A COMPARATIVE STUDY OF THE DEVELOPMENT OF COWPEA WEEVIL CALLOSOBRUCHUS MACULATUS (F) (COLEOPTERA: BRUCHIDAE) IN SOME KENYAN COWPEA VARIETIES AS A MEASURE OF THEIR RESISTANCE TO THE PEST

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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This thesis has been submitted for examination with my approval as University supervisor.

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SUMMARY

Experiments were undertaken to compare the performance of the bruchid Callosobruchus maculatus (F) on four different cowpea varieties commercially cultivated in Kitui district, Eastern province, Kenya. The local varieties tested were Ndamba (Kitui red), Kathoka (Kitui cream), Kanga'u (Kitui white) and Ndune (Kitui brown). One exotic variety Tvu 2027 which is known to be resistant to C. maculatus was used as a standard resistance check for the local varieties. The parameters tested were namely: oviposition preference and the associated adult bruchid emergence; egg hatching patterns, adult emergence patterns over one generation of bruchid development inside the seed; population increase over three generations and the associated seed weight loss.

Initial field infestation was found to be very low (below 3%). On the variety Kitui white only 2.65% infestation was observed while infestations of 2.56, 2.53% and 2.50% were recorded on Kitui brown, Kitui red and Kitui cream, respectively.

Oviposition preference tests showed significant (P = 0.05) differences in the average number of eggs laid on samples of 20 seeds of each local variety. Based on the number of eggs laid, the variety Kitui brown which had the highest number (4.14) of eggs deposited per seed was apparently the most susceptible

of these local varieties. On the other hand the variety Kitui red with 2.84 eggs/seed deposited was considered the least susceptible variety while Kitui white (3.76) and Kitui cream (3.38) were regarded as being intermediates.

Observations on the associated bruchid emergence also followed a similar trend, with Kitui brown (2.88 adults/seed) being considered the most susceptible variety and Kitui red (2.24 adults/seed) as the least susceptible variety. Again the varieties Kitui white (2.67 adults/seed) and Kitui cream (2.54 adults/seed) emerged as intermediates between the two in their levels of susceptibility.

The results of egg-adult survival however indicated that Kitui red with 78.87% was a potentially highly susceptible variety. This was confirmed by experiments carried out over four bruchid generations. In these experiments, Kitui red yielded the highest number of adults at the three temperatures (20°C, 27°C and 34°C) tested and lost the greatest weight. Kitui white on the other hand yielded the least number of adults over each of the three temperature regimes used and lost the least amount of weight. Based on these results, Kitui white finally emerged as the least susceptible among the local varieties tested while Kitui red was the most susceptible to the pest.

When the local varieties were tested against the standard resistant check Tvu 2027, it was found that all the local varieties were susceptible. There were significant differences ($P = 0.05$) between Tvu 2027 and all the local varieties together in the preference for oviposition and also in the adult bruchids that emerged from the eggs. On Tvu 2027, a 21.81% egg-adult survival was recorded. Local varieties had much higher egg-adult survival percentages (Kitui red = 77.34; Kitui brown = 70.19%; Kitui white = 75.00%; and, Kitui cream = 74.19%). It was therefore concluded that these local varieties did not have appreciable levels of resistance to the pest.

In addition it was observed that the variety Kitui white received fewer eggs when the local varieties were tested together with Tvu 2027. This was in comparison with the situation when Kitui white was tested together with other local varieties in the absence of Tvu 2027. This alteration in the oviposition behaviour of the bruchids was attributed to the similarity of the colour of seeds of the two varieties. It was considered that the non-preference effect on oviposition of the bruchids of the seeds of Tvu 2027 which are white in colour and have rough seed coats was transferred to the white and smooth seeds of the local variety, Kitui white.

In addition, the experiments revealed that at a lower temperature (20^{o}C) the pest population increase was lower than at higher temperatures (27^{o}C and 34^{o}C). Similarly seed weight loss for all the varieties was the lowest at 20^{o}C.

In conclusion, the studies reported here revealed the following:

a) that all the local varieties tested did not possess any appreciable levels of resistance to the pest, but that their levels of susceptibility were variable with Kitui white on the overall being least susceptible;

b) that infestation of the seeds started in the field but the level of infestation was very low (below 3%);

c) that Tvu 2027 (resistant check) when presented together with the local varieties altered the oviposition preference of the bruchid, with fewer eggs being deposited on seeds of Kitui white whose colour was similar to that of Tvu 2027 than when the variety was presented together with only the local varieties;

and

d) that at 20°C the damage to cowpea seeds by the pest was relatively less than at 27°C and 34°C.

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CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

1.1.1 Grain Legumes and their uses

Grain legumes form an important component of the tropical cropping systems where their production is based on more than a dozen species (Rachie and Roberts, 1974). The most commonly cultivated species include cowpea, also called the black eyed bean (Vigna unguiculata (L) Walp.), the common bean (Phaseolus vulgaris L.), azuki bean (Phaseolus radiatus Prain.), soybean (Glycine max (L) Merr.), groundnut (Arachis hypogea (L), pigeon pea (Cajanus cajan (L) Millsp.) and bambara groundnut (Voandzeia subterranea (L.) Thouars.) (Singh and Van Emden 1979).

In Africa, grain legumes are cultivated either as monocrops or as mixed crops with other crops particularly cereals; they perform well in a diversity of soils and environments (Singh and Van Emden, 1979). In subsistence agriculture practised on small farms such as those found in Kenya, the nitrogen fixing ability of grain legumes is of added advantage as the majority of the farmers cannot afford the cost of artificial nitrogenous fertilizers (Rachie and Roberts 1974; Singh and Van Emden 1979; Olubayo, 1980).

Grain legumes are a major source of proteins (Rachie and Roberts 1974). They are about three times richer in proteins than the cereals (Parkin and Bills 1955 Singh 1979). Additionally grain legumes, particularly cowpea, are rich in other nutrients including carbohydrates, calcium, iron, vitamins and carotene (Oyenuga 1967; Singh 1979). They also provide roughage and can be used as animal feed and for soil improvement (Parkin and Bills 1955).

Among the already enumerated grain legumes cultivated in Africa, cowpea was reported by Sellschop (1962) as ranking third in importance after groundnuts (A. hypogea) and bambara groundnuts (V. subterranea) in the continent. In Kenya, this crop ranks second in importance after the common bean (P. vulgaris) (Khaemba 1980; Olubayo 1980).

Cowpea has several advantages over other food crops including certain legumes. These have been enumerated as including the following: wide agronomic and environmental adaptability, draught resistance, possession of a broad genetic diversity and a high seed protein content, ability to grow rapidly and compete with weeds and finally, it has a wider acceptability as a food, being used in many forms (Booker 1965 b: 1967; Singh 1979; Dolvo et al. 1976; . Oyenuga 1967; Williams 1975; Rachie and Roberts 1974). In West Africa for example only the dry seeds are eaten (Booker 1965 b) while in East Africa particularly in Kenya, dry seeds as well as young green pods and tender young shoots and leaves are eaten (Khaemba 1980).

The work reported here concerned cowpea and its interaction with one of its major storage pests in Kenya, the cowpea bruchid Callosobruchus maculatus (F.). Because of this it was felt that before reviewing relevant literature pertaining to the topic, the following immediate general sections be devoted to the distribution and production as well as the yield constraints and losses of the crop.

1.1.2 Distribution, production and economic value of cowpea

Major regions of cowpea production in the world have recently been documented (Singh and Van Emden 1979, Singh 1979). Africa is the largest producer of cowpea where the bulk of the crop is produced in West Africa (4.8 m. ha) and in East Africa (1.0 m. ha) (Singh 1979). Other cowpea producing countries include India (0.85 m. ha), South East Asia (0.6 m. ha), Brazil (1.5 m. ha), and the United States (0.2 m. ha) (Singh and Van Emden 1979).

That Africa is the leading producer of cowpea is not surprising in view of the fact that the crop probably originated in this continent (Faris 1965; Smartt 1976; Irvine 1948; Burkill 1953; Sauer 1953; Piper 1913; Nwanze 1971; Taylor 1971; Rachie and Roberts 1974).

Nevertheless other centres of origin for the crop particularly India have been proposed (Wight 1903; Adams and Pipoly 1980).

In Kenya, cowpea occupies about 67,000 ha. of crop land (Anon. 1978c). About 83% of the crop is grown in the marginal rainfall areas of Eastern Province, 15% in the Coast Province and the remaining portion in Central, Nyanza and Western Provinces (Khaemba 1980). In Eastern Province where the bulk of the crop is grown, the cultivation of the crop has particular significance since other food crops do not perform well due to low precipitation. The growing of cowpea therefore puts into economic use land that would otherwise be of less value. In addition, the crop is an important income source for peasant farmers in areas where it is grown in Kenya. For instance in 1978, the sale of cowpeas fetched K.£ 142,500 for farmers in central Province (Anon. 1978 b).

1.1.3 Cowpea yield constraints and losses

Reported yield . of cowpea in Kenya are dismally low, averaging about 80 Kg/ha. (Khamala 1978). Elsewhere in Africa yields are equally low and are often below 400 Kg/ha. (Singh 1978, 1979). In Nigeria where cowpea entomology has had a long tradition, studies have shown that low yields are not inherent in cowpeas (Taylor and Ezedinma 1964; Taylor 1964, 1965, 1971).

It has been demonstrated in that country that insect pests are the main factor limiting cowpea yields (Taylor 1968; 1971; Singh and Taylor 1978; Williams 1975; Singh and Allen 1978, 1980; Singh 1976, 1977, 1978; Raheja 1976; Booker 1963. 1965 a, b). Yield losses attributable to field insect pests range from 20 to 90% in Nigeria (Booker 1965 b; Singh and Allen 1980; Raheja 1976).

Although research in cowpea entomology in Kenya is of comparatively recent origin, evidence from available literature strongly implicate insect pests as one of the major limiting factors to achieving high yields (Khaemba 1980; ; Khaemba and Khamala 1978, 1979; Karel 1979). In other East African countries, insect pests are reported to constitute the major constraint to cowpea production (Nyiira 1971, 1978; Kayumbo 1975, 1978; Koehler and Mehta 1972; Bohlen 1973; Siddiqi 1976; Mphuru 1979).

In Kenya the little portion of the grain yield that is left over by the field insect pests is harvested and held by small-scale farmers in their stores for some time. The stored crop is attacked by storage pests particularly C. maculatus which seems to be prevalent wherever cowpea is grown in Kenya (Khamala 1978; Le Pelley 1959). Despite the widespread occurence of this pest in Kenya, estimates of the yield losses caused by the pest have not been worked out.

In Nigeria the damage caused by storage insect pests particularly C. maculatus has been estimated at 10-100% in terms of seed weight loss (Anon. 1982; Singh and Allen 1980; Cutler 1956; Caswell 1961, 1968; Riley 1963). In that country, losses caused to the stored cowpea seeds by C. maculatus alone was valued by Caswell 1973) to be $1.6 m. per year. Such a loss is incurred through the reduction of market value following weight loss, seed contamination by dead adults within and among the seeds, caking of infested seeds, as well as failure of infested seeds to germinate (Gurchan and Chua 1977, Caswell 1961; 1973; Cockbill 1953;

The control of cowpea storage insect pests including C. maculatus has been achieved elsewhere largely by the use of insecticides (Chipeta and Roberts 1974; Bastos 1965; Tyler and Binns 1977; Carter et al 1975; Bato and Sanches 1972). In Kenya, the use of chemicals for the protection of cowpea grains in storage against C. maculatus has not been documented. However small scale subsistence farmers in most developing countries like Kenya hardly ever afford or use insecticides to protect their crop (Applebaum and Birk 1972; Singh and Allen 1980).

The potential of using vegetable oils and plant repellents to protect cowpea grains against C. maculatus has been demonstrated elsewhere (Singh et al 1978 a Schoonhoven 1978; Pereira 1983; Taylor 1975). This method however has not been adapted for use in Kenya where small-scale farmers employ a variety of traditional storage methods such as mixing grains with ashes to prevent pest damage.

In view of the rising costs of insecticides and related problems arising from their use such as chemical residues in food, development of insect resistance to insecticides and environmental pollution (Metcalf 1980; FAO 1978; Singh and Allen 1980; Applebaum and Birk 1972), there is need to find alternative but viable methods for use by Kenyan small-scale farmers to safeguard their cowpea grains against C. maculatus while in storage.

One viable and environmentally sound method that may be employed, and which apparently may be very appealing to the farmers because it is cheaper than other control measures is the growing of varieties that have qualities that cause the grains to resist infestation and damage by the pest (Metcalf and Luckman 1975; Applebaum and Birk 1972). In Nigeria for example, Singh and Allen (1980) reported that some local cowpea cultivars possessed appreciable degrees of resistance to C. maculatus.

Similar type of work has not been conducted in Kenya and the potential for resistance to C. maculatus by local cowpea cultivars has not been studied. In the current studies an attempt was made to investigate and ascertain whether among the cowpea varieties grown in Eastern Province of Kenya, there are any that posses qualities resistant to C. maculatus. The studies involved comparison of some aspects of the performance of the pest on four selected local cowpea varieties and one exotic variety Tvu 2027 from the Internatio al Institute of Tropical Agriculture (IITA) which has been reported as being resistant to the pest (Singh 1977, Anon 1978a).

1.2 LITERATURE REVIEW

1.2.1 General Cowpea entomology

1.2.1.1 Field insect pests of cowpea

Since the work reported here concerned stored cowpea entomology, only a brief mention of the pests that attack cowpea in the field will be made in this section.

Cowpea is an example of a crop with multiple and often overlapping insect pests (Jackai 1982). Large numbers of insect pests covering the main phytophagus taxa between them attack all parts of the cowpea plant at all stages from seedling to harvest and beyond (Taylor 1971, 1964, 1965; Singh and Van Emden 1979; Van Emden 1980; Booker 1963, 1965 a, b). The biology, ecology and distribution of field pests of cowpea in Asia and Africa have been comprehensively reviewed and documented (Singh 1977; Singh and Taylor 1978; Singh *et al.* 1978b; Singh and Van Emden 1979; Singh 1979).

In Kenya, important field pests of cowpea have recently been documented by Khamala (1978) Khaemba and Khamala (1978, 1979) Khaemba (1980) Karel and Mueke (1978) Karel (1979). These authors reported that important pre-flowering insect pest species include cowpea aphid *Aphis craccivora* (Koch) and various coleopteran beetles such as the foliage beetle *Ootheca mutabilis* (Sahlb) and some lepidopteran larvae. They also reported further that post-flowering pests consisted mainly of the legume bud thrips *Megalurothrips sjostedti* (Tryb), legume pod borer *Maruca testulalis* (Geyer), the African bollworm *Heliothis armigera* (Hb) and a variety of pod sucking bugs occurring in the genera *Riptortus*, *Nezara*, *Anoplocnemis*, and *Acanthomia*.

Maturing and pre-harvest pods while still in the field are attacked by several species of coleopterans belonging to the families *Bruchidae* and *Curculionidae* (Prevett 1961 b; Booker 1967; Raina 1971; Koehler and Mehta 1972; Singh 1979; Raheja 1976). When the pods are finally harvested, these pests are carried along with them into storage where they complete their development. Because of this it was felt that it would be appropriate to review them under the next section which deals with cowpea storage insect pests.

1.2.1.2 Cowpea storage insect pests

Reported cowpea storage insect pests belong exclusively to the order Coleoptera (Munro 1966; Southgate 1978, 1979; Prevett 1961a; Caswell 1961). Major pest species belong to the family Bruchidae (Rai 1979) while minor pest species have been reported from the family Curculionidae (Phelps 1956, Koehler and Mehta 1972). In the latter family, recorded pests belong to the genus Apioninae which is represented by the species Apion chiridanum (Wagner) (Phelps 1956; Prevett 1961 b). In the former family the most important pest species belong to the genera Callosobruchus, Bruchus, Bruchidius and Zabrotes (Howe 1971; Prevett 1961 a; William 1980, Pointell 1967; Southgate et al 1957, Booker 1967, Howe and Currie 1964, Wightman and Southgate 1982, Southgate 1958).

In Kenya, Khamala (1978) and Olubayo (1980) reported that Acanthoscelides obtectus (Say), feeds and breeds on cowpea seeds. This is in contradiction to the recent reports of Wightman and Southgate (1982) who indicated that this particular species was not a pest of plant species in the genus Vigna to which cowpea belongs.

Insect pests in the genera Bruchus and Bruchidius, represented by Bruchidius pisorum (L) and Bruchidius atrolineatus (Pic) infest cowpea pods at maturity while in the field before the crop is harvested and complete their first generation within a period of one or two months of grain storage (Booker 1967; Prevett 1961 a, b; Southgate 1965, 1979; William 1980). These workers reported further that adults of the first generation of these pests returned to the field to re-infest the maturing crop and then start the cycle all over again. These pests do not therefore continue multiplication while in storage beyond the first generation, and because of this they have been considered as being of less economic importance compared with the other cowpea bruchid pests (Raina, 1971). B. atrolineatus was reported infesting cowpea in the Eastern and Coastal regions of Kenya (Mcfarlane 1975, Le Pelley 1959).

Economically important stored cowpea insect pests belong to the genus Callosobruchus and include the following species: C. maculatus, C. chinensis (Linn), C. rhodesianus (Pic); C. analis (F) and C. phaseoli (Gylh) (Southgate 1958, 1978; Howe 1971; Yeshbir 1976; Giga and Smith 1981, 1983; Doria and Raros 1975; Yeshbir et. al 1980; Wightman and Southgate 1982; William 1980; Mphuru 1978).

C. rhodesianus is mainly confined to Southern Africa although it is sporadically reported in West and East Africa (Southgate 1964, 1965; Le Pelley 1959; Giga and Smith 1981; Wightman and Southgate 1982). C. phaseoli and C. analis are important pests in Asia and Africa (Wightman and Southgate 1982). These pests have been reported infesting stored cowpea in Kenya (Mcfarlane 1975; Le Pelley 1959).

The species C. chinensis and C. maculatus are the most important pests in the genus Callosobruchus and have wide occurrence in almost all regions where cowpea is grown (Yeshbir et al. 1980; Southgate 1958; Wightman and Southgate 1982). Particularly notorious of these two pests is the species C. maculatus which has been cited by several researchers as being the most destructive wherever it occurs (Singh 1979; Le Pelley 1959, Singh and Allen 1979, 1980; Khamala 1978; Mphuru 1978; William 1980; Howe and Currie 1964; Southgate et al. 1957; Koura et al. 1971). C. maculatus infests cowpea while it is still in the field just before harvesting so that the seeds coming into the store contain immatures of the pest, and the population of the pest builds up soon after the commencement of seed storage (Booker 1967, Prevett 1961 a, b; Caswell 1973

In Kenya both C. maculatus and C. chinensis were observed attacking cowpea grains in storage (Le Pelley 1959; Mcfarlane 1975). In addition, Mcfarlane (1975) working at the Kenyan coast observed that among these two species, C. maculatus was a more serious pest of cowpea than C. chinensis. Additionally, Khamala (1978) also reported that C. maculatus was the only serious pest of stored cowpea in Kenya. In Uganda both species have been reported (Nyiira 1971, 1978; Davies 1960). In Tanzania Mphuru (1978) reported the occurrance of both species in addition to C. rhodesianus, C. analis and C. phaseoli.

1.2.2. The biology of C. maculatus and some aspects of its development on different cowpea varieties.

The biology of C. maculatus has been studied by several workers, notably by Southgate 1979, Howe 1971, Howe and Currie 1964, Gokhale 1973, Gokhale and Srivastava 1975, Utida and Kakemi 1959, Nwanze and Horber 1976 and Osuji 1982.

Immediately after emergence, female C. maculatus mate and start ovipositing and each individual female may lay 20 - 100 eggs in its lifespan (Southgate 1979). Gokhale and Srivastava (1975) reported that the majority of the eggs (about 88%) were laid within the first five days of the female life. Other workers reported that eggs laid later during the oviposition period of the female were less viable (Howe 1967, Gokhale 1973, Howe and Currie 1964).

Eggs are usually glued onto the seedcoat at oviposition (Southgate 1979). Newly laid eggs are grey or inconspicuous or transluscent in appearance (Howe. 1971; Osuji 1982). Females have been observed to display a characteristic ovipositional behaviour in which they select and lay eggs on some beans and not on others (Wasserman and Futuyma 1981). Furthermore it has been observed that smooth and well filled seeds were preferred for oviposition to rough wrinkled and flat seeds (Booker 1967; Nwanze and Horber 1975, 1976; El-Sawaf 1956; Larson 1927; Gokhale and Srivastava 1975)

Nwanze and Horber (1975, 1976) demonstrated that well-filled and compact seeds provided enough food for the developing larva and because of this females would prefer to oviposit on them. Additionally, Nwanze et al. (1975) using electron microscopy showed that rough testas possessed deep pits which the females perceived and avoided during oviposition. They did not observe these pits on seeds with smooth testas. Other studies conducted at IITA showed that the colour of the seeds affected selection for oviposition by the females (Anon 1982). From these studies, seeds with a brown seed-coat had a relatively higher percentage of oviposition than seeds with red seed-coats. These findings conform to the reports by Southgate (1979) that most bruchids including C. maculatus are diurnal in oviposition and thus perceive the colour of the host seeds.

On the sites of the seeds which were preferred for egg-laying, Osuji (1982) observed that most eggs were deposited on the cheeks rather than on the eye, the hilum and the keel of the seeds. Earlier Nwanze et al. (1975) showed that the hilum was spongy and fibrillary in texture and because of this it was less preferred for oviposition. In addition, Wasserman (1981) reported that females prefer to oviposit on seed types that they fed on as immatures.

Eggs hatch within 3-10 days after oviposition (Singh et al. 1978b, Osuji 1982) with an average incubation period of 5.5 days (Siddiqi 1978) depending on the variety of host seeds. On hatching, it has been reported that the larva bores straight through the testa into the cotyledons where it starts feeding (Southgate 1979; Osuji 1982; Wasserman and Futuyma 1981). As the larva bores through the testa and starts feeding, it produces frass which it pushes into the empty egg case (Wasserman and Futuyma 1981) making the egg to appear white, thus being distinguishable from the unhatched eggs (Osuji 1982). This parameter was used during the current studies to identify and distinguish hatched eggs from the unhatched ones.

Depending on the suitability, as a host, of the seed variety and the capacity of the larva to survive and develop in the particular seed it is in, Utida and Kakemi (1959) reported that the larva developed through four instars before pupating. Recently, however, Osuji (1982) studying the development of C. maculatus using radiographic techniques observed a final stage after the fourth instar larva which he called the pre-pupa stage. His findings are in agreement with the reports on Wightman and Southgate (1982) which indicated that there was a final (5th) instar stage before pupation in the development of bruchids. In his studies, Osuji (1982) found that in more susceptible varieties the larval period was shorter than in the resistant varieties. He found that among the varieties he studied, larval period lasted 13 - 16 days in different varieties.

The adult weevil emerges from the pupal case by pushing through the emergence "Window" constructed by the last larval instar. The females then mate and start ovipositing immediately (Wasserman 1981; Osuji 1982; Anon 1981). The whole life cycle takes about 3-7 weeks depending on the seed type and the environmental conditions (Wasserman and Futuyma 1981; Singh and Allen 1979).

Investigating on the factors that determine larval survival and development in the seeds, Janzen (1977) observed that on seeds with thick testas, first instar larvae failed to penetrate through the testa and died as they could not reach the food. Other workers have observed that increased larval density within a seed, which results from more eggs being laid and therefore hatching in one seed, increased larval food competition thereby reducing larval survival and development to pupae and adults (Yeshbir et al 1981; Booker 1967; Nwanze and Horber 1976; Utida 1972; Giga and Smith 1981).

Giga and Smith (1981) observed that when more than ten larvae developed within one seed, the number of adults emerging from that seed was greatly reduced. As a result, varieties that had more eggs laid on them had comparatively fewer adults emerging from them due to the increased larval mortality arising from the competition for food.

Furthermore, other research reports have showed that in seeds of certain cowpea varieties, even when there was enough food available for each larva within the seed, the larva still failed to develop and the young larvae died soon after the initial tunnelling into the seed cotyledons (Dina 1971; Yeshbir et al 1980; Giga and Smith 1981; Anon 1982). Several workers notably Applebaum and Birk 1972, Gatehouse et al. 1979, Giga and Smith 1981, Painter 1958 and Singh and Allen 1980 reported that seeds of certain plant varieties possessed varying amounts of toxic chemical metabolites and inhibitors which cause adverse effects on the physiological processes of the larvae. This antibiotic effect is the basic source of cowpea resistance to C. maculatus (Singh and Allen 1980).

Such antibiotic effects of a plant variety on the developing insect pest constitutes the phenomenon referred to as host plant resistance (HPR). Snelling (1941) defined HPR as including "those characteristics which enable a plant to avoid, tolerate, or recover from the attacks of insects under conditions that would cause greater injury to other plants of the same species".

Modifying the foregoing definition, Painter (1951, 1958) stated HPR as "the relative amount of heritable qualities possessed by a plant which influence the ultimate damage done by the insect". Later this definition was further modified by Beck (1965) to mean "the collective heritable characteristics by which a plant species, race or clone or individual may reduce the probability of successful utilization of that plant as a host by an insect species, race, biotype or individual". The effects of host plant resistance on the development of insect pests have been very well documented (Painter 1958, Metcalf and Luckmann 1975, Horber 1972; Maxwell 1972).

The use of and effect of insect resistance varieties in reducing insect damage on plants is a conspicuous result as demonstrated by higher crop yields in resistant varieties (Painter 1951). In stored cowpea, resistant varieties suffer less seed-weight loss than susceptible varieties (Caswell 1956, 1961; Cutler 1956).

Using parameters such as oviposition prefer-ence, adult emergence, egg-adult development period, population increase of the pest and the seed-weight loss due to infestation by the pest, many different cowpea cultivars have been tested for their resistance or susceptibility to C. maculatus (Osuji 1976, 1982; Singh And Allen 1980; Yeshbir 1976; Yeshbir et al 1980; Giga and Smith 1981; Cutler 1956; Anon 1978a, 1980, 1982).

In Kenya although many different local cowpea varieties are grown, similar studies have not been conducted to ascertain their levels of resistance to the pest. Bearing in mind the foregoing information, it was felt that it would be of interest to study a few selected Kenyan cowpea varieties currently grown by farmers in Kitui district in Eastern Province where the bulk of the cowpea crop in Kenya is grown. The purpose of the studies reported here was to find out whether there are differences in the oviposition preference, adult emergence, population increase and seed-weight loss when C. maculatus are bred on these varieties. The information obtained would be useful in determining whether some of the varieties studied were resistant or susceptible to C. maculatus. A resistant cowpea variety (Tvu 2027) to the pest (Anon. 1978a) was used as a standard resistance check to determine the level of resistance or susceptibility in the selected local cowpea varieties.

CHAPTER TWO

2.0 MATERIALS AND METHODS

2.1.0 General preparation and procedures

Freshly harvested untreated seeds of four different cowpea varieties commonly grown in Kitui District, situated in Eastern Province of Kenya, were obtained from that District. These seeds were different in size, colour and seed-coat characteristics. Based on colour differences, they were designated into four groups, namely, Kitui White (KW), Kitui Red (KR), Kitui Cream (KC) and Kitui Brown (KB) (Table 1).

The dust and debris of crushed cowpea seeds were removed by sieving the seeds using a 4.0 mm sieve. The sieve had holes only big enough to allow the debris and not the whole seeds to pass through. Additionally an exotic cowpea variety, Tvu 2027 known to be resistant to C. maculatus was acquired from IITA through Dr. R.S. Singh for comparative studies together with the local cowpea varieties.

Each cowpea variety was placed in a separate polythene bag before being placed into the fumigation chamber at the National Agriculture Laboratories (NAL) Kabete. The seeds were fumigated for seven days using phostoxin pellets placed inside the bags. This treatment was necessary to stop further development of any bruchids that may have infested the crop in the field

Table 1: A description of the cowpea varieties collected from Kitui District for testing for resistance against C. maculatus.

Seed type (colour)	Size (seed diameter across the cheek in mm)*	Seed coat texture on a 1-5 scale **	Average shape of the cheeks of seeds	Kamba (local) name	Name adopted in this work
White	7.47	1	Fairly filled	Kangau	Kitui white (KW)
Red	8.03	3	Round and very well filled	Ndamba	Kitui red (KR)
Brown	7.68	1	Well filled	Ndune	Kitui brown (KB)
Cream	6.64	2	Fairly round and well filled	Kathoka	Kitui cream (KC)

* The diameter was measured with the seed lying on its side and the eye facing upwards; therefore = the length of the longitudinal section.

** Scale used : 1 = very smooth; 2 = smooth; 3 = average; 4 = rough; 5 = very rough before it was harvested.

After fumigation, the seeds were then removed and stored in a cool enclosed storage chamber that was kept clean and free from infestion by C. maculatus. In addition the polythene bags containing the seeds were tightly tied with strings to prevent entry into the bags by any insect pests.

The bags were then placed in separate nylon sacs before being placed in the storage chamber. This technique of storing cowpea seeds after freshly having been fumigated was found to be effective in preventing the re-infestation of cowpea seeds by insect pests especially C. maculatus for the whole of the experimental period which was about seven months.

Before the seeds were used for experimental purposes, the required amount of seeds (depending on the particular experiment) was taken out of the bags and spread on a 45 cm x 27 cm x 7 cm tray. The seeds were aired in open laboratory and additional fresh air was circulated by the use of a fan (TR6 Termizeta) for 1-6 hours. For instance seeds required for ovipositional preference studies (=20 gms) were aired for a maximum period of one hour before the start of the experiment while those used for adult emergence studies (=150 gms) were aired for six hours.

Fanning and airing the seeds was necessary in order to remove any residual dusts and vapours of the fumigant from the seeds. This was found necessary so as to ensure that the seeds used in the studies were free from any insecticide contaminations and did not carry any external chemical that would have adverse effects on the behaviour of the pest. Seeds considered well aired were then subsequently placed in the experimental room for seven days so as to equilibrate them to the experimental conditions. The moisture content of equilibrated experimental seeds was determined using the method explained by Pixton (1967) and was found to be 13.5 ± 1.5% for all the varieties.

In the study room, experimental conditions of average temperatures of 27.5 ± 1^{o}C and relative humidity (RH) of 70 ± 5% were maintained by using a thermostastically controlled heater (Model TR6 Termozeta) which is provided with a fan and a heating element. To maintain a high and fairly constant RH, several open water baths were placed in the study room to provide a large surface from which water evaporated. A Jennson Deluxe 50^{o} Celcius thermometer and a Pastorelli and Rapkins hygrometer were used to check and ensure that the temperature and the RH, respectively, were maintained at the required levels. Thus the experimental conditions ere established and checked on daily basis for two weeks to ascertain their consistency before bringing the cowpea seeds into the room to equilibrate them.

All experiments described in this work were carried out either in glass jars or glass vials. All glassware used in each experiment was first thoroughly washed in water containing soap solution and rinsed in clean tap water before being dried and sterilised in an air oven at 100^{o}C for one hour. After sterilisation the glass-ware was left to cool and remain in the oven until it was required for experiments.

The bruchids were usually separated from the beans for counting by sieving them out through a sieve (size 2.00mm). The sieve had holes large enough to just permit the passage of the insects and not the beans. After separation the number of adult bruchids was determined by using a mechanical (manual) hand tally counter (type H 102-4).

The glass jars or vials used in these studies had their mouth ends sealed off with a filter paper (Whatman No. 91) held in place by molten paraffin wax. This was done only when such jars or vials contained test materials of cowpea seeds and bruchids. After having been sealed off the jars of vials were then placed on supports of kilner jar ring tops or petri dishes (diameter 8 cm) which were half way or so immersed in liquid contained in a 45 cm x 27 cm x 7 cm trays (Fig. 1). This was necessary in addition to sealing the mouth ends of the jars or vials in order to prevent infestation of the bruchids by predatory Pyemotid mites and parasitic wasps like Neocatolaccus mamezophagus.

The first generation of bruchids was conditioned to the experimental conditions for two consecutive

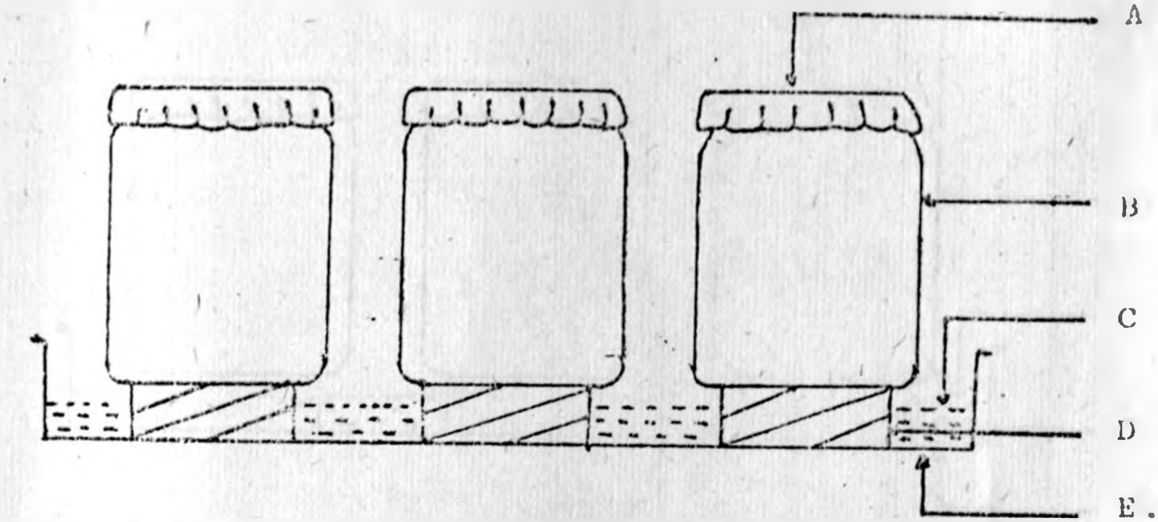

Fig. 1: A diagramatic representation of the experimental set-up.

Note:

A = Filter paper (Whatman no. 10) glued on the mouth of the experimental Kilner jar.

B = Kilner jar with the experimental material (C. maculatus adults (1 ♀ : 1 ♂) and different cowpea seed varieties).

C = Liquid paraffin poured evenly in the tray.

D = Kilner jar ring tops half emersed in oil, the Kilner jars are supported off the tray by these ring tops.

E Plastic tray holding all the Kilner jars used in one replication of an experiment.

generations (which took about 7 weeks) before the bruchids were used for experiments. At the end of the 7 weeks all the adult bruchids were sieved out from the seeds and discarded. The seeds were incubated for the next 24 hours to allow fresh adult bruchids to emerge. These bruchids were then sieved out and introduced into separate jars containing fresh seeds of the same rearing variety.

After every four weeks the culture population of the bruchids were inspected and any adults found were taken out and introduced to fresh cowpea seeds of the rearing variety. This was considered to be necessary so as to prevent resulting competition for ovipositional sites and food, arising from crowded rearing conditions.

The rearing of the bruchids was manipulated such that there were two groups of the insects which were different in age from each other by two weeks. This was found to be necessary in order that a steady supply of experimental insects whenever required was ensured or guaranteed.

To obtain bruchid adults of the same age (one day old) usually the rearing beans were examined and all the emerged adults removed and discarded. The seeds were then incubated and any adults produced within a period of 24 hours were removed and used for experimental purposes. The bruchids were sexed before being used in the experiments.

All visual observations of the bruchids as well as the eggs were made using a binocular microscope (Magnification: x 10). The design of all experiments was uniform, being of a completely randomised block design. All the data collected was subjected to statistical analysis to ascertain whether there were significant differences among the cowpea varieties studied for the parameters that were measured.

2.2.0 Determination of the original damage by *C. maculatus* on seeds of four different cowpea varieties collected from Kitui District, Eastern Province, Kenya.

The objective of this experiment was to assess the original damage caused by *C. maculatus* to four local cowpea varieties grown in Kitui District. This information would be useful in estimating the field infestation and damage caused by bruchids to different cowpea varieties. This study would also serve to indicate if there was any pre-harvest selection preference for any of the varieties studied.

One hundred seeds of each cowpea variety collected from Kitui district were picked at random from each of the bags containing each variety. Individual seeds in each of the 100 seed samples of each variety were examined for signs of infestation such as dark windows adult emergence holes and presence of eggs on the seeds.

The number of seeds with such symptoms out of one hundred seeds was recorded. Examined seeds were not returned to their respective bags but placed in their own separate containers. This was necessary in order to ensure that the same seeds were not picked for the next sample. Ten such samples for each cowpea variety were examined and an average field infestation determined for each cowpea cultivar.

2.3.0 Oviposition preference of C. maculatus on seeds of four local cowpea varieties and one exotic variety (Tvu 2027) and the associated emergence of adult bruchids

The objective of this experiment was to ascertain if there was any preference for oviposition on any particular variety when all the four local varieties were presented together to C. maculatus and when these varieties were presented to bruchids together with Tvu 2027 as a resistant check. The other objective of this study was to determine the proportional survival to adult emergence of the eggs laid on the seeds of the test varieties.

Samples of twenty clean seeds were randomly picked from the equilibrated test seed material of each of the five cowpea varieties to be studied. These samples of seeds numbering 100 for all the five varieties were placed in Kilner jars (size 450 ml) and then mixed together thoroughly. Eighteen adult bruchids aged one day (sex ratio 1:1) were introduced into the jars containing the mixed seed material. After this the jars were sealed off and arranged so that they were free from predators as previously described (Section 2.1). . This experiment was repeated five times.

Another set of samples of twenty clear seeds was randomly picked as before from the local cowpea varieties only. These samples of seeds numbering 80 for the four local varieties were placed into each of the five Kilner jars (size 450 ml) and then mixed together thoroughly. Sixteen adult bruchids aged one day (sex ratio 1:1) were introduced into the jars containing the mixed seed material. The jars were then sealed off as before. The foregoing experiment was repeated five times.

The insects in both sets of experiments were then left to mate and the females to lay eggs for five days. At the end of this period all the adults were sieved out. The seeds were then removed and regrouped into specific varieties for each replication of the experiments in both the sets of the experiments. Beans in each group were then examined individually and the eggs laid on them by C. maculatus counted.

After counting the eggs, the seeds of each group (i.e. per variety per replication) were then incubated in separate vials for the next thirty days for the bruchids to develop through to adult stage and emerge.

Emerged adults were removed and counted. These seeds were incubated further and checked daily for emerged adults which were usually removed if found and counted. When no more adults emerged for a period of seven consecutive days, the seeds were then dissected and the mature adults that died within the seeds removed and counted.

2.4.0 Incubation and hatching pattern of the eggs of C. maculatus on seeds of four different cowpea varieties.

The purpose of the experiment reported here was to ascertain whether eggs of C. maculatus hatched at different intervals or rates when laid on seeds of the four local cowpea varieties studied. Sixteen adult bruchids aged one day old (sex ratio 1:1) were introduced into each of the five Kilner jars (size 450 ml) containing 20 seeds of each test variety which had been thoroughly mixed. The insects were left to mate and the females to lay eggs for four days. After four days the adults were then removed and the seeds re-grouped into specific varities before the eggs laid on them were counted.

The seeds were subsequently inspected daily to determine the number of eggs hatching every day. Hatched eggs were identified from the unhatched eggs by the change of apprearance from transluscent or opaque when not hatched to milky white when the eggs had hatched.

After eggs that had hatched had been counted, they were then all carefully removed by using a scapel, to ensure that they were not counted again. The number of eggs hatching daily was recorded until no more eggs hatched for seven consecutive days, At the end of the experimental period all eggs that did not hatch as well as the seeds were discarded.. This experiment was repeated five times.

2.5.0 The pattern of emergence of adult C. maculatus in four different local cowpea varieties

This experiment was carried out to investigate the pattern of adult bruchid emergence and the cumulative emergence of the bruchids in four different local cowpea varieties. The aim of the study was to determine the resistance of the local varieties by comparing their performance as hosts for the development of the pest.

Fifty adults of C. maculatus aged one day (sex ratio 1:1) were introduced into each of the four Kilner jars (size 850 ml) each containing 450 gms of only one of the test varieties. The insects were left to mate and the females to lay eggs for five days. After this period the adult bruchids were removed and discarded. The seeds were incubated for the next 15 days to allow the bruchids to develop. After this incubation period, the seeds were inspected for signs of onset of emergence. The onset of emergence is indicated by the presence of dark windows on the seed coat. Emerged adults were removed from the jar, counted and recorded before being discarded. The seeds were left until the next day when emerged adults were again removed and counted. This procedure was repeated daily until no more adults emerged from the seeds for seven consecutive days. The experiment was repeated five times.

2.6.0 Cumulative emergence of adult C. maculatus and the subsequent loss of weight of seeds of four cowpea varieties at three different temperature regimes over a four month period.

The objectives of this study were as follows: To investigate the loss of weight inflicted on the seeds of different cowpea varieties by C. maculatus over prolonged storage period; to determine the relationship between bruchid population increase and seed weight loss in the cowpea varieties studied; and, to study the effect of temperature on weevil population increase and seed weight loss caused by the bruchids.

Twenty adults of C. maculatus aged one day old (sex ratio 1:1) were introduced into each of the four Kilner jars (size 450 ml) each containing 200 grams of seeds of each of the test cowpea variety. The jars were sealed and placed in an incubator at 20 ± 1°C and left undisturbed for five consecutive days for the bruchids to mate and the females to lay eggs. This procedure was repeated at two other temperature regimes which were 27 $\pm$ 1^{o}C and 34 $\pm$ 1^{o}C.

After the oviposition period, the adults were sieved out and the eggs that had been laid left to hatch and the larva to develop into adults for a period of three weeks. At the end of this period the adults that had emerged were counted and recorded before being discarded. The seeds were then weighed after the bruchids had been removed. After this operation the jars were then re-sealed and placed back in their respective experimental conditions. The jars were left for a further seven days at the end of which adults that had emerged were again removed, counted and recorded before being discarded. The seeds were then weighed as before. This operation was repeated for 13 consecutive weeks. The experiment was repeated five times.

CHAPTER THREE

3.0 RESULTS AND BRIEF DISCUSSION

3.1.0. Results of the determination of original damage by *C. maculatus* on seed of four different cowpea varieties obtained from Kitui District, Eastern Province, Kenya.

Table 2a shows the average number of seeds that were damaged in five samples of 100 seeds each of the four local varieties of cowpea that were studied. From these results (Table 2a) it was evident that the initial damage on the seeds of these varieties was low, being less than 3% for all the varieties. The variety Kitui white which had the highest number (2.65%) of seeds damaged per sample was regarded as being the most susceptible and most preferred by the bruchids before harvesting. The other varieties, namely: Kitui brown, Kitui red and Kitui cream sustained 2.56%, 2.53% and 2.50% of damaged seeds per sample, respectively. These results suggested that the bruchid *C. maculatus* did not have ready access to the seeds while still in pods.

Table 2a: The average number of seeds damaged by C. maculatus in four different cowpea varieties obtained from Kitui District.

Variety	Replications						
	I	II	III	IV	V	Total	X
Kitui white	2.92	2.43	2.45	2.55	2.92	13.27	2.65
Kitui red	3.00	2.00	2.35	2.74	2.55	12.64	2.53
Kitui cream	3.16	2.55	2.45	2.35	2.00	12.51	2.50
Kitui brown	2.66	2.66	2.55	1.87	3.08	12.82	2.56

Table 2b: Analysis of variance for the number of seeds damaged by C. maculatus in four different cowpea varieties from Kitui district.

Source	df	SS	MS	F	
Total	19	2.3648			
Varieties	3	0.0649	0.0216	0.1503	NS
Error	16	2.2999	0.1437		

Variety means: KW = 2.65 KR = 2.53 KC = 2.50 KB = 2.56

S.E. of a mean = 0.1695 CV = 14.81%

The analysis of variance (Table 2b) revealed that the initial field damage was almost equal in all the four varieties sampled. The mean numbers of damaged seeds of these varieties showed no significant differences at the level of significance of P = 0.05.

3.2..0 Results of the oviposition preference of <u>C. maculatus</u> on seeds of four local and one exotic cowpea varieties and the associated emergence of adult bruchids.

During these investigations, it was observed that the highest number of eggs were deposited on the large seeded, smooth and brown variety Kitui brown (Table 3a). An average of 4.14 eggs per seed were recorded on the seeds of this variety. It had on average 0.38 more eggs laid per seed than on seeds of Kitui white (KW) which on average had 3.76 eggs per seed laid on them. Interestingly this variety (Kitui white) also had exactly 0.38 eggs per seed more than the number of those deposited on the variety Kitui cream. An average of 3.38 eggs per seed was recorded on seeds of this variety (Table 3a). Furthermore seeds of the variety Kitui red which are bigger in size but possess a comparatively rough testa had the least number of eggs deposited on them. On this variety, only 2.84 eggs were laid per seed (Table 3a). This is about 0.54 eggs less than the number of eggs laid on seeds of the variety Kitui cream which is the variety closest to it in terms of the number of eggs deposited per seed (Table 3a). Additionally, this value is 1.3 eggs less than the number of eggs which were recorded on the Kitui brown.

The foregoing results indicated that the variety Kitui brown was the most preferred of all the other varieties tested for oviposition by the females of C. maculatus. The variety Kitui red emerged as being the least preferred for oviposition by these bruchids. The other varieties, namely, Kitui white, and Kitui cream were intermediate between Kitui brown and Kitui red in their influence on the female bruchids as hosts for oviposition. Similar preference for oviposition on seeds with a smooth testas was observed by Booker (1967), and Nwanze and Horber (1975, 1976).

When the data collected was subjected to statistical analysis (Table 3b) it was further revealed that there were significant ($P = 0.01$) differences in the number of eggs laid on seeds of the four different test varieties. At this level of significance ($P = 0.01$) it was found that no two varieties influenced oviposition of females in the same way. Each variety was different from the others in its suitability as a host for oviposition. Considering that all the varieties were presented together to the bruchids, and that the seeds

Table 3a: The mean number of eggs of C. maculatus laid per seed in four local cowpea varieties.

Variety	Replications I	II	III	IV	V	Total	X
Kitui white	3.85	3.64	3.64	3.74	3.91	18.78	3.76
Kitui red	2.90	2.80	2.82	2.78	2.90	14.20	2.84
Kitui cream	3.43	3.37	3.30	3.30	3.52	16.92	3.38
Kitui brown	4.23	4.05	4.15	4.01	4.26	20.70	4.14

Table 3b: Analysis of variance for the number of eggs of C. maculatus laid per seed on four local cowpea varieties.

Source	df	SS	MS	F
Total	19	4.7580		
Varieties	3	4.6030	1.5343	158.1787***
Error	16	0.1550	0.0097	

Variety means: KW = 3.76 KR = 2.84 KC = 3.38 KB = 4.14

S.E. of a variety mean = 0.0440

CV = 2.79%

LSD 0.05 = 0.13

LSD 0.01 = 0.18

were evenly spread, differences in the number of eggs deposited on their seeds was influenced by other factors such as colour and morphological characteristics of the seeds.

The eggs thus laid were incubated and the larvae left to develop until the adult bruchids emerged. Data on the average number of adult C. maculatus that emerged from the seeds of the test varieties is shown in Table 4a. The variety Kitui brown yielded the most number of adults per seed, this being 2.88 as compared to 2.67, 2.54 and 2.24 adults in the varieties Kitui white, Kitui cream and Kitui red, respectively. This is not surprising in view of the fact that the distribution of eggs on the seeds of these varieties (Table 3a) followed a similar trend. These results (Table 4a) suggested that the variety Kitui brown was a much better host for the development of C. maculatus than any other varieties that were tested. On the other hand Kitui red was the worst host and because of this it was considered as having some levels of resistance to the pest.

Statistical analysis of the number of adult bruchids yielded by seeds of each of the varieties is shown on table 4b. Results of this analysis indicated that there were significant (P = 0.01) differences among the test varieties with regard to the number of adult C. maculatus that successfully completed development inside the seeds. This meant that seeds of different

Table 4a: The average number of adults emerged per seed in four local cowpea varieties

Variety	Replications						
	I	II	III	IV	V	Total	X
Kitui white	2.67	2.66	2.65	2.63	2.73	13.34	2.67
Kitui red	2.25	2.22	2.23	2.18	2.30	11.18	2.24
Kitui cream	2.55	2.51	2.48	2.48	2.68	12.70	2.54
Kitui brown	2.91	2.85	2.85	2.81	2.97	14.39	2.88

Table 4b: Analysis of variance for the number of adults emerged per seed.

Source	df	SS	MS	F
Total	19	1.1393		
Varieties	3	1.0824	0.3608	101.4552***
Error	16	0.0569	0.0036	

Variety means: KW = 2.67 KR = 2.24 KC = 2.54 KB = 2.88

S.E. of variety mean = 0.0268

CV = 2.32%

LSD 0.05 = 0.08

LSD 0.01 = 0.11

varieties had different capacities to support the bruchid development. This finding confirmed earlier observations which gave similar results (Osuji 1982). It was concluded from the data presented (Table 4a and b) that the internal environment of seeds of the variety Kitui brown was more suitable for bruchid development than of seeds of the other varieties.

To verify this matter, it became necessary to ascertain whether the higher number of adults yielded by the variety was due to the higher number of eggs deposited on its seeds. A correlation coefficient test between the number of eggs deposited on the seeds and the number of adults that emerged from the test varieties was performed. This test showed that there was a very high correlation ($r = + 0.9885$) between the number of eggs deposited and the number of adults produced. The observed high correlation coefficient value ($r = + 0.9885$) indicated that adult bruchid emergence increased with the increase of number of eggs deposited. This is best illustrated in a scattergram showing the relationship between the two parameters as shown in Fig. 2. It is not surprising therefore that the variety Kitui brown which had the most number of eggs deposited on its seeds also had the largest number of adults yielded.

Interestingly however, the proportion of the egg-adult survival (Table 5; Fig. 3) showed that it was in the variety Kitui red that the highest percentage of eggs laid completed development and emerged as

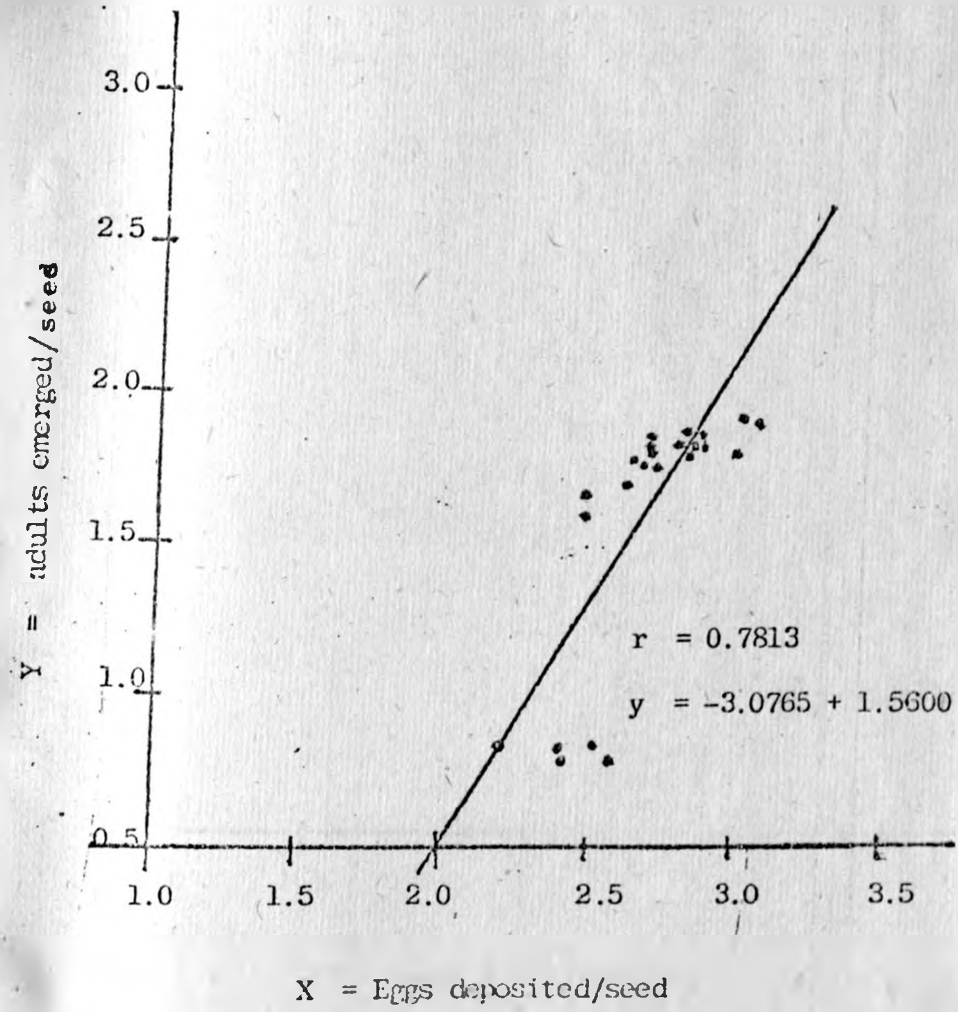

Fig. 2: Correlation between the mean number of eggs laid per seed and the mean number of adults emerged from the seeds.

Table 5: The egg-adult proportion survival in four local cowpea varieties tested.

Variety	Average no. of eggs/seed	Average no. adults/seed	Percentage egg-adult survival
Kitui white	3.76	2.67	71.01
Kitui red	2.84	2.24	78.87
Kitui cream	3.38	2.54	75.15
Kitui brown	4.14	2.88	69.57

$$\text{Percentage egg-adult survival} = \frac{a}{b} \times 100$$

where a = number of adults emerged per seed.

b = number of eggs laid per seed

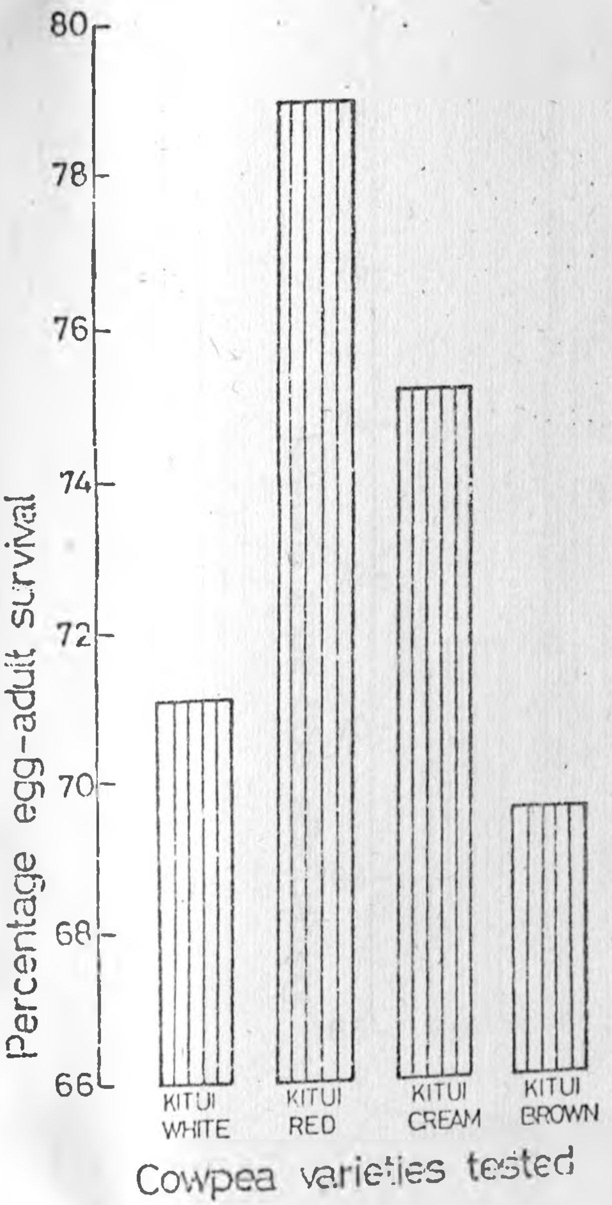

Fig 3: Percentage of egg-adult survival of C. *maculatus* in the four local cowpea varieties.

adults. In this variety, 78.87% of the eggs that were deposited on the seeds successfully completed development and then emerged as adults. The variety Kitui brown which had the highest number of eggs laid on its seeds and subsequent adults emerged turned out to give the lowest egg-adult proportional survival. On this variety 69.57% of the total eggs laid developed to adults. Kitui cream, which in the previous tests (Tables 2a and 3a) was about the third best preferred host gave the second highest egg-adult proportional survival value, (75.15%). In the variety Kitui white, 71.01% of the eggs laid developed to adults. These results indicated that where fewer eggs were deposited per seed, most of them hatched and the larvae developed successfully

The results (Tables 4a and b) obtained in this experiment showed that the variety Kitui brown was the most suitable host for oviposition and development of C. maculatus. Therefore, it was taken as being the most susceptible host.

To find out the extent of resistance of the test varieties it become necessary to test them against an exotic variety Tvu 2027 which has been reported (Anon. 1982) as being resistant to C. maculatus. When Tvu 2027 was presented together with the local cowpea varieties used in these studies for oviposition by C. maculatus, there was a marked difference in the distribution of eggs (Table 6a) from that which was observed when only local varieties (Table 3a) were presented to the pest.

Table 6a shows the average number of eggs that were deposited per seed on the different cowpea varieties studied. From these results (Table 6a) it was observed that the local varieties Kitui brown and Kituti white had fewer eggs deposited on them while the varieties of Kitui red and Kitui cream received more eggs than in the previous experiments (Table 3a) when only the local varieties were tested. On the variety Kitui brown 3.82 eggs per seed were recorded compared to 4.14 eggs per seed when Tvu 2027 was not used. The difference (0.32 eggs) constituted a 7.73% drop in the number of eggs deposited on this variety. On seeds of Kitui white 3.32 eggs per seed (Table 6a) were deposited as compared with 3.76 eggs per seed in the previous experiment (Table 3a). There was therefore reduction of 11.70% in the number of eggs laid.

On the other hand, there was a marked increase of about 16.55% in the number of eggs deposited on seeds of the variety Kitui red. While in the previous investigation (Table 3a) only 2.84 eggs per seed were deposited, when Tvu 2027 was introduced, an average of 3.31 eggs per seed were recorded. Similarly in the variety Kitui cream, there was an increase of 10.06% in the number of eggs laid on the seeds. In the experiment involving only the local varieties this variety had an average of 3.38 eggs deposited per seed. When the local varieties were tested together with Tvu 2027 this variety (Kitui cream) received an average of 3.76 eggs

Table 6a: The average number of eggs of C. maculatus deposited per seed on five different cowpea varieties.

Variety	Replications					Total	X
	I	II	III	IV	V		
Kitui white	3.40	3.65	2.90	3.20	3.43	16.58	3.32
Kitui red	3.60	3.35	2.95	3.25	3.40	16.55	3.31
Kitui cream	3.98	3.78	3.33	3.68	3.83	18.60	3.72
Kitui brown	4.10	3.80	3.58	3.68	3.95	19.11	3.82
Tvu 2027	3.03	3.08	2.48	2.80	2.80	14.19	2.84

Table 5b: Analysis of variance for the number of eggs of C. maculatus deposited per seed on five cowpea varieties.

Varieties	df	SS	MS	F
Total	24	4.2344		
Varieties	4	3.0508	0.7627	12.8878***
Error	20	1.1836	0.0592	

Variety means: KW = 3.32 KR = 3.31 KC = 3.72

KB = 3.82 Tvu 2027 = 2.84

S.E. of a variety mean = 0.1088

CV = 7.15%

LSD 0.05 = 0.32

0.01 = 0.44

per seed. In this experiment Tvu 2027 had the lowest number of eggs deposited on it, this being 2.84 eggs per seed (Table 6a).

Statistical analysis of the data collected (Table 6b) showed that there were no significant (P = 0.05) differences between the varieties Kitui brown and Kitui cream (Table 6b). These two varieties influenced oviposition in the same way and were the most preferred for oviposition by the bruchids. The other varieties preferred for oviposition were the Kitui red and Kitui white which showed no significant differences between them at 5% level of significance. These two varieties were significantly (P = 0.05) different from Kitui cream. Lastly the variety Tvu 2027 which was the least preferred for oviposition was found to be significantly (P = 0.05) different from all the local varieties tested.

These results (Tables 6a and b) showed that the local varieties were all good hosts for oviposition by the bruchid C. maculatus as compared to the exotic variety Tvu 2027. This confirmed the results (Tables 4a and b) from the previous experiment which also indicated that all the local varieties were suitable hosts for oviposition by the bruchid. It was again observed that Kitui brown was better preferred for oviposition than the other local varieties. Kitui red on the other hand with the least number of eggs, indicated more resistance than the other local varieties. Preference for oviposition on the brown seeds is not a peculiar occurence as studies conducted at IITA (1982) showed.

In addition the results (Table 6a) presented here revealed a very important phenomenon. This is the possibility of colour of one variety influencing the acceptability of another variety of the same colour for bruchid oviposition. This was demonstrated by the reduced number of eggs deposited on the seeds of the local variety Kitui white when the variety Tvu 2027 was present (Table 6a), in comparison to when only the local varieties were tested alone (Table 3a). This suggested that the similarities in colour between Tvu 2027 and Kitui white caused the bruchids to avoid seeds of Kitui white which they had accepted before.

The eggs laid on local varieties and Tvu 2027 were incubated until adults developed and emerged. The results of emerged adults are shown on table 7a. These results indicated that the variety Kitui cream with 2.76 adults emerged per seed yielded the highest number of adults. Comparing the number of eggs laid with the number of adults hatched in different varieties, it was found that although the variety Kitui red had fewer adults emerged than Kitui cream, it had the highest (77.34%) percentage of eggs surviving to adult (Table 8; Fig. 4). Furthermore the variety Kitui brown with the highest number of eggs laid on it gave the lowest (70.91%) egg-adult survival of all the local varieties.

These results confirmed earlier findings in which it was observed that although the variety Kitui red had fewer eggs deposited on its seeds, it had a higher

Table 7a: The average number of adult C. *maculatus* emerged per seed in five cowpea varieties.

Variety	Replications					Total	X
	I	II	III	IV	V		
Kitui white	2.55	2.70	2.18	2.40	2.65	12.48	2.49
Kitui red	2.75	2.55	2.37	2.58	2.55	12.80	2.56
Kitui cream	2.90	2.67	2.68	2.65	2.88	13.78	2.76
Kitui brown	2.80	2.73	2.68	2.65	2.70	13.56	2.71
Tvu 2027	0.65	0.55	0.65	0.58	0.62	3.05	0.61

Table 7b: Analysis of variance for the number of adults emerged per seed in five cowpea varieties.

Source	df	SS	MS	F
Total	24	16.8794		
Varieties	4	16.5474	4.1369	249.2108***
Error	20	0.3320	0.0166	

Variety means KW = 2.49 KR = 2.56 KC = 2.76 KB = 2.71

Tvu 2027 = 0.61

S.E. of a variety mean = 0.0576

CV = 5.79%

LSD 0.05 = 0.17

0.01 = 0.23

potential than any of the other local varieties to support development of the bruchid (Table 5).

It was observed in these studies that Tvu 2027 had the lowest number of adults emerged, this being 0.61 adults per seed (Table 7a). This value was significantly (P = 0.01) different from the corresponding values obtained for the local varieties (Table 7b). The egg-adult survival value in this variety was also very low, being 21.81% (Table 8). Since this variety had the lowest number of eggs deposited on its seeds, it would be expected that it would have the highest egg-adult survival percentage because there would be less competition for food by larvae. The extremely low yield of adults in this variety points to the possibility of there being a "factor" within the seeds that hinders either most of the eggs from hatching or the hatched larvae from developing to maturity. Clearly, this factor is lacking in the local varieties - as is indicated by their high egg-adult survival rates. For example the variety Kitui red which in the previous experiment had an average of 2.84 eggs deposited per seed (which was the same number of eggs deposited on Tvu 2027 in this experiment) had the highest egg-adult survival rate of 78.87% compared to the 21.81% in Tvu 2027 (Table 8).

From the results of the experiments reported in this section it was concluded that, compared to Tvu 2027, all the local varieties tested were susceptible to C. maculatus. In both oviposition preference and adult

Table 8: The egg-adult proportion survival in the five cowpea varieties tested.

Variety	Average no of eggs/seed	Average no of adults/seed	Percentage egg-adult survival
Kitui white	3.32	2.49	75.00
Kitui red	3.31	2.56	77.34
Kitui cream	3.72	2.76	74.19
Kitui brown	3.82	2.71	70.91
Tvu 2027	2.84	0.61	21.81

$$\text{Percentage egg-adult survival} = \frac{a}{b} \times 100$$

where a = number of adults emerged/seed

b = number of eggs laid per seed

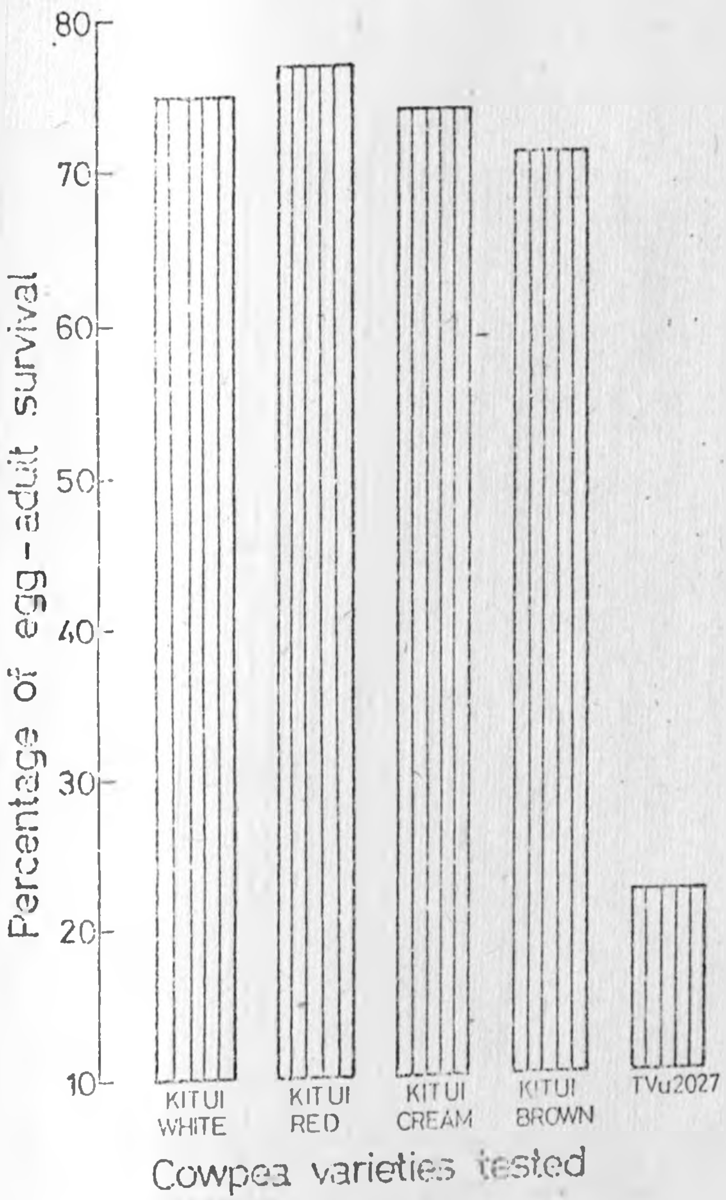

Fig. 4: Percentage of egg-adult survival of <u>C. maculatus</u> in five Cowpea varieties.

emergence, these local varieties proved to be the more suitable hosts for this pest than the resistant check Tvu 2027. Among the local varieties it was further concluded that Kitui brown was the most suitable host for oviposition by the bruchids. However Kitui red, though initially avoided for oviposition, had a high potential for supporting both eggs hatching and larval development. This potential to some extent was lacking in Kitui brown and was varying in the other local varieties tested.

3.3.0 Results of the hatching pattern of eggs of C. maculatus on seeds of four different local varieties

Results of the daily hatching of eggs of C. maculatus on seeds of local cowpea varieties studied are shown on Table 9. From these results (Table 9) it was observed that the incubation period lasted for an average of days in Kitui white and Kitui cream. On the other hand in the cowpea varieties Kitui red and Kitui brown the hatching period lasted for 9 days (Table 9). In the latter varieties the hatching of eggs started a day earlier as compared to those eggs laid on Kitui white and Kitui cream. It was also observed that hatching of eggs ended on the same day for all the varieties (Table 9). This was on the ninth day after the start of hatching of the first eggs.

It was further observed (Table 9) that on the varieties Kitui red and Kitui brown, the hatching peak was reached on the 4th day after the commencement of hatching. In Kitui red, 33.96% of the eggs hatched on the 4th day. Similarly Kitui brown 28.18% of the eggs hatched on this same day. Hatching peak in the other two varieties also occurred on this day. However, this was the 3rd day after the onset of hatching for the eggs deposited on these varieties (Table 9). On this day a total of 32.29% of the eggs hatched on the variety Kitui white while on the variety Kitui cream, 31.68% of the eggs hatched.

These results (Table 9) would suggest that the varieties Kitui red and Kitui brown were better hosts in terms of an earlier onset of hatching of eggs of C. maculatus. However it was also found that on the first day of hatching, only about 0.38% and 0.28% eggs were hatched on Kitui red and Kitui brown, respectively. On the other hand 3.45% and 3.96% of the total eggs laid on Kitui white and Kitui cream, respectively, hatched on the first day of hatching on these varieties. The short time in which the peak of hatching was reached in the varieties Kitui white and Kitui cream and the higher percentage of hatched eggs at the onset of hatching indicated that these two varieties were considerably better than Kitui red and Kitui brown as hosts for stimulation of hatching of C. maculatus eggs.

Additionally, the cumulative frequency (Table 9) showed that most of the eggs were hatched on variety Kitui brown, this being 18.10 eggs per seed while on varieties Kitui white, cream and red totals of 15.95, 15.15 and 13.25 eggs respectively, were recorded. This confirmed earlier observations established in the oviposition preference experiments (Tables 3a and 6a) which showed that this variety was a suitable host for oviposition. Therefore, the higher number of egg that hatched were taken as resulting from an equivalent higher number of eggs initially laid. The earlier onset of hatching on this variety probably resulted from the fact that eggs were first deposited on it before the bruchids started laying eggs on other varieties.

An interesting observation here was on the variety Kitui red. In the previous investigation, (Section 3.2) this variety, was found to be the least preferred for oviposition. It would be assumed that seeds of this variety were utilized as hosts by C. maculatus only after the seeds of other varieties had been used. However, hatching started earlier on this variety as on Kitui brown, than on Kitui cream and Kitui white. In addition Kitui red had the highest hatching peak in terms of the percentage of hatched eggs (33.96%) (Table 9). The reasons for these peculiarities regarding this variety were not immediately known.

Table 9: The average number of *C. maculatus* eggs hatched per seed and their cumulative hatching frequency in four local varieties of cowpeas.

Days after start of egg-hatching *		Mean no. of eggs hatched per seed in each variety				Cumulative frequency of egg-hatching in each variety			
		KW	KR	KC	KB	KW	KR	KC	KB
1.	(5)	-	-	-	-	-	-	-	-
2.	(6)	0.00	0.05	0.00	0.05	0.00	0.05	0.00	0.05
3.	(7)	0.55	0.55	0.60	0.75	0.55	0.60	0.60	0.80
4.	(8)	3.85	2.80	3.00	4.15	4.40	3.40	3.60	4.95
5.	(9)	5.15	4.50	4.80	5.10	9.55	7.90	8.40	10.05
6.	(10)	4.00	3.45	4.45	4.55	13.55	11.35	12.85	14.60
7.	(11)	1.55	1.20	1.40	2.00	15.10	12.55	14.25	16.60
8.	(12)	0.60	0.50	0.60	1.00	15.70	13.05	14.85	17.60
9.	(13)	0.20	0.15	0.25	0.45	15.90	13.20	15.10	18.05
10.	(14)	0.05	0.05	0.05	0.05	15.95	13.25	15.15	18.10
11.	(15)	0.00	0.00	0.00	0.00	15.95	13.25	15.15	18.10

* Figures in the brackets are the number of days after the on set of oviposition.
Day 1 of hatching corresponds to day 5 after oviposition and it is on this day that adult bruchids were removed from the experimental jars.

3.4.0 Results of the pattern of emergence of adults of *C. maculatus* in four different local cowpea varieties

The emergence of adult bruchid commenced on the 25th day after oviposition started in all the varieties and continued for the next fourteen days, until the 39th day (after oviposition commenced). Table 10 shows the mean number of adult bruchids that emerged from the seeds expressed as adults per gram of the seed material. From these results it was observed that the highest number of bruchids emerged per gram of seeds was 0.98 and was recorded on the variety Kitui white. The peak emergence in this variety was recorded on the 5th day after emergence commenced. Similarly the peak of emergence of bruchids from seeds of the variety Kitui brown was also reached on the same (fifth) day although the number recorded was 0.96 adults per gram of seeds. Peak emergence in the other two varieties occurred one day later i.e. on the 6th day after emergence began. The variety Kitui cream had 0.95 adults per gram of seeds while Kitui red yielded only 0.94 adults per gram seeds.

This indicated that the internal constituents of seeds of the varieties Kitui white and Kitui brown provided a more suitable substrate on which *C. maculatus* larvae developed faster than that provided by the seeds of the varieties Kitui red and Kitui cream. Considering

Table 10: The average (mean) number of adults of C. maculatus emerged per gram of seeds of four local different cowpea varieties, and the cumulative adult-emergence frequency in the four varieties

Days after start of adult emergency	*	Mean no. of adults emerged in each variety				Cumulative frequency of adults emerged			
		KW	KR	KC	KB	KW	KR	KC	KB
1.	(25)	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.04
2.	(26)	0.22	0.20	0.21	0.23	0.26	0.23	0.24	0.27
3.	(27)	0.62	0.56	0.59	0.63	0.88	0.79	0.83	0.90
4.	(28)	0.86	0.82	0.85	0.86	1.74	1.61	1.68	1.76
5.	(29)	0.98	0.90	0.94	0.96	2.72	2.51	2.62	2.72
6.	(30)	0.93	0.94	0.95	0.92	3.65	3.45	3.57	3.64
7.	(31)	0.80	0.79	0.81	0.81	4.45	4.24	4.38	4.45
8.	(32)	0.60	0.62	0.59	0.62	5.05	4.86	4.97	5.07
9.	(33)	0.41	0.40	0.39	0.41	5.46	5.26	5.36	5.48
10.	(34)	0.21	0.21	0.21	0.22	5.67	5.47	5.57	5.70
11.	(35)	0.12	0.11	0.11	0.13	5.79	5.58	5.68	5.83
12.	(36)	0.05	0.05	0.06	0.06	5.84	5.63	5.74	5.89

Table 10 continues

Table 10 Continued

13.	(37)	0.02	0.02	0.03	0.02	5.86	5.65	5.77	5.91
14.	(38)	0.01	0.01	0.01	0.01	5.87	5.66	5.78	5.92
15.	(39)	0.00	0.00	0.00	0.00	5.87	5.66	5.78	5.92
16.	(40)	0.00	0.00	0.00	0.00	5.87	5.66	5.78	5.92

* Figures inside the brackets refer to the number of days after the onset of oviposition.

that hatching occurred earlier in Kitui brown and Kitui red than in Kitui white and Kitui cream (table 9), it can be deduced that the varieties Kitui brown and Kitui white were indeed more suitable hosts for developing larvae than Kitui red and Kitui cream. The latter two varieties therefore are comparatively resistant to the larvae development than the former.

The pattern of emergence of the bruchids in all the four varieties over the whole emergence period (Table 10, Fig. 5) showed that in all the varieties, the largest majority of adults was recorded between days 4-7 after the start of emergence. This indicated that in general all the four varieties influenced the developing larvae in the same pattern. The cumulative emergence frequency (Table 10, Fig. 6), further confirmed that except for the numbers that emerged in different varieties there was a similar pattern in the increase of the total numbers emerged after each day. The developmental period of the bruchid in these varieties was the same.

It was concluded from these results that all the four varieties tested were suitable for the development of C. maculatus. This observation was confirmed by the number of adults produced in the very first few days of emergence (Table 10) and the steep rise in the emergence curve (Fig. 6).

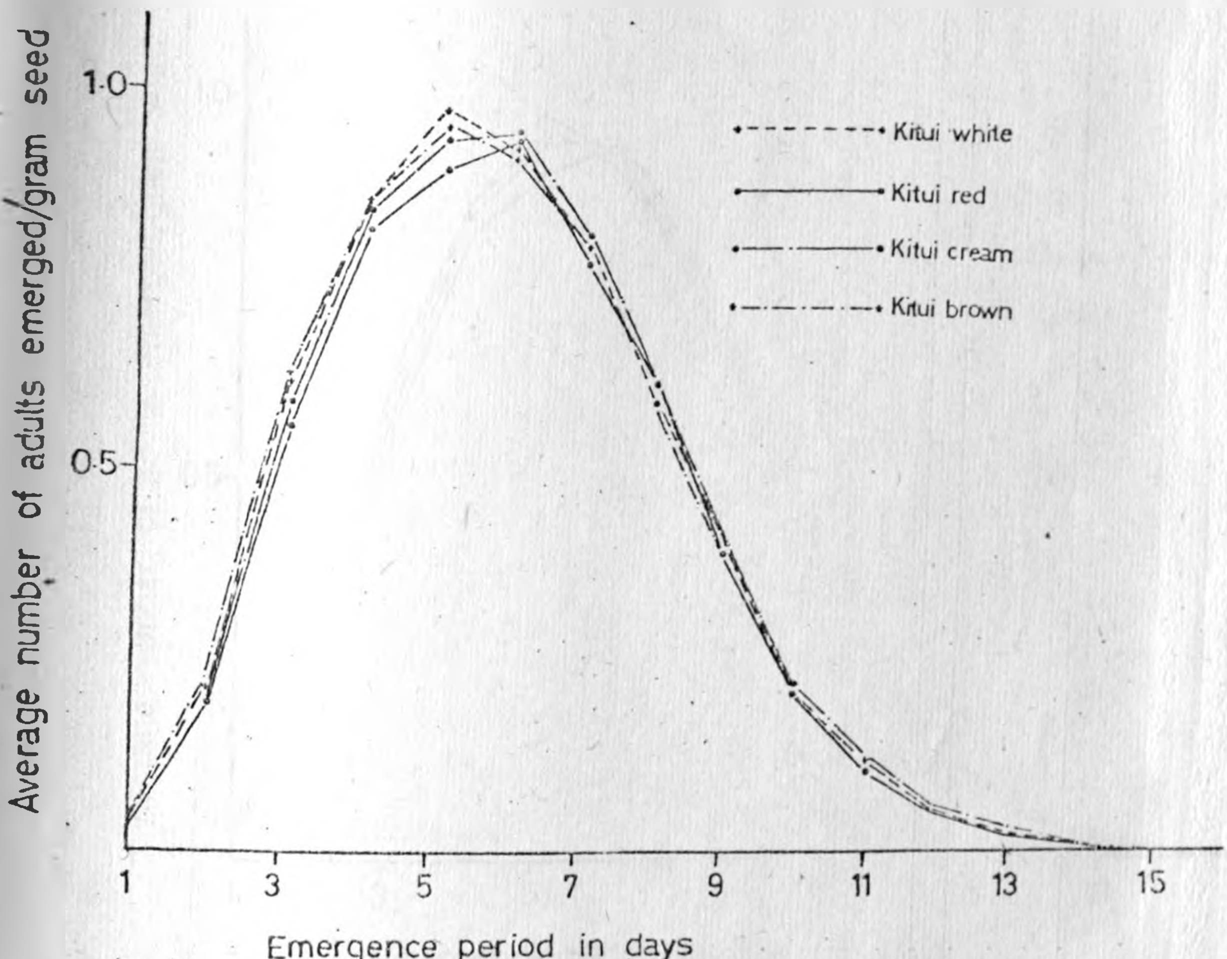

Fig.5: The average daily emergence of adult C. maculatus from seeds of four cowpea varieties during one generation of bruchids.

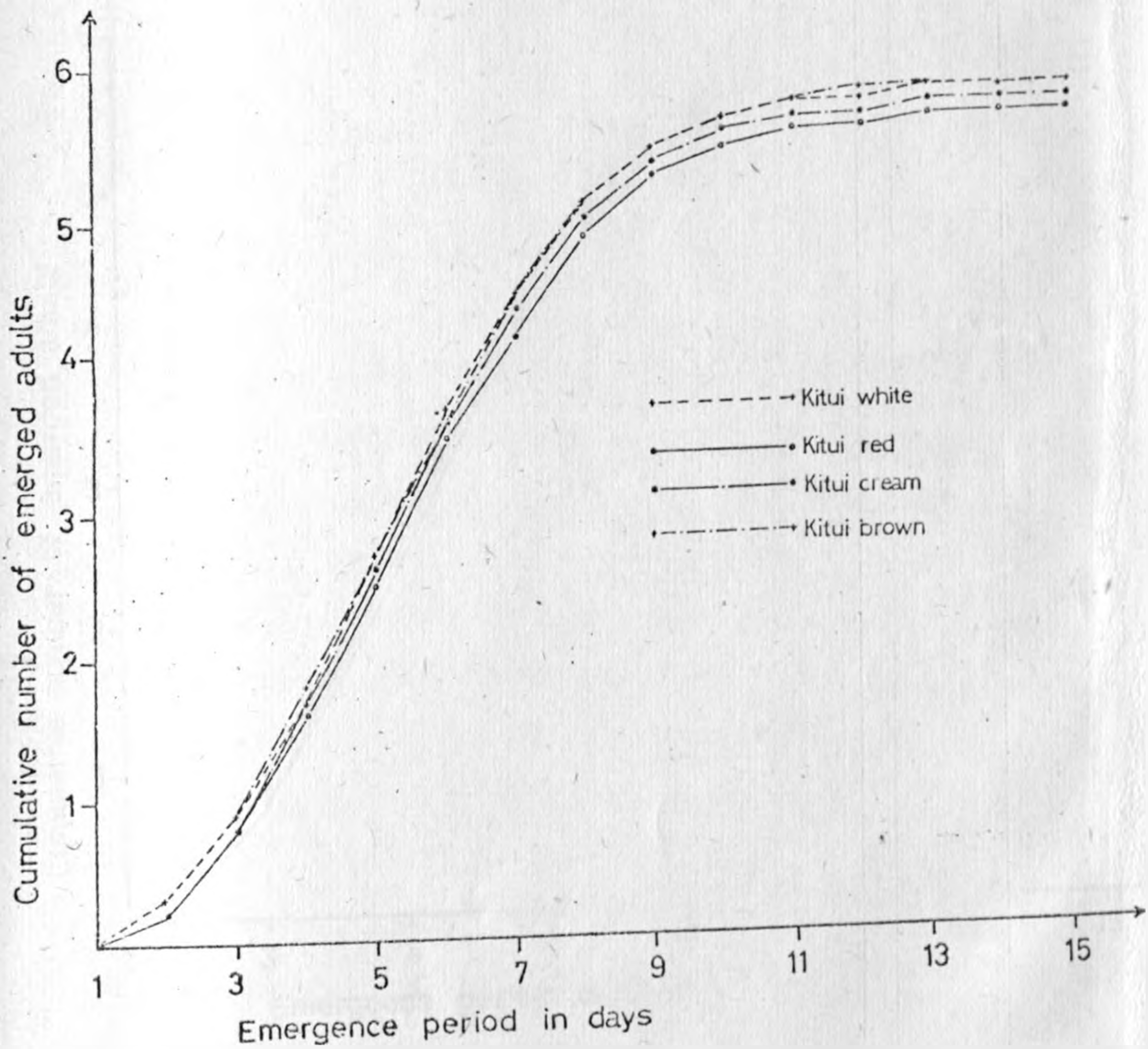

Fig. 6: The cumulative emergence of adult *C. maculatus* from seeds of four cowpea varieties during one generation of bruchids

3.5.0 Results of the cumulative emergence of adult *C. maculatus* and associated loss of weight in seeds of four cowpea varieties held at three different temperature regimes over a period of four months

The total numbers of bruchids emerged from seeds held at different temperatures by the end of four months are shown on table 11a. The weight loss incurred by the seeds due to the development and emergence of adult bruchids is shown on table 11b.

From these results it was found that at 20°C, 27°C and 34°C the variety Kitui red yielded the largest number of adult bruchids (Table 11a) and suffered the greatest weight loss (Table 11b). It was also found that the variety Kitui white had the least number of emergence adults recorded and also the least amount of weight lost by the seed.

The varieties Kitui cream and Kitui brown were intermediate in the number of adults produced and the total weight lost. However, Kitui cream yielded more bruchids than Kitui brown and also had more weight lost by the seeds.

Results of this experiment indicate that the variety Kitui red was the best host for the development of *C. maculatus*. It was in this variety that most bruchids emerged and greatest weight lost by the seeds. This contradicts earlier findings in the previous experiments

Table 11a: The average number of adult C. maculatus that emerged from seeds of four different cowpea varieties at three temperature regimes for a period of four months.

Variety	Average number of bruchids emerged at different temperature regimes		
	20°C	27°C	34°C
Kitui white	11204.50	19210.00	18119.00
Kitui red	11333.50	19662.00	18342.50
Kitui cream	11313.00	19466.00	18273.00
Kitui brown	11277.50	19227.50	18071.50

Table 11b: The average weight in grams lost by seeds of different varieties after adult C. maculatus emerged from them at three temperature regimes for a period of four months.

Variety	Average weight in grams lost by seeds at different temperature regimes		
	20°C	27°C	34°C
Kitui white	36.06	55.40	48.60
Kitui red	37.98	58.90	51.30
Kitui cream	37.64	57.90	50.40
Kitui brown	36.61	56.63	49.31

whereby the variety Kitui brown was found to be the most suitable host for *C. maculatus* and Kitui red to be the least suitable host (sections 3.2 and 3.4). This is true when the totals, at the end of the four month period only are considered.

Weekly emergence of bruchids at different temperatures (Appendices 1, 2 and 3) showed that there were fewer bruchids emerging per week from the variety Kitui red in the first six weeks of emergence than at 27°C and 34°C. At 20°C the variety Kitui red yielded the least number of adult bruchids until the fifth week (Appendix 1). Thus if the experiments were stopped at the fifth week for all the varieties at the three temperature regimes, the variety Kitui red would have emerged as the least suitable host for *C. maculatus* development. Like in the experiments reported earlier in this work, the variety Kitui brown would have emerged as the best suitable host for the development of the bruchid.

Totals of emerged bruchids after the eighth week at 27°C and 34°C (Appendices 2 and 3 respectively), and the tenth week at 20°C (Appendix I) showed that the variety Kitui red yielded more bruchids each week than the other varieties. The variety Kitui brown yielded the least number of adults each consecutive week as compared to the other three varieties. This indicated that the ability to support the development of the bruchids decreased with time in the variety Kitui brown while it increased in Kitui red. These differences in the final totals of emerged adults may be explained in terms of larval food competition (Giga and Smith 1981). Because there were fewer eggs deposited per seed in Kitui red in the initial oviposition (Table 3a), there was less larval food competition. As a result most of the eggs laid hatched and successfully developed to adults. The large and well filled seeds of the variety Kitui red (Table 1) are able to sustain a higher population after the 2nd generation (weeks 4-7 in appendices 1, 2 and 3) than the other varieties. In the variety Kitui brown for example, where intially more eggs are deposited (Table 3a) the increased larval food competition within the first and second generations (weeks 4-7 in appendices 1, 2 and 3) reduced the population increase in the third and fourth generations.

After the 9th week it was observed that in the varieties Kitui brown, Kitui white and Kitui cream many bruchids died on emergence before they laid any eggs . . This factor definitely had a negative effect on the increase of the pest population in these varieties. On the other hand, the variety Kitui red continued to produce healthy adults until the 12th week. On the 13th week, it was observed that some adults emerged and died immediately.

Considering the weight lost by the seeds after each bunch of bruchids emerged each week, it is clear that the seeds of the variety Kitui brown were more susceptible than those of other varieties in the first four weeks of emergence. In the last four weeks of the experiment, the seeds of the variety Kitui red lost more weight compared to those of other varieties. These results showed that increased loss in weight by the seeds corresponded to the increased number of adults emerging. It is therefore not surprising that the variety Kitui red, which yielded the most number of bruchids over the whole period at the three temperature regimes also had the greatest seed weight loss recorded.

The results from this experiment confirmed that the variety Kitui brown was a more suitable host for C. maculatus in the first 1½ months of grain storage. During prolonged storage, the variety Kitui red became a more suitable host. This indicate that all the four varieties tested were suitable for the development of the cowpea bruchid C. maculatus and as such they were all susceptible to the pest. However, the susceptibility to the pest of different varieties varies with the extent of the storage period. The variety Kitui red was found to be the least susceptible of the four local varieties in the initial 1 - 1½ months of storage.

CHAPTER FOUR

4. GENERAL DISCUSSION AND CONCLUSION

From the data collected during the current investigations it was shown that the local varieties tested were highly susceptible to C. maculatus. This was indicated by the fact that the bruchid developed successfully in all of them. This was in comparison to the variety Tvu 2027 which is known to be resistant to the pest (Anon 1978a, 1982). This observation is not peculiar considering that only four local varieties were tested. Cowpea varieties are generally known to be highly susceptible to many of their major pests that attack them (Anon 1978a, Khaemba 1980, Singh and Allen 1979). This fact can be appreciated by for example considering that in the search for sources of resistance to C. maculatus, over 4000 entries of cowpea germplasm had to be screened. Out of this number only one was found to have seeds that resist the pest's damage (Anon 1978a, Singh and Van Emden 1978, 1979, Singh and Allen 1979).

Although none of the local varieties tested showed any appreciable levels of resistance to the bruchids, the levels of susceptibility among them were however variable. Based on the oviposition preference when the local varieties were tested in absence of Tvu 2027, the least susceptible variety was apparently Kitui red.

On this variety the least number of eggs were deposited. Consequently fewer adults were produced within the short period of one generation. On the other hand, Kitui brown was rated as being the most susceptible variety while Kitui white and Kitui cream were regarded as being intermediates, lying between the two varieties cited above.

It is known that in varieties whose seeds have wrinkled testas, fewer eggs are deposited on them (Booker 1965, 1967; Nwanze and Horber 1975). Additionally where the internal seed environment is less suitable for development, fewer eggs survive to adult emergence (Howe 1971, Sokoloff et. al. 1966). Resistance may therefore be expressed by the fewer adult progeny resulting (Nwanze and Horber 1975).

In the light of the foregoing reports it became evident that basing judgement on the egg-adult percentage survival, the variety Kitui red which was least preferred for oviposition, may not, from that point of view, be regarded as being the least susceptible of all the local varieties. The reason for this was that although fewer eggs were laid on it, the majority of them hatched and developed into adults. Thus a high egg-adult percentage survival was recorded on this variety. Given this kind of trend outlined above over few generations of the pest, large populations of the pest would develop on seeds of Kitui red, leading to considerable damage. This observation was supported by the fact that when the pest was bred on Kitui red over three generations, its damage was just as high as in the other local varieties. Apparently deposition of few eggs per seed was advantageous to the pest in that hatching larvae did not experience intensive competition for food resources within the seed.

The variety Kitui white which yielded the least number of adults and incurred the lowest seed weight loss was regarded as being the least susceptible variety during the four generations of the pest's development. Kitui brown and Kitui cream were considered as being intermediates between Kitui red and Kitui white. The four months period over which these tests were run roughly corresponds to the period between harvesting and planting which is the length of time the crop in the stores. The response of the seeds to the pest is very important to the farmer during this long period of storage. In this case the variety Kitui white which sustained the least seed weight loss would be a comparatively better variety for farmers to cultivate and store as it would suffer less damage as compared to the other local varieties tested.

Since all the local varieties tested proved to be highly susceptible, research should be aimed at development of sound storage methods to protect the crop from the pest attacks. In addition future workers should direct their work on searching for sources of resistance in other cowpea varieties available in the

Investigations on pre-harvest infestation revealed that the level of pest damage was very low, being less than 3% in all the local test varieties. This was attributed to the fact that the bruchids perhaps did not have good access to the seeds while the crop was still in the field with the dry pods unshelled. It was therefore speculated that the pods acted as a barrier, protecting the seeds in them against extensive damage by the pest. This view was supported by the work of Akingbohunge (1976) who demonstrated that in some susceptible varieties, the seeds could be stored with less damage being incurred if the shells were left intact. Similar studies have not been condu-cted on Kenyan cowpea varieties with a view to assessing seed damage when the crop is stored in unshelled condition.. This kind of storage method, if found viable, could be economically as well as ecologically sound for adoption by farmers.

In addition, the fact that there was some field infestation indicated that probably adult C. maculatus flew from infested beans in the nearby homesteads to infest the ripening crop in the fields. This finding is not peculiar to this study. In Nigeria, these bruchids were reported as migrating from the stores to re-infest cowpea while still in the field (Booker 1967; Cashwell 1961, 1971, Prevett 1961a). From the foregoing observations it is apparent that the habit of farmers in Kitui district and indeed elsewhere in

Kenya of growing their cowpea crop in their backyards is undesirable. There is need to investigate further research on the flight range of the bruchids so as to arrive at an accurate recommendation regarding how far cowpeas should be grown from the homesteads to curb or minimize their infestation by the pest.

On the temperature conditions of storage, results here indicated that the rate of population build up was comparatively much lower at a lower temperature. At this low temperature, there was the least number of bruchids yielded by seeds in all the four local varieties tested. In addition seeds of all the varieties lost the least weight at this temperature. These observations conform to the reports of Larson and Simmons (1924) who showed in their work that the development of the bruchid could be hampered by cold temperatures. Based on the these observations and on the reports by these workers, it was concluded that the storage of cowpeas at lower temperatures can be used by farmers to reduce the pest population increase and subsequent damage to their crop. The construction of well aerated granaries that keep cool during the hot season would be recommended for cowpea storage in Kitui District.

A very interesting phenomenon observed was the peculiar oviposition behaviour displayed by the bruchids when the resistant variety Tvu 2027 was presented together with the local varieties for oviposition. There was an alteration in the number of eggs laid on the variety Kitui white whose seeds had the same colour as those of Tvu 2027. Fewer eggs were deposited on it in the presence of Tvu 2027 than the number deposited in absence of Tvu 2027, as compared to the number of eggs deposited on seeds of the other varieties.

Due to the similarities in colour of the seeds of the two varieties, it was speculated that ovipositing females which first had experience with seeds of Tvu 2027 apparently also disregarded laying eggs on seeds of Kitui white. The basis of non-acceptability of Tvu 2027 for oviposition by the bruchids was attributed to the rough testas the seeds possess (Booker 1967, Nwanze and Horber 1975). Observational evidence showed that seeds of Kitui white possessed smooth seed coats. It was therefore concluded that it was not the morphology of the seed coat but rather it was apparently the colour of the seeds that caused the alteration in the oviposition behaviour of the pest. From the survey of available literature this phenomenon has not been reported before in stored cowpeas.

From this observation it was concluded that seeds of a resistant variety such as Tvu 2027 can be mixed with seeds of the same colour of susceptible varieties to minimise their damage while in storage. If adopted this would be a very cheap method of safely storing cowpea seeds for future use by peasant farmers who commonly grow the crop in Kenya.

In conclusion, it is evident that there is need for more studies aimed at searching for sources of resistance among the cowpea varieties grown in Eastern Province as well as in other parts of Kenya. Other areas of research would be on improvement of methods of crop storage, especially those leading to less use of insecticides. The use of natural plant oils for example in combination with the other strategies suggested above would go a long way in reducing our high dependence on insecticides for crop storage in view of their high costs and the ecological hazards they pose.

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Appendix 1: Average number of bruchids emerged each week and the corresponding weight lost after the bruchids emerged at 20°C in different varieties.

Week	Number of bruchids emerges				Weight in grams lost by seeds			
	KW	KR	KC	KB	KW	KR	KC	KB
1.	35.5	23.5	31.5	37.5	2.375	1.625	1.805	2.625
2.	91.5	63.5	82.5	112.5	0.780	0.675	0.780	0.715
3.	170.0	109.0	150.5	183.0	2.275	2.155	2.055	2.090
4.	350.0	306.0	342.0	379.0	2.715	2.425	2.430	2.700
5.	515.5	454.5	482.0	533.5	3.245	3.050	3.060	3.185
6.	883.0	910.5	935.5	923.0	2.745	2.850	2.755	2.600
7.	1172.0	1165.0	1163.0	1160.5	2.285	2.520	2.700	2.135
8.	1235.0	1272.5	1211.5	1316.0	2.995	3.635	4.100	3.200
9.	1394.5	1378.0	1370.0	1284.0	3.535	3.775	3.495	3.545
10.	1352.5	1364.5	1368.0	1289.5	3.385	3.665	3.915	3.325
11.	1354.0	1425.5	1415.5	1334.0	3.135	4.165	4.000	3.345
12.	1350.5	1410.5	1371.5	1356.5	2.825	3.780	3.040	2.930
13.	1359.0	1450.5	1389.5	1368.5	3.770	3.655	3.505	4.215
Total	11264.5	11333.5	11313.0	11277.5	36.060	37.980	37.640	36.610

Appendix 2: The average number of bruchids emerged each week and the corresponding weight lost after the bruchids emerged at 27°C in different varieties.

Week	Number of bruchids emerged				Weight (in grams) lost by seeds			
	KW	KR	KC	KB	KW	KR	KC	KB
1.	61.0	33.0	47.5	77.5	3.750	3.570	3.585	3.820
2.	132.0	74.0	95.0	158.0	3.685	3.720	3.705	3.725
3.	217.0	163.5	181.5	245.5	3.155	2.985	3.090	3.355
4.	440.5	432.5	500.5	520.5	3.970	4.115	4.060	3.920
5.	1026.0	978.5	1012.5	1026.5	4.155	4.045	4.275	4.065
6.	1522.0	1555.5	1583.5	1637.5	2.295	2.860	2.785	3.380
7.	2341.0	2404.5	2421.0	2374.5	4.405	4.860	4.780	4.245
8.	2298.5	2426.0	2332.5	2284.5	5.430	5.895	5.720	5.045
9.	2348.0	2387.5	2360.5	2246.0	6.690	6.655	6.445	6.100
10.	2299.5	2398.0	2273.5	2225.0	4.142	4.875	4.720	5.365
11.	2202.0	2274.5	2289.0	2177.5	4.140	4.455	4.880	4.330
12.	2174.5	2337.0	2200.5	2131.5	5.230	5.860	5.245	4.895
13.	2098.0	2197.5	2168.5	2123.0	4.325	5.000	4.615	4.385
Total	19210.0	19662.0	19466.0	19227.5	55.400	58.900	57.910	56.620

Appendix 3: The average number of bruchids emerged each week and the corresponding weight in grams lost after the bruchids emerged at $34^{O}C$ in different varieties.

Week	Number of bruchids emerged				Weight (in grams) lost by seeds			
	KW	KR	KC	KB	KW	KR	KC	KB
1.	74.5	46.0	61.0	82.0	3.820	2.535	2.860	3.990
2.	132.5	104.0	130.5	144.5	3.995	2.545	3.340	3.620
3.	211.5	169.0	199.0	236.5	2.425	4.790	3.845	2.800
4.	499.5	469.0	479.5	506.5	3.430	3.30	3.245	3.440
5.	1036.0	1011.0	1030.0	1051.5	2.815	3.165	3.020	3.205
6.	1478.5	1451.5	1452.5	1516.0	3.025	2.955	3.120	3.025
7.	2112.5	2120.5	2125.5	2119.0	5.665	4.220	3.255	3.540
8.	2102.0	2223.5	2176.5	2089.0	2.345	4.290	4.810	4.255
9.	2139.5	2193.5	2175.0	2080.5	5.050	5.415	5.100	5.040
10.	2153.0	2245.0	2173.5	2102.5	4.050	4.615	5.520	4.415
11.	2072.5	2115.0	2100.0	2062.5	4.300	4.300	4.090	3.875
12.	2081.5	2121.5	2107.0	2078.0	3.825	4.950	4.765	4.255
13.	2035.0	2073.0	2063.0	2003.0	3.850	4.220	4.305	3.850
Total	18119	18342.5	18273.0	18071.5	48.600	51.300	50.400	49.310