

**EVALUATION OF PIGEONPEA AND COWPEA
GENOTYPES FOR BRUCHID RESISTANCE
(Bruchidae)**

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I. INTRODUCTION

Grain legumes popularly known as pulses, play an important role in Indian Agriculture not only to increase soil fertility for obtaining reasonably high yields from succeeding crops but also in providing proteinaceous grain and nutritive fodder. Pulses contain at least two to three times more protein than cereal grains and the amount of lysine is also two to three times higher in their proteins as compared to the protein of cereal grains. For vegetarian diet, pulses form the major source of protein. Infact, lysine is the most limiting essential amino acid in cereals which is very well supplemented by the protein of pulses. Though, the importance of pulses in our daily diet and soil fertility has been fully established, there has been no major break through in the production of pulses in our country.

India is one of the largest producer and consumers of pulses, accounting for 33 per cent of world area and 24 per cent of world production. At present in India, the total area under pulses is 21.12 million ha with a total production of 11.31 million tonnes with a productivity of 536 kg per ha (Anon., 2005). The per capita availability of pulses has declined from 64 g per capita per day in 1951-56 to less than 40 g per capita per day as against the FAO/WHO's recommendation of 80 g per capita per day. The total pulse requirement for consumption by 2005 AD would figure about 23 million tonnes.

Among the important pulses grown in India, pigeonpea (*Cajanus cajan* L. Millsp.) is of immense importance. It is an important multi-purpose grain legume extensively grown in arid and semiarid tropics. The green pods of pigeonpea are used as vegetables. In addition to grain, it gives fodder and fuel wood for rural people. Pigeonpea fits well in different cropping systems due to its relative drought tolerance. As it is a deep rooted crop, it is well suited for rainfed agriculture. It has ability to fix the atmospheric nitrogen in soil at the rate of 20 kg per ha in association with symbiotic bacteria under favourable conditions.

Pigeonpea has been considered as second most important crop after chickpea. India has virtual monopoly in pigeonpea production accounting to 90 per cent of world's total production. In India, it occupies an area of 3.73 million ha with a production of 2.12 million tonnes (Anon., 2003). In Karnataka it is cultivated over an area of 0.48 million ha with a production of 0.15 million tonnes (Anon., 2003). It is often grown on marginal lands and is usually intercropped with other pulses. However, farmers are growing pigeonpea as sole crop and the crop is increasingly gaining the status of cash crop.

Cowpea is mainly grown in tropical and sub tropical regions in the world for vegetable and seed purpose and to lesser extent as a fodder crop. It is a most versatile pulse crop because of its smothering nature, drought tolerant characters, soil restoring properties and multi-purpose uses. As a pulse crop, cowpea fits well into most of the cropping systems. In India, cowpea is grown in an area of about 3.9 million hectares with the productivity of 567 kg per ha. The productivity of the crop in Karnataka is low (420 kg/ha) as compared to the national productivity.

Besides low productivity, other production constraints are post-harvest technology of pulses, the insect pest problems, improper sanitation and storing methods inflicting both qualitative and quantitative loss to pulses. Totally, 25 species of insects attack pulses (Prabhakar, 1979). Of these, coleopteran insect pests cause major damage to stored grain and grain products worldwide. Among them, *Callosobruchus* spp. belonging to the family Bruchidae, are very serious pests of legumes in storage. It is estimated that about 8.5 per cent of the total damage to stored grains is inflicted by insect pests amounting to great loss. Pulse beetles assume greater importance as they damage both in the field and storage (Anon., 1970). About hundred and seventeen species of bruchids belonging to 11 genera have been recorded from India (Arora, 1977). The genus *Callosobruchus* includes a number of economically important species that attack stored pulse throughout the world. *C. chinensis* (L.) and *C. maculatus* (F.) are predominant species and cause heavy damage to pigeonpea and cowpea. Pingale *et al.* (1956) recorded zero per cent germination due to the bruchids (*C. chinensis*) infestation after six months in stored greengram. During storage, pulses undergo some chemical changes due to the presence of insects. They alter the flavour and nutritive value of grains which reduce the marketability and acceptability of pulses.

The most common method to minimize this loss has been the use of chemical pesticides, which cause environmental and health hazards and most importantly, development of resistance among the insects. In such a situation, use of sustainable methods becomes the only alternative to the problem. Gene based resistance is one of the most satisfactory and sustainable methods of pest control, particularly as a basic element in integrated pest management approach.

Legume seeds are a rich and varied source of secondary plant compounds many of which are toxic to or antimetabolic towards insect pests. Knowledge of the biochemical mechanisms of resistance to insects enables the plant breeder to assess their potential and to exploit such traits in plant breeding programs in a more directed fashion. Among the antimetabolites, protease inhibitors are usually present in storage tissues such as seeds and tubers and their expression are both developmental regulated and induced in response to insect and pathogen attack.

Keeping these aspects in view, the present study was initiated with the following objectives.

1. Evaluation of redgram genotypes for resistance to *C. chinensis* and *C. maculatus*.
2. Evaluation of cowpea genotypes for resistance to *C. chinensis* and *C. maculatus*.
3. To study the biochemical basis for bruchid resistance in redgram and cowpea genotypes.

II. REVIEW OF LITERATURE

Pulse production in India has been practically stagnant for the last few decades. The cropped area as well as production is fluctuating. Considerable basic research is needed to increase the productivity of redgram and cowpea and other pulses to meet the expanding requirements. Besides its low productivity other production constraints are post-harvest technology. The insect pest problem, improper sanitation and storage methods which cause both qualitative and quantitative loss to pulses. The development of insect resistant/tolerant cultivars is important in integrated pest management and for decreased probability of environmental contamination from an appropriate use of insecticides. A brief review of literature concerning, the aspects presented and documented in this dissertation is outlined under the following heads.

2.1 EVALUATION OF REDGRAM GENOTYPES FOR RESISTANCE TO *C. chinensis* and *C. maculatus*

Wadnerkar *et al.* (1978) studied the development of *Callosobruchus maculatus* Fab. on four varieties of Arhar and three varieties of gram. Arhar was more preferred to gram for oviposition and Arhar No. 148 was the most preferred variety. Development was significantly faster in white gram. Prabhat variety of Arhar showed maximum percentage loss in weight, while it was lowest in white gram. Adult emergence did not differ significantly.

Kameswara Rao and Krishnamorthy Rao (1982) reported life cycle of *Callosobruchus maculatus* between 33 and 42 days in the pigeonpea varieties C-53 Hy-2 and PDM-1, while it extended to about 40 to 44 days in other varieties, UPAS-120, ST-1, Mukta and BDN-1. Largest number (307) of adult developed in C-53, while only 50 adults developed in UPAS-120. Maximum egg laying was observed on C-53 followed by Hy-2, ST-1, BDN-1, while in PDM-1, UPAS-120 and Mukta significantly low number of eggs were deposited the percentage of grain damage was the highest in C-53 while UPAS-120 and Mukta showed least damage by the bruchid *C. maculatus*.

Dushyant *et al.* (1991) studied comparative susceptibility of 33 genotypes of pigeonpea (*Cajanus cajan*) to pulse beetle tested in laboratory conditions. Significant variation was found in the degree of resistance with none being completely immune.

Dogre *et al.* (1993) evaluated seeds of 24 accessions of pigeonpea (*Cajanus cajan* (L.) Millsp.) and four other species of *Cajanus* (formerly *Atylosia*) for their resistance to infestation by *Callosobruchus maculatus* (F.). None of the pigeonpea accessions was resistant but resistance was evident in three species of *Cajanus*. In *C. platecarpus* most of the larvae failed to enter the hard seed coats but the few which did enter the seeds, developed normally. Adults did not emerge from the seeds of *C. scarbaeoides*, even though most of the larvae entered the seeds. In *A. sericeus*, the number of larvae entering the seeds as well as adult emergence was significantly reduced.

Relative susceptibility of 44 pigeonpea varieties to attack by *C. chinensis* and factors involved in their susceptibility were determined in study by Modi *et al.* (1994). Based on number of eggs per 50 grains and grain damage, cultivars ICPL-89044, KM-9 and KPAS-120 were found to be less susceptible than the other varieties and susceptibility was affected by size and shape of seed but not by seed colour.

Kadoo and Rane (1995) used 12 commonly grown varieties of pigeonpea to study the extent of damage and varietal resistance and susceptibility to *C. chinensis*. None of the 12 varieties were found to be immune to infestation by *C. chinensis*. However, there were significant differences in the relative susceptibility of different varieties to bruchid attack.

Ahmed *et al.* (1989) evaluated eighteen chickpea (*Cicer arietinum* L.) genotypes for their susceptibility to pulse beetle, *Callobruchus maulatus* F. (bruchidae) taking into account the number of undamaged seeds (resistance to bruchids), number of eggs oviposited (ovipositional preference) and number of emergence holes (Adult survival) per 50 seeds. Resistance to bruchids appeared to be a more heritable trait than the other two damage

characters. The number of emergence holes is a better indicator of seed resistance than the number of eggs present on the seeds.

Ahmed *et al.* (1993) evaluated seeds of 39 chickpea varieties infested with *C. chinensis* for number of damaged seeds, number of hole seed surface texture and seed coat thickness. They found that the varieties with a rough, hard, wrinkled and thick seed coat showed less damage and number of holes and therefore were more resistant than varieties with small, soft and thin seed coats. Correlation between the two damage parameters was positive and highly significant.

Swaroop Singh and Gireesh Sharma (2001) evaluated thirteen varieties of chickpea viz., GNG-663, PG-2, H86-1, L-550, RG-44 and KGD-1168 for oviposition preference and subsequent larval development of the pulse beetle *Callosobruchus chinensis* (L.) of which PG-5 was the most resistant variety with minimum growth index of 1.358 and longest grub development period of 28.33 days. On the other hand GNG-663 was found to be the most susceptible with maximum growth index of 2.211 and minimum grub development period of 28 days.

Swaroop Singh and Gireesh Sharma (2003) evaluated seven varieties viz., L-4076, DPL-61, K-75, K-303, Sehore-747, DPL-59 and L-414-7 of lentil. *Lens culinaris* L. The pulse beetle showed high ovipositional preference for all the varieties, as grain laid with eggs in the varieties ranged from 97.0 to 99.6 per cent. Of the varieties evaluated DEP-3 was observed to be the most preferred one with growth index of 1.376; the grub developmental period in the variety was 33.66 days. The variety RPG-3 had minimum growth index of 0.671 (Developmental period, 38.00 days). The pest growth index ranged from 1.051 (BR-12) to 0.805 (L-116) in the other varieties.

2.2 EVALUATION OF COWPEA GENOTYPES FOR RESISTANCE TO *C. chinensis* and *C. maculatus*

The oviposition response and development of *C. chinensis* was studied on eight varieties of cowpea. The pulse beetle preferred all the varieties for egg laying, the grains with eggs in the varieties ranged from 99.1 to 99.5 per cent. Out of the eight varieties evaluated, CPD-2 had maximum growth index of 2.235, which was the most preferred one; it had the fastest growth of grubs, with a minimum development period of 18.33 days. Minimum growth index (1.094) was observed in variety GC-3, which had a developmental period of 24.33 days. The growth index of the pulse beetle ranged from 1.652 (Ajmeer selection) to 1.096 (RC-19) in rest of the varieties (Swaroop Singh and Gireesh Sharma, 2003).

Manohar and Yadav (1990) studied the extent of damage ten commonly grown cultivars of cowpea viz., Udaipur-1, Udaipur-2, P-1309, P-1302, P-1414, P-454-157, IC-11352, CS-152, CO-1 and Kanpur black (141.23) pulse beetle *C. maculatus*, Udaipur-2 variety suffered maximum loss of 44.97 per cent in apparent weight, while Co-1 variety had the least loss of 16.25 per cent. The respective real weight losses were 56.78 and 20.40 per cent. The loss in seed variability ranged from 9.0 to 49.34 per cent on CO-1 and Udaipur-1 varieties. Further, Udaipur-2 and P-1309 were preferred most for oviposition and adult development while the CO-1 was the least preferred. Conclusively Co-1 was relatively resistant to *C. maculatus* Fab. as compared to other varieties.

Singh *et al.* (1985) screened over 8000 germplasm lines of cowpea. Three sources of resistance to cowpea weevil have been identified viz., TVu2027, TVu11952 and Tyu11953. Screening for bruchid resistance was done by placing 10 seeds of each variety in separate plastic boxes and infesting with two pairs of bruchids to lay eggs for 15 hours. The total number of eggs laid in each box was determined and a daily count of emerging adults was made until 50 days after infestation. The per cent damaged seeds ranged from 25 to 26 per cent in the resistant lines and 95 per cent for life brown susceptible line.

Mabata (1992) studied the effect of interaction between seed characters and ovipositional marker of *C. maculatus* on seeds of soybean, cowpea, *Vigna subterranea* and *Sphenostylis stenocarpa*. Study showed that female bruchid were able to distinguish egg laid seeds from fresh seeds in all four types of seeds used.

Ofuya and Credland (1995) evaluated 11 popularly resistant varieties of cowpea as well as 2 susceptible lines against 3 populations of *C. maculatus*, originating from Cameroon, Brazil and Burkina faso. Larval survival was poor on resistant varieties.

Kapila and Rajni (1989) screened seeds of 17 cultivars of *Phaseolus vulgaris* for resistance to *Zabrotus subfaciatus* in the laboratory and concluded that neither size nor colour of the seeds were important with regard to susceptibility.

Guzman-Maldonado *et al.* (1996) characterized seeds of 17 common bean cultivars for resistance to infestation by *Zabrotus subfaciatus* and *Acanthoscelides obtectus* under no choice and free choice conditions. To determine the relationship of some physical and chemical characteristics of the seeds for resistance to bruchids; seed hardness, seed coat, thickness, tannins, lectins, trypsin inhibitors and protein content were evaluated in the 17 cultivars. Three of the cultivars were resistant to *Z. subfaciatus* but none were resistant to *A. obtectus*. A correlation was found between lectin content and both oviposition and adult emergence in a choice experiment with *Z. subfaciatus*, confirming the importance of lectins for resistance against bean weevil. No correlation was found with seed hardness, seed coat thickness, tannins, trypsin inhibitors or protein content.

In AVRDC (Anon., 1986) one hundred and one mungbean breeding lines were tested for their susceptibility to bruchid in a laboratory screening. Five breeding lines viz., VC1535-11-1B-1-3B, VC-2764-B-7-2 -Bm VC-2764-B-7-1-B, VC-1209-3B-1-2-B and VC-1482-C-12-2-B were least damaged by the bruchids. The number of adults that emerged from these resistant entries was on par with no adult emergence from VM-2164, the resistant check.

At AVRDC (Anon., 1988) seeds of 500 mungbean accessions were screened for resistance to *C. chinensis*. Ten accessions were classified as highly resistant. Two entries, V-2802-G and V1128B-B2 were found free from bruchid infestation, V-2802BG is a selection from a resistant accession V8202.

Gobindan *et al.* (1989) screened seven legume species namely sweet peas, greengram (*V. radiata*), blackgram (*V. mungo*), bengalgram (*C. arietinum*), cowpea (*V. unguiculata*), pigeonpea (*C. cajan*) and wild mung (*V. vexillata*) against *C. chinensis*. They found *V. vexillata* to be the least susceptible.

Laboratory study conducted at AVRDC (Anon., 1991) showed that *C. chinensis* resistant mungbean (*Vigna radiata*) accessions (V2709 and V2802) and one blackgram (*V. mungo*) accession (VM2164) were equally resistant to *C. maculatus*, the second most important pest of *V. radiata* seeds in storage.

Talekar and Lin (1992) investigated on the characteristics of resistance to *Callosobruchus chinensis* in two mungbean and one blackgram accessions in a series of lab tests. They concluded that smaller seed size of the accessions was not responsible for the resistance. The results indicated the possible presence of antibiotic factors in the resistant accessions.

AVRDC (Anon., 1992) conducted genetic studies using a wild mungbean accession *Vigna radiata* sublobata (TC1966) and two mungbean accessions (V2709 and V2802) revealed that they were immune or highly resistant. Studies further showed that in each resistant line, resistance was controlled by a single dominant gene and these three resistance genes were not allelic.

Sison *et al.* (1996) screened several mungbean varieties for resistance to *C. chinensis*. Results of both free choice and no choice tests showed that TC 1966 was highly resistant while pag-asa (1, 3, 5 and 7) were susceptible.

Eight different varieties of mungbean (*Vigna radiata*) were evaluated for their susceptibility to *C. chinensis* by Muhammad Hussain *et al.* (1997) on the basis of number of eggs laid, duration of development of the immature stages, percentage adult emergence and weight loss due to damage by the pest. The varieties MB-2456 and Kanti were found to be highly susceptible, with 13.6 and 13.0 per cent loss in the weight of seeds, respectively. The size, colour and protein content of the seeds had no influence on the susceptibility of mungbean seeds to *C. chinensis*.

Both artificial and natural infestation of *C. chinensis* were used by Liu-xuming *et al.* (1998) in the identification of resistance source of mungbean (*Vigna radiata*). Among the tested germplasms 17 lines from AVRDC showed moderate resistance to immunity, while only 3 land races from Gangxi showed moderate resistance.

Lambrides and Imrie (2000) screened twenty six mungbean (*Vigna radiata*) varieties and accessions for resistance to 4 bruchid species. On the basis of percentage of seed damage, all Australian commercial mungbean varieties tested were highly susceptible to strains of *C. chinensis* and *C. maculatus*. Three accessions (TC1966, ACC23 and ACC41) appeared to have bruchid resistance. All the three accessions had wild mungbean characteristics like small seed size and the presence of well formed texture layer on the seed.

2.3 BIOCHEMICAL BASIS FOR BRUCHIDS RESISTANCE

2.3.1 Protein

Umrao and Verma (2003) studied on protein composition of 20 pea genotypes to see their protein composition for preference of *C. chinensis*. It was found that low protein content 21.51, 21.87, 22.07, 22.09 and 22.47 on DMR-29, KPMR-186, H+SP-2, KPMR-347, KPMR-327 and HUDP-10, respectively were least susceptible while, higher protein 24, 24, 23.72, 23.61, 23.53, 23.42 and 23.24 per cent on genotypes HUP-13, MDP-3, MDP-1, KPMR-389, KPMR-157 and KPMR-397, respectively were highly susceptible to pulse beetle. After 120 days of infestation the protein content of each pea variety was significantly more and was due to infestation of *C. chinensis*. The relationship of fresh grain protein with the infestation (fecundity, F1 progeny and index susceptibility) was positive and significant. It means the increased protein contents of the pea genotypes certainly increases the infestation.

The varieties susceptible to pests or diseases were found to possess higher amount of proteins (Chakravarthy and Sahni, 1972).

The protein content of seeds was found to have no influence on susceptible of mung bean to *C. chinensis* (Chakraborty *et al.*, 2004).

Trypsin inhibitor

The occurrence of protease inhibitors is wide spread in plant families (Pusztai, 1967 and Ryan, 1973). They have been known to occur in storage organs such as seeds, tubers and other plant parts. Their occurrence has been reported well in plants of leguminosae, gramineae and solanceae (Ryan, 1973). The naturally occurring trypsin inhibitors have been compiled and discussed in the first review on the subject during 1954 by Laskowski and Laskowski Jr. Richardson (1977) gave details specifying occurrence, distribution, modern methods of isolation, purification and assay of the inhibitors.

Narioka *et al.* (1988) screened 34 leguminosae species seeds for trypsin and chymotrypsin inhibiting activities of two families of inhibitors and concluded that primitive leguminosae species contain mainly the Kunitz family inhibitors whereas those of the more advanced ones had Bowman-birk family inhibitors.

Baumgartner and Chrispeels (1976) reported that germination of mungbean (*Vigna radiata*) is accompanied by an increase in the activity of the endopeptidase, involved in storage protein metabolism. Enzyme activity in the cotyledons increases 25 fold during the first 5 days of germination. The cotyledons also contain inhibitory activity against the endopeptidase and this inhibitor activity declines during germination suggesting that inhibitors may play a role in regulating the activity of the endopeptidases.

Lorensen *et al.* (1981) reported that ungerminated seeds of mungbean contain a single major species (F) or trypsin inhibitor with five minor species (A-E), separable on diethylamino ethyl cellulose. During germination the level of trypsin inhibitor activity decreases from 1.8 units per gram to 1.2 units per gram in cotyledons of 5 day germinated seeds.

Modgil and Mehta (1997) studied the effect of bruchid infestation on selected antinutritional factors. Saponin, phytic acid and trypsin inhibitor activity (TIA), increased with

increased storage period. It was concluded that the difference between the contents of antinutritional factors were significant during different storage periods.

Marconi *et al.* (1997) analysed the seeds of eight wild species of *Vigna* for their chemical contents. Significant positive correlations were found between seed resistance to bruchids and trypsin inhibitor, tannin and starch contents.

Kakade *et al.* (1969) evaluated natural vs synthetic substrates for measuring the antitryptic activity of soybean samples. In the modifications they have used 2 per cent caesin (instead of 1%). The use of synthetic substrate benzoyl-DL-arginine-p-nitroanilide (BAPA) proved to be a convenient and reliable method of assaying trypsin inhibitor activity. Trypsin inhibitor activity was expressed as trypsin units inhibited per ml extract of zero concentration of the inhibitor. Although, a series of soybean samples could be ranked in the same relative order to inhibitor activity by using either caesin or BAPA, the quantity of trypsin inhibited was consistently higher when BAPA was employed as substrate.

Royer *et al.* (1974) demonstrated the presence of trypsin inhibitors in cotyledonary albumins of *Vigna unguiculata* against trypsin. Purified trypsin inhibitors partially inhibit the caseinolytic activity of albumins but do not influence their hydrolytic activity towards Benzoyl-DL-arginine-p-nitroanilide (BAPA). Biochemical basis of insect resistance in cowpea was revealed by Gatehouse *et al.* (1979). When seeds of cowpea varieties were tested for the presence of various antimetabolic secondary compounds, only inhibitory activity against trypsin, to much lesser extent chymotrypsin could be detected. The resistant variety of cowpea contained significantly higher level of inhibitors, about twice as much as any other variety.

Gatehouse *et al.* (1980) isolated and purified the trypsin inhibitor from cowpea. The total trypsin inhibitor was divided into inhibitor active against trypsin only and active against trypsin and chymotrypsin. They also showed several iso-inhibitors by isoelectric focusing and gel electrophoresis. The chymotrypsin/trypsin was shown to be composed of several iso-inhibitors.

Gatehouse *et al.* (1978) tested number of cowpea varieties including resistant types for the presence of a physical resistance to *C. maculatus* in terms of repulsion of oviposition or of failure of larvae to enter the seeds. No evidence of a physical resistance was found when seeds of cowpea varieties were tested for the presence of various antimetabolic secondary compounds. Only inhibitory activity against trypsin was found. The resistant variety of cowpea contained a significantly higher level of inhibitors, about twice as much as any other variety. It was concluded that insect resistance in cowpea was due to the elevated level of trypsin inhibitor.

Gatehouse and Boulter (1983) carried out insect feeding trials. Cowpea trypsin inhibitor (CpTI) was incorporated at various levels upto 10 per cent in pelleted meals of both a susceptible variety of cowpea and another susceptible species of legume, the chickpea. It was concluded that CpTI was an effective antimetabolite to *C. maculatus* and that this type of mechanism could be widespread.

Hilder *et al.* (1987) reported that a gene encoding a cowpea trypsin inhibitor has been transformed to tobacco. The level of CpTI within the seeds of cowpea correlated well with field resistance to their major pest, the bruchid beetle, *C. maculatus*. More importantly feeding trials with purified CpTI, incorporated at physiological levels into artificial seeds, have shown these inhibitors to be anti-metabolite against wide range of insects, including genera such as *Heliothis*, *Spodoptera*, *Diabrotica* and *Tribolium*.

Xavier Filho *et al.* (1989) reported that the development of bruchid (*C. maculatus*) was found to be poor on seeds of resistant cowpea cultivars, TVu2027, IT81D-1045 and IT81D-1064, compared to the cultivars CE-31, CE-11 and CE-524. There was no correlation between proteinase inhibitory activity and the resistance shown by the cultivars.

Marconi *et al.* (1993) analysed seed of the wild species *Vigna vexillata* and *Vigna unguiculata* accessions for protein content and levels of trypsin and chymotrypsin inhibitors and lectins. *V. vexillata* showed higher values for both inhibitors and lower values for lectins

as compared with the *V. unguiculata*. It is suggested that trypsin inhibitors and proteinase inhibitors either promoter are component of the plants defense mechanism.

Cowpea seeds of eight lines differing in storage resistance were analysed by Piergiovanni *et al.* (1994) for inhibitors of the amylase, chymotrypsin and trypsin. Principal component analysis indicated that resistant lines were characterized by high levels of both antitryptic and antiamylasic activity. Moreover, high activity of a single inhibitor class is typical of the bruchid susceptible lines. Hence, breeding for high contents of these protein inhibitors could be an effective way of obtaining lines that are naturally resistant to storage pest attack.

Six cowpea genotypes were selected as resistant to various insect pests by Prasad *et al.* (1996). Genotypes C152, C190 and V154 were resistant against bruchids. Variation in enzyme inhibitory activity was correlated with degree of field pest resistance. The highest trypsin inhibitor and chymotrypsin inhibitor activities were found in GC82-7, whereas highest proteinase inhibitor and α -amylase inhibitor activities were observed in TV \times 7, alpha amylase inhibitor activity was absent in V154 and DPLC216.

Oluwatosin (1999) studied the relative influence of genotype, environment and genotype \times environment effects on four antinutritional factors (g/kg) of importance in cowpea using 15 local and improved cowpea genotypes grown in 12 environments. It was found that genotypic effects were strongest in controlling trypsin inhibitor content and trypsin inhibitor was positively correlated with phytic acid and haemagglutinins but negatively correlated with tannin contents.

Ignacimuthu *et al.* (2000) reported that seeds of the wild pulses *Dumbaria ferrunginea*, *Neonotonia wightii*, *Tephrosia cararensis*, *Cajanus albicans* and *Vigna bourneae* show resistance to bruchid infestation due to higher levels of trypsin/chymotrypsin inhibitors. SDS-PAGE analysis of seed proteins of *Dolichos lablab* and *Rhynchoea cana* revealed the presence of high levels of vicilins, alpha-amylase inhibitors and lectins in quantities that may impart resistance to *C. maculatus*.

Gennis and Cantor (1976) isolated two new double headed proteinase inhibitors from black eyed peas. Black eyed pea chymotrypsin and trypsin inhibitor (BEPCI) inhibited trypsin and chymotrypsin simultaneously. They concluded that a dual physiological function of inhibition and protection of the seed protease.

Guzman Maldonado *et al.* (1996) characterized 17 common bean cultivars for resistance to infestation by *Zabrotes subfasciatus* and *Acanthoscelides obtectus*. Correlation was found between lectin content and both oviposition ($r = -0.3$, $P < 0.05$) and adult emergence ($r = -0.33$, $P < 0.01$) in a no-choice experiment with *Z. subfasciatus* confirming the importance of lectins for resistance against bean weevil. No correlations were found with seed hardness, seed coat thickness, tannins, trypsin inhibitors or protein content. The resistant cultivar Bayocel showed intermediate values of seed hardness and lectin content and high levels of seed coat thickness tannins and trypsin inhibitors.

Giri *et al.* (1998) studied in vitro and in vivo proteolysis of the early and late stage specific trypsin inhibitors and found that the chickpea proteinase inhibitors were prone to proteolytic digestion by *H. armigera* gut proteinases. They opined that survival of *H. armigera* on chickpeas may result from the production of inhibitor insensitive proteinases and by secretion of proteinases that digest chickpea proteinase inhibitors.

Patankar *et al.* (1999) reported that developing seeds of eight chickpea (*Cicer arietinum*) cultivars (12-60 days after flowering) showed a significant variation in the trypsin inhibitor (TI) and the *Helicovera armigera* gut proteinase inhibitor (HGPI) content. The highest TI (198 units/g) and HGPI (23 units/g) activities were exhibited by mature seeds of ICCV-2, whereas the lowest inhibitor activities were observed in PG8505-7 and Vijay.

Phenols

In many crops including cotton, tannins, exhibited themselves as powerful factors in imparting resistance to insects and diseases. Tannins form the most important group of defensive secondary metabolites and powerful feeding deterrent to all herbivores (Swain, 1979).

Rao (1989) noticed a low tannin content in bollworm susceptible genotypes. He also observed a positive association of tannins in reproductive parts and seed cotton yield.

The presence of tannins did not influence the penetration rates in the two species of *C. chinensis* and *C. maculatus*. The rate of larval penetration was through seed coats not significantly different with or without tannin (Desroches *et al.*, 1994).

Chakravarthy and Sahni (1972) on a study of biochemical basis of resistance to jassids (*Empoasca* spp.) in cotton genotypes reported that as a result of insect attack tannin content increased. Tolerant and resistant strains exhibited high tannin content than the susceptible strains. However, McClare (1972) failed to support the trend observed by the former authors as he did not find qualitative difference among total phenols and gossypol content between the two resistance and two susceptible varieties to *Meladogyne incognita* and the quantitative difference were small.

Krishnananda (1972) while working on biochemical basis of jassid resistance in cotton concluded that susceptible varieties contained low quantity of phenols compared to the varieties resistant to jassids. Bhaskaran and Muthuswamy (1974) reported that tannins and orthodihydroxy phenols were more in resistant strains than in the susceptible strains to verticillium wilt of cotton. Bhaskaran *et al.* (1975) were of the same opinion. They reported that leaves of resistant varieties of *G. arboreum* were higher in polyphenol oxidase activity and total phenols content than the susceptible varieties of *G. hirsutum* to *Alternaria macrospora*.

III. MATERIAL AND METHODS

The information on the materials used and techniques adopted during the course of investigation are presented hereunder. Three experiments were conducted to take up the objectives set out for the study of evaluation of redgram and cowpea genotypes for resistance to *C. chinensis* and *C. maculatus* and biochemical basis for bruchids resistance in redgram and cowpea genotypes.

The experiments were carried out at the Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad during the year 2003-05.

3.1 EVALUATION OF REDGRAM GENOTYPES FOR RESISTANCE TO *C. chinensis* and *C. maculatus*

3.1.1 Maintenance of stock culture

The adult beetles of two species of *Callosobruchus viz.*, *C. chinensis* and *C. maculatus* were collected from the infested grains of redgram and cowpea, respectively from the farm stores and stock culture was maintained on redgram by releasing ten pairs of freshly emerged beetles of each of the species separately in glass jars and the mouth of the jar was covered with muslin cloth fastened by rubber band. Fresh grains were provided periodically for the development of beetles and culture so maintained was used in further experiments both redgram and cowpea genotypes.

3.1.1.1 Evaluation of redgram genotypes against bruchids

Samples of sixteen genotypes of redgram *viz.*, Pg-44, ICPL-99032-1, GPS-2003, ICPL-87119, ICPL-2009-1, v-71, PG-27, GMS-1, GS-1, ICPL-8863, DFPS-3, WRP-230-1-1, WRP-266, ICPL-2008-1, DEPS-9 and PG-12 were obtained from the Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad.

At the commencement of experiment, the moisture content of all the genotypes was recorded for determination of germination per cent of seeds. A random sample of 100-seeds was taken out from the each genotypes and seeds were kept in between blotting papers soaked with distilled water. Germinated seeds were counted and per cent germination was calculated and also at the end of experiment the 100-seed were taken out from replicate of the infested seeds separately and were kept in between blotting papers soaked with distilled water. Germinated seeds were counted and per cent loss of germination was calculated.

For the study of genotype preference, 100 number weighed seeds of sixteen genotypes were kept separately in half litre plastic container and two pairs of one to two days old adults (2 males and 2 females) of *C. chinensis* and *C. maculatus* were released in the container separately. The mouth of the containers was covered with double folded muslin cloth fastened with rubber band. This experiment was replicated thrice for each species. The released insects were removed after 72 hours with the expectation of maximum oviposition during this period and number of eggs laid on seeds of each genotypes were recorded. The experiment was continued for 30 more days, to observe the adult emergence. The number of emerged adults with their sexes on each genotype were also recorded. The period taken from oviposition to adult emergence was regarded as developmental period. The per cent adult emergence divided by developmental period in days was taken as growth index. The reduction loss in seed weight (g) was taken after the infestation and it was deducted from the initial seed weight recorded earlier before infestation and per cent loss in seed weight was calculated for each genotype and bruchid species.

3.2 EVALUATION OF COWPEA GENOTYPES FOR RESISTANCE TO *C. chinensis* and *C. maculatus*

3.2.1 Evaluation of cowpea genotypes against bruchids

Samples of 13 genotypes of cowpea *viz.*, C-3, V-188, TV × 944, T-4, KM-5, C-70, KM-1, DCP-2, Goa local, T-1, KM-4, T-9 and V-585 were obtained from the Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad.

3.3 BIOCHEMICAL BASIS FOR BRUCHID RESISTANCE IN REDGRAM AND COWPEA GENOTYPES

3.3.1 Estimation of soluble proteins by Lowry's method

Protein concentration in the extracts was determined by the method of Lowry *et al.* (1951) using bovine serum album as the standard protein.

Reagents

- a. 0.1 N NaOH : 4 g of NaOH in 100 ml of distilled water
- b. 2% Na₂CO₃ in NaOH : 2g Na₂CO₃ in 98 ml 0.1 N NaOH
- c. 1% sodium potassium tartarate :1g Rochelle salt in 99 ml distilled water
- d. Copper reagent : 1 g copper sulphate in 98 ml of 1% sodium potassium tartarate
- e. Reagent A : 50 ml of reagent (b) + 1 ml of reagent (d)
- f. Reagent B : Commercially available FCR was diluted in the ratio of 1:1 with distilled water

Procedure

To 100 mg of fine seed powder, 1.0 ml of 0.1 N NaOH was added followed by 5 ml of sodium carbonate reagent and allowed to stand for 10 minutes, 0.5 ml FCR was added rapidly and allowed to stand for 30 minutes. It was read at 660 nm against a suitable blank.

Standard curve was prepared using Bovine serum Albumin and protein content was expressed as mg per g seed.

3.3.2 Trypsin inhibitor

Laboratory experiment to estimate enzyme inhibitor was conducted in the laboratory as detailed below.

3.3.3 Preparation of reagents

- i. Phosphate buffer : 0.1 M, pH 7.6

Stock solutions

- A. 0.2 M monobasic sodium phosphate NaH₂PO₄ 31.202 g dissolved in 1000 ml H₂O – 0.2 M.
- B. 0.2 M solution of dibasic sodium phosphate Na₂HPO₄.2H₂O. 35.6 g dissolved in 1000 ml H₂O – 0.2 M.

Thirteen ml of A was mixed with 87 ml of B and diluted to a total of 200 ml to obtain 0.1 M phosphate buffer with pH. 7.6.

- ii. 1% casein : 100 ml phosphate buffer was taken into conical flask and kept on boiling water bath. One gram of casein was added pinch by pinch and it was kept on water bath for one hour, later it was cooled and volume was made upto 100 ml with distilled water. This 1% casein was prepared fresh every time.

- iii. 5% TCA : 5 g of TCA was weighed and dissolved in 100 ml of distilled water.

- iv. A. Trypsin stock solution : Ten mg of trypsin was dissolved in 10 ml of 0.001 M, HCl and was stored in deep freezer.

- b. Trypsin working solution : One ml of stock solution was diluted with 10 of 0.001 M HCl.

3.3.4 Determination of proteolytic activity

This was determined by following casein digestion method described by Birk *et al.* (1962) and activity was measured at an absorbancy of 280 nm (Kunitz, 1947).

The reaction mixture consisted of 0.9 ml of buffer and 0.1 ml of enzyme solution. This was incubated at room temperature for 5 minutes 1 ml of preincubated 1 per cent casein solution was added at 37°C to start the reaction. Enzymatic activity was terminated after 20 minutes of incubation at 37°C by adding 3 ml of Trichloroacetic acid. After 30 minutes, the reaction mixture was filtered through Whatman No. 1 filter paper and absorbance at 280 nm was measured.

One unit of enzyme is the amount of enzyme that causes an increase of 1 unit of absorbance at 280 nm per minute of digestion of casein under the assay conditions (Birk, 1976).

3.3.5 Trypsin inhibitor activity (TIA)

3.3.5.1 Reagents required

- a. Phosphate buffer 0.1 M, pH 7.6
- b. 5% TCA
- c. 1% casein

3.3.5.2 Procedure

The finely ground sample was extracted with phosphate buffer, in a pestle and mortar. The homogenate was centrifuged for 15 minutes. Supernatant was collected and volume made to 10 ml with buffer.

The trypsin inhibitor activity was determined by the method described by Kakade *et al.* (1969) using casein as substrate.

Inhibitory activity was determined by including suitable amounts of inhibitory (seed extract) in the assay system. A known amount of enzyme solution was taken in an assay system containing 0.1 M phosphate buffer with 7.6 pH and final volume was made to 1 ml after adding known amount of inhibitor extract. Enzyme and inhibitor were pre-incubated for 10 minutes at room temperature. The reaction was started by adding 1 ml of 1 per cent casein. After 20 minutes at 37°C, the reaction was terminated by adding 3 ml of 5 per cent TCA. To the control, TCA was added before casein. The contents were allowed to settle for 30 minutes at room temperature before being filtered through Whatman No. 1 filter paper. Alternatively absorbance of the filtrate was read at 280 nm. Decrease in caseinolytic activity in the test system compared with the control was a measure of inhibitory activity.

One trypsin inhibitor unit is defined as the amount of inhibitor inhibiting one enzyme unit under the assay conditions. One TIU is arbitrarily defined as decrease of 0.01 absorbance units at 280 nm with reference to enzyme control.

3.3.6 Estimation of pre-phenols by Folin-Ciocalteu Reagent (FCR) method

The term phenols include large group of organic aromatic compounds having one or more hydroxyl groups on the benzene ring. They are known to provide resistance to the plants and are easily oxidised by phenol oxidases to quinones which highly reactive and toxic to the insects, pathogens and their enzymes.

Reagents

- a. 20% Na₂CO₃ : 20 g of sodium carbonate in 50 ml distilled water.
- b. FCR : Commercially available FCR was diluted with distilled water in the ratio of 1:1

Procedure

Known volume of the sample aliquot taken from the stock solution was made to 3 ml with distilled water. 0.5 ml FCR was added and allowed to stand for 20 minutes followed by addition of 2 ml 20% Na₂CO₃. The blue colour developed was read at 650 nm after making up the volume to 10 ml with distilled water against suitable blank. Standard curve was obtained using catechol. Phenols were expressed as mg per g dry weight.

IV. EXPERIMENTAL RESULTS

4.1 EVALUATION OF REDGRAM GENOTYPES FOR RESISTANCE TO *C. chinensis* AND *C. maculatus*

4.1.1 Seed parameters

All the genotypes showed significant differences in initial weight (Table 1). The weight varies from one genotype to other genotype. The highest weight 12.96 g was recorded in ICPL-99032-1 which was at par with GPS-2003 (12.52 g) and WRP-266 (12.22 g). The lowest weight was recorded in GMS-1 (9.27 g) and ICPL-2009-1 (9.58 g) these were at par with PG-12 (9.77 g) and PG-27 (9.67 g).

The per cent moisture content exhibited not significantly differ among genotypes (Table 1). It varied from 9.5 to 10.1 per cent. The lowest was recorded in ICPL-8863 (9.5%), ICPL-99032-1 (9.6%), DEPS-9 (9.6%) and WRP-230-1-1 (9.6%). The highest was recorded in GMS-1 (10.1%), GS-1 (10.0%) and PG-44 (10.0%).

4.1.2 Growth performance of *C. chinensis* on redgram genotypes

The number of eggs laid by two pairs of insects was observed from the data (Table 2). All the genotypes of redgram were received the eggs by *C. chinensis*. The mean number of eggs laid on the test genotypes ranged from 53 to 98 eggs. The genotypes DEPS-9 (53), WRP-230-1-1 (53), ICPL-2008-1 (54.54) and PG-12 (55) were least preferred for oviposition. The genotypes PG-27 (98), PG-44 (96) and WRP-266 (95) were received highest number of eggs compared to other genotypes.

The highest per cent adult emergence was (91.78) noticed in genotype GS-1 which was on par with GPS-2003 (89.16%) followed by ICPL-2009-1 (88.16%), WRP-266 (82.36%), PG-27 (86.38%) and ICPL-99032-1 (82.36%). The lowest per cent adult emergence was seen in genotype DEPS-3 (32.15%) followed by ICPL-2008-1 (38.88%), DEPS-9 (42.13%), WRP-230-1-1 (47.75%) and PG-12 (52.10%).

The developmental period was found to vary significantly which ranged from 24.33 days to 32 days. The highest developmental period was 32 days noticed in DEPS-3, which was on par with DEPS-9 (31 days), PG-12 (31 days) and followed by ICPL-2008-1 (30.33 days). The least developmental period was 24.33 days in ICPL-87119 and GPS-2003, there were on par with PG-27 (24.66 days), PG-44 (25 days) followed by ICPL-99032-1 (26 days), ICPL-2009-1, V-71 and WRP-266 (26.33 days).

All the genotypes showed significant difference in growth index values (Table 2). It was vary from 1.00 to 3.66. The least growth index value was found in DEPS-3 followed by ICPL-2008-1 (1.28), DEPS-9 (1.35), WRP-230-1-1 (1.59) and PG-12 (1.68). The highest growth index value was 3.66 in GPS-2003, which was on par with PG-27 (3.5) and followed by ICPL-2009-1, GS-1 (3.39), WRP-266 (3.31) and ICPL-87119 (3.24).

Per cent loss of germination observed from the data (Table 3) indicated that all the genotypes showed significant differences. The highest per cent loss of germination was 83.5 per cent recorded in PG-27 followed by WRP-266 (78.0%), PG-44 (69.2%), V-71 (68.1%) and ICPL-99032-1 (65.9%). The least per cent loss of germination was in DEPS-3 (12.00%) followed by WRP-230-1-1 (14.9%), ICPL-2008-1 (15.50%), DEPS-9 (17.3%) and PG-12 (21.1%).

The per cent grain weight loss (Table 3) caused due to feeding by grubs was highest of 42.7 per cent recorded in PG-27 followed by PG-44 (37.06%), WRP-266 (35.55%), ICPL-8863 (33.15%) and ICPL-2009-1 (33.19%). The lowest weight loss was observed in DEPS-3 (15.44%) followed by ICPL-2008-1 (16.97%), DEPS-9 (16.98%) and WRP-230-1-1 (19.47%).

Table 1: Seed parameters of sixteen genotypes of redgram genotypes

Genotype	Initial weight of 100-seeds (g)	Moisture content (%)	
ICPL-8863	10.71def	9.5	(18.14)
ICPL-2008-1	10.84fg	9.8	(18.24)
ICPL-99032-1	12.96a	9.6	(18.25)
ICPL-2009-1	9.58h	9.7	(18.24)
ICPL-87119	11.57c	9.9	(18.23)
GS—1	11.50c	10.0	(18.23)
GMS-1	9.27h	10.1	(18.23)
GPS-2003	12.52ab	9.9	(18.33)
DEPS-3	11.20cd	9.8	(18.24)
DEPS-9	11.13cd	9.6	(18.25)
WRP-266	12.22b	9.8	(18.24)
WRP-230-1-1	10.52f	9.6	(18.21)
V-71	11.07cd	9.7	(18.24)
PG-12	9.77gh	9.8	(18.24)
PG-27	9.67gh	9.9	(18.23)
PG-44	10.36f	10.0	(18.23)

Figures in the parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT (p = 0.05)

Table 2: Growth performance of *C. chinensis* on redgram genotypes

Genotype	No. of eggs laid by 2 pairs of insect	Per cent of adult emergence	Developmental period	Growth index
ICPL-8863	78.00c (8.52)	80.76de (63.97)	28.00b-e (5.29)	2.88de (1.69)
ICPL-2008-1	54.54f (7.24)	38.88j (38.57)	30.33abc (5.50)	1.28h (1.13)
ICPL-99032-1	87.00b (9.32)	82.36d (65.16)	26.00def (5.09)	3.16c (1.77)
ICPL-2009-1	62.00de (7.86)	88.16bc (69.87)	26.00def (5.09)	3.39abc (1.84)
ICPL-87119	73.00c (8.53)	78.98ef (62.68)	24.33f (4.93)	3.24bc (1.80)
GS—1	65.00d (8.07)	91.78a (72.82)	27.00cde (5.19)	3.39abc (1.84)
GMS-1	74.00c (8.63)	76.56fg (61.04)	28.66bc (5.35)	2.67e (1.63)
GPS-2003	77.00d (8.81)	89.16ab (70.78)	24.33f (4.93)	3.66a (1.91)
DEPS-3	57.00ef (7.54)	32.15k (34.54)	32.00a (5.65)	1.00i (0.99)
DEPS-9	53.00f (7.20)	42.13j (40.46)	31.00ab (5.56)	1.35h (1.62)
WRP-266	95.00a (9.74)	87.36bc (69.16)	26.33def (5.13)	3.31bc (1.81)
WRP-230-1-1	53.00f (7.20)	47.75l (43.71)	30.00abc (5.47)	1.59g (1.26)
V-71	87.00b (9.34)	80.83de (63.95)	26.00def (5.09)	3.10cd (1.76)
PG-12	55.00f (7.28)	52.10h (46.20)	31.00ab (5.56)	1.68g (1.29)
PG-27	98.00a (9.98)	86.38c (68.34)	24.66ef (4.96)	3.50ab (1.87)
PG-44	96.00a (9.79)	73.95g (59.30)	25.00ef (4.99)	2.99f (1.70)

Figures in the parentheses indicate mean values

Figures in parentheses are angular transformed values in per cent adult emergence

Means followed by common letter are not significantly differ by DMRT (p = 0.05)

Table 3: Per cent germination and weight loss caused by *C. chinensis* in redgram genotypes

Genotype	Per cent loss of germination	Per cent grain weight loss
ICPL-8863	59.5h (50.47)	33.42d (35.36)
ICPL-2008-1	15.5o (23.18)	16.97i (24.31)
ICPL-99032-1	65.9e (54.27)	29.78f (32.73)
ICPL-2009-1	48.8l (44.88)	33.19d (35.18)
ICPL-87119	50.0k (45.00)	28.52g (32.28)
GS—1	52.2j (46.26)	29.30f (32.77)
GMS-1	53.2l (46.83)	38.16c (36.37)
GPS-2003	63.1g (52.71)	29.87e (33.13)
DEPS-3	12.0p (20.27)	15.44k (23.13)
DEPS-9	17.3n (24.57)	16.98l (24.32)
WRP-266	78.0b (62.03)	35.35c (36.48)
WRP-230-1-1	14.9o (22.71)	19.47l (26.17)
V-71	68.1d (55.60)	28.72g (32.38)
PG-12	21.1m (27.34)	25.28h (30.18)
PG-27	83.5a (66.03)	42.70a (40.80)
PG-44	69.2c (56.29)	37.06b (37.49)

Figures in parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT ($p = 0.05$)

4.1.3 Growth performance of *C. maculatus* on redgram genotypes

The number of eggs laid by two pairs of *C. maculatus* was observed from the data (Table 4). All the genotypes of redgram received the eggs by the *C. maculatus*. The mean number of egg laid on the test genotypes ranged from 49 to 92.66 eggs. The genotypes DEPS-9 (49.00) and DEPS-3 (50.00) received least number of eggs, which were on par with ICPL-8863 (53.33) and followed by GMS-1 (56.66 eggs). The genotypes GPS-2003 (92.66), ICPL-87119 (89.33) and PG-44 (85.00) received highest number of eggs followed by ICPL-99032.1 (82.33) and V-71 (75.66) eggs.

The highest per cent adult emergence was noticed in ICPL-2009-1 (93.00%) followed by PG-27 (89.94%), GPS-2003 (86.335), ICPL-87119 (83.95), GMS-1 (81.18) and PG-44 (80.00%). The lowest adult emergence was noticed in GS-1 (43.33%) followed by ICPL-2008-1 (45.41%), PG-12 (46.66%), WRP-230-1-1 (47.05), DEPS-3 (58.00%) and DEPS-9 (61.22%).

The development period was found to vary significantly which ranged from 26.33 days to 32.33 days. The highest developmental period was 32.33 days noticed in PG-12, which was on par with DEPS-9 (31.33), WRP-266 (31.33), ICPL-2008-1 (31) and DEPS- (31). The lowest development periods were found in PG-44 (26.33) and ICPL-87119 (26.33) which were on par with V-71 (27.00) followed by ICPL-99032-1 and ICPL-2009-1 (27.33) days.

All the genotypes showed significant difference in growth index value (Table 4), it varied from 1.44 to 3.45. The lowest growth index value noticed in PG-12 (1.44), ICPL-2008-1 (1.46), GS-1 (1.47) and WRP-230-1-1 (1.50) followed by DEPS-3 (1.87) and DEPS-9 (1.95). The highest growth index value was noticed in GPS-2003 (3.45) and ICPL-2009-1 (3.36) followed by PG-27 (3.21), ICPL-87119 (3.18) and PG-44 (3.03).

The per cent loss of germination observed from the data (Table 5) all the genotypes showed significant differences. The highest per cent loss of germination was GPS-2003 (78.80%) followed by PG-44 (74.7%), ICPL-87119 (72.00%) and PG-27 (62.7%). The least per cent loss of germination was noticed in ICPL-2008-1 (22.20%) followed by GS-1 (23.30%), PG-12 (23.30%), DEPS-3 (24.1%), WRP-230-1-1 (26.10%) and DEPS-9 (27.10%).

The per cent grain weight loss (Table 5) caused due to feeding by *C. maculatus* was highest 39.72 per cent in PG-27 followed by PG-44 (36.72%), ICPL-2009-1 (35.07%), ICPL-87119 (34.55%), GPS-2003 (32.60%) and WRP-230-1-1 (32.04%). The lowest weight loss was observed in ICPL-2008-1 (17.18%) followed by GS-1 (18.48%), DEPS-3 (19.46%) and DEPS-9 (19.74%).

Table 4: Growth performance of *C. maculatus* on redgram genotypes

Genotype	No. of eggs laid by 2 pairs of insect	Per cent of adult emergence	Developmental period	Growth index
ICPL-8863	53.33hi (4.20)	75.00h (60.00)	28.66cd (5.35)	2.61d (1.61)
ICPL-2008-1	61.60fg (7.85)	45.41m (42.35)	31.00b (3.56)	1.46f (1.20)
ICPL-99032-1	82.33b (9.07)	71.66i (57.82)	27.33ef (5.22)	2.62d (1.61)
ICPL-2009-1	66.66de (8.28)	93.00a (74.68)	27.66ef (5.26)	3.36a (1.85)
ICPL-87119	89.33a (9.44)	83.95d (66.36)	26.33g (5.13)	3.18b (1.79)
GS—1	64.66ef (8.04)	43.33n (41.16)	29.33c (5.41)	1.47f (1.21)
GMS-1	56.66gh (7.52)	81.18e (64.27)	28.66cd (5.35)	2.83c (1.68)
GPS-2003	92.66a (9.62)	86.33c (68.28)	25.00h (5.00)	3.45a (1.85)
DEPS-3	50.00i (7.06)	58.00k (49.00)	31.00b (5.56)	1.87e (1.36)
DEPS-9	49.00i (7.00)	61.22j (51.48)	31.33b (5.59)	1.95e (1.39)
WRP-266	60.66g (7.78)	75.83gh (66.55)	31.33b (5.59)	2.70cd (1.64)
WRP-230-1-1	58.33g (7.60)	47.00l (43.28)	28.00cd (5.35)	1.50f (1.21)
V-71	75.66c (8.69)	76.65g (61.10)	27.00fg (5.19)	2.83c (1.68)
PG-12	64.33ef (8.01)	46.66l (43.08)	32.33a (5.68)	1.44f (1.20)
PG-27	72.66cd (8.52)	89.94b (71.51)	28.00de (5.29)	3.21b (1.79)
PG-44	85.00a (7.74)	80.00e (63.44)	26.33g (5.13)	3.03b (1.74)

Figures in the parentheses indicate mean values

Figures in parentheses are angular transformed values in per cent adult emergence

Means followed by common letter are not significantly differ by DMRT ($p = 0.05$)

Table 5: Per cent germination and weight loss caused by *C. maculatus* in redgram genotypes

Genotype	Per cent loss of germination		Per cent grain weight loss	
ICPL-8863	33.71j	(35.49)	26.84j	(32.20)
ICPL-2008-1	22.20o	(28.11)	17.18p	(24.05)
ICPL-99032-1	54.90f	(47.81)	25.90k	(30.59)
ICPL-2009-1	55.60e	(48.21)	35.07c	(36.30)
ICPL-87119	72.00c	(58.65)	34.55d	(36.00)
GS—1	23.30n	(28.86)	18.48o	(25.44)
GMS-1	41.10h	(39.70)	30.40g	(33.45)
GPS-2003	78.80a	(62.61)	32.60e	(34.82)
DEPS-3	24.10m	(29.40)	19.46n	(26.17)
DEPS-9	27.10k	(31.37)	19.74m	(26.37)
WRP-266	39.00i	(38.64)	27.18l	(32.45)
WRP-230-1-1	26.10l	(30.74)	32.64e	(32.84)
V-71	53.40g	(46.94)	31.16f	(33.88)
PG-12	23.30n	(28.86)	25.46l	(30.29)
PG-27	62.70d	(52.36)	39.72a	(39.07)
PG-44	74.70b	(59.80)	36.72b	(37.29)

Figures in parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT (p = 0.05)

4.2 EVALUATION OF COWPEA GENOTYPES FOR RESISTANCE TO *C. chinensis* and *C. maculatus*

4.2.1 Seed parameter

All the genotypes showed significant differences in initial weight (Table 6). The weight varied from 9.6 g to 12.12 g except Goa local (22.97 g). The highest weight 12.96 g was recorded in C-70, which was on par with TVX 944 (11.83 g) and T-1 (11.30 g). The lowest weight was recorded in KM-5 (9.60 g), which was on par with V-585 (9.73) and C-3 (9.8 g).

No significant difference in per cent moisture content was seen in all genotypes (Table 6). It varied from 9.7 to 10.3 per cent. The lowest per cent moisture content was recorded in genotypes T-9 (9.7%), KM-4 (9.8%), V-118 (9.8) and Goa local (9.8). The highest per cent moisture content was seen in genotypes KM-1 (10.3%), T-4 (10.3%), TVX 944 (10.3%) and C-3 (10.2%).

4.2.2 Growth performance of *C. chinensis* on cowpea genotypes

The number of eggs laid by two pairs of *C. chinensis* on cowpea genotypes were observed from the data (Table 7). The mean number of eggs laid on the test genotypes ranged from 53.33 to 85.33 eggs. The genotypes T-4 (85.33), V-118 (84.00), C-3 (83.66), C-70 (82.33) and DCP-2 (78.66) received highest number of eggs followed by V-585 (67.66), which was on par with KM-4 (65.66) and KM-1 (64.66). The genotype T-1 (53.33) received least number of eggs which was on par with T-9 (57.31) followed by Goa local (57.38) and TVX 944 (57.00).

The highest per cent adult emergence was noticed in DCP-2 (84.3%) followed by V-118 (79.76%), C-70 (78.53%), KM-4 (77.67%), T-4 (77.34%), V-585 (77.34%) and t-9 (75.62%). The lowest per cent adult emergence was noticed in KM-1 (27.99%) followed by T-1 (39.00%), Goa local (49.41%) and KM-5 (53.04%).

The developmental period was found to vary significantly which ranged from 25.66 days to 32.66 days. The highest developmental period was recorded in Goa local (32.66 days, KM-1 (32 days) and T-1 (32 days) followed by T-9 (29.66 days) and TVX 944 (29.66 days). The least developmental period was 25.66 day in DCP-2 followed by C-70 (27.00 days), KM-5 (27.33 days) and T-4 (27.66 days).

All the genotypes showed significant differences in growth index value (Table 7). It varied from 0.87 to 3.28. The least growth index value was 0.87, noticed in KM-1 which was on par with T-1 (1.00) followed by Goa local (1.51) and KM-5 (1.94). The highest growth index value was 3.28 recorded in DCP-2 which was on par with V-118 (3.10) followed by C-70 (2.90).

As regards per cent loss of germination observed from the data (Table 8), all the genotypes showed significant differences. The highest per cent loss of germination was 64.8 per cent recorded in DCP-2 followed by V-118 (64.4%), T-4 (63.00%) and C-70 (61.5%). The least per cent loss of germination was 13.1 per cent recorded in KM-1 followed by Goa local (19.00%), TVX 944 (30.07%) and T-1 (33.30%).

The per cent grain weight loss caused due to feeding by grubs is presented in Table 8. The highest weight loss was seen in genotypes KM-4 (36.03%), T-4 (36.00%), C-3 (35.51%) and DCP-2 (35.43%) followed by V-118 (33.27), KM-5 (31.88) and V-585 (31.75%). The minimum weight loss was 9.49 per cent recorded in Goa local followed by KM-1 (16.80%), T-1 (20.17%) and TVX 944 (20.75%).

Table 6: Seed parameters of thirteen genotypes of cowpea genotypes

Genotype	Initial weight of 100-seeds (g)	Moisture content (%)	
C-3	9.8f	10.2	(18.62)
C-70	12.12b	10.1	(18.73)
Km-1	10.23ef	10.3	(18.77)
Km-4	10.10f	9.8	(18.74)
Km-5	9.60f	9.9	(18.63)
T-1	11.30bcd	10.0	(18.43)
T-4	10.12f	10.3	(18.72)
T-9	10.50def	9.7	(18.64)
DCP-2	10.30ef	9.9	(18.63)
V-118	11.06cde	9.8	(18.74)
V-585	9.73f	10.1	(18.63)
TV × 944	11.83bc	10.3	(18.72)
Goa Local	22.97a	9.8	(18.74)

Figures in the parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT ($\rho = 0.05$)

Table 7: Growth performance of *C. chinensis* on cowpea genotypes

Genotype	No. of eggs laid by 2 pairs of insect	Per cent of adult emergence	Developmental period	Growth index
C-3	83.66a (9.14)	74.10f (59.39)	26.66de (5.16)	2.79cd (1.67)
C-70	82.33a (9.07)	78.53c (62.39)	27.00cde (5.19)	2.90bc (1.70)
Km-1	64.66bc (7.96)	27.99k (31.93)	32.00a (5.68)	0.87h (0.93)
Km-4	65.66bc (8.10)	77.67d (61.79)	28.33bc (5.32)	2.74cd (1.65)
Km-5	60.33cd (7.76)	53.04h (46.74)	27.33cd (5.22)	1.94ef (1.39)
T-1	53.33e (7.20)	39.00j (38.30)	32.00a (5.65)	1.00gh (1.36)
T-4	85.33a (9.23)	77.34d (61.54)	27.66cd (5.26)	2.79cd (1.67)
T-9	57.31de (7.56)	75.62e (60.42)	29.66b (5.44)	2.54de (1.59)
DCP-2	78.66a (8.86)	84.32a (66.31)	25.66e (5.06)	3.28a (1.81)
V-118	84.00a (9.16)	79.76b (63.20)	27.00cde (5.19)	3.10ab (1.76)
V-585	67.66b (8.22)	77.34d (61.57)	28.33bc (5.32)	2.72cd (1.64)
TV × 944	57.00d (7.54)	61.98g (51.90)	29.66b (5.44)	2.08e (1.44)
Goa Local	57.38d (7.56)	49.41i (41.65)	32.66a (5.71)	1.51g (1.22)

Figures in the parentheses indicate mean values

Figures in parentheses are angular transformed values in per cent adult emergence

Means followed by common letter are not significantly differ by DMRT ($p = 0.05$)

Table 8: Per cent germination and weight loss caused by *C. chinensis* in cowpea genotypes

Genotype	Per cent loss of germination		Per cent grain weight loss	
C-3	58.2e	(49.72)	35.51a	(36.58)
C-70	61.5d	(51.65)	29.53d	(32.93)
Km-1	13.3m	(21.38)	16.80g	(24.25)
Km-4	49.4g	(44.65)	36.03a	(36.90)
Km-5	50.3f	(45.15)	31.88c	(34.43)
T-1	33.3j	(35.32)	20.17f	(26.71)
T-4	63.0c	(52.52)	36.00a	(36.86)
T-9	39.00i	(38.72)	26.00e	(30.65)
DGP-2	64.8a	(53.66)	35.43a	(36.80)
V-118	64.4b	(53.43)	33.27b	(35.25)
V-585	48.8h	(44.31)	31.75c	(34.30)
TV × 944	30.7k	(33.65)	20.37f	(26.85)
Goa Local	19.0l	(25.70)	9.49h	(12.92)

Figures in parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT (p = 0.05)

4.2.3 Growth performance of *C. maculatus* on cowpea genotypes

The number of eggs laid by two pairs of *C. maculatus* was observed from the data (Table 9). All the genotypes of cowpea received the eggs. The mean number of eggs laid on the test genotypes ranged from 53.33 to 77.0 eggs. The genotypes KM-1 (77.00) received maximum number of eggs which was on par with KM-5 (73.66) followed by T-4 (69.66), TVX 944 (69.33), V-118 (67.33), C-70 (65.00) and C-3 (64.33). The genotypes T-9 (53.33), DCP-2 (54.33) received least number of eggs being on par with Goa local (55.00) and KM-4 (55.33).

The highest per cent adult emergence was observed in genotypes C-70 (95.38), DCP-2 (94.47) followed by C-3 (88.07), V-585 (86.70), T-4 (85.17) and V-118 (85.14). The lowest per cent adult emergence was seen in genotypes KM-1 (32.02) followed by Goa local (44.13), T-1 (54.63) and TVX 944 (57.20).

The developmental period was found to vary significantly which ranged from 27.00 to 32.66 days. The highest developmental period recorded was 32.66 days in Goa local which was on par with KM-1 (31.66 days). T-1 and TVX 944 (30.66 days). The lowest developmental period was 27 days recorded in C-70 which was on par with C-3 and V-118 (27.33 days).

All the genotypes showed significant differences in growth index value (Table 9). It varied from 1.01 to 3.53. The highest growth index value was 3.53 recorded in C-70 followed by C-3 (3.22) which was on par with DCP-2 (3.18) and V-118 (3.11) followed by V-585 (3.02) and T-4 (3.00). The lowest growth index value was 1.01 recorded in KM-1 followed by Goa local (1.35), T-1 (1.78) and TVX 944 (1.86).

As regards per cent loss of germination observed from the data (Table 10), all the genotypes showed significant difference. The highest per cent loss of germination was 59.3 per cent noticed in C-70 followed by KM-5 (55.9%), T-4 (58.4%), V-118 (54.4%), C-3 (52.7%) and V-585 (51.1%). The lowest per cent loss of germination was 18.8 per cent noticed in KM-1 followed by Goa local (21.7%), T-1 (27.7%) and T-9 (31.8%).

The per cent grain weight loss (Table 10) caused due to feeding of grubs indicated that highest per cent weight loss was seen in genotype KM-5 (34.58%) followed by T-4 (33.32%), C-3 (32.85%), V-585 (32.57%) and V-118 (30.77%). The lowest weight loss was observed in genotype Goa local (8.58%) followed by KM-1 (19.5%), T-1 (20.76%), TVX 944 (21.36) and T-9 (23.87%).

Table 9: Growth performance of *C. maculatus* on cowpea genotypes

Genotype	No. of eggs laid by 2 pairs of insect	Per cent of adult emergence	Developmental period	Growth index
C-3	64.33cd (8.01)	88.07b (69.78)	27.33cd (5.22)	3.22b (1.79)
C-70	65.00cd (8.02)	95.38a (77.59)	27.00d (5.19)	3.53a (1.87)
Km-1	77.00a (8.77)	32.02g (34.46)	31.66ab (5.62)	1.01i (1.02)
Km-4	55.33ef (7.40)	76.50c (61.00)	29.33a-d (5.41)	2.60e (1.57)
Km-5	73.66ab (8.58)	78.74c (62.53)	28.00bcd (5.29)	2.81d (1.65)
T-1	61.00de (7.80)	54.63f (44.31)	30.66abc (5.53)	1.78g (1.31)
T-4	69.66bc (8.34)	85.17b (67.34)	28.33bcd (5.32)	3.00c (1.72)
T-9	53.33f (7.30)	70.61b (57.17)	31.00ab (5.56)	2.27f (1.49)
DCP-2	54.33f (7.36)	94.47a (76.37)	29.66a-d (5.42)	3.18bc (1.76)
V-118	67.33bcd (8.17)	85.14b (67.31)	27.33cd (5.22)	3.11bc (1.74)
V-585	62.66d (7.85)	86.70b (68.60)	28.66bcd (5.35)	3.02c (1.73)
TV × 944	69.33bc (8.32)	57.20e (49.14)	30.66abc (5.53)	1.86g (1.33)
Goa Local	55.00ef (7.40)	44.13f (41.72)	32.66a (5.71)	1.35h (1.07)

Figures in the parentheses indicate mean values

Figures in parentheses are angular transformed values in per cent adult emergence

Means followed by common letter are not significantly differ by DMRT ($p = 0.05$)

Table 10: Per cent germination and weight loss caused by *C. maculatus* in cowpea genotypes

Genotype	Per cent loss of germination		Per cent grain weight loss	
C-3	52.7e	(46.54)	32.85c	(34.98)
C-70	59.3a	(50.36)	29.16f	(32.69)
Km-1	18.8m	(25.67)	19.15j	(26.18)
Km-4	38.4h	(38.29)	29.11f	(32.65)
Km-5	55.9b	(48.39)	34.58a	(36.01)
T-1	27.7k	(31.57)	20.76i	(27.09)
T-4	55.4c	(48.10)	33.32b	(35.26)
T-9	31.8j	(34.33)	23.87g	(29.24)
DCP-2	47.2g	(43.39)	29.64e	(33.18)
V-118	54.4d	(47.52)	30.77d	(33.68)
V-585	51.1f	(45.61)	32.57c	(34.78)
TV × 944	35.1i	(36.35)	21.36h	(27.53)
Goa Local	21.7l	(27.73)	8.58k	(17.01)

Figures in parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT (p = 0.05)

4.3 BIOCHEMICAL BASIS FOR BRUCHID RESISTANCE IN REDGRAM AND COWPEA GENOTYPES

4.3.1 Biochemical basis for bruchid resistance in redgram

4.3.1.1 Protein content of redgram genotypes

Protein content (mg/g seed) was recorded and the data is shown in Table 11. The highest protein content was found in genotypes ICPL-2009-1 and PG-27 (236.00), ICPL-87119 and PG-44 (235.00), GPS-2003 and WRP-266 (234.00) followed by GMS-1 and V-71 (233.00). The lowest protein content genotypes seen in GS-1 (222.00), which was on par with DEPS-3 (224.00), DEPS-9 (227.00) and ICPL-2008-1 (277.66).

4.3.1.2 Trypsin inhibitor units of redgram genotypes

Trypsin inhibitor values are expressed as trypsin inhibitor units for milligram of protein (TIU/mg protein) (Table 12). The variation was observed ranging from 11.06 to 14.36 TIU/mg protein. The highest TIU amount was seen in genotypes DEPS-3 (14.36), ICPL-2008-1 (14.34) which were on par with PG-12 (13.66) and WRP-230-1-1 (13.59) followed by DEPS-9 (13.00). The lowest TIU amount genotypes were PG-27 (11.06) and GPS-2003 (11.08).

4.3.1.3 Phenol content in redgram genotypes

Phenol content (mg/g seed) was recorded and the data is presented in Table 13. The highest phenol content was seen in genotype GS-1 (0.411) followed by ICPL-2008-1, DEPS-3 and DEPS-9 (0.402). The lowest was recorded in GMS-1 (0.302) followed by ICPL-87119 (0.347) and PG-27 (0.349).

4.3.1.4 Adult emergence of *C. chinensis*

All the genotypes differed significantly in adult emergence (Table 2). The highest adult emergence was recorded in PG-27 (84.66), WRP-266 (83.00) followed by ICPL-99032-1 (71.66) and PG-44 (71.00). The least adult emergence was recorded in DEPS (18.33), which was on par with ICPL-2008-1 (21.00) and followed by DEPS-9 (22.33), WRP-230-1-1 and PG-12 (28.66).

4.3.1.5 Adult emergence of *C. maculatus*

All the genotypes differed significantly in adult emergence (Table 4). The highest adult emergence was recorded in GPS-2003 (80.00), PG-44 (76.00), ICPL-87119 (75.00) followed by PG-27 (65.00) and ICPL-2009-1 (62.00). The least adult emergence was recorded were ICPL-2008-1 (28.00) and GS-1 (28.00) being on par with DEPS-3 (29.00) and DEPS-9 followed by WRP-230-1-1 (32).

4.3.2 Biochemical basis for bruchid resistance in cowpea genotypes

4.3.2.1 Protein content of cowpea genotypes

Protein content (mg/g seed) was recorded and the data is shown in Table 14. The highest protein content was recorded in genotypes KM-4 and T-4 (257.00), which were on par with C-3 (256.00), DCP-2 (255.00), V-118 (254.00), KM-5 (251.00). The lowest protein content was seen in genotypes Goa local (240.00), TVX 944 and KM-1 (241.00), which were on par with T-1 (242.00) and T-9 (243.00).

4.3.2.2 The trypsin inhibitor units of cowpea genotypes

Trypsin inhibitor units variation was observed ranging from 10.12 to 14.25 TIU/mg protein. The highest TIU amount was found to be in genotype KM-1 (14.25) followed by Goa local (13.91), T-1 (13.42) and TVX 944 (13.30). The lowest TIU amount was seen in genotypes was C-70 (10.12) followed by V-588 (10.20), C-3 (10.22) and V-118 (10.23).

Table 11: Protein content (mg/g) of redgram genotypes, number of adult emergence of *C. chinensis* and *C. maculatus*

Genotype	Protein content (mg/g)	Number of adult emergence	
		<i>C. chinensis</i>	<i>C. maculatus</i>
ICPL-8863	231.00ab	63.00cd (7.93)	40.00d (6.72)
ICPL-2008-1	227.66bcd	21.00hi (4.57)	28.00f (4.34)
ICPL-99032-1	230.00abc	71.66b (8.46)	59.00d (7.08)
ICPL-2009-1	236.00a	54.66e (7.39)	62.00c (7.67)
ICPL-87119	235.00a	57.66de (7.59)	75.00a (8.73)
GS—1	222.00d	59.66de (7.72)	28.00f (5.34)
GMS-1	233.00b	56.66de (7.52)	46.00e (6.77)
GPS-2003	234.00a	68.66bc (8.28)	80.00a (8.73)
DEPS-3	224.00cd	18.33l (4.21)	29.00ef (5.40)
DEPS-9	227.00cd	22.33gh (4.72)	30.00e (5.79)
WRP-266	234.00a	83.00a (9.40)	46.00d (6.82)
WRP-230-1-1	232.00ab	25.31fg (5.00)	32.00ef (5.65)
V-71	233.00b	70.33b (8.38)	58.00c (7.83)
PG-12	229.00abc	28.66f (5.35)	30.00e (5.79)
PG-27	236.00a	84.66a (9.32)	65.00bc (7.97)
PG-44	235.00a	71.00b (8.42)	76.00a (8.71)

Figures in the parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT ($p = 0.05$)

Table 12: The trypsin inhibitor level of redgram genotypes, No. of adult emergence of *C. chinensis* and *C. maculatus*

Genotype	Trypsin inhibitor units/mg of protein	No. of adult emergence	
		<i>C. chinensis</i>	<i>C. maculatus</i>
ICPL-8863	12.16c	63.00cd (7.93)	40.00d (6.72)
ICPL-2008-1	14.34a	21.00hi (4.57)	28.00f (5.34)
ICPL-99032-1	11.78cd	71.66b (8.46)	59.00d (7.08)
ICPL-2009-1	11.21d	54.66e (7.39)	62.00c (7.67)
ICPL-87119	11.48cd	57.66de (7.59)	75.00a (8.73)
GS—1	12.15c	59.66de (7.72)	28.00f (5.34)
GMS-1	12.08c	56.66de (7.52)	46.00e (6.77)
GPS-2003	11.08d	68.66bc (8.28)	80.00a (8.73)
DEPS-3	14.36a	18.33l (4.21)	29.00ef (5.40)
DEPS-9	13.00b	22.33gh (4.72)	30.00e (5.79)
WRP-266	11.49cd	83.00a (9.40)	46.00d (6.82)
WRP-230-1-1	13.59ab	25.31fg (5.00)	30.00e (5.79)
V-71	11.46cd	70.33b (8.38)	58.00c (7.83)
PG-12	13.66ab	28.66f (5.35)	30.00e (5.79)
PG-27	11.06d	84.66a (9.32)	65.00bc (7.97)
PG-44	11.87cd	71.00b (8.42)	76.00a (8.71)

Figures in the parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT (p = 0.05)

Table 13: Phenol content (mg/g) of redgram genotypes, number of adult emergence of *C. chinensis* and *C. maculatus*

Genotype	Phenol content (mg/g)	Number of adult emergence	
		<i>C. chinensis</i>	<i>C. maculatus</i>
ICPL-8863	0.376c	63.00cd (7.93)	40.00d (6.72)
ICPL-2008-1	0.402b	21.00hi (4.57)	28.00f (4.34)
ICPL-99032-1	0.379c	71.66b (8.46)	59.00d (7.08)
ICPL-2009-1	0.359d	54.66e (7.39)	62.00c (7.67)
ICPL-87119	0.347g	57.66de (7.59)	75.00a (8.73)
GS—1	0.411a	59.66de (7.72)	28.00f (5.34)
GMS-1	0.302h	56.66de (7.52)	46.00e (6.77)
GPS-2003	0.354def	68.66bc (8.28)	80.00a (8.73)
DEPS-3	0.402b	18.33l (4.21)	29.00ef (5.40)
DEPS-9	0.402b	22.33gh (4.72)	30.00e (5.79)
WRP-266	0.351efg	83.00a (9.40)	46.00d (6.82)
WRP-230-1-1	0.374c	25.31fg (5.00)	32.00ef (5.65)
V-71	0.355de	70.33b (8.38)	58.00c (7.83)
PG-12	0.377c	28.66f (5.35)	30.00e (5.79)
PG-27	0.349fg	84.66a (9.32)	65.00bc (7.97)
PG-44	0.351efg	71.00b (8.42)	76.00a (8.71)

Figures in the parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT ($p = 0.05$)

Table 14: Protein content (mg/g) of cowpea genotypes, number of adult emergence of *C. chinensis* and *C. maculatus*

Genotype	Protein content (mg/g)	Number of adult emergence	
		<i>C. chinensis</i>	<i>C. maculatus</i>
C-3	256.00ab	62.00a (7.87)	56.66abc (7.50)
C-70	249.00bc	64.66a (8.04)	62.00a (7.90)
Km-1	241.00d	18.10g (4.23)	24.66f (4.80)
Km-4	257.00a	51.00b (7.14)	42.33d (6.24)
Km-5	251.00ab	52.10b (7.21)	58.00ab (7.60)
T-1	242.00cd	32.00e (5.65)	33.33e (5.76)
T-4	257.00a	66.00a (8.12)	59.33ab (7.70)
T-9	243.00cd	43.33c (6.58)	37.66de (6.05)
DCP-2	255.00ab	66.33a (8.14)	51.33c (7.16)
V-118	254.00ab	67.00a (8.18)	57.33bc (7.39)
V-585	249.00bc	52.33b (7.23)	54.33bc (7.27)
TV × 944	241.00d	35.33d (5.94)	39.66de (6.29)
Goa Local	240.00d	28.33f (5.32)	24.33f (4.92)

Figures in the parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT ($p = 0.05$)

Table 15: The trypsin inhibitor level of cowpea genotypes, No. of adult emergence of *C. chinensis* and *C. maculatus*

Genotype	Trypsin inhibitor units/mg of protein	No. of adult emergence	
		<i>C. chinensis</i>	<i>C. maculatus</i>
C-3	10.22h	62.00a (7.87)	56.66abc (7.50)
C-70	10.12l	64.66a (8.04)	62.00a (7.90)
Km-1	14.25a	18.10g (4.23)	24.66f (4.80)
Km-4	11.59f	51.00b (7.14)	42.33d (6.24)
Km-5	11.59f	52.10b (7.21)	58.00ab (7.60)
T-1	13.42c	32.00e (5.65)	33.33e (5.76)
T-4	10.18hf	66.00a (8.12)	59.33ab (7.70)
T-9	12.85e	43.33c (6.58)	37.66de (6.05)
DCP-2	10.66g	66.33a (8.14)	51.33c (7.16)
V-118	10.23h	67.00a (8.18)	57.33bc (7.39)
V-585	10.20h	52.33b (7.23)	54.33bc (7.27)
TV × 944	13.30d	35.33d (5.94)	39.66de (6.29)
Goa Local	13.91b	28.33f (5.32)	24.33f (4.92)

Figures in the parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT ($\rho = 0.05$)

Table 16: Phenol content (mg/g) of cowpea genotypes, number of adult emergence of *C. chinensis* and *C. maculatus*

Genotype	Phenol content (mg/g)	Number of adult emergence	
		<i>C. chinensis</i>	<i>C. maculatus</i>
C-3	0.358c	62.00a (7.87)	56.66abc (7.50)
C-70	0.351de	64.66a (8.04)	62.00a (7.90)
Km-1	0.418ab	18.10g (4.23)	24.66f (4.80)
Km-4	0.356cd	51.00b (7.14)	42.33d (6.24)
Km-5	0.345fg	52.10b (7.21)	58.00ab (7.60)
T-1	0.421a	32.00e (5.65)	33.33e (5.76)
T-4	0.349ef	66.00a (8.12)	59.33ab (7.70)
T-9	0.416ab	43.33c (6.58)	37.66de (6.05)
DCP-2	0.342g	66.33a (8.14)	51.33c (7.16)
V-118	0.351de	67.00a (8.18)	57.33bc (7.39)
V-585	0.344fg	52.33b (7.23)	54.33bc (7.27)
TV × 944	0.415b	35.33d (5.94)	39.66de (6.29)
Goa Local	0.420ab	28.33f (5.32)	24.33f (4.92)

Figures in the parentheses indicate angular transformed values
Means followed by common letter are not significantly differ by DMRT (p = 0.05)

4.3.2.3 Phenol content of cowpea genotypes

Phenol content (mg/g seed) was recorded (Table 13). The highest phenol content was found in genotypes T-1 (0.421) and Goa local (0.420) followed by KM-1 (0.418), T-9 (0.416) and TVX 944 (0.415). The lowest was recorded in DCP-2 (0.342), V-585 (0.344) and KM-5 (0.345).

4.3.2.4 Adult emergence of *C. chinensis*

All the genotypes differed significantly in adult emergence (Table 7). The highest adult emergence was recorded in V-118 (67.00), DCP-2 (66.33), T-4 (66.00), C-70 (64.66), C-3 (62.00) followed by V-585 (52.33), KM-5 (52.10) and KM-4 (51.00). The least adult emergence was recorded in KM-1 (18.00) followed by Goa local (28.33) and T-1 (32.00).

4.3.2.5 Adult emergence of *C. maculatus*

All the genotypes differed significantly in adult emergence (Table 9). The highest adult emergence was 62.00 recorded in C-70 which was on par with T-4 (59.33) and KM-5 (58.00) followed by V-118 (57.3), C-3 (56.66) and V-585 (54.33). The least adult emergence was recorded in Goa local (24.33) and KM-1 (24.60) followed by T-1 (33.33), T-9 (37.66) and TVX 944 (39.66).

V. DISCUSSION

Evaluation of redgram and cowpea genotypes for resistance to *C. chinensis* and *C. maculatus* and biochemical basis for bruchids, resistance studies under laboratory condition and finding of the investigation as discussed below.

5.1 EVALUATION OF REDGRAM GENOTYPES FOR RESISTANCE TO *C. chinensis* and *C. maculatus*

5.1.1 Seed parameter

All the genotypes showed significant difference in initial weight. The highest weight of 12.96 g was recorded in ICPL-99032-1. The lowest weight was noticed in GMS-1 (9.27 g) rest of the genotypes were intermediate in initial weight which might be due to genetic character of genotypes. The difference in initial weight was not influenced on infestation by *C. chinensis* and *C. maculatus*. The per cent moisture which varies from 9.5 to 10.1 per cent was not influenced on the insect infestation.

5.1.2 Growth performance of *C. chinensis* on redgram genotypes

The preference difference of egg laying by *C. chinensis* was observed among redgram genotypes. The eggs laid by insect was more in case of PG-27 (98), PG-44 (96) and WRP-266 (95). The genotypes DEPS-9 (53), WRP-230-1-1 (53), ICPL-2008-1 (54.54) and PG-12 (55) were least preferred for oviposition. The rest were shown intermediate preference for oviposition. The varied preference for oviposition was noticed among genotypes. Lokhale and Srivastava (1975) also reported such variation in oviposition by *C. chinensis* in certain pulses.

The highest per cent adult emergence was noticed in GS-1 (91.78%), which was at par with GPS-2003 (89.165). The lowest per cent adult emergence genotype was DEPS-3 (32.15%) followed by ICPL-2008-1 (38.88%), DEPS-9 (42.13%), WRP-230-1-1 (47.75%) and PG-12 (52.10%). The developmental period was found to be significantly different in all the genotype which ranged between 24.33 to 32 days. The highest developmental period was 32 days noticed in DEPS-3 which was on par with DEPS-9 and PG-12 (31 days). The minimum developmental period were 24.33 days in ICPL-87119 and GPS-2003. These were on par with PG-27 (24.66 days) and PG-44 (25 days). The growth index value of all genotypes were showed significant difference. The highest index value genotype was GPS-2003 (3.66), which was on par with PG-27 (3.5). The DEPS-3 (1) was significantly least growth index value which was followed by ICPL-2008-1 (1.28), DEPS-9 (1.35), WRP-230-1-1 (1.59) and PG-12 (1.68) rest of the genotypes were intermediate value. The germination per cent was showed significant difference in all genotypes. The susceptible genotypes were showed highest loss of germination which was 83.5 per cent recorded in PG-27 followed by WRP-266 (78.0%). The least susceptible genotypes were showed minimum per cent loss of germination which was DEPS-3 (12.00%) followed by WRP-230-1-1 (14.9%), ICPL-2008-1 (15.50%), DEPS-9 (17.3%) and PG-12 (21.00%), rest of the genotypes were intermediate loss of germination. The per cent grain weight loss was more significant differences in all genotypes of redgram. The highest grain weight loss was noticed in susceptible genotypes were WRP-266 (35.55%), ICPL-8863 (33.15%) and ICPL-2009-1 (33.19%). The lowest weight loss was observed in DEPS-3 (15.44%) followed by ICPL-2008-1 (16.97%), DEPS-9 (16.98%) and WRP-230-1-1 (19.47%). The lowest value of per cent adult emergence, growth index, per cent loss of germination, weight and highest developmental period (days) genotypes showed significantly least susceptible to *C. chinensis* these were DEPS-3, DEPS-9, PG-12, ICPL-2008-1 and WRP-230-1-1. The susceptible genotypes were PG-27, PG-44, GPS-2003, WRP-266, ICPL-8863, ICPL-2009-1 and ICPL-99032-1 were showed maximum per cent adult emergence, growth index, per cent loss of germination, weight and lowest developmental period (days). None of the genotypes were completely resistant to the attack of *C. chinensis* differed in the susceptibility, which may seems to be due to the seed characters like hard seed coat, physiological character and biochemical factor like protein, phenols and antimetabolites. The present study is in close agreement with the reports of Bhagwat *et al.* (1995), Oigiangbe and

Onigbinde (1996), Yadav *et al.* (2000), Bhatnagar *et al.* (2001), who reported the similar findings on different pulse genotypes.

5.1.3 Growth performance of *C. maculatus* on redgram genotypes

The study revealed that none of the test genotype was highly resistant to the attack of *C. maculatus*, the GPS-2003 (92.66) was highly preferred by beetles for egg laying followed by ICPL-87119 (89.33) and PG-44 (85.00). The lowest preferred genotypes DEPS-9 (49.00) and DEPS-3 (50.00). The genotypical response to permit the growth of larvae and per cent of adult emergence. The highest per cent adult emergence genotype was noticed in ICPL-2009-1 (93.00), which was on par with PG-27 (89.94%). The lowest per cent adult emergence genotype was GS-1 (43.33%), followed by ICPL-2008-1 (45.41%), PG-12 (46.66%) and WRP-230-1-1 (47.05%). The developmental period was found to significantly difference. The highest developmental period was 32.33 days noticed in PG-12 which was on par with DEPS-9 and WRP-266 (31.33 days). The lowest developmental period genotypes were PG-44 and ICPL-87119 (26.33 days) which were on par with V-71 (27.00), ICPL-99032-1 and ICPL-2009-1-1 (27.33 days). The lowest growth index value genotype were PG-12 (1.44), ICPL-2008-1 (1.46), GS-1 (1.47) and WRP-230-1-1 (1.50) significantly superior over the highest growth index value genotypes were GPS-2003 (3.45) and ICPL-2009-1 (3.36) followed by PG-27 (3.21) and ICPL-87119 (3.18). The lowest per cent loss of germination genotype were ICPL-2008-1 (22.20%) followed by GS-1 and PG-12 (23.30%), DEPS-3 (24.1%), WRP-230-1-1 (26.10%) and DEPS-9 (27.10%). The highest per cent loss of germination genotypes were GPS-2003 (78.80%) followed by PG-44 (74.705) and ICPL-87119 (72.00%). The highest loss of germination was due to more infestation of *C. maculatus*. The per cent grain weight loss caused due to feeding of grubs. The highest 39.72 per cent in PG-27 followed by PG-44 (30.72%). The significant lowest per cent weight loss in ICPL-2008-1 (12.18%) followed by GS-1 (18.48%), DEPS-3 (19.46%) and DEPS-9 (19.74%). The lowest per cent adult emergence, germination, weight loss, lowest growth index value and highest developmental period (days) genotypes were ICPL-2008-1, PG-12, GS-1, DEPS-3, DEPS-9 showed relative resistance to *C. maculatus* compare to the other susceptible genotype were ICPL-2009-1, GPS-2003, PG-44 and ICPL-87119. The relative resistance seems to be due to a hard seed coat and biochemical basis like phenols, tannins and antimetabolites. Dogre *et al.* (1993) reported that lower the growth index value and higher developmental period (days) genotypes showed resistance to *C. maculatus*. The presence of toxic compound either in the testa of cotyledons or some physical factor responsible for resistance to *C. maculatus* was reported by Simmonds *et al.* (1989). The present study is in close agreement with Wadnerkar *et al.* (1978) and Kameswara Rao and Krishnamorthy Rao (1982), who reported the similar finding in redgram genotypes to *C. maculatus*.

5.2 EVALUATION OF COWPEA GENOTYPES FOR RESISTANCE TO *C. chinensis* and *C. maculatus*

5.2.1 Seed parameters

The initial weight of all genotypes showed significant difference. The Goa local genotype significantly highest initial weight (22.97 g) remaining genotypes weight varies from 9.60 to 12.12 g. The initial weight of individual genotype depend upon genetic character of the differences in initial weight was not influence on infestation by *C. chinensis* and *C. maculatus*. The per cent moisture content of the cowpea genotypes differed not significantly which varies from 9.7 to 10.3 per cent. The present per cent moisture content was not influence on the insect infestation.

5.2.2 Growth performance of *C. chinensis* on cowpea genotypes

The genotypes T-4 (85.33), V-118 (84.00) and C-3 (83.66) were highly preferred by *C. chinensis* for egg laying and recorded as significantly inferior. The significantly least preferred genotypes for oviposition were T-1 (53.33%), T-9 (57.31), Goa local (57.38) and TVX 944 (57.00). The genotype response permitted the growth of larvae and thus allowed the adults to emergence and the per cent adult emergence was significantly highest was DCP-2 (84.3%) followed by V-1 (79.76), C-70 (78.53), KM-4 (77.67%), T-4 (77.54) and V-585 (77.34). The significantly least per cent adult emergence genotypes in the ascending order

were KM-1 (27.99), T-1 (39.00), Goa local (49.41) and KM-5 (53.04). The developmental period (days) was significantly highest was 32.66 days in Goa local followed by KM-1 and T1 (32 days). The significantly least developmental period (Days) genotype was DCP-2 (25.66 days) followed by C-70 (27.00 days), KM-5 (27.33 days) and T-4 (27.66 days), the significant differences in growth index in all the genotypes. The significantly highest growth index value was 3.28 noticed in DCP-2 followed by V-118 (3.10) and C-70 (2.90). The significantly lowest growth index was 0.87 noticed in KM-1 followed by T-1 (1.00) and Goa local (1.51). The highest loss of germination 64.8 per cent was recorded in DCP-2 followed by V-118 (64.4%) and T-4 (63.00%). The significantly least per cent loss of germination was 13.1 recorded in KM-1 followed by Goa local (19.00%), TVX 944 (30.07%) and T-1 (33.30%). The per cent weight loss caused to feeding by grubs. The significantly highest per cent loss of weight were KM-4 (36.03%), T-4 (36.00%) followed by C-3 (35.5%) and DCP-2 (35.43%). The significantly least per cent loss of weight was noticed in Goa local (9.49%) followed by KM-1 (16.80%), T-1 (20.17%) and TVX 944 (20.37%). The lowest per cent adult emergence, germination, weight loss, lowest growth index value and highest developmental period (days) genotype were KM-1, Goa local, T-1 and TVX 944 showed relative resistance to *C. chinensis* compared to the other susceptible genotypes were DCP-2, V-118, T-4, C-3 and KM-4. The relative resistance due to seed character and biochemical basis like antimetabolic, phenols and proteins. Chavan *et al.* (1997a and 1997b) screened several cowpea lines against *C. chinensis* and observed that cowpea lines with rough seed surface were less preferred for oviposition and observed that on less susceptible cowpea lines. The growth index of pest was less than two and highest developmental period (days). Singh and Sharma (2003) also reported similar findings in cowpea genotypes like GC-3.

5.2.3 Growth performance of *C. maculatus* on cowpea genotypes

The genotype KM-1 (77.00) was highly preferred by *C. maculatus* for egg laying which was on par with KM-5 (73.66) and recorded as significantly inferior. The significantly least preferred genotypes for oviposition were T-9 (53.33) and DCP-2 (54.33) followed by Goa local (55.00) and KM-4 (55.33). The genotypes response permitted the growth of larvae and thus allowed the adult to emergence and the per cent adult emergence was significantly highest C-70 (95.38%), which was on par with DCP-2 (94.47%) followed by C-3 (88.07%) and V-585 (86.70%). The significantly least per cent adult emergence genotypes in the ascending order were KM-1 (32.02%), Goal local (44.13%), T-1 (54.63) and TVX 944 (57.20%). The developmental period (days) was significantly highest was 32.66 days recorded in Goa local which was on par with KM-1 (31.66 days) followed by T-1 and TVX 944 (30.66 days). The significantly least developmental period (days) genotypes was 27.33 days recorded in C-70 which was on par with C-3 and V-118 (27.33 days). The significant difference in growth index in all the genotypes. The significantly highest growth index value was 3.53 recorded in C-70 followed by C-3 (3.22) and DCP-2 (3.18). The significantly least growth index value was 101 recorded in KM-1 followed by Goa local (1.35), T-1 (1.78) and TVX 944 (1.86). The per cent loss of germination in all genotypes was due to feeding of *C. maculatus* which was damage the germinating part of seed. The significantly highest per cent loss of germination was noticed in C-70 (59.3), followed by KM-5 (55.9%) and T-4 (58.4%). The significantly lowest per cent loss of germination was 18.8 per cent noticed in KM-1 followed by Goa local (21.7%) and T-1 (27.75), rest of the genotypes were intermediate. The per cent loss of weight was due to feeding of grubs, it results loss in weight of grain. The significantly highest per cent loss of weight was noticed in KM-5 (34.58%) followed by T-4 (33.32%), C-3 (32.85%), V-585 (32.57%) and V-118 (30.77). The significantly lowest weight loss genotype was Goa local (8.58%) followed by KM-1 (19.5%), T-1 (20.76%), TVX 944 (21.36) and T-9 (23.87%) rest of the genotypes were intermediate. The lowest per cent adult emergence, germination, weight loss, lowest growth index value and highest developmental period (days) genotypes were KM-1, Goa local, T-1 and TVX 944 showed relative resistance to *C. maculatus* compared to the other susceptible genotypes were C-70, C-3, V-118 and DCP-2. The relative resistance was due to the seed physical factor and biochemical factor like protein, phenols and antimetabolites. Manohar *et al.* (1990) reported that minimum weight loss and lowest per cent adult emergence genotypes were least susceptible to *C. maculatus*. Singh *et al.* (1985) reported that lowest per cent damaged seed ranged from 25 to 26 per cent in the resistance lines and 95 per cent damaged lines were susceptible to *C. maculatus*. Ofuya and Credland (1995) and Mabata (1992) reported simlad findings in cowpea genotypes against *C. maculatus*.

5.3 BIOCHEMICAL BASIS FOR BRUCHID RESISTANCE IN REDGRAM AND COWPEA GENOTYPES

5.3.1 Biochemical basis for bruchids resistance in redgram genotypes

The protein content (mg/g seed) significantly lowest in GS-1 (222.00) and ICPL-2008-1 (227.66). The significantly highest protein content genotypes were ICPL-2009-1 and PG-27 (236.00), ICPL-87119 and PG-44 (235.00) followed by GPS-2003 and WRP-266 (234.00). The significantly lowest adult emergence genotypes were DEPS-3, ICPL-2008-1, DEPS-9 and WRP-203-1-1 showed in lowest protein content genotypes of redgram compared to susceptible genotypes GPS-2003, ICPL-2009-1, PG-27 and WRP-266 showed highest adult emergence in both *C. chinensis* and *C. maculatus* and these susceptible genotypes highest protein content. The susceptibility increases with increase the protein content of genotypes and susceptibility was lowest in low protein content genotypes. The present study is in close agreement with the reports of Umarao *et al.* (2003) reported that least protein content genotypes were least susceptible to *C. chinensis* and *C. maculatus*. The varieties susceptible to pest or disease were found to proven higher amount of proteins (Chakravarthy and Sahni, 1972). The contrasting finding high protein genotypes were lesser egg deposition, F1 progeny and index of susceptibility as reported by Singh *et al.* (1995). The significantly highest trypsin inhibitor units per mg of protein amount genotypes were DEPS-3 (14.36), ICPL-2008-1 (14.34), which were on par with PG-12 (13.66), WRP-230-1-1 (13.59) and DEPS-9 (13.00) showed relative resistance to both *C. chinensis* and *C. maculatus*. In these genotypes, lower adult emergence, growth index, weight loss and higher developmental period were noticed. The lowest trypsin inhibitor units genotypes PG-27 (11.06), GPS-2003 (11.08), ICPL-2009-1 (11.21) and V-71 (11.46) were susceptible to bruchids. The highest trypsin units acts as antimetabolites to insects, inhibit the feeding of grubs as result higher trypsin content genotypes showed relative resistance. Morconi *et al.* (1997) reported that significant positive correlation were found between seed resistance to bruchids and trypsin inhibitor. Modgil and Metha (1997) concluded that the difference between the contents of antinutrition factor were significant during different storage period. Prasad *et al.* (1996) reported that cowpea genotypes C-152, C-190 and V-154 were resistant against bruchids these genotypes were higher level of trypsin inhibitor. The significantly highest phenol content genotypes of redgram was GS-1 (0.411) followed by ICPL-2008-1, DEPS-3, DEPS-9 (0.402). The significantly lowest was recorded in GMS-1 (0.302) followed by ICPL-87119 (0.347) and PG-27 (0.349). The highest level of phenol content genotypes of redgram were lowest adult emergence, growth index and higher developmental period (days). The higher levels of phenol content genotypes showed relatively resistance to *C. chinensis* and *C. maculatus*. The lower level phenol content genotypes were susceptible to both bruchids. Phenols may affect on the metabolic enzymes so the phenol act as antimetabolic factor. The present study is in close with the Swain (1979) reported phenols important secondary metabolites, Rao (1989) also finding similar result in cotton genotypes against bollworm.

5.3.2 Biochemical basis for bruchid resistance in cowpea genotypes

The significantly highest protein content (mg/g of seed) genotypes KM-1 and T-4 (257.00), which were on par with C-3 (256.00), DCP-2 (258.00) and V-118 (254.00). The significantly lowest protein content genotypes were Goa local (240.00), KM-1 and TVX 944 (241.00), which were on par with T-1 (242.00) and T-9 (243.00). The lowest protein genotype of cowpea showed relative resistance to both bruchids, in this genotypes lower adult emergence, growth index, weight loss and higher the developmental period compared to higher level protein content genotypes. Higher the protein content higher the susceptible to both bruchids. The present study is in close agreement with Umarao *et al.* (2003) and Chakravarthy and Sahni (1972). The significantly higher trypsin inhibitor genotypes were KM-1 (14.25) followed by Goa local (13.91), T-1 (13.42) and TVX 944 (13.30). The significantly lowest TIU amount genotypes was C-70 (10.72) followed by V-588 (10.20), C-3 (10.22) and V-118 (10.23). Higher TIU amount genotypes were relatively resistance to both bruchids because in these genotypes least adult emergence, to growth index, loss of weight and higher developmental period compared to least TIU amount genotypes, lower the TIU amount genotypes were susceptible to the both bruchids. The trypsin inhibitor affect on metabolic enzyme activity, so as result the insect growth was inhibited. Gatehouse *et al.* (1978)

concluded that insect resistance in cowpea was due to the elevated level of trypsin inhibitor. Gatehouse and Boulter (1983) reported CPTI was an effective antimetabolite to *C. maculatus*. Hilder *et al.* (1987) and Xavier Filho *et al.* (1989) reported similar finding in cowpea genotypes against bruchids. The significantly highest phenol content (mg/g of seed) was found in T-1 (0.421) and Goa local (0.420) followed by KM-1 (0.418), T-9 (0.416) and TVX 944 (0.415). The lowest phenol content was recorded in DCP-2 (0.342), V-585 (0.344) and KM-5 (0.345). The higher level of phenol content genotypes showed least adult emergence, loss of weight, growth index value and higher developmental period. So these genotypes relatively resistance to both bruchid compared to lower level of phenol content genotypes. Higher level phenol content affect on feeding and growth of insect. Krishnananda (1972), while working on biochemical basis of jassid resistance in cotton concluded that susceptible varieties contained low quantity of phenols compared to the varieties resistant to jassids. Bhaskaran and Muthuswamy (1974) reported that phenols more in resistant genotypes of cotton to the verticillium wilt.

FUTURE LINE OF WORK

Based on information available and results of the present study following future line of work can be proposed to identify the resistance genotypes to bruchids.

1. Investigations need to be initiated on ovipositional stimulants or deterrents in resistant and susceptible genotypes.
2. Investigations need to be conducted on the role of seed physical factor to bruchid resistance.
3. The study need to be initiated to know about the role of other biochemical like amylase inhibitor activity and lectin *etc.* in seeds against bruchid resistance.

VI. SUMMARY

Investigations were carried out on the comparative study on evaluation of redgram and cowpea genotypes against bruchid resistance and biochemical basis for bruchid resistance in redgram and cowpea genotypes under laboratory condition during 2003-05 and the findings are summarized hereunder.

The initial weight of redgram genotypes were varies from 9.27 to 12.96 g. The lowest weight genotypes were GMS-1 and ICPL-2009-1 and highest weight genotypes were ICPL-99032-1 and GPS-2003. The per cent moisture content of redgram genotypes varies from 9.5 to 10.1 per cent.

The eggs laid by *C. chinensis* was more in PG-27, PG-44 and WRP-266 and the genotypes DEPS-9, WRP-230-1-1 and ICPL-2008-1 were received least eggs compared to other genotypes. The lowest value of per cent adult emergence, growth index, per cent loss of germination, weight and highest developmental period (days) genotypes showed significantly least susceptible to *C. chinensis* these were DEPS-3, DEPS-9, PG-12, ICPL-2008-1 and WRP-230-1-1. The susceptible genotypes were PG-27, PG-44, GPS-2003, WRP-266, ICPL-8863, ICPL-2009-1 and ICPL-99032-1 were showed maximum per cent adult emergence, growth index, per cent loss of germination, weight and lowest developmental period (days). None of the genotypes were completely resistant to the attack of *C. chinensis* differed in the susceptibility, which may seems to be due to the seed characters like hard seed coat, physiological character and biochemical factor like protein, phenols and antimetabolites.

The eggs laid by *C. maculatus* were more in GPS-2003, ICPL-87119 and PG-44. The least preferred genotypes for oviposition were DEPS-9 and DEPS-3. The lowest per cent adult emergence, germination, weight loss, lowest growth index value and highest developmental period (days) genotypes were ICPL-2008-1, PG-12, GS-1, DEPS-3, DEPS-9 showed relative resistance to *C. maculatus* compare to the other susceptible genotype were ICPL-2009-1, GPS-2003, PG-44 and ICPL-87119. The relative resistance seems to be due to a hard seed coat and biochemical basis like phenols, tannins and antimetabolites.

The initial weight of cowpea genotypes were varies from 9.60 to 12.12 g except Goa local (22.97 g). The present moisture content of the cowpea genotypes differed not significantly which varies from 9.7 to 10.3 per cent. The eggs laid by *C. chinensis* was highly significant preferred genotypes were T-4, V-118 and C-3. The significantly least preferred genotypes for oviposition were T-1, T-9, Goa local and TVX 944.

The lowest per cent adult emergence, germination, weight loss, lowest growth index value and highest developmental period (days) genotype were KM-1, Goa local, T-1 and TVX 944 showed relative resistance to *C. chinensis* compared to the other susceptible genotypes were DCP-2, V-118, T-4, C-3 and KM-4. The relative resistance due to seed character and biochemical basis like antimetabolic, phenols and proteins.

The genotypes KM-1 was highly preferred by *C. maculatus* for egg laying which was on par with KM-5 (73.66). The significantly least preferred genotypes for oviposition were T-9, DCP-2, Goa local and KM-4.

The lowest per cent adult emergence, germination, weight loss, lowest growth index value and highest developmental period (days) genotypes were KM-1, Goa local, T-1 and TVX 944 showed relative resistance to *C. maculatus* compared to the other susceptible genotypes were C-70, C-3, V-118 and DCP-2.

The relative resistance was due to the seed physical factor and biochemical factor like protein, phenols and antimetabolites.

The significantly lowest adult emergence genotypes were DEPS-3, ICPL-2008-1, DEPS-9 and WRP-203-1-1 showed in lowest protein content genotypes of redgram compared to susceptible genotypes GPS-2003, ICPL-2009-1, PG-27 and WRP-266 showed highest adult emergence in both *C. chinensis* and *C. maculatus* and these susceptible genotypes highest protein content. The susceptibility increases with increase the protein content of genotypes and susceptibility was lowest in low protein content genotypes.

The significantly highest trypsin inhibitor units per mg of protein amount genotypes were DEPS-3, ICPL-2008-1, which were on par with PG-12, WRP-230-1-1 and DEPS-9 showed relative resistance to both *C. chinensis* and *C. maculatus*. In these genotypes, lower adult emergence, growth index, weight loss and higher developmental period were noticed. The lowest trypsin inhibitor units genotypes PG-27, GPS-2003, ICPL-2009-1 and V-71 were susceptible to bruchids. The highest trypsin units acts as antimetabolites to insects, inhibit to the feeding of grubs as result higher trypsin content genotypes showed relative resistance. The highest level of phenol content genotypes of redgram were lowest adult emergence, growth index and higher developmental period (days). The higher levels of phenol content genotypes showed relatively resistance to *C. chinensis* and *C. maculatus*.

The lowest protein genotype of cowpea showed relative resistance to both bruchids, in these genotypes lower adult emergence, growth index, weight loss and higher the developmental period compared to higher level protein content genotypes. Higher the protein content higher the susceptible to both bruchids. Higher TIU amount genotypes were relatively resistance to both bruchids because in these genotypes least adult emergence, to growth index, loss of weight and higher developmental period compared to least TIU amount genotypes, lower the TUI amount genotypes were susceptible to the both bruchids. The trypsin inhibitor affect on metabolic enzyme activity, so as result the insect growth was inhibited. The higher level of phenol content genotypes showed least adult emergence, loss of weight, growth index value and higher developmental period. So these genotypes relatively resistance to both bruchid compared to lower level of phenol content genotypes. Higher level phenol content affect on feeding and growth of insect.

VII. REFERENCES

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EVALUATION OF PIGEONPEA AND COWPEA GENOTYPES FOR BRUCHID RESISTANCE (Bruchidae)

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ABSTRACT

Investigation on comparative evaluation of pigeonpea and cowpea genotypes against bruchid resistance and biochemical basis for bruchid resistance under laboratory condition during 2003-05 at Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad.

In pigeonpea genotypes, the lowest value of per cent adult emergence, growth index value, per cent loss of germination, weight loss, highest developmental period (days), lowest protein content (mg/g), highest trypsin inhibitor (unit/mg of protein) and highest phenol content (mg/g) genotypes showed significantly least susceptible to *C. chinensis*, these were DEPS-3, DEPS-9, PG-12, ICPL-2008-1 and WRP-230-1-1 and other genotypes were PG-27, PG-44, GPS-2003, WRP-266, ICPL-8863, ICPL-2009-1 and ICPL-99032-1 were showed more susceptible to *C. chinensis*. The lowest per cent adult emergence, germination, weight loss, lowest growth index value, highest developmental period, lowest protein content, highest trypsin content and phenol content genotypes were ICPL-2008-1, PG-12, GS-1, DEPS-3, DEPS-9 showed relative resistance to *C. maculatus* compared to the other susceptible genotypes were ICPL-2009-1, GPS-2003, PG-44 and ICPL-87119.

The cowpea genotypes were KM-1, Goa local T-1 and TV × 944 showed least susceptible to *C. chinensis* and these having lowest per cent adult emergence, germination, weight loss, growth index value, highest developmental period, low protein, highest trypsin and phenol content. The genotypes were DCP-2, V-118, T-4, C-3 and KM-4 showed susceptible to *C. chinensis* the lowest per cent adult emergence, germination loss, weight loss, lowest growth index value, highest developmental period, low protein content, highest trypsin and phenol content genotypes were KM-1, Goa local, T-1 and TV × 944 showed relative resistance to *C. maculatus* compared to the other susceptible genotypes were CO-7, C-3, V-118 and DCP-2. The relative resistance was due to the seed physical factors and biochemical factors like protein, phenols and antimetabolites.