.4	10.8
	3	8.28	66.8	45.3	26.2	3.51	18.1	24.6	8.0
	4	8.45	62.8	40.0	28.0	3.48	18.3	20.0	9.0
L_2	1	7.46	75.8	51.1	21.0	3.76	38.6	30.1	14.0
	2	6.93	60.1	49.0	28.0	4.08	35.8	36.6	16.4
	3	8.86	70.2	38.1	19.6	2.96	30.4	34.0	10.2
	4	7.13	65.7	27.4	16.5	5.10	18.0	32.2	18.5
H	1	7.74	68.3	34.3	26.2	4.31	32.5	25.9	6.1
	2	7.40	62.0	37.2	23.5	4.20	30.0	25.7	4.1
	3	7.58	64.2	37.3	26.3	5.40	22.8	23.5	8.6
	4	7.76	67.1	31.8	23.0	3.97	24.6	21.0	9.3

Table IX (c) 32°C and 10% R.H.

A	1	7.10	64.3	34.0	18.9	7.53	20.1	16.1	12.0
	2	6.90	55.1	32.7	16.1	7.69	15.5	14.7	7.4
	3	6.63	60.6	30.1	24.2	8.00	17.7	22.0	8.2
	4	7.48	60.3	22.8	20.3	8.14	14.0	18.0	6.1
C	1	7.16	46.7	30.9	23.6	5.46	20.2	10.1	6.3
	2	6.90	45.1	35.1	33.7	4.81	22.1	8.4	4.2
	3	7.12	43.6	32.4	30.4	6.13	18.4	11.2	5.1
	4	7.31	41.7	30.0	25.3	5.07	15.8	9.0	4.0
D	1	6.90	55.7	36.8	18.0	3.16	24.8	10.3	6.5
	2	7.53	48.3	31.3	19.0	3.51	25.4	9.0	9.3
	3	7.14	56.2	35.9	23.3	3.21	29.3	10.6	8.4
	4	7.35	49.0	32.2	20.1	3.48	26.0	11.3	8.1
L_1	1	7.49	41.7	34.6	22.7	3.14	23.1	11.7	5.4
	2	7.60	48.6	30.8	26.5	2.86	16.7	9.3	4.6
	3	7.29	46.3	29.2	20.5	2.50	17.3	8.8	4.0
	4	8.03	50.2	36.1	18.6	3.06	19.3	10.5	5.2
L_2	1	8.04	41.7	37.6	21.7	3.85	20.6	20.7	11.4
	2	7.51	56.3	28.1	24.3	2.50	24.8	24.4	6.1
	3	6.96	54.1	28.9	22.2	2.67	28.0	15.1	8.0
	4	8.03	63.2	34.0	23.2	3.14	20.2	17.0	9.6
H	1	7.45	36.4	23.1	13.4	4.80	16.7	10.2	5.1
	2	7.32	40.3	27.8	14.8	5.17	13.4	8.7	3.7
	3	7.72	35.8	25.0	18.1	4.39	20.6	9.1	5.0
	4	7.16	39.7	30.2	20.0	4.67	24.0	11.0	4.8

Duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity and progeny production in different cultures when reared at:

Table X (d) 33°C and 90 percent R.H.

Cultures	Rep.No.	Develop-mental period (days)	% adult emergence	Adult longevity Female (hrs.)	Adult longevity Male (hrs.)	Sex-ratio Females/male	Total reproductive period in females (hrs.)	Fecundity	Progeny production per female
A	1	6.81	59.7	39.6	25.2	6.17	28.9	26.3	11.0
	2	7.27	68.2	32.0	14.0	5.00	17.1	28.2	17.3
	3	7.09	50.7	29.3	20.6	4.60	12.1	19.7	9.1
	4	7.49	64.5	28.4	30.7	5.08	15.4	27.6	10.2
C	1	7.62	71.1	24.8	20.3	6.14	23.8	14.6	5.2
	2	7.21	66.7	27.3	21.6	5.30	20.5	13.4	4.2
	3	8.10	62.6	28.3	18.2	6.29	22.7	21.2	8.6
	4	7.39	61.6	26.2	22.2	7.67	20.1	23.5	7.3
D	1	6.24	50.1	26.7	16.0	3.14	16.5	17.2	5.3
	2	7.14	45.3	23.0	20.5	2.65	14.4	14.3	7.2
	3	6.12	41.6	20.6	14.1	3.00	13.7	12.3	8.0
	4	8.04	51.5	28.4	22.6	2.45	15.1	13.6	7.1
L_1	1	7.80	30.4	20.0	13.8	2.70	14.8	8.0	1.0
	2	7.72	25.6	22.2	14.5	3.14	13.4	9.5	1.3
	3	8.32	29.4	25.7	15.0	2.63	10.6	10.3	1.5
	4	7.92	28.1	27.2	12.3	2.83	11.5	11.1	1.1
L_2	1	9.81	36.3	33.1	32.3	3.10	10.1	9.3	3.0
	2	8.43	30.4	42.5	28.7	2.94	14.8	4.0	1.8
	3	7.90	45.9	31.2	29.1	4.15	16.0	13.7	4.8
	4	8.10	29.6	26.0	20.0	5.06	16.4	6.1	2.6
H	1	6.94	30.6	21.8	12.8	4.85	20.5	12.0	6.3
	2	7.61	24.0	18.9	16.0	3.40	20.0	11.7	4.3
	3	6.51	32.6	16.5	15.3	5.30	16.3	8.7	3.3
	4	7.18	25.4	16.4	13.2	4.61	16.1	8.4	3.9

Table XI (e) 33°C and 75% R.H.

A	1	7.10	65.3	40.0	24.0	5.00	34.3	25.3	14.1
	2	6.59	59.0	23.5	16.8	4.53	28.6	30.2	17.4
	3	7.20	67.6	28.1	20.1	3.72	25.4	20.7	9.3
	4	7.09	70.4	32.7	27.2	6.69	30.7	31.6	15.1
C	1	6.82	55.4	33.8	27.4	5.48	22.3	15.2	5.6
	2	7.04	61.2	26.5	26.1	5.32	21.7	20.0	6.5
	3	6.76	48.5	34.1	23.2	7.01	25.7	15.8	8.8
	4	6.10	50.1	28.0	21.6	6.48	17.2	19.6	8.4
D	1	6.99	65.5	37.1	21.8	3.64	25.2	22.7	12.7
	2	7.14	71.3	39.1	22.9	2.98	30.4	27.2	12.8
	3	7.25	61.8	34.0	18.6	3.01	22.2	13.3	7.6
	4	7.51	65.2	42.5	17.4	2.65	25.6	16.5	10.4
L_1	1	8.60	52.3	26.0	24.1	3.72	20.2	16.6	6.0
	2	8.56	48.0	22.0	17.5	3.43	19.6	13.1	2.7
	3	8.52	52.4	20.3	21.3	3.28	16.2	11.7	3.8
	4	8.12	48.0	24.5	20.6	3.17	16.7	13.5	3.0
L_2	1	7.03	60.5	49.2	19.0	2.84	35.0	21.1	12.1
	2	6.00	58.4	33.6	20.7	3.14	24.3	18.4	7.0
	3	8.14	61.7	28.0	22.1	3.00	17.8	26.4	13.4
	4	8.25	70.6	30.1	19.3	2.60	19.0	25.2	12.6
H	1	7.31	60.2	24.7	21.4	4.14	21.0	14.6	4.7
	2	6.85	66.1	32.0	24.7	5.00	23.1	15.9	5.7
	3	7.04	54.0	31.3	18.6	4.67	27.0	11.3	6.8
	4	7.26	52.8	32.2	18.1	4.27	25.8	10.3	6.5

Table XII (f) 33°C and 10% R.H.

A	1	7.13	54.5	27.8	23.7	7.08	21.3	15.1	6.1
	2	7.80	61.3	24.4	24.5	6.10	10.2	10.6	4.7
	3	8.14	70.5	26.1	18.9	8.31	14.9	8.2	3.2
	4	7.06	60.6	22.5	18.0	8.47	18.5	9.3	7.0
C	1	6.76	46.0	29.2	27.0	6.42	16.3	6.6	2.8
	2	7.40	45.7	25.4	21.6	4.98	17.0	8.3	4.1
	3	6.92	38.6	32.2	22.4	6.02	14.6	7.5	3.2
	4	7.28	41.1	28.7	26.5	7.10	13.5	5.9	4.6
D	1	7.46	63.1	40.2	18.4	2.82	22.6	10.6	7.7
	2	7.75	41.0	34.1	17.2	3.15	20.5	7.0	6.1
	3	7.01	50.7	31.5	14.7	2.72	26.4	12.1	8.5
	4	7.10	56.6	30.7	14.0	3.08	23.9	13.0	9.3
L_1	1	7.63	47.1	30.0	21.7	3.14	14.8	6.0	3.0
	2	7.61	41.5	32.1	18.3	2.70	17.0	6.2	2.7
	3	7.12	41.4	27.6	20.1	2.53	16.2	8.5	4.1
	4	7.96	50.6	22.6	17.6	2.79	14.4	9.4	3.0
L_2	1	8.13	44.5	30.4	20.1	2.89	18.0	21.6	10.6
	2	7.14	50.4	26.0	14.3	3.14	16.1	16.1	12.2
	3	6.56	53.5	23.8	18.5	4.96	15.7	13.7	10.9
	4	7.82	60.7	32.1	22.0	2.10	21.2	14.0	8.3
H	1	6.81	37.6	15.3	14.1	4.81	14.0	6.1	2.8
	2	7.40	37.2	21.1	19.0	5.95	15.2	6.0	3.2
	3	6.63	34.0	18.1	15.3	5.02	12.1	8.5	2.1
	4	7.02	32.1	18.8	10.5	4.70	17.3	9.4	2.9

Duration of development, percentage adult emergence, adult longevity, sex-ratio, total reproductive period in females, fecundity, progeny production and percentage adults with malformed wings at:

Table XIII (g) 35°C and 90 percent R.H.

ltures	Rep.No.	Develop-mental period (days)	% adult emer-gence	Adult longevity Female (hrs.)	Male	Sex-ratio Females/ male	Total rep-roductive period in females (hrs.)	Fecun-dity	Progeny product-ion per female	Percentage adults with malformed wings Females	Males
A	1	6.50	41.6	30.4	24.6	9.08	13.3	6.3	1.0	61.8	36.7
	2	6.17	36.0	28.9	19.3	8.14	16.1	10.1	3.1	51.0	24.8
	3	6.08	47.3	39.1	18.1	6.89	21.4	5.2	-	71.2	41.9
	4	7.41	35.7	32.7	28.7	10.05	10.0	9.0	2.5	64.3	50.4
C	1	6.72	38.2	21.4	14.0	6.45	23.0	1.8	1.0	70.0	42.0
	2	6.14	38.1	18.6	18.2	7.14	20.9	-	-	51.3	40.0
	3	6.36	36.0	23.5	21.7	6.28	14.7	2.1	1.2	61.3	45.6
	4	7.02	34.3	17.6	12.9	8.21	14.9	1.3	-	64.5	46.3
D	1	7.13	37.7	28.0	14.8	3.09	14.1	6.0	2.0	61.6	46.5
	2	7.78	32.0	33.7	17.0	2.64	7.5	7.0	4.0	50.0	49.2
	3	6.90	36.4	28.1	21.0	3.14	10.1	5.7	3.1	54.8	53.1
	4	7.43	34.6	32.6	19.7	2.93	9.6	6.1	4.9	59.0	52.4
L_1	1	7.48	24.6	22.3	14.0	2.63	12.5	1.6	-	65.1	42.5
	2	8.20	22.3	14.1	11.2	2.43	10.9	-	-	59.5	47.6
	3	7.44	20.3	15.1	15.2	2.38	8.2	-	-	61.1	47.2
	4	7.56	18.8	17.3	10.3	2.36	12.6	-	-	58.3	50.0
L_2	1	6.74	28.2	26.0	22.0	2.65	14.1	4.1	-	67.6	40.0
	2	5.98	20.0	38.1	16.8	2.79	10.4	6.0	1.0	59.4	43.7
	3	7.21	36.6	30.6	20.1	3.00	12.9	8.4	2.3	79.4	66.0
	4	7.13	40.5	19.4	24.9	3.14	8.0	2.8	-	74.0	41.9
M	1	7.27	28.3	17.7	8.0	4.14	12.7	4.4	2.8	61.5	44.0
	2	7.18	23.9	16.3	9.9	4.10	9.2	2.8	-	60.5	40.3
	3	6.15	24.5	22.1	14.1	5.08	8.4	4.3	2.0	64.3	52.4
	4	6.76	28.6	23.2	9.6	4.28	10.2	2.6	-	63.6	50.7

Table XIV (h) 35°C and 75% R.H.

A	1	6.85	41.3	28.0	13.6	10.1	11.3	7.0	1.1	65.3	37.3
	2	7.10	50.1	24.7	18.1	14.0	9.2	6.1	2.0	71.4	23.1
	3	7.51	36.3	21.1	22.8	8.1	17.6	4.2	1.3	68.2	31.7
	4	7.32	53.6	37.3	17.8	12.0	4.4	2.5	1.0	63.6	47.4
C	1	6.83	27.1	21.8	17.4	7.09	17.4	-	-	65.1	48.2
	2	7.14	26.4	23.4	20.7	6.76	14.6	2.0	1.0	56.4	40.2
	3	6.63	20.7	32.2	16.9	6.73	18.2	-	-	54.6	51.5
	4	6.52	23.1	20.6	22.4	7.10	13.1	1.1	-	63.6	45.0
D	1	6.97	40.5	32.7	12.8	2.46	14.1	5.0	1.6	63.7	51.5
	2	7.34	36.0	28.0	13.0	2.90	16.1	7.1	2.4	55.2	42.0
	3	6.77	30.2	26.9	16.6	3.14	15.2	6.8	2.9	50.6	53.5
	4	7.08	34.8	30.5	16.2	2.09	14.7	5.9	2.5	62.8	45.3
L1	1	7.04	13.2	15.6	10.1	2.90	11.8	1.0	-	68.1	34.2
	2	6.85	13.4	14.0	8.2	2.84	10.6	-	-	58.7	36.2
	3	7.68	8.7	18.1	12.1	3.96	9.0	-	-	60.1	37.3
	4	7.19	10.7	15.3	10.0	2.70	11.5	1.1	-	63.2	43.7
L2	1	7.41	48.9	28.1	17.0	3.07	14.0	5.6	2.1	71.3	61.6
	2	6.90	41.1	31.0	20.0	2.54	9.6	4.0	2.0	81.4	48.8
	3	7.10	45.2	20.6	14.8	2.09	6.1	9.2	4.0	60.0	55.0
	4	6.56	30.8	22.8	10.1	2.84	11.7	4.1	1.8	75.5	70.1
M	1	6.92	27.4	30.0	9.1	4.81	16.2	2.4	1.0	65.4	52.3
	2	6.72	26.7	23.0	11.6	5.63	17.1	1.5	-	71.4	58.3
	3	6.67	24.0	23.8	13.9	4.00	14.5	-	-	57.1	62.5
	4	7.25	23.2	18.8	13.6	4.60	12.6	1.7	1.1	68.7	54.4

Table XV (i) 35°C and 10% R.H.

A	1	7.64	43.4	31.3	16.1	10.51	15.1	6.7	1.0	69.1	34.1
	2	8.13	40.1	30.4	10.5	8.47	10.3	3.0	-	85.0	38.6
	3	6.83	32.4	21.2	21.7	8.65	8.6	4.6	2.1	74.8	46.1
	4	7.24	30.5	18.6	11.0	10.13	10.7	3.2	-	68.6	28.4
C	1	7.12	15.9	20.4	16.0	6.48	9.6	-	-	76.2	74.6
	2	6.64	16.2	20.3	11.0	7.28	11.5	2.0	-	80.1	63.2
	3	7.10	19.5	21.2	12.8	7.62	12.3	-	-	75.2	77.5
	4	6.82	21.4	18.4	17.4	7.42	8.0	-	-	65.5	65.2
D	1	7.36	35.1	26.3	18.0	3.06	28.0	6.2	4.3	74.6	61.7
	2	7.04	42.3	35.3	14.1	2.54	23.2	4.5	2.0	60.9	52.2
	3	6.84	44.0	26.6	17.7	2.70	22.4	6.3	2.5	67.3	55.1
	4	7.24	41.3	32.4	15.6	2.74	17.6	4.7	1.8	74.1	63.4
L1	1	7.63	16.5	15.9	14.6	2.50	10.2	-	-	82.1	68.3
	2	7.30	14.2	15.0	9.6	2.40	7.1	-	-	75.3	64.3
	3	7.10	15.6	13.2	11.0	2.58	8.1	1.2	-	71.8	75.8
	4	7.69	12.7	12.1	13.0	3.15	6.9	-	-	72.7	56.2
L2	1	7.16	36.3	19.2	16.6	2.90	10.1	6.0	2.4	70.6	50.6
	2	6.00	40.9	26.1	20.0	3.14	20.0	10.1	3.1	69.4	45.9
	3	7.43	41.4	30.7	22.1	2.54	11.2	2.8	1.7	68.1	53.7
	4	6.92	50.2	25.4	14.7	4.00	16.4	8.3	0.9	71.5	42.8
M	1	7.20	31.4	12.1	10.0	5.61	6.1	1.2	-	72.5	76.2
	2	7.12	19.2	16.6	13.4	5.78	11.6	3.2	-	70.0	80.6
	3	7.62	18.3	11.4	10.8	5.47	9.3	1.4	-	65.2	70.8
	4	7.41	21.6	15.7	12.6	5.36	7.5	3.4	1.1	65.3	71.4

Table XVI

Performance of the Ludhiana 'P' culture when reared at increasing temperatures from 30° to 35°C and at different relative humidity levels.

Gen. No.	Rep. No.	Conditions of rearing Temp °C	R.H.	Percentage adult emergence	Adult longevity (hours) Female	Male	Sex-ratio (females/ male)	Total rep. period	Fecundity	Progeny Production
1	2	3	4	5	6	7	8	9	10	11
4	1	30	60	74.0	60.0	40.5	3.50	40.3	39.7	14.8
"	2	76.	"	76.5	61.6	31.8	5.10	36.8	36.0	11.7
"	3	"	"	77.9	56.8	40.2	4.60	34.5	41.8	16.0
"	4	"	"	70.4	50.6	30.1	3.08	40.8	40.6	20.6
8	1	30	40	73.6	54.0	24.8	4.10	31.8	37.1	10.7
"	2	30	40	76.1	46.3	34.0	3.67	36.0	32.1	18.4
"	3	30	40	72.8	49.1	28.9	4.00	36.4	33.7	13.0
"	4	30	40	77.3	60.3	36.6	3.21	42.4	38.3	18.4
16	1	30	20	65.3	50.4	34.6	3.71	26.6	26.0	15.4
"	2	30	20	61.0	35.5	30.0	4.27	29.3	33.2	9.2
"	3	30	20	62.1	45.9	27.2	3.15	30.5	29.7	10.7
"	4	30	20	60.4	40.7	30.7	2.94	37.5	31.4	15.7
20	1	30	10	61.2	41.8	26.4	2.96	31.0	18.1	11.3
"	2	30	10	66.7	43.7	27.8	4.37	29.3	28.4	11.8
"	3	30	10	70.2	40.3	24.6	5.00	27.0	34.7	12.7
"	4	30	10	61.1	36.5	26.4	3.09	28.6	23.2	13.5
24	1	30	10	63.4	34.4	26.3	3.12	28.4	22.6	10.3
"	2	30	10	58.3	43.1	28.1	2.86	25.1	23.8	12.1
"	3	30	10	56.7	30.7	24.2	4.35	27.0	26.1	10.1
"	4	30	10	64.5	34.3	21.5	3.32	24.7	22.4	12.7
34	1	33	10 a	66.7	35.3	26.7	5.00	29.8	22.6	10.6
"	2	33	10 a	60.6	36.4	23.4	4.20	27.4	24.2	17.1
"	3	33	10 a	61.3	29.0	18.0	3.67	20.1	21.6	14.5
"	4	33	10 a	78.7	30.1	20.6	3.46	23.3	20.4	11.8
38	1	33	10 b	64.0	31.2	25.0	4.10	29.4	24.0	12.4
"	2	33	10 b	62.6	33.0	23.2	4.24	21.6	23.6	13.7
"	3	33	10 b	65.6	28.6	21.8	4.30	20.3	22.8	16.9
"	4	33	10 b	62.0	30.2	26.0	3.76	23.3	22.4	11.8
35	1	35 a	75 a	64.2	34.3	24.3	3.04	14.30	10.3	5.2
"	2	35	75 a	57.4	35.2	17.5	4.21	20.9	10.9	8.4
"	3	35	75 a	61.3	29.1	18.0	3.76	10.7	12.5	6.2
"	4	35	75 a	50.6	23.9	20.6	4.21	15.7	11.2	4.3
36	1	36 b	75 b	50.2	28.6	18.1	4.13	12.3	4.3	1.6
"	2	35	75 b	53.4	33.7	19.2	3.65	11.2	6.9	2.8
"	3	35	75 b	49.3	21.2	15.3	4.00	14.7	9.0	3.1
"	4	35	75 b	50.9	24.4	13.2	4.46	10.8	8.1	3.2

Table XVIII (b)

Performance of the Delhi 'P' culture when reared at increasing temperatures from 30° to 35°C and at different relative humidity levels.

4	1	30	60	73.6	34.0	25.0	4.10	34.9	26.1	20.1
"	2	30	60	72.0	33.6	26.8	3.63	36.1	35.5	15.4
"	3	30	60	79.6	42.3	30.2	4.49	31.9	28.7	17.2
"	4	30	60	78.1	40.1	31.7	4.10	18.0	24.1	14.0
8	1	30	40	73.4	35.6	28.0	3.29	34.0	30.1	18.3
"	2	30	40	69.7	40.0	24.5	3.60	36.0	32.0	16.4
"	3	30	40	74.9	32.8	27.1	4.04	30.6	28.6	14.7
"	4	30	40	75.8	35.9	30.0	3.67	33.1	24.8	15.8
12	1	30	30	73.3	34.7	30.1	3.11	28.7	27.1	13.6
"	2	30	30	64.0	40.1	20.4	4.07	32.1	23.6	13.0
"	3	30	30	72.9	36.0	26.7	3.46	30.4	26.7	19.6
"	4	30	30	79.4	34.1	26.0	3.50	26.3	27.8	16.4
16	1	30	20	65.7	43.5	30.4	3.61	31.00	18.3	10.4
"	2	30	20	68.8	37.8	27.0	4.00	25.00	14.2	8.4
"	3	30	20	58.1	35.6	27.3	3.18	26.4	12.9	11.0
"	4	30	20	61.4	35.2	26.7	3.09	31.8	23.3	7.3
20	1	30	10	60.40	40.0	27.0	4.03	27.5	13.0	10.0
"	2	30	10	61.6	36.6	26.2	3.15	23.0	16.1	14.0
"	3	30	10	57.1	34.5	21.7	3.48	26.5	13.2	12.3
"	4	30	10	57.7	36.9	23.4	3.23	31.3	16.4	12.1
24	1	32	10	57.3	34.1	24.0	4.02	27.6	11.1	12.3
"	2	32	10	61.0	36.0	24.4	3.40	26.8	14.0	7.0
"	3	32	10	51.5	40.1	24.6	3.48	24.2	12.0	10.6
"	4	32	10	62.6	32.0	21.3	3.28	27.1	13.8	9.4

(Contd. ....)

Table XVIII contd.

1	2	3	4	5	6	7	8	9	10	11
34	1	33	10 a	58.3	34.6	20.7	3.20	24.6	11.1	10.5
"	2	33	10 a	55.0	30.1	25.8	3.14	25.3	14.9	9.2
"	3	33	10 a	61.5	34.0	21.0	3.19	23.1	12.3	9.7
"	4	33	10 a	58.4	36.6	18.2	3.14	23.3	14.0	8.4
38	1	33	10 b	53.6	30.1	22.0	3.36	22.0	14.0	8.0
"	2	33	10 b	58.0	29.6	23.0	3.52	21.5	15.5	12.0
"	3	33	10 b	56.0	32.4	21.4	3.10	21.3	12.8	8.4
"	4	33	10 b	58.4	28.9	21.0	3.62	21.3	13.7	10.9
35	1	35	75 a	46.8	33.1	17.0	3.34	20.10	10.2	6.2
"	2	35	75 a	51.3	28.2	16.5	4.36	24.4	11.6	5.1
"	3	35	75 a	48.7	32.7	14.3	3.57	17.8	8.4	4.1
"	4	35	75 a	54.2	33.4	17.9	3.40	16.5	9.6	6.5
36	1	35	75 b	42.1	27.6	16.1	4.60	18.1	8.2	4.0
"	2	35	75 b	40.0	26.8	18.3	4.52	18.2	6.7	2.0
"	3	35	75 b	45.1	21.8	10.6	3.14	16.0	4.9	2.2
"	4	35	75 b	38.2	26.6	14.1	4.35	17.0	4.2	1.3

Table XX (c)

Performance of the Ambajipet 'P' culture when reared at increasing temperatures from 30° to 35°C and at different relative humidity levels

4	1	30	60	75.1	40.8	34.1	3.98	35.0	30.0	15.8
"	2	30	60	70.1	45.1	40.8	4.70	34.2	28.1	13.7
"	3	30	60	85.9	53.0	36.1	6.14	40.3	27.4	22.1
"	4	30	60	79.2	31.2	25.2	6.73	29.7	37.0	27.4
8	1	30	40	76.3	44.0	30.1	6.51	19.6	30.1	12.1
"	2	30	40	81.5	30.2	19.7	5.83	11.4	26.4	18.2
"	3	30	40	70.8	29.7	27.0	4.60	26.0	31.0	22.0
"	4	30	40	82.1	33.1	23.2	7.50	25.1	32.0	25.6
12	1	30	30	77.7	38.6	23.2	7.14	26.6	22.0	13.0
"	2	30	30	66.4	40.1	28.0	7.00	22.1	23.5	14.8
"	3	30	30	70.3	41.7	21.7	5.39	25.8	18.4	14.2
"	4	30	30	72.6	32.4	23.6	5.70	21.7	30.3	17.5
16	1	30	20	74.3	36.9	31.8	4.30	21.8	24.9	16.3
"	2	30	20	68.6	30.2	25.9	4.62	24.8	20.5	12.8
"	3	30	20	71.2	34.1	28.1	5.14	23.9	19.7	13.1
"	4	30	20	69.7	37.7	20.0	6.86	26.6	21.4	10.0
20	1	30	10	65.4	35.1	20.1	6.34	20.5	25.1	11.0
"	2	30	10	69.6	31.2	25.0	4.00	24.9	22.8	9.8
"	3	30	10	63.8	29.0	20.2	5.12	26.4	20.3	14.7
"	4	30	10	68.9	31.4	24.7	6.91	25.1	18.7	13.2
24	1	33	10	70.6	27.6	16.0	4.36	24.1	21.0	10.2
"	2	33	10	65.1	35.1	26.1	5.63	20.3	26.1	16.1
"	3	33	10	67.8	34.3	24.4	5.00	25.0	16.2	13.0
"	4	33	10	62.0	36.2	24.0	6.00	18.2	18.6	10.0
34	1	33	10 a	72.8	30.0	20.6	3.14	25.1	12.8	8.3
"	2	33	10 a	68.7	24.1	18.9	5.00	20.8	15.9	7.5
"	3	33	10 a	59.1	20.0	26.1	5.32	12.0	11.7	9.7
"	4	33	10 a	60.7	32.4	19.8	6.10	23.5	16.6	8.5
38	1	33	10 b	67.0	27.0	18.0	6.10	21.0	15.4	7.1
"	2	33	10 b	68.4	28.9	18.9	5.00	22.4	13.2	8.0
"	3	33	10 b	66.0	26.4	22.6	4.87	19.2	12.4	9.3
"	4	33	10 b	69.8	29.7	20.8	4.99	17.6	13.2	8.0
35	1	35	75 a	57.4	27.0	12.0	6.2	15.1	8.1	3.9
"	2	35	75 a	48.1	26.0	23.0	5.1	14.7	5.9	4.3
"	3	35	75 a	50.8	23.9	25.0	6.2	24.0	6.0	6.2
"	4	35	75 a	60.1	25.1	21.0	10.3	20.7	7.1	3.6
36	1	35	75 b	41.9	24.1	20.7	5.3	15.8	1.8	-
"	2	35	75 b	53.4	28.3	17.6	6.2	12.4	6.0	1.0
"	3	35	75 b	40.8	21.8	14.0	9.5	13.3	2.7	1.3
"	4	35	75 b	43.7	18.1	18.1	6.8	10.0	3.1	2.9

Table XVII

Performance of the Ludhiana 'Q' culture at various temperature-humidity combinations

Generation No.	Replication No.	Conditions of rearing: Temp °C	Conditions of rearing: R.H.	Adult emergence	Fecundity	Progeny production
1	2	3	4	5	6	7
4	1	30	60	73.2	38.1	21.8
"	2	30	60	72.5	39.3	12.4
"	3	30	60	70.8	41.4	16.3
"	4	30	60	76.3	36.2	15.4
8	1	30	40	64.8	28.1	10.8
"	2	30	40	74.6	27.8	11.0
"	3	30	40	70.3	30.1	12.1
"	4	30	40	68.8	34.4	16.6
12	1	30	30	65.6	30.4	12.6
"	2	30	30	67.3	28.1	8.4
"	3	30	30	63.3	20.2	9.1
"	4	30	30	61.9	28.1	10.2
16	1	30	20	65.9	23.4	10.1
"	2	30	20	61.3	19.7	6.4
"	3	30	20	63.4	27.4	8.6
"	4	30	20	60.8	25.7	9.9
20	1	30	10	61.8	24.0	10.4
"	2	30	10	55.7	19.6	8.6
"	3	30	10	52.5	23.3	10.0
"	4	30	10	58.3	18.1	7.8
24	1	32	10	41.7	20.7	11.4
"	2	32	10	57.9	24.4	6.1
"	3	32	10	53.1	15.1	8.0
"	4	32	10	60.2	17.0	9.6
34	1	33	10	44.5	21.6	14.2
"	2	33	10	50.5	16.1	11.9
"	3	33	10	53.2	13.7	8.6
"	4	33	10	60.7	14.0	7.3
35	1	35	75	40.9	5.6	2.1
35	2	35	75	41.1	4.0	2.0
"	3	35	75	45.2	9.2	4.0
"	4	35	75	30.8	4.1	1.8

Table XIX

Performance of the Delhi 'Q' culture at various temperature-humidity combinations

4	1	30	60	76.2	28.4	20.4
"	2	30	60	74.0	28.3	14.0
"	3	30	60	75.3	31.5	12.8
"	4	30	60	87.0	30.2	13.4
8	1	30	40	74.7	28.1	18.0
"	2	30	40	74.2	25.4	12.0
"	3	30	40	68.3	30.2	13.6
"	4	30	40	76.0	20.7	12.2
12	1	30	30	70.40	15.7	9.3
"	2	30	30	65.20	24.4	11.7
"	3	30	30	65.0	21.4	10.0
"	4	30	30	72.3	18.1	10.6
16	1	30	20	54.0	14.6	9.4
"	2	30	20	60.6	14.5	10.7
"	3	30	20	54.1	21.0	9.2
"	4	30	20	58.5	18.1	10.8
20	1	30	10	60.7	13.8	8.1
"	2	30	10	53.2	10.3	10.0
"	3	30	10	52.1	14.2	11.7
"	4	30	10	52.5	9.6	8.6
24	1	32	10	55.7	10.3	6.5
"	2	32	10	48.3	9.0	9.3
"	3	32	10	56.2	10.6	8.4
"	4	32	10	49.0	11.3	8.1
34	1	33	10	52.1	10.6	9.3
"	2	33	10	41.0	7.9	6.1
"	3	33	10	50.7	12.1	8.5
"	4	33	10	56.6	12.7	7.7

(Contd. ...)

Table XIX contd.

1	2	3	4	5	6	7
35	1	35	75	40.5	5.0	1.6
"	2	35	75	38.0	7.1	2.4
"	3	35	75	39.2	6.8	2.9
"	4	35	75	34.8	5.9	2.5

21

Table XXI

Performance of the Ambajipet 'Q' culture at various temperature-humidity combinations

4	1	30	60	75.60	33.5	20.1
"	2	30	60	70.80	38.3	31.7
"	3	30	60	78.20	32.0	26.5
"	4	30	60	80.20	30.1	20.2
8	1	30	40	65.7	31.2	23.4
"	2	30	40	70.4	23.4	18.6
"	3	30	40	72.0	17.0	14.7
"	4	30	40	72.1	19.7	25.0
12	1	30	30	67.8	18.6	13.8
"	2	30	30	61.7	20.4	11.4
"	3	30	30	65.0	22.0	12.8
"	4	30	30	62.0	25.6	11.6
16	1	30	20	62.6	15.6	9.7
"	2	30	20	65.3	19.0	14.3
"	3	30	20	64.7	15.4	11.0
"	4	30	20	52.1	20.1	10.2
20	1	30	10	70.1	18.1	9.8
"	2	30	10	60.4	11.4	6.1
"	3	30	10	61.4	13.6	7.3
"	4	30	10	52.9	20.8	14.1
24	1	33	10	64.3	18.1	12.0
"	2	33	10	55.1	14.7	7.4
"	3	33	10	60.6	22.0	8.2
"	4	33	10	60.3	18.0	6.1
34	1	33	10	64.60	15.1	6.1
"	2	33	10	61.30	10.6	4.7
"	3	33	10	70.60	8.2	3.2
"	4	33	10	63.60	9.3	7.0
35	1	35	75	41.3	7.0	1.1
"	2	35	75	60.1	6.1	2.0
"	3	35	75	38.5	4.2	1.3
"	4	35	75	58.6	2.3	1.0

Table XXII

Effect of gamma radiation on the percentage adult emergence, sex-ratio, fecundity, progeny production in the Ludhiana culture

Rep. No.	Dose	Percentage adult emergence	Sex-ratio (females/male)	Fecundity	Progeny production
1	2	3	4	5	6
1	500 r	81.6	4.06	40.8	29.6
2	"	78.4	5.11	31.5	25.5
3	"	75.9	4.32	35.0	22.1
4	"	70.6	3.90	38.2	22.4
1	1000 r	69.3	3.80	30.5	23.9
2	"	70.4	4.06	34.2	26.7
3	"	65.1	3.51	28.4	19.9
4	"	68.9	4.48	28.2	18.3
1	1500 r	67.9	5.06	29.60	18.3
2	"	70.8	4.50	28.5	21.9
3	"	66.8	2.92	34.6	21.7
4	"	65.3	4.71	31.4	20.9
1	2000 r	63.4	3.07	14.8	9.6
2	"	59.8	3.68	15.4	14.5
3	"	70.4	0.14	16.0	12.0
4	"	55.7	4.07	18.3	13.5
1	2500 r	51.8	3.20	13.9	12.9
2	"	57.6	3.98	16.8	16.3
3	"	53.0	3.12	14.3	12.8
4	"	61.4	3.86	22.4	15.7
1	3000 r	57.8	3.48	12.8	8.0
2	"	52.1	3.37	14.8	10.9
3	"	49.1	2.96	16.7	14.3
4	"	54.0	3.14	13.6	10.7
1	3500 r	49.8	3.50	13.1	9.4
2	"	46.7	3.17	15.0	10.7
3	"	43.0	3.24	17.2	12.5
4	"	48.4	2.67	12.9	9.8
1	4000 r	50.6	2.61	14.8	12.8
2	"	48.5	2.87	16.0	8.8
3	"	45.9	3.04	11.2	8.0
4	"	49.8	2.17	13.5	10.4
1	4500 r	45.3	3.10	9.0	5.8
2	"	48.6	2.61	13.6	9.1
3	"	41.0	2.17	14.8	4.7
4	"	42.9	2.53	10.2	6.0

(Contd. ...)

Table XXII contd.

1	2	3	4	5	6
1	5000 r	36.7	3.08	13.6	6.3
2	"	43.6	2.76	16.1	4.8
3	"	39.8	2.44	15.1	5.2
4	"	41.5	3.15	12.8	8.2
1	5500 r	49.2	3.08	6.3	1.9
2	"	39.4	2.59	9.0	2.4
3	"	38.6	2.40	10.4	5.1
4	"	41.3	2.97	11.2	4.2
1	6000 r	26.7	2.91	10.8	1.1
2	"	34.5	3.01	8.5	4.3
3	"	28.0	2.67	9.8	1.5
4	"	31.6	2.48	11.3	2.2
1	6500 r	32.3	2.10	4.8	1.6
2	"	24.6	2.39	6.2	4.3
3	"	29.1	2.46	6.5	1.8
4	"	28.5	2.11	7.2	6.9
1	7000 r	33.1	2.55	9.3	1.4
2	"	34.3	3.18	11.8	2.0
3	"	25.7	2.86	7.1	1.1
4	"	31.7	2.10	7.6	3.7
1	7500 r	26.9	2.09	6.7	1.2
2	"	30.4	2.48	4.0	-
3	"	27.9	2.37	3.9	1.0
4	"	26.1	2.23	4.5	2.3
1	8000 r	32.3	2.17	6.8	-
2	"	28.5	3.04	5.3	1.0
3	"	24.6	2.76	4.2	2.2
4	"	30.1	2.32	3.5	-
1	8500 r	20.5	2.14	3.8	-
2	"	16.6	2.05	2.6	-
3	"	15.3	2.86	6.7	1.1
4	"	19.8	2.50	4.1	-
1	9000 r	14.9	1.59	2.1	-
2	"	21.6	2.70	5.0	0.4
3	"	13.6	2.04	3.8	-
4	"	18.7	1.67	2.5	-
1	9500 r	20.7	2.45	7.6	-
2	"	13.3	1.86	2.3	0.3
3	"	10.8	1.41	5.9	-
4	"	17.1	2.28	1.0	0.5

(Contd. .....)

Table XXII contd.

1	2	3	4	5	6
1	10000 r	14.8	1.50	3.1	0.3
2	"	13.5	1.36	-	-
3	"	16.7	2.08	3.3	0.2
4	"	19.8	1.70	2.4	-
1	control	89.6	3.62	28.6	20.1
2	"	80.8	5.00	39.0	28.0
3	"	74.2	2.81	51.1	34.6
4	"	70.1	4.73	47.2	28.9

Table XXIII

Performance of the pooled population (P_g) at 33°C and 35°C (at 75 per cent R.H.)

Gen. No.	Rep. No.	Percentage adult emergence	Adult longevity		Sex-ratio (female/male)	Total repr. period (hours)	Fecundity	Progeny production
			Female	male				
33°C and 75 per cent R.H.								
1	1	75.0	24.6	21.8	3.59	22.1	20.3	6.0
"	2	69.1	32.5	25.5	3.64	25.0	16.4	8.5
"	3	72.3	31.2	23.0	3.72	23.9	20.0	9.8
"	4	81.5	30.7	25.8	3.66	21.2	16.2	8.2
2	1	72.2	25.1	24.4	3.44	20.1	18.7	10.0
"	2	70.3	29.7	26.3	4.12	27.2	23.5	9.8
"	3	70.1	26.4	27.3	3.28	21.4	22.4	8.6
"	4	62.4	30.2	24.8	3.80	27.0	16.5	8.2
3	1	71.4	23.9	19.3	4.51	18.9	16.3	7.4
"	2	72.1	21.4	25.7	4.08	18.2	12.4	9.5
"	3	70.3	28.1	17.4	4.43	21.7	14.0	6.3
"	4	68.3	32.5	20.5	3.86	28.7	18.8	11.6
4	1	72.6	34.1	21.0	3.24	26.5	20.7	12.3
"	2	61.3	25.7	27.0	3.56	22.6	13.4	9.3
"	3	68.4	29.7	23.2	3.72	25.0	14.8	9.6
"	4	76.2	31.2	25.5	3.36	28.3	16.9	10.6
35°C and 75 per cent R.H.								
1	1	32.1	20.5	11.8	5.14	11.0	5.1	1.6
"	2	36.9	26.3	15.0	3.37	16.2	4.2	2.0
"	3	30.1	18.6	9.7	4.68	9.6	3.7	3.2
"	4	28.6	21.3	14.4	6.12	18.5	5.1	4.3

Table XXIV

Performance of the M_2 progeny* from irradiated cultures at 33°C and 75 per cent R.H.

Details of cultures	Rep. No.	Adult emergence %	Fecundity	Progeny production	Sex-ratio
Ir 'A'	1	58.5	26.7	13.6	5.10
"	2	60.1	28.0	13.5	4.60
"	3	62.0	26.3	16.8	5.26
"	4	61.2	28.2	16.0	6.93
Ir 'C'	1	56.0	14.6	5.3	6.27
"	2	50.8	17.3	6.4	15.49
"	3	53.7	13.2	6.8	5.30
"	4	61.1	16.7	8.7	6.15
Ir 'D'	1	63.6	20.3	12.0	3.40
Ir 'D'	2	74.6	12.9	8.0	3.50
"	3	77.9	13.2	7.0	2.98
"	4	65.3	13.1	7.8	4.80
Ir 'L_1'	1	50.2	12.4	1.8	3.86
"	2	51.3	13.9	2.5	3.31
"	3	45.0	15.1	6.0	3.90
"	4	46.3	15.7	4.1	2.32
Ir 'L_2'	1	60.3	27.4	16.2	2.86
"	2	63.7	22.7	14.5	3.41
"	3	62.4	19.3	13.2	3.80
"	4	57.8	17.8	14.9	3.00
Ir 'M'	1	54.8	13.0	8.0	4.62
"	2	63.1	12.8	6.6	3.96
"	3	52.4	15.0	9.0	4.23
"	4	54.2	16.8	6.4	4.03

* Progeny from irradiated Ambajipet Cuddalore, Delhi Luchiana, Lucknow and Mandya cultures.

Table XXV

Performance of a selected culture from irradiated Mandya stock at 33°C and 75 per cent R.H.

Gen. No.	Rep. No.	Adult emergence %	Adult longevity (hours) Female	Adult longevity (hours) Male	Total repr. period in females (hrs.)	Fecundity	Progeny production	Sex-ratio
M_2	1	65.0	24.0	19.6	17.6	20.0	10.4	3.64
"	2	60.1	28.0	24.7	19.1	18.6	11.0	3.80
"	3	68.0	26.7	20.8	17.0	22.3	12.2	4.02
"	4	66.9	27.9	27.3	18.7	25.1	16.3	2.78
M_3	1	55.4	23.8	18.0	14.5	16.7	11.6	2.90
"	2	63.2	21.6	22.6	16.2	20.8	14.2	3.54
"	3	60.0	26.8	21.4	13.0	21.4	10.7	2.83
"	4	57.0	30.9	25.2	18.7	22.7	15.6	3.13
M_4	1	68.1	25.4	17.0	22.0	25.0	11.7	4.10
"	2	60.8	27.0	15.8	16.4	19.6	9.8	3.60
"	3	58.4	29.2	20.7	20.5	21.4	13.0	3.90
"	4	73.4	31.7	20.9	23.1	28.4	16.7	4.48
M_5	1	59.0	25.0	26.0	10.2	22.0	15.0	3.50
"	2	65.6	28.6	20.5	15.3	18.7	16.2	4.21
"	3	62.8	23.9	23.8	14.8	22.5	13.1	3.00
"	4	59.7	32.9	26.5	15.7	24.1	13.7	4.77
M_6	1	66.5	28.0	18.0	18.2	25.0	11.8	3.60
"	2	69.6	24.5	21.4	16.4	21.8	14.6	4.52
"	3	58.7	26.0	19.6	15.0	20.8	13.2	3.88
"	4	62.4	27.2	24.2	21.6	24.9	16.6	4.40
M_{10}	1	65.6	26.0	22.0	18.2	20.0	15.0	3.50
"	2	58.7	28.7	21.0	16.4	22.6	14.2	3.38
"	3	65.3	23.1	19.5	15.0	21.4	13.8	2.90
"	4	66.4	22.2	23.7	21.6	23.2	11.9	3.10

Table XXVI

Abstracts from the Analysis of Variance tables

Table No.	Sl. No. of character	Source M.P.S. and D.F. Treatment D.F.	Treatment M.P.S.	Block D.F.	Block M.P.S.	Error D.F.	Error M.P.S.
4	1	5	0.6426	3	0.2110	15	0.2475
"	2	5	2.6635	3	0.7681	15	51.3906
"	3	5	212.4332	3	3.7000	15	66.6055
"	4	5	43.1008	3	38.9750	15	31.4883
"	5	5	3.4539	3	0.8219	15	0.3341
"	6	5	70.816	3	36.26	15	93.4358
"	7	5	266.158	3	16.582	15	45.570
"	8	5	146.8334	3	9.0133	15	36.3443
5	1	5	0.9955	3	0.2136	15	0.3035
"	2	5	23.3320	3	15.1950	15	47.7185
"	3	5	154.5214	3	27.8863	15	26.0589
"	4	5	92.1520	3	24.3066	15	24.1853
"	5	5	7.7011	3	0.8713	15	0.4300
"	6	5	136.0484	3	8.0736	15	23.0474
"	7	5	321.3703	3	35.2696	15	32.6348
"	8	5	198.2532	3	33.6819	15	18.9218
6	1	5	0.5394	3	0.1139	15	0.0955
"	2	5	64.700	3	1.5400	15	23.6306
"	3	5	162.6003	3	83.3130	15	72.7516
"	4	5	97.0088	3	3.8016	15	32.6338
"	5	5	6.2770	3	0.7460	15	0.6503
"	6	5	97.4778	3	31.4906	15	49.1804
"	7	5	178.8178	3	10.8193	15	26.4086
"	8	5	208.7876	3	33.4920	15	16.2919
7	1	5	8.4000	3	2.5612	15	3.6000
"	2	5	73.1170	3	12.4905	15	28.1174
"	3	5	10.6377	3	0.1204	15	4.3420
"	4	5	9.4127	3	0.3480	15	5.1302
"	5	5	14.6220	3	4.1635	15	1.5741
"	6	5	11.4723	3	0.3867	15	5.1270
"	7	5	13.4013	3	1.9769	15	2.4331
"	8	5	17.1880	3	1.0030	15	4.6277
8	1	5	0.6127	3	0.2280	15	0.2310
"	2	5	32.4463	3	5.5870	15	19.4063
"	3	5	154.1280	3	26.1478	15	78.5900
"	4	5	91.2106	3	4.502	15	45.6207
"	5	5	17.1880	3	1.0030	15	4.6277
"	6	5	60.1750	3	20.1214	15	25.5832
"	7	5	160.1480	3	3.452	15	27.5800
"	8	5	41.2380	3	0.9147	15	6.4130
9	1	5	0.0030	3	0.0868	15	0.2322
"	2	5	76.9120	3	105.560	15	23.0740
"	3	5	20.7354	3	80.8750	15	30.2265
"	4	5	74.0308	3	0.9058	15	16.1673
"	5	5	3.4038	3	0.3621	15	0.3307
"	6	5	67.588	3	20.6630	15	30.5547
"	7	5	73.4734	3	27.0473	15	11.6638
"	8	5	52.0332	3	0.5154	15	10.0188
10	1	5	0.5426	3	0.2347	15	0.2417
"	2	5	456.6580	3	38.2180	15	19.1478
"	3	5	204.3276	3	6.1430	15	78.1920
"	4	5	98.0043	3	4.5064	15	22.7800
"	5	5	4.5327	3	0.4028	15	0.3108
"	6	5	78.5320	3	27.0801	15	14.0830
"	7	5	71.1180	3	25.0470	15	10.3763
"	8	5	48.0804	3	1.8067	15	8.4236
11	1	5	1.4597	3	0.1425	15	0.3431
"	2	5	125.3276	3	12.5500	15	32.4136
"	3	5	122.5510	3	11.0360	15	18.9172
"	4	5	144.0138	3	1.6472	15	26.3888
"	5	5	7.7611	3	0.8390	15	0.4754
"	6	5	48.5906	3	25.0461	15	12.2761
"	7	5	170.6867	3	2.4637	15	12.0514
"	8	5	276.5634	3	2.3566	15	4.2978
12	1	5	1.5199	3	0.2294	15	0.1907
"	2	5	167.1134	3	10.8506	15	28.1238
"	3	5	104.4248	3	44.3030	15	20.0950
"	4	5	10.0024	3	7.6026	15	10.0911
"	5	5	6.1870	3	0.0461	15	0.4260
"	6	5	63.2214	3	22.4750	15	12.3752
"	7	5	114.9256	3	18.7828	15	15.3947
"	8	5	67.5000	3	1.4050	15	6.0113

(Contd. .....)

Table XXVI contd.

Table No.	Sl. No. of character	Source M.S.S. and D.F. Treatment D.F.	Treatment M.S.S.	Block D.F.	Block M.S.S.	Error D.F.	Error M.S.S.
13	1	5	0.8147	3	0.1369	15	0.4731
"	2	5	148.3510	3	30.1470	15	26.7430
"	3	5	147.1260	3	7.5410	15	26.7130
"	4	5	80.1432	3	12.5470	15	14.6321
"	5	5	20.2368	3	0.8176	15	0.5890
"	6	5	51.2860	3	18.3100	15	14.3320
"	7	5	98.2268	3	16.1137	15	12.4400
"	8	5	22.9731	3	0.7814	15	4.0378
14	1	5	0.7130	3	0.1366	15	0.2722
"	2	5	193.225	3	28.2126	15	21.4480
"	3	5	173.139	3	6.7450	15	22.8103
"	4	5	88.853	3	11.3938	15	11.9372
"	5	5	25.2804	3	0.5364	15	0.4862
"	6	5	41.9434	3	17.9926	15	11.9496
"	7	5	32.3189	3	0.5919	15	2.6465
"	8	5	5.9520	3	7.6006	15	6.2073
"	9	5	99.9462	3	92.8503	15	26.0253
"	10	5	299.4404	3	94.7616	15	68.8148
15	1	5	0.0792	3	0.0477	15	0.0921
"	2	5	652.664	3	24.4986	15	24.6216
"	3	5	97.7675	3	0.3633	15	22.8536
"	4	5	49.1390	3	8.4788	15	8.3178
"	5	5	42.9194	3	1.2697	15	1.2390
"	6	5	27.3788	3	8.3626	15	8.9584
"	7	5	22.7662	3	2.3178	15	3.7214
"	8	5	4.6066	3	0.1583	15	0.3960
"	9	5	78.9462	3	85.5423	15	45.7453
"	10	5	70.6138	3	158.2963	15	34.7242
16	1	5	0.4100	3	0.1173	15	0.1971
"	2	5	612.8568	3	2.5750	15	19.2618
"	3	5	183.9900	3	3.1536	15	15.4936
"	4	5	25.5404	3	9.9637	15	9.6184
"	5	5	30.7081	3	0.3913	15	0.3032
"	6	5	120.3716	3	8.9437	15	9.8498
"	7	5	28.3606	3	1.2116	15	3.0173
"	8	5	8.4494	3	0.0848	15	0.6545
"	9	5	39.9880	3	31.3000	15	29.3453
"	10	5	835.4032	3	92.5056	15	32.1205
23	1	20	1615.9170	3	166.5500	60	13.7330
"	3	20	235.9079	3	4.6642	60	8.2365
"	4	20	2.5424	3	0.2875	60	0.1732
"	2	20	509.3426	3	6.4620	60	10.2179
"	[illegible]	20					

Table XXVI
Abstracts from the Analysis of Variance tables

Table No.	Source	S.S.	D.F.	M.S.S.	F. ratio	Inference
1	2	3	4	5	6	7
29	Rep.	366674.00	3	122224.66	56.9688	**
"	Main plots	394413.00	5	78882660	36.7671	*
"	Error ((Main plot)	32182.00	15	2145.46	-	-
"	Bet.sub plots	35689.70	11.0	3517.24	3.5171	**
"	Int.between main and sub plots	1763127.80	165	10681.56	10.6857	**
"	Total error	88002.68	88	1000.03	-	-
30	Rep.	63328.00	3	21109.33	8.1191	**
"	Main plots	127941.00	5	25588.20	9.8418	*
"	Error main plot	38999.00	15	2599.93	-	-
"	Bet-sub plots	14689.90	11.0	1335.44	4.5010	**
"	Int.bet. Main & sub-plots	739772.50	165	4483.46	15.112	**
"	Total error	26107.03	88	296.6713	-	-

(Contd. .....)

Table XXVI contd.

1	2	3	4	5	6	7
31	Rep.	5365.20	3	1788.40	1.5908	N.S.
"	Main plot	102531.40	5	20506.00	18.2407	*
"	Error main plot	16863.00	15	1124.20	-	-
"	Bet.sub plots	5484.36	11	498.56	2.73	**
"	Int.bet. main and sub plots	348528.67	165	2112.28	11.5664	**
"	Total error	16070.71	88	182.6217	-	-
32	Rep.	60.28	3	20.09	0.5551	N.S.
"	Main plots	172.94	5	34.58	0.9555	N.S.
"	Error main plot	542.93	15	36.1953	-	-
"	Bet.sub-plots	320.153	11	29.1048	2.5820	**
"	Int. between main & sub plots	17094.150	165	103.0554	9.7122	**
"	total error	988.1191	88	11.2286	-	-
33	Rep.	6093.60	3	2031.20	1.8860	N.S.
"	Main plots	106504.50	5	21300.90	19.77	N.S.
"	Error main plot	16154.60	15	1076.97	-	-
"	Between sub plots	8706.22	11	791.47	3.5773	**
"	Int. bet. main & sub plots	378193.80	165	1686.01	7.6205	**
"	Total	19469.62	88	221.245	-	-
34	Rep.	77952.00	3	25984.00	24.00	**
"	Main plots	17061.50	5	3412.30	3.1524	*
"	Error main plots	16236.30	15	1082.42	-	-
"	Bet. sub plots	12273.74	11	1124.88	2.7978	**
"	Int. bet. main & sub plots	261051.53	165	1582.13	3.9360	**
"	Total error	35381.26	88	402 .05	-	-
Duration of Dev.						
	Rep.	16639.11	3	5546.37	3.7635	*
	Bet.main plots	52994.90	5	10598.98	7.1922	*
	Error main plots	22104.87	15	1473.658	-	-
	Bet.sub plots	4003.121	11	363.93	3.1977	*
	Int. bet. main & sub-plots	21476.40	165	130.16	1.1437	N.S.
	Total error	10014.881	88	113.805	-	-
Progeny production						
	Rep.	63599.63	3	10533.21	18.5713	**
	Main plot	38520.75	5	7704.15	7.3247	*
	Error main	15776.99	15	1051.799	-	-
	Sub plots	5127.13	11	466.103	2.7587	**
	Int. Bet. main and sub plots	86390.154	165	520.546	1.3068	N.S.
	Total error	14562.615	88	165.593	-	-
Fecundity (in selected cultures)						
	Rep.	33.04	3	11.01	2.57	-
	Main plot	110.08	1	110.08	25.72	
	Error main plot	12.84	3	4.28	-	-
	Sub plots	304.63	2	152.31	35.25	**
	Int.bet.main and sub plots	18.96	2	19.48	2.42	-
	Total error	47.08	11	3.92	-	-

N.S. Non Significant
* Significant at 5% level
** Significant at 1% level