The ovposition and development of a Pakistani biotype of *Callosobruchus macultus* (F.) (Coleoptera: Bruchidae) on different host legumes

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Abstract

The study was conducted to observe the preferential response of a Pakistani biotype of *Callosobruchus maculatus* (F) to two different Pakistani varieties each of *Vigna radiata* (NM92 & NCM209) (green gram) and *Vigna mungo* (NARC1 & NARC3) (*black gram*) The number of eggs, development period, percentage adult emergence, weight of newly emerged adults and growth index were studied Number of eggs was recorded for four consecutive generations Oviposition occurred on all varieties For the first two generations, Hopkin's host varieties selection principle could be applied, but in third and fourth generations, the larval host effect on ovipositing female did not occur, suggesting that oviposition decisions by the pulse beetle are not only determined by Hopkin's principle

In general, the maximum number of eggs was laid on NM92, while on NARC1 a minimum number of eggs was laid Preference for oviposition was also an indication of suitability for larval development There was significant difference between the development pattern in seeds of green gram and that in seeds of black gram The slowest development was recorded in NARC1 (43 6 days), while the fastest was recorded in NM92 (27 2 days) On the basis of growth index, NM92 proved to be of maximum food value for the insects while NARC1 proved to be of minimum food value The heaviest insects were recorded from cowpea (which were especially used in this bioassay to observe the response of *C maculatus* on a standard host)

Introduction

By 1st January 1997, the total population of Pakistan was estimated to be 135 28 million (Economic Survey of Pakistan 1996 – 97) Per capita income at constant prices of 1980 – 81 indicated a decrease of 0 4 percent per year (Economic Survey of Pakistan 1996 – 97) As a result of accelerating population increase and declining per capita income, the majority of the people in Pakistan are malnourished Most of them are unable to afford animal proteins as a food source

Pulses contain 20 – 30 per cent proteins and can provide a comparatively cheaper alternative to animal proteins They are short duration plants and the high lysine level in the protein makes them ideal supplements to cereals (Fernandez and Talker, 1990) Among the important pulses consumed in Pakistan, *Vigna mungo* (black gram) and *Vigna radiata* (green gram) are the most widely grown Owing to small land holding, poor farming techniques, scarcity of inputs and low literacy rate among the farming community, yields of pulses are low The situation is further exacerbated by insect pests, which damage pulses during storage (Dhepe et al, 1993) Birch et al (1985) and Redden et al (1983) described bruchids as one of the most important insect groups attacking both grain and legume plants in the arid tropics

Among the bruchids, *Callosobruchus maculatus* (F) is one of the most destructive pests of stored pulses in India and Pakistan The damage in some pulses can be so extensive that the whole of the seed material is eaten and only seed coats with empty cavities are left behind (Vir and Jindal, 1981)

It has been established that *C maculatus* can occur in geographically distinct populations (biotypes) which exhibit different biological characteristics (Credland, 1990) Earlier studies have revealed that occurrence of insect biotypes, able to successfully utilise a plant supposedly resistant, can hinder pest management programmes (Gould, 1978, Futuyama and Peterson, 1985) The response of three populations of *C maculatus* to seed resistance in selected varieties of *Vigna unguiculata* (cowpea) was studied by Ofuya and Credland, (1995) Kitamura et al (1990) undertook their investigations to characterise bruchid resistance factors present in *Phaseolus vulgaris* (kidney bean) and *Vigna sublobata* (the wild mung bean) Credland (1990) studied the biotypic variation and host change in bruchids, using ten biotypes of *C maculatus* against

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Vigna unguiculata (cowpea) and *Lens culinaris* (lentils) as host pulses Vir and Jindal (1981), studied oviposition response and development of *C maculatus* on four pulses viz, *Vigna radiata* (mung), *Vigna aconitifolia* (moth), *Vigna unguiculata* (cowpea) and *Cajanus cajan* (pigeon pea)

Very little work has been done on Pakistani biotypes of *C maculatus* Personal communication with workers from Pakistan pointed at a possible preference of *C maculatus* for green gram against black gram This preference was confirmed in a preliminary experiment where adults of *C maculatus* were free to choose their host for oviposition from black gram (NARC1, NARC3), green gram (NM92, NCM209), control bean and cowpea (*Vigna unguiculata*) (Sulehrie, Unpublished data) In most storage conditions, the opportunities for insects to choose their preferred host from a variety of hosts are rare Therefore the present investigation was undertaken in a 'no choice situation' The results presented here are also analysed in the context of Hopkin's Host Selection Principle (Hopkins 1916 cited in Wasserman, 1981), which could explain the preference of *C maculatus* for green gram The Hopkins principle states that adult female insects will prefer to oviposit on the host upon which they had fed as immatures

The first stage in the insect's life where preference for a particular host could be manifested is at oviposition Mitchell (1975) observed that *C maculatus* are selective in the kind and size of beans on which they lay eggs so the first set of experiments was conducted to check the ovipositional response of females on different hosts

The second bioassay was undertaken to assess differences during the remaining stages of the insect's life cycle, i e larval development, adult weight at emergence and fecundity of the newly emerged adults Redden & McGuire (1983) determined the most discriminating measurements of resistance within the seed accessions to *C maculatus* to be mean emergence day (the development period), followed in decreasing order by percentage adult emergence, percentage of undamaged seeds, mean number of holes per seed and percentage loss in seed weight The effect on larval development was determined using Redden & McGuire's parameters, mean emergence day and percentage adult emergence

Material and Method

Origin and routine maintenance of strain of *C. Maculatus*

All insects used in this study were obtained from a stock culture of *C maculatus* collected from National Agricultural Research Council, (Islamabad) Pakistan The insects had been in culture since October 1995 at NRI, Chatham, Kent The insects in the stock culture were reared on a commercially available Australian cultivar of green gram All the experiments were undertaken in a constant temperature and humidity (CTH) room (27 ± 1℃ and 70 ± 10% rh)

Standardisation of seeds

Prior to experimentation, all seeds investigated were frozen at −20℃ for one week and then stored at 4℃ to prevent infestation Small samples of each legume variety were equilibrated in a CTH room for a minimum of three weeks before use This stabilised the moisture contents of seeds at about 11% (Parr et al, 1996) All seeds were visually examined and those having hard, rough, cracked or damaged testa were excluded as these factors are known to influence a seed's acceptability, (Nwanze & Horber, 1976, Messina, 1984)

Ovipositional bioassay

Two hundred seeds each of green gram, *Vigna radiata* (varieties NM92 & NCM 209), and black gram, *Vigna mungo* (varieties NARC 1 & NARC 3) were placed separately in a 70 mm × 40 mm crystallising basin, respectively, with one pair of newly emerged male and female insects that had been allowed to mate for two hours Commercially available Australian cultivar of green gram was used as a control Twenty replicates were undertaken for each legume variety Two hundred seeds were allocated to each replicate, because a preliminary study of ovipositional pattern revealed that the maximum number of eggs laid by a single female was 156

The number of eggs laid in each replicate was recorded when the female reached 10 days old, following Dick and Credland (1984) who reported that oviposition is completed in about 8 days and females die about 10 − 12 days after their emergence Seeds with one egg were selected and placed in microtitre plates in the CTH room until adults emerged Newly emerged females were crossed with standard males (reared in control seeds) of known age The oviposition bioassay was repeated using these insects as parents of the next generation Following Credland (1987), generations were numbered in relation to the habitat of the larval stage Thus, the first generation (F1) of NM92 are those larvae in NM92 produced by adults, which were themselves reared on control beans (F0)

Development Bioassay of *C. maculatus*

For each of six varieties of host legume (NM92, NCM209, NARC3, NARC1, cowpea and control), 250 seeds were placed in six 70 mm × 40 mm crystallising basins *C maculatus* is commonly known as the cowpea beetle and most of the workers have used cowpea in bioassays Therefore, commercially available cowpea from California was included in this bioassay to compare the test varieties with a standard host Eight pairs of newly emerged male and female adults that had been allowed to mate for two hours were introduced into each crystallising basin and were kept in the CTH room for six hours The insects were removed, and 150 seeds with one egg were isolated from each of six legume varieties The weight of each individual seed was recorded on a microbalance (Sartorius) weighing to ± 0 001mg The weighed seeds were placed in Sterilin 100mm × 100mm 'repli dishes' with 25 compartments (Merck Ltd), so that each seed occupied a separate compartment The dishes were placed in the CTH room for rearing

The seeds were examined and adult emergence recorded twice daily, beginning 21 days after the oviposition occurred, which is the minimum development period of *C maculatus*, as recorded by Dobie et al (1991) until there was no emergence for three consecutive days (Credland, 1987)

All the newly emerged insects were sexed and weighed soon after emergence on a microbalance (Mettler AE160) weighing to ± 0 0001 gram The emerged insects were removed after each observation to prevent any chances of mating and oviposition of newly emerged insects The suitability of food was assessed on the basis of a growth index defined as log of percentage emergence of adults/ mean development period in days (Vir and Jindal, 1981)

Calculations and data analysis

The statistical package used for all the calculations was SPSS for Windows (release 6 1 3 , 5 Dec 1995) Applying 'GENERAL FACTORIAL ANOVA', customised model, carried out analysis of variance Residual plots, means of dependent variable/s, within ± residual error term and unique sum of squares were displayed in SPSS output Data were subjected to appropriate transformation where required to reduce the residual errors

Oviposition Bioassay

The total number of eggs laid on each variety was recorded and subjected to general factorial analysis of variance, as described above In case of the parent generation (F0), data was transformed into square roots for number of eggs laid to reduce the residual error

Developmental Bioassay

The following parameters were measured for each variety

- Hatching percentage (Number of eggs hatched × 100/ total number of eggs) ,
- The developmental period (time of egg laying to adult emergence from seed),
- Percentage adult emergence (number of emerged adults × 100/ total number of seeds),
- Growth index (Log of percentage emergence of adults/ mean development period in days),
- Sex ratio (total number of males/ total number of females),
- Average weight of males and females (mg)

Data were subjected to general factorial analysis of variance. Data on growth index were first multiplied by 1000 and then subjected to ANOVA

The correlation coefficient was calculated between the weight of seeds and insect weight, between the weight of seeds and development period, and between the insect weight and development period

Results

Egg laying on different hosts

Adults of *C maculatus*, which had developed in control green gram for more than 15 consecutive generations, laid eggs on all the test varieties of black gram and green gram The maximum and minimum number of eggs was laid on control beans and on NARC1, respectively (Table 1) With the exception of NARC1, there were no significant differences among all other host legumes (LSD at 5% level = 2 08 when square roots of the total number of eggs laid were taken)

Table 1. Means of egg count (± SE) for different host legumes, laid by F0 females

Host Legumes	Mean total number of eggs laid/female ± SE
Control mung	57 80 ± 6 60
NM92	46 15 ± 9 72
NCM209	52 30 ± 9 92
NARC1	21 00 ± 5 02
NARC3	49 05 ± 9 97

For the F1 generation, the maximum number of eggs was laid by females reared from seeds of NM92 and placed on seeds of NM92, while the minimum were laid by females reared on seeds of NCM209 and placed on control seeds (Table 2) With the exception of females reared from seeds of NARC3, where there was a non significant difference, all the other females laid significantly higher numbers of eggs on their respective larval hosts than on control beans (LSD at 5% level = 16 96)

For F2 generation females, there were no significant differences among the number of eggs laid on control beans and those laid on seeds of their respective larval hosts, with the exception of females reared in seeds of NARC1 where the number of eggs laid on the control were significantly higher than those laid on its larval host (LSD at 5% level = 18 23) (Table 3)

There were significantly greater numbers of eggs laid by F3 females reared in seeds of NARC1, on control seeds compared with seeds of the larval hosts However, the opposite was observed for females reared in seeds of NM92 For F3 females reared in seeds of NCM209 and NARC3, there was no significant difference between the total number of eggs laid on their larval hosts as compared with the control mung (LSD at 5% level = 12 21) (Table 4)

Table 2 Means of egg count (± SE) for different host legumes, laid by F1 females

Legume varieties		Mean total number of eggs laid/female ± SE
Host	Test	
NM92	Control	80 00 ± 3 21
NM92	NM92	114 10 ± 9 72
NCM209	Control	59 45 ± 5 70
NCM209	NCM209	87 15 ± 2 55
NARC1	Control	67 75 ± 8 77
NARC1	NARC1	92 20 ± 4 73
NARC3	Control	72 00 ± 6 38
NARC3	NARC3	80 00 ± 9 19

Host parental developmental variety
Test Pulses on which number of eggs was recorded

Table 3. Means of egg count (± SE) for different host legumes, laid by F2 females

Legume varieties		Mean total number of eggs laid/female ± SE
Host	Test	
M92	Control	58 20 ± 8 21
NM92	NM92	72 25 ± 8 39
NCM209	Control	60 70 ± 6 40
NCM209	NCM209	75 65 ± 4 02
NARC1	Control	94 35 ± 6 09
NARC1	NARC1	73 75 ± 5 00
NARC3	Control	82 70 ± 7 75
NARC3	NARC3	80 85 ± 5 58

Host parental developmental variety
Test Pulses on which number of eggs was recorded

Table 4. Means of egg count (± SE) for different host legumes, laid by F3 females

Legume varieties		Mean total number of eggs laid/female ± SE
Host	Test	
NM92	Control	42 60 ± 5 29
NM92	NM92	55 80 ± 3 94
NCM209	Control	72 25 ± 3 03
NCM209	NCM209	83 15 ± 4 25
NARC1	Control	87 85 ± 4 72
NARC1	NARC1	67 75 ± 4 99
NARC3	Control	64 70 ± 2 87
NARC3	NARC3	58 10 ± 4 77

Host parental developmental variety
Test Pulses on which number of eggs was recorded

Table 5. Means (± SE) of the larvaldevelopment periodfor different host legumes

Host Legumes	Mean Development Period (days) ± SE
Control mung	27 85 ± 0 12
Cowpea	29 51 ± 0 23
NM92	27 23 ± 0 77
NCM209	28 55 ± 0 86
NARC1	43 63 ± 0 16
NARC3	41 07 ± 0 32

Table 6. Means (± SE) of male weight from different host legumes

Host Legumes	Mean Male Weight (mg) ± SE
Control mung	8 18 ± 0 08
Cowpea	8 53 ± 0 11
NM92	7 54 ± 0 17
NCM209	4 86 ± 0 16
NARC1	7 06 ± 0 31
NARC3	7 27 ± 0 15

Hatching Percentage

Seeds of all treatments containing one egg per seed were observed for hatching 10 days after oviposition Maximum hatching occurred in NCM 209 (89 47%) while it was minimum for NM92 (75 23%) For NARC1, NARC3 and the control, the values of 80 71%, 80 66 and 79 30% were recorded, respectively All values non-significantly differed from each other

Development Period on different hosts

The development period of larvae (Table 5) was found to range from 27 23 days in seeds of NM92 to 43 63 days in seeds of NARC1 Development periods differed significantly among all varieties under investigation (LSD at 5% Level = 0 53) However, the development period in NARC1 and NARC3 (black gram) was much longer and distinctive than NM92, NCM209, control mung (green gram) and cowpea

Growth Index

On the basis of the growth index (Fig 1), maximum growth was obtained for adults reared in seeds of NM92 with a value of 0 0695 The next best legume for insect growth was control bean followed by NCM209 Poor development was observed in both the varieties of black gram (NARC3 and NARC1) with growth indices of 0 0454 and 0 0426, respectively There was no significant difference between the growth index of insects reared in NM92 and in control seeds and between those reared in NARC1 and NARC3 Growth indices were significantly different among the rest of the host legumes (LSD at 5% level = 0 0023)

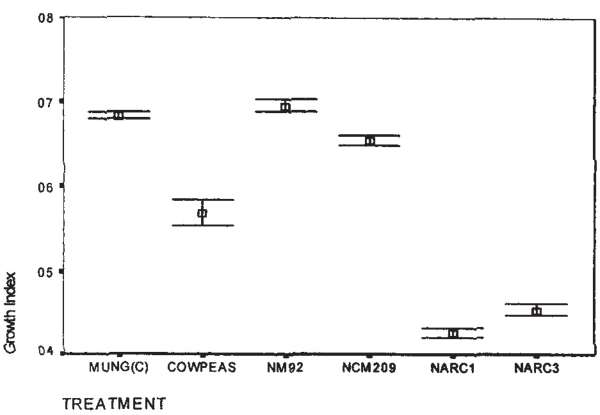

Fig. 1 Mean growth index of *C maculatus* reared in seeds of different host legumes

Seed weight

All host legumes were significantly different among each other for seed weight (LSD at 5% level = 4 44) Cowpea seeds, with an average weight of 213 mg, were the heaviest, while those of NCM209, with an average weight of 31 39 mg, were the lightest Average weight of control bean, NM92, NARC1 and NARC3 was 61 41, 59 99, 52 96 and 46 45 mg, respectively

Insect weight at emergence

Newly emerged adults were weighed The heaviest males and females were reared in seeds of cowpea The lightest males and females emerged from seeds of NCM209 No significant difference was determined between the weight of males emerging from seeds of the control and cowpea However, a significant difference was determined among these males (reared in control seeds and cowpea) and those emerging from seeds of the remaining varieties under investigation, (LSD at 5 % level = 0 51)(Table 6)

No significant difference was determined between the weight of females reared in seeds of NARC1 and NARC3 However, females reared in seeds of the other test varieties significantly differed with each other for weights (LSD at 5% level = 0 057 when square roots were taken for mean female weights) (Table 7)

Table 7. Means (± SE) of female weight for different host legumes

Host Legumes	Mean Female Weight (mg) ± SE
Control mung	9 58 ± 0 10
Cowpea	10 57 ± 0 24
NM92	9 33 ± 0 10
NCM209	5 22 ± 0 21
NARC1	7 42 ± 0 21
NARC3	7 68 ± 0 14

The Correlation Coefficient

The correlation coefficient was calculated between the weight of female insects and development period, between the weight of female insects and seed weight, between the weight of male insects and development period, between the weight of male insects and seed weight, and between the weight of seeds and development period

- Between weight of seeds and development period A correlation was determined between seed weight and development period in seeds of the NM92 ($r = -0$ 5892)
- Between weight of female insects and weight of seeds: The correlation coefficient between seed weight and weight of female insects was strong for insects reared from seeds of control bean ($r = 0$ 685) and those from seeds of NCM209 ($r = 0$ 740)
- Between weight of male insects and weight of seeds There was a very strong correlation between male insects emerged from NM92 and weight of NM92 seeds (0 876)
- Between weight of female insects and development period Development period was correlated with the weight female insects reared in seeds of the cowpea ($r = -0$ 530)
- Between weight of male insects and development period The correlation coefficient between weight of male insects and development period was very strong for male insects reared in cowpea ($r = 0$ 912) It was strong for insects emerged from NARC1 and NM92 (values of $r = 0$ 778 and -0 753 respectively) and quite strong for those emerged from NCM209 (0 568)

Discussion

The study was undertaken to assess the ovipositional and developmental responses of a Pakistani biotype of *C maculatus* against different host legumes It is apparent from the results that this biotype is well adapted to survive on the commercially available Australian cultivar of green gram on which it had been reared for many generations (control) It has not, however, become so specialised that it has lost the capacity to survive on other hosts Females were therefore, able to lay eggs on seeds of all the pulses investigated (a phenomenon shared with the Turkish strain of *C maculatus* which was adapted to survive on lentils but also developed in cowpea (Credland, 1987)

Hopkins host selection principle states that adult female insects prefer to oviposit on the host upon which they had fed as immature larvae (Hopkins, 1916, cited in Wasserman, (1981)) Insects used for this experiment were obtained from a population cultured on control beans for 15 generations The maximum number of eggs was laid on beans from the larval host while minimum number of eggs were laid on seeds of NARC1 by F0 generation (parental) females

Second generation females (F1) also laid more eggs on their larval hosts than on control beans However females reared in seeds of NARC3 showed no significant difference in number of eggs on the larval host and on the control

Wasserman (1981) suggested that insects marking utilised hosts are more likely to switch onto less preferred hosts, when the preferred hosts are scarce, than non-marking species. His main emphasis was on impact of ovipositional markers on female behaviour resulting in oviposition patterns mimicking a Hopkins effect Yamamoto (1990) described the effect of BCS (biological conditioning substances, a mixture of lipids consisting of fatty acids, hydrocarbons and triglycerides and mono-and di-glycerides as minor components) on female ovipositional behaviour and quoted Yoshida ((1961) cited in Yamamoto, (1990)) that *C maculatus* females prefer non-or less-BCS conditioned beans for further oviposition

In setting up these experiments, attempts were made to minimise the effect of ovipositional markers through providing more seed than the maximum number of eggs a female could lay

The third and fourth generation females from seeds of NARC1 laid significantly more eggs on control seeds than on their larval host The fourth generation females from NM92 also laid more eggs on control beans than on their larval hosts, while there was no significant difference for the rest of the treatments The ovipositional behaviour of first two generations would be consistent with Hopkins Host Selection principle but no such evidence was found from the third and fourth generations Earlier research has tested for the existence of Hopkins effect Dethier (1954), Ishii ((1952) cited in Wasserman 1981) and Wasserman (1981) could not find any experimental evidence for its existence while Craighead (1921), Phillips and Barens (1975), and Smith and Cornell (1979) indicated existence of a positive Hopkins effect

Redden and McGuire (1983) determined that percentage adult emergence and mean development period were the two most important indicators of seed resistance to bruchid damage in cowpea In this study, the development period was shortest in seeds of NM92 and longest in seeds of NARC1 Among green gram varieties, there was a significant difference for seed size Although NCM 209 was the smallest, the development period was similar for all green gram varieties Although all varieties differed significantly with each other for development period, black gram and green gram could be easily categorised into two separate groups Development was much slower in black gram varieties This may be due to the chemical composition of the seed, which could slow down the metabolic activities of the developing insects, the non-adaptability of larvae to utilise the seed proteins or the presence of other deterrent effects in the host seed

Vir and Jindal (1981) assessed suitability of food on the basis of a growth index We observed a maximum growth index in seeds of NM92 indicating that this variety was the most suitable food for larvae of the biotype under study The minimum growth index was observed in seeds of NARC1 indicating that according to Vir and jindal's criteria, it was less suitable as a food source Keeping in view Redden and Mcguire's parameters, Vir and Jindal's criteria and our preliminary work on free choice tests (Sulehrie, unpublished data), it is evident that seeds of NM92, in this context, are the preferred host for oviposition as well as for development of pulse beetles, while seeds of NARC1 were least preferred

In the present study, oviposition preference concurs with suitability for larval development This is in contrast to the findings of Vir and Jindal (1981) who quoted Singh et al (1977) in their support, and found that oviposition preference is not an indication of suitability for development One of the reasons for this contrast may be a result of the fact that Vir and Jindal studied the oviposition behaviour for a single generation while we studied it for four consecutive generations The use of different biotypes of *C maculatus* or use of different host varieties may be other factors responsible for this difference as Vir and Jindal (1981) observed the oviposition pattern of an Indian biotype of *C maculatus* on different varieties of host legumes Furthermore, they laid out free choice tests while we conducted free choice as well as no choice tests Regarding Singh et al , they worked on a different species, *C* *chinensis*

Ofuya and Credland (1995) reported a significant correlation between development period and adult weight at emergence They used three biotypes of *C maculatus* and thirteen varieties of cowpea On cowpea, our study confirms their results with another biotype of *Callosobruchus maculatus*

For control bean and NCM209, a strong correlation was present between seed weight and weight of female insects emerging from them There was a very strong correlation between the weight of male insects emerging from NM92 and the weight of NM92 seeds No such correlation was present for black gram or for cowpea As it has been observed that insects laid comparatively more eggs on green gram varieties than on black gram varieties and that the food index was also greater for green gram varieties than black gram, a correlation would indicate the possibility that heavy seed weight contributed to an insect's weight at emergence

The number of eggs, the development period, the growth index of green gram varieties and the presence of a correlation between seed weight in green gram varieties and insect weight are the main characteristics which show that the biotype of *C maculatus* under study does better on green gram than on black gram

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