The results obtained in this study on the aspects of cowpea genotype preference in relation to bruchus and use of non chemical substances of different origin have been discussed in the forth coming pages in the light of the previous studies on these and/or related aspects.

Factors for Germplasm Resistance:

Many workers have reported different varieties/germplasm of cowpea and other legumes to correlate the morphological features viz., seed coat texture (rough versus smooth), seed shape, seed coat colour, seed size (large/ small, broad/ narrow, seed width/ length etc.) with the oviposition preference/resistance or otherwise. The results obtained in the present study do not suggest that seed coat factors are in any way correlated with the oviposition preference/non preference.

The thirty-two germplasm tested under the present study includes 28 accessions having smooth textured (Bundel Lobia-1, IL3178, IL362, IL4216, IL1086-2, IL160-B, IL904, IL461-4, IL680, IL1072-1, IL460-B, IL1050-3, IL4166, IL1063, IL1072, IBM, RA-2, EC240998, EC244409, EC244243,
EC244236, CS88, GFC-1, GFC-2, GFC-3, GFC-4, CO-5, HFC42-1) and four (IL855, HY5P52-2, Ht78P-5-A and FS-68) having rough seed surface. Highest level of oviposition is seen in Bundel Lobia-1, which has come out with maximum number of % seed with eggs (81.33). This genotype is smooth surfaced whereas another smooth surfaced seed genotype IL 1072-1 has the minimum % seeds with eggs (9.66). Similarly other smooth surfaced genotypes having % seeds with eggs in lower numbers are IL 160-B (11.66), RA-2 (13.66), IL 3178 (14.66), IL- 680 (16.66). Genotypes Ht78P-5-A (17.66), HY5P52-2 (19.33), IL 855 (43.33) and FS-68 (47.66) are rough seed coat texture but are placed some where in the middle of the group of seeds with eggs (%). These lines are placed at 6th, 9th, 21st and 23rd respectively. This indicates that seed coat texture alone does not have any role to play as far as oviposition preference is concerned.

Bhatnagar et al. (2001), have reported that there was a significant difference among the varieties for oviposition. Although varieties IFC 9907 and IFC 9909 were less preferred for orientation and oviposition and the survival percentage and food consumed per grub was also less in these varieties but there was no significant relationship of seed colour and seed size with orientation and oviposition of the beetle. Kadoo and Sane (1995), Manohar and Yadava (1990), have reported that there were significant differences in the relative susceptibility of different varieties to bruchid attack as reported in the earlier study. None of the 12 varieties tested was found to be immune to infestation by C. chinensis. The reported results are similar to the findings of this study and those of Dabi et al., (1979) who have reported that the weight, volume,
hardness and colour of the seed of cowpea varieties had no effect on the susceptibility. The results obtained in the present study are in confirmation to these studies.

Chavan et al. (1997), have reported that the cowpea lines with rough seed surfaces were less preferred for oviposition, resulting in a smaller percentage of grains infested with eggs and smaller number of eggs/grain. C. Chinensis distributed eggs uniformly on grains of different cowpea lines and oviposited a small number of eggs/grain. Similarly, Katiyar and Khare (1987), Brewer and Horber (1986) and Seddiqui (1972), have also worked on ovipositional preference of this weevil on different cowpea lines and have reported that bruchus preferred lines with smooth surfaced seed to lines with rough surfaced seed. The results of this study do not support these findings.

As regards to the ovipositional preference based on seed coat colour, Chavan et al. (1997) have reported that the cowpea lines with Brown, Black, Grey and Red coloured seeds were more preferred than white coloured seeds. Both these findings that rough seed surface is preferred for oviposition and Brown, Black, Grey and Red coloured seeds were more preferred than White coloured seeds are in contradiction of the findings of this study. Dias (1986) has worked on this and other related aspects and has reported that dark brown coloured seed were preferred over light coloured ones. The present study does not confirm these earlier findings no correlation was found between seed colour and oviposition. Bundel Lobia-1, IL362, IL680, IL1072-1, RA-2 have dark brown seeds. IL1050-3, IL461-4, IL460-B, EC240998,
EC244236, HY5P52-2, Ht78P-5-A, CS-88, GFC-1, GFC-2, GFC-3, GFC-4, CO-5, IL904 have brown to dark brown coloured seeds. IL3178, IL4216, IBM, EC244243, IL4166 are having light brown coloured seeds. IL 855 has black; IL1086-2, dark red; IL160-B, red; IL1063 and EC244409, mottled brown; IL1072, blackish gray; FS68, cream and HFC42-1 has cream with brown coloured seeds. If these colour patterns are superimposed with the oviposition behavior, then we find that Bundel Lobia-1, IL362, IL680, IL1072-1, RA-2 have dark brown seeds and the oviposition status is 81.33, 37.66, 9.66, 13.66% seeds with eggs respectively. IL1050-3, IL461-4, IL460-B, EC240998, EC244236, HY5P52-2, Ht78P-5-A, CS-88, GFC-1, GFC-2, GFC-3, GFC-4, CO-5, IL904 have brown to dark brown coloured seeds. These genotypes have 67.33, 21.33, 34.33, 39.00, 31.66, 19.33, 17.66, 59.33, 73.66, 51.00, 29.00, 71.66 and 333.33% seeds with eggs respectively. IL3178, IL4216, IBM, EC244243, IL4166 are having light brown coloured seeds. The % seeds with eggs in these are- 14.66, 31.33, 19.33, 53.66 and 26.66 respectively. % Seed with eggs is 43.33 in IL 855 which has black coloured seeds; IL1086-2 with 47.00 % seeds with eggs is dark red; IL160-B is Red coloured with 11.66 % eggs laid seeds; IL1063 and EC244409 mottled brown coloured seed have 19.33 and 37.66 percent seeds with eggs; IL1072, blackish gray in colour has 9.66%; FS-68 with cream coloured seed has 47.66 and HFC42-1 having cream with brown coloured seeds has 54.66% seeds with eggs. A critical perusal of the results would indicate that there is no correlation between seed coat colour and the oviposition. However, these finding are based on forced oviposition and need to be verified using different method allowing a free
choice to female bruchus for oviposition for ascertaining any role of this morphological character of the germplasm tested in the present study.

Edde and Amatobi (2003), in a very important study conducted to compare the oviposition preference of the cowpea seed beetle *Callosobruchus maculatus* (F.) on twenty two cowpea varieties, with and without seed coat including five resistant, four moderately resistant and thirteen susceptible varieties. Ten of the varieties had smooth seed coats while twelve were wrinkled. Mean numbers of eggs laid on smooth and wrinkled varieties were not significantly different. The survival of the bruchid was also assessed on intact and decorticated seeds of five varieties, comprising two resistant varieties, a moderately resistant variety and two susceptible varieties. There was no correlation of resistance level with the number of eggs oviposited on cowpea varieties. Under limited and free-choice conditions, cowpea seeds with intact seed coats were preferred to decorticate seeds for oviposition. Adult emergence, mean development periods and pre-adult mortality were similar when seed coats were removed or left intact. It was concluded through this study that the seed coat is not important aspect of bruchid resistance in cowpea varieties. This is in conformity with the results obtained form the present study.

Manohar and Yadava (1990), in their study to see the relative resistance and susceptibility of cowpea cultivars to pulse beetle, *Callosobruchus maculatus*, have studied ten commonly grown cultivars of cowpea viz. Udaipur 1 and 2, P 1309, 1302, 1414, 454-157, IC 11352, CS 152, CO 1 and Kanpur Black (14/2-
3) for reaction of this pest. The results have indicated that Udaipur 2 was the most and CO 1 the least susceptible variety to this pest. Udaipur 2 and P 1309 were the two most preferred for ovipositional and adult development while CO 1 was least preferred. They have concluded this to the morphological features of these varieties i.e., Udaipur 2 having the large flat seeds having smooth and loose testa with reddish brown colour are considered favorable for all vital activities of the pest then the small and oval seeds having rough and tight testa in CO 1.

When these results are compared with those of the present study, it would be seen that there is no relationship between these characters and ovipositional preference. The results obtained rule out any correlation with any of the seed morphological characters with ovipositional preference or otherwise. Ganapathy and Janarthanan (1995), have linked seed damage to the size of the seed based upon their finding that seed damage was lowest in small-seeded YKR 415/2 (90.0%) and VB3 (90.0%). Manohar and Yadava (1990), have found that the large flat seeds having smooth and loose testa with reddish brown colour are favorable for all vital activities of the pest then the small and oval seeds having rough and tight testa in cowpea germplasm they have tested. The present study does not confirm these two related findings since correlation was not found between seed size and oviposition/damage. The present finding confirms the earlier findings of Girish et al., (1974) who have reported that weight, volume and colour of the seed had no effect on the resistance of the variety. Satayavir (1984) has reported that physical factors of
the varieties such as seed weight, seed size, texture or colour did not have any influence on any of the factors like oviposition, adult emergence etc.

The correlations analysis has been conducted on the results of different results obtained in this study in relation to seed morphological characters. The correlation values indicate that none of the seed characters, viz. 100 seed weight, seed coat texture, seed coat colour and seed shape had any relationship with per cent seeds with eggs and adult bruchid production. Among the seed characters seed coat colour and seed coat texture were positively correlated (=0.547). The percent seeds without eggs had significant negative correlation with adult bruchid production indicating thereby, less the percent seeds without eggs more the number of bruchid or more the number seeds with eggs results in higher number of bruchid produced.

The most important and practically proved result are given by Edward and Gunathilagaraj (1994), who have found that the number of eggs laid by the bruchid was not associated with the suitability of the seed for further development. Afzal et al., (1987), have studied the genetic parameters of resistance to *Callosobruchus maculatus* in chickpea. The results indicate that the number of adults emerged had the true negative correlation with the resistance to bruchid attack thereby meaning that the number of oviposited eggs are not in any way reliable indication of the resistance. Edde and Amatobi (2003), have also reported that there was no correlation of resistance level with the number of eggs oviposited on cowpea varieties. They have on the basis of the results obtained in this study concluded that the seed coat
may not be a useful aspect to consider for breeding of bruchid resistance into cowpea varieties. This is in confirmation to the results obtained in the present study.

The correlation studies have indicated that none of the seed morphological characteristics viz., seed coat texture, shape, size (width, length), seed volume, and eye pattern have any role to play in oviposition. Summing up the impact of seed physical parameters in relation to ovipositional preference and related resistance /susceptibility, there is no agreement between the previous workers. Some of them have reported positive relationship between smooth seed coat textures. Chavan et al., (1997) have reported that the cowpea lines with rough seed surfaces were less preferred for oviposition where as Manohar and Yadava (1990), in there finding have found smoothness of the seed coat in association with other physical factors like large, flat seed to be more preferred over the small and oval seeds having rough surface. Katiyar and Khare (1987), Horber (1986) and Seddiqui (1972), have reported that bruchus preferred lines with smooth surfaced seed to lines with rough surfaced seed. Ganapathy and Janarthanan (1995), have also linked seed damage to the size of the seed based upon their finding that seed damage was lowest in small-seeded cowpeas. On the contrary to these findings, the results obtained in the present study do not support these views but support the findings of earlier workers like Girish et al., (1974) Dabi et al., (1979), Satayavir (1984), Kadoo and Sane (1995), Bhatnagar et al. (2001) and others who have solely or in combination indicated that physical characters do not play a role in the preference for oviposition by bruchus. The most important
findings are those of Edde and Amatobi (2003) who studied the oviposition preference of the cowpea seed with and without seed coat.

Mean numbers of eggs laid on smooth and wrinkled varieties were not found to be significantly different in the above-referred study. There was no correlation of resistance level with the number of eggs oviposited on cowpea varieties.

The physical seed characteristics, as has been established, do not have a role in the resistance or susceptibility of cowpea genotypes to weevil. But some cowpeas do exist, which definitely show resistance to weevil. The studies so far conducted, indicate that in some of genotypes of cowpea and other pulses do not support normal growth of bruchus. Devereau et al., (2003), on the basis of their study have shown that there exist significant differences in activity of the pest apparently between susceptible and resistant cowpea varieties. Edward and Gunathilagaraj (1994), have found that the number of eggs laid by the bruchid was not associated with the suitability of the seed for further development. The accession NEC-1592 was more suitable for development with a suitability index of 0.0620 and suffered a weight loss of 62.42% due to the infestation. The accession RBH99 had a suitability index of 0.0138 with a weight loss of only 2.06%. It seems that the resistance to C. maculatus was due to antibiosis as reflected in lower survival, prolonged development period, emergence of more males and sub-sized adults with reduced longevity.
Dongre et al., (1996) found none of the cultivated accessions either of black
gram or mung bean was found to be resistant. However, resistance was
evident in a wild progenitor of black gram, *Vigna mung* var. Silvestris. The
mechanism of resistance in this variety was examined and they found it to be
larval antibiosis expressed as reduced survival, longer developmental period
and reduced body weight.

In such genotypes definitely there is some biochemical factor, which is
responsible for larval antibiosis expressed as reduced survival, longer
developmental period and reduced body weight including some deformities.
Ignacimuthu et al., (2000), in their study have reported the presence of high
levels of non-nutrient chemicals such as vicilins, α-amylase inhibitors, and
lectins in different quantities and suggested that these chemicals may be
responsible for resistance to *C. maculatus*.

Macedo et al., (1995), purified and studied the properties of storage proteins
(Vicilins) from cowpea (*Vigna unguiculata*) seeds, which are susceptible or
resistant to the bruchid beetle *Callosobruchus maculatus*. Vicilins (7S storage
proteins) from the seeds of cowpea cultivars, which were susceptible, or
resistance to the bruchid *C. maculatus* were purified by size-exclusion and ion
exchange chromatography. They identified variant vicilins from resistant
seeds and reported that they were more strongly bound to DEAE sepharose,
suggesting differences in charge between various molecules.

Appleby and Credland (2004), reported significant interactions between
environment and seed variety and between environment and population were
identified in certain parameters, suggesting performance of a resistant variety may vary significantly across populations, with seed variety and in response to differences in environmental conditions.

All the above and other studies suggest that the biochemical factors play more important role in assigning resistance or susceptibility status to cowpea or any other seeds more decisively rather then the morphological features. It is unlikely that seed characters have a role towards this. The physical factors may be responsible indirectly (or coincidently), in a small way to add to these factors.

**SEED PROTECTANTS**

The plant materials are reported to play an important role in protection of stored commodities. These materials have been under use /household practice since time immemorial. Many attempts have been made in the past to test the chemical factor(s) responsible, work out doses, formulations and combinations of these raw materials. Under this category, fixed and essential oils and other secondary metabolites have been considered and their characteristics and potentials have been added to the scientific knowledge in this sphere. One of the very common factors for protection of damage in stored products is the unsuitability of the stored commodity because of dusty coating on the seeds. Various workers have explained their results differently but as far as mode of action of these dusts/ powdered botanicals/ inert materials is concerned every one agrees that these materials are able to provide different levels of protection to the commodities under storage.
A number of procedures have been employed by various investigators to screen plant materials for grain protection. Each of them is directed towards a definite purpose. Nwanze and Horber (1975), Singh (1977), and Bhaduri et al., (1985), Chiranjeevi (1991), adopted procedures which monitor the ability of test material to reduce egg laying ability of cowpea weevil. This could be because of some factor in the test material, which acts as ovipositional deterrent or may even have ovicidal properties. Su (1977) and Ajayi et al., (1987), Mohamed (1996), Naito (2000), recorded the ability of test materials to kill adult weevils. Khan and Borle (1985), tested plant material that proved to be quite effective in arresting the development activities of the pulse beetle attacking stored gram. Hassan et al., (1990), evaluated the efficacy of natural products to repel adult weevils. Onu and Aliyu (1995), in their study on fruits of four peppers (Capsicum Spp.) for the control of Callosobruchus maculatus (F.) on stored cowpea seed have reported that various pepper powders in small quantities were effective in reducing oviposition and damage to cowpea seeds. The seed quality and viability were not affected by the powdered pepper treatment.

These bioassay techniques are reliable but very specific. A grain protectant could control storage pests by suppressing oviposition or exterminating eggs, larva, and pupa or adult stage of pests, through antifeedance, repellence, contact or systemic poisoning. A highly specific bioassay may have restricted field of view and thus was unsuitable as a primary screening procedure of plants for grain protection effects. Fatope et al., (1995), suggested that based upon the WPI values a protectant may be classified as strong, weak or
negative grain protectant, the effects to be detected, irrespective of their mode of action. This seems practical as many protectants may work at different targets with the total effect on the reduced grain damage.

The materials those have been tested in the present research project include three types of materials viz. i) oils of plant origin, ii) ashes of plant origin, iii) ashes of animal origin and iv) sand /dust. Some of these are in use as a common household practice since a long time and are form of Indigenous Technological Knowledge (ITK). The use Neem leaves has been under use for the protection of stored grains since many generations in our country. Similarly Africa and other countries, utilization of local vegetations/herbs is a common practice. These practices/ information have resulted in to many researches at these places to find out / standardize the optimum/ effective doses for the purpose. Some of the findings in these studies have yielded very good information having application potential on large scale at farm level. The results obtained in different treatments tested in the present study have been discussed with reference to some of the important previous studies.

BOTANICALS

Neem and its components:

Many workers have reported the findings of their researches on different plant parts of neem those include leaf, bark, stem, root and fruits. Singh (2004) and Satya Vir (2004 a & b) have studied different aspects/ components of neem in their pursuit to control different types of stored grain pests including pulse

Mahanthi and Gour (2004), Singh *et al.*, (2001), Babaran, V.B. (1997), Donato and Pables (1993, 1996) tested the effectiveness of *Neem* leaves and reported that it possesses controlling properties as an antifeedant and repellent, and causes mortality in the insects. Mahanthi and Gour (2004), tested neem seed kernal powder. Pandey and Singh (1997) have tested effect of neem bark powder. Mayura, (1994), studied neem tree seeds were tested for controlling cowpea weevil. All these workers have reported efficacy of neem oil; neem seed karnel aqueous extract; admixing of powdered neem bark, leaf, and root etc.

The neem materials used in the present study include neem oil in different dozes (0.1%, 0.25%, 0.55 and 1.0%), neem leaf powder (5% and 10%) and de-oilled neem cake (2.5% and 5.0%). The results obtained in all these treatments indicate different degree of control against this pest as compared to untreated seeds. Neem oil 0.5 and 1.0 percent was able to provide 100% protection to cowpea seeds under storage. Other dose of this oil was able to protect the stored seeds to a reasonable degree. Treatment with 0.25% and 0.10%, showed seed damage to the extent of 4.00 and 12.33% respectively. The treatment with leaf powder in two doses was not as effective as
treatments with neem oil but as compared to the control, these were statistically significant. Results with Deoiled neem cake showed that the two treatments were able to provide a good protection over untreated control. The present findings are therefore in agreement with the earlier reports that neem oil and other ingredients of neem are able to provide protection from seed weevil.

While attempting to find out the possible mode of action of these materials the perusal of the results obtained here would indicate that these treatments viz., Neem oil 0.1%, 0.25%, 0.5% and 1.0% showed 21.0%, 6.33%, 0.00, 0.00; seeds with eggs laid respectively while in neem leaf powder treatments 5.0% and 10.0%, the egg laying was to the extent 91.33, 51.67 and in Deoiled neem cake treatments 2.5% and 5.0% 95.67 and 96.00 respectively. When percent seeds with eggs is compared with the percent damaged seeds in each replication i.e., 12.33, 4.00, 0.00, 0.00; 65.00, 45.67, 47.00, 59.67 percent respectively and also the Weevil Perforation Index 13.30, 4.74,0.00, 0.00; 44.72, 36.24; 36.91, 42.62 respectively some conclusions can be drawn.

It is obvious that with the application of higher doses of neem oil, there develops deterrence to oviposition by this pest. No egg lying was observed in these treatments. This could be because of repellent action of this oil as has been reported by Singh (2004), Satya Vir (2004 a & b), Bhatnagar et al., (2001), Naqvi et al., (1996) and others.

The observations also reveal that the percentage of actual damaged seeds in these treatments is less then the percent seeds with eggs. This has the

**Vegetable oils**

Amongst this category the researches conducted can be grouped under different categories viz., essential oils, fixed oils, grounded leaves/plant material etc. Under the first category i.e., the essential oils, the researches conducted by workers like Kéïta et al., (2000), who reported their work on essential oils extracted from four West African plant species viz., Tagetes minuta, Hyptis suaveolens, Ocimum canum and pepper Piper guineense; Tun et al., (2000), tested the essential oil from anise Pimpinella anism, cumin Cuminum cyminum, eucalyptus Eucalyptus camaldulensis, oregano Origanum syriacum var. bevanii and rosemary Rosmarinus officinalis; Castellanos (1999) studied the activity of essential oils from of Chrysanthemum coronarium; Namrata et al. (1997), studied contact and fumigant action of

Some of the important studies those have been conducted on utilization of materials of plant origin, and have shown promise and are worth a mention are Affi *et al.*, (1989) on extracts of lupin seed and caraway fruits; Don-Pedro (1989a, b) on fixed vegetable oils against eggs, oviposition and adult mortality; Olaifa and Erhun (1988) on *Piper guineense*; Das (1985 and 1986) on edible oils namely soybean, sesame, coconut, and mustard; Nasiruddin (1986) on tishi (*Linum usitatissimum*), til (*Sesamum indicum*) and Soybean (*Glycine max*); Khan (1986) on *Acorus calamus* L. rhizome powder; Don-Pedro (1985) worked on citrus peels; Khan and Borle (1985) tested *Acorus calamus* L. rhizome powder and activated clay; Nizan (1983) used pepper, ash and oil to control storage pests of cowpea and other stored commodities.
All the above studies have concluded that the materials used have importance in the management of stored grains/commodities and many of them are in common use in the geographical areas of their occurrence.

Many other researchers have studied the role of fixed/vegetable oils as protectants of the stored grains. Bhatnagar et al., (2001) in the study on six vegetable oils namely groundnut, sesame, soybean, coconut, mustard and neem as repellent, ovipositional deterrent and ovicidal effect against pulse beetle. Kéita et al., (2001), reported the efficacy of essential oils from sweet basil, *Ocimum basilicum*, and African basil, *O. gratissimum*; Singh et al., (2001), tested efficacy of different indigenous plant products viz., leaf powder of *lantana*, *sadabahar*, *neem*, *madar* and *kali tulsi*;

Olivería et al. (1999) studied the toxicity of jack bean (*Canavalia ensiformis*). Javid and Mpotokwane (1997), studied, powders obtained from Eucalyptus, *Melia azedarach* and *Croton gratissimus* which is shown to have some insecticidal activity against the pest. Mohamed (1997), tested effectiveness of *datura* leaf extracts against the cowpea beetle *Callosobruchus maculatus*. Maheshwari and Dwivedi (1997), in their study on screening of some plant extracts for their oviposition deterrent properties against the pulse beetle have shown the efficacy of theses plant extracts against this pest.

Mansoor (1997), tested effectiveness of plant oils as protectants of mung bean *Vigna radiata* against *Callosobruchus chinensis* infestation. Negi et al., (1997), studied egg laying and adult emergence of *Callosobruchus chinensis* on green gram (*Vigna radiata*) treated with *Pongam oil*. Onu and Sulyman

Results obtained in the present study on *Pongamia pinnata* (Karanj), indicated that the oviposition in the treatment 0.25% was 95%, in 0.50% this was 91.00%, in 0.75%, seeds with eggs were 51.67% and in 1.0% treatment there was absolutely no egg laying. The corresponding damage was 79.00, 72.67, 42.33 and 0.00%. WPI in relation to eggs laid and seed damage was 47.49, 49.58, 34.51 and 0.00% respectively. These results indicate that like some other oils of botanical origin as reported in earlier reported results. *Pongamia* oil is effective against this pest. Negi *et al.* (1997) have reported similar test results in their study on use of this oil against oviposition and adult emergence of pulse beetle.

Su (1991a, b, 1986,1985, 1977) has performed laboratory evaluation of toxicity of black pepper, *Calamus* oil and *Chenopodium* oil, coriander seed and *Cinnamomum cassia*; Giga and Munetsi (1990), tested five vegetable oils and reported castor oil as most effective in reducing oviposition. It was further established that vegetable oils were more effective and reduced oviposition and egg hatch more than the citrus oil.

Ogunwolu and Odunlami (1996) worked on *Zanthoxylum zanthxyloides* (Lam.) root bark powder and compared its efficacy in terms of primiphosmethyl. Seck *et al.*, (1996), have worked out alternative protection of cowpea seeds using *Bosca senegalensis* as botanical protectant. Onu and Aliyu (1995) in their study evaluated fruits of four peppers (*Capsicum* Spp.). They have reported that various pepper powders in small quantities were effective in reducing oviposition and damage to cowpea seeds. The seed quality and viability were
not affected by the powdered pepper treatment. The results of this study are indicative of potential for use of powdered fruits of some of pepper types in protecting stored cowpea seeds. Mbata et al. (1995), studied insecticidal action of preparations from the brown pepper, *piper quinense* schum, seed of *Callosobruchus maculatus* (Fab). Mayura, (1994), reported garlic bulbs (*Allium sativum* Linn.) sugar apple seeds (*Annona squanosa* Linn.), castor bean seeds (*Ricinus communis* L.) and neem tree seeds (*Azadirachta indica* Juss)) as botanical insecticides against cowpea weevil. Ogunwolu and Idowu (1994), in their study on potential of powdered *Zanthoxylum zanthoxyloides* root bark for control of the cowpea seed bruchid, a commonly used material in Nigeria was found to be very effective. Talukdar and Howse (1994), have studied and reported repellent, toxic, and food protectant effects of pithraj, *Aphanamixis polystachya* extracts against pulse beetle, in storage. Zibokere (1994) had described the insecticidal potency of red pepper (*Capsicum annuum*) on pulse beetle infesting cowpea seeds during storage. Bandara and Seneviratna (1993) have reported the effect of wild ginger, *Zingiber purpureum* roscoe. on cowpea seed bruchid in stored cowpea. Naqvi and Perveen (1993) have studied and described the toxicity of three plant extracts (*Calotropis procera*, *Carissa carandass* and *Nerium indicum*) in comparison to Coopex (Bioallethrin: Permethrin) against stored grain pest. Seck et al., (1993), tested leaves, fruits and extract of the African shrub *Bosca senegalensis*. George and Patel (1992) tested mint, *Mentha spicata* and have reported it as a promising botanical protectant; Okonkow and Okoye (1992) tested dried and grounded *Ricinus communis* (L.) leaves as used in Nigeria.
Lale (1992) tested products from dry chili pepper fruits, Capsicum sp. for oviposition deterrent and repellent effects; Ofuya et al., (1992), studied crude ether extract of seeds of Monodora myristica (Gaertn); Adgeh and Rejesus (1991) lagundi (Vitex negundo L.) and Oregano (Coleus amboinicus Lour.); Ahamad and Ahmed (1991), reported the efficacy of rhizomes of the plants belonging to Zingiberaceae family as seed protectants.

Garcia (1990), studied the toxicity, repellency, growth inhibitory, anti ovipositional and ovidicial actions of several extracts (petroleum ether, ethanol, water and oil) from five plant species against the bean weevil. Ivbijaro (1990) tested Piper guineense and Ofuya (1990), reported oviposition deterrence and ovidicial properties in some powdered plants.

Fatope et al., (1995), in their study conducted in sub- Sahelian West Africa, have reported the use of twenty indigenous plant species from fifteen families used in indigenous grain storage methods in north Nigeria. They have screened ten species and have reported that Hyptis suaveolens Poit. and Sphenoclea zeylanica Gearth showed the best grain protectant effect based upon the Weevil Perforation Index (WPI). It is reported that a mixture of dried and grounded shoots of Hyptis suaveolens or Sphenoclea zeylanica could protect seeds from severe damage during storage. They have indicated that terpenoids as reported by Luz et al., (1984), triterpenoides as reported by Misra et al., (1981), Mukherjee et al., (1984), or steroids contains in Hyptis suaveolens as reported by Saluja and Santani (1984) are responsible for insecticidal activity against this pest. It is obvious that plant species reported
to have some effect in reducing the population built up and resulted in a reduced WPI, must be having some volatile factor causing repellency, or other chemicals those are ovicidal do not support development etc.

Ashes/ sand etc.

Many workers have attempted to utilize ashes of different origin in the management of pests of different crops and commodities. Stathers et al., (2004), have worked out efficacy and persistence of two commercially available enhanced diatomaceous earth (DE) products against four common tropical storage pests. The results indicated that each insect species differed in its susceptibility to the DE treatments, highlighting the need for field application rates to be based upon the entire spectrum of pest species likely to be present during storage. Attempts have been made to develop technologies acceptable to farmers in controlling pests at farm/ village level.

Apuuli and Villet (1996) suggested that any dry, powdery substance might serve as a good protective medium for stored seeds. Mohamed (1996), tested cotton stem and cow dung ashes for the control of Callosobruchus. Result showed that average mortalities of C. maculatus reached only 6.7 and 16.7% for cotton stems and cattle dung ashes, respectively, and for C. chinensis 16.7 and 25.6% respectively. Khan and Borle (1985), studied various pulse protectants viz., Acorus calamus L. rhizome powder and activated clay and cow dung ash smearing with groundnut oil. Acorus calamus L. rhizome powder and activated clay both in the proportion of 0.1, 0.3 and 0.5% by
weight proved to be quite effective in arresting the development activities of the pulse beetle attacking stored gram.

Javaid and Ramatlakapela (1995), studied the management of cowpea weevils in cowpea seeds by using ash. Lienard and Seck (1994) have suggested that the use of inert substances as well as indigenous plants or their by-products have given satisfactory control of C. maculatus in many cases. The ashes are reported to be reasonably effective on the egg laying capacity, adult emergence and developmental period pulse beetle in green gram Chiranjeevi (1991). Suyono and Naito (1991), have studied the effectiveness of natural substances, ashes and lime on the soybean stored pest, Callosobruchus analis (F.) and have reported different level of protection by these substances against this pest.

The ashes and dusts tested in the present study namely Cow dung ash, 20%; Cow dung ash, 10%; Goat pallet ash, 20%; Goat pallet ash, 10%; Ipomea ash, 20%; Ipomea ash, 10%; Inert dust, 2.5%; and the Inert dust 5%. The egg laying percent was recorded as 5.33, 57.67, 26.67, 43.67, 3.00, 57.67, 98.67 and 100 respectively. This indicates that these treatments (accept the Inert dust 5%) are in one-way or the other, able to effect reduced egg lying. Ipomea ash, 20% and Cow dung ash, 20% were very effective with only 3.00 and 5.33 percent seeds with eggs respectively. The same results were found in these two treatments for seed damage also. As regards the damage Ipomea ash 20% with 2.00% seeds damaged, Cow dung ash 20% with 2.67%, Goat pallet ash 20%, 20.00%; Ipomea ash 10%, 25.33%; Goat pallet ash 10%, 26.33%;
Cow dung ash 10%, 33.33%; inert dust 5%, 72.67% and inert dust 2.5% with 59.33% damaged seeds. The results of the study indicate that as reported in the previous studies, the dusts of different nature are able to reduce oviposition and are able to reduce the damage in the stored pulses. The ability of Cow dung ash (20%) and Ipomea ash (20%), to have given very good protection is comparable to Malathion in chemical protection and Neem oil and Karanj oil amongst non-chemicals.

The results obtained on the basis of WPI indicates that cowpea seeds treated with Karanj oil 1.0%, Neem oil 1.0% and 0.5% and 2 cm layer of fine sand have the WPI as zero, thereby meaning that there is not a single perforation in these treatments. These were followed by Ipomea ash 20% (2.42), Cow dung ash 20% (3.21), Neem Oil 0.25% (4.74), Coarse sand layer 2cm (5.11), Fine sand layer 1cm (6.59), Malathion dust 0.7% (8.71), Coarse sand layer 1cm (8.71), Neem Oil 0.1% (13.30), Goat pallet ash 20% (19.93), Ipomea ash 10% (23.97), Goat pallet ash 10% (24.68), Coarse sand 40% (28.48), Cow dung ash 10% (29.32), Karanj Oil 0.75% (34.51), Neem leaf powder 10% (36.24), De-oiled neem cake 2.5% (36.91), Fine sand 20% (39.89), Fine sand 40% (41.36), Inert dust 2.5% (42.48), De-oiled neem cake 5% (42.62), Coarse sand 20% (42.89), Neem leaf powder 5% (44.72), Karanj Oil 0.25% (47.49), Inert dust 5% (47.49) and the maximum was found in the treatment with Karanj Oil 0.5% (49.58).

Fatope et al., (1995) have made comments on different bioassay methods used by other workers. They are of the opinion that the bioassay techniques
used by previous workers are reliable but very specific viz., efficacy for oviposition, adult emergence or development period etc. A grain protectant could control storage pests by suppressing oviposition or exterminating eggs, larva, pupa or adult stages of pests, through antifeedance, repellence, contact or systemic poisoning. A highly specific bioassay may have restricted field of view and thus was unsuitable as a primary screening procedure of plants for grain protectant effects. Of various screening procedures, the cowpea weevil bioassay is the most convenient for general use in a small laboratory. Weevil Perforation Index values are recorded for tests in which the damage levels of control seeds are not less than 50%. In this bioassay, a WPI value of 15 or less after 4 months of storage with plant materials at a dosage of 10% (wt/wt) is considered to be a strong effect. WPI values of 50 shows that equal amounts of treated and untreated cowpea seeds were perforated. This bioassay procedure thus allows plant materials with strong, weak or negative grain protectant effects to be detected, irrespective of their mode of action. A WPI more than 50 would indicate that the treatment has supported the infestation. In the present case the WPI in the treatment with Karanj Oil 0.5% was 49.58, Karanj Oil 0.25% and Inert dust 5% it was 47.49 indicating that these treatments are not as effective as other. The suggested indicator is a good way to conduct preliminary bioassays for a large number of materials.

Naito (2000), while attempting this in Indonesia found three kinds of natural substances, namely, rice husk ash, wood ash and lime, were mixed while storing soybean seeds. It was found that rice husk ash had a marked effect on the mortality rate. Mixtures with 0.5% and 1% gave 100% mortality which
continued for three months after treatment. The lethal effect of wood ash did not last as long as that of rice husk ash. Treatment with lime was less effective than with the other substances. The number of deposited eggs indicated that the rice husk ash act as ovipositional deterrent. The technology developed suggests the mixing of 1% in weight of the ash in the seeds before storage effectively protects the seeds from pest infestation. The main ingredient of rice husk ash is silica (SiO₂), accounting for 96% of the total content. The ash has almost the same composition as diatomaceous earth, commercially named "Insect", is effective in controlling pests of stored grain. The high silica content must have a lethal effect on insects.

Matsumoto (1987), has reported that some Indonesian farmers used rice husk ash in storing soybean seeds. In those cases, seeds were mixed with ash at a ratio of 10% of seed weight in plastic bags or cans. Good results were obtained, and the rice husk ash also promoted the drying of grain. Similar results have been reported by Tee (1981), for powered paddy husk ash as a grain protectant against stored product beetles. The use of paddy husk ash against five beetles infesting stored grains studied was found effective at a rate of 1-2.5% (by weight), in providing different levels of protection.

Ahn et al., (1998), studied insecticidal and acaricidal components from sawdust of Thujopsis dolabrata against eight species of arthropod pests including Callosobruchus. Wolfson et al., (1991), studied the efficacy of ash for controlling infestations of Callosobruchus maculatus (F.) in stored cowpea. They have also reported the traditional use of wood ash to control bruchid
beetles attacking cowpea seeds in Africa, including South Africa and Cameroon. Ofuya (1986), tested wood ash and other material also in an attempt to reduce the damage in cowpea seeds during storage. The cowpea seed treated with wood ash were least damaged as compared to other treatments (powdered onion scales and dry chili pepper fruits). The viability of seeds was not affected by any of these treatments. Nizan (1983) used pepper, ash and oil to control storage pests on sorghum, millet, cowpea, groundnut and maize.

Javaid and Ramatlakapela (1995) studied the management of cowpea weevils (*Callosobruchus maculatus* Fab.) in cowpea seeds by using sand. The results showed that sand performed poorly but were better than the untreated control that provided partial control. Kranz *et al.* (1977), have reported storing cowpea seeds with dry sand for protecting seed from damage by this pest. Similarly, Whitney (1971) has reported that the traditional farmers’ practice of mixing fine-seeded millet or sand with large seeded sorghum or maize in storage is effective against moth pests because it prevents access by filling the inter-granular spaces.

The findings in this study support the findings of the previous studies and the views expressed by Whitney (1971), that the sand or some other small seeded grain prevents access of the pests by filling in the inter-granular spaces and thus not allowing exposure of the seeds/grains for oviposition. It was found in the present study that the there was absolutely no egg laying in treatment as 2cms layer of fine sand. In case of 1 cm layer of fine sand, the
egg laying was seen on 7.33 percent eggs, 1cm layer of coarse sand with 12.33%, 2cm layer of coarse sand with 5.0 percent seeds with bruchus eggs. These treatments were taken to see the penetration of female weevils in the sand for oviposition. It is also indicated from the findings that the spaces in the coarse sand makes it easier for the bruchus to get in to the sand layer and reach the seeds. The mixing of the sand was apparently not effective, as the results would indicate (fine sand 20% with 95.67% seeds with eggs, fine sand 40% with 83.00%, coarse sand 20% with 95.00% seed with eggs and coarse sand 40% with 51.67% seeds with eggs). The careful observations revealed that the quantities of sand used for admixing was not sufficient to cover the stored quantities of seeds. The seeds, which showed the egg deposition, were the ones, which were exposed (not covered by sand) to bruchids i.e. the upper layer of stored seeds. The shifting of the storage jars also disturbed this ratio (covered/exposed seeds). This is in all probability, the reason for oviposition in the seeds with treatment with sand. This could also possibly be the reason for reported poor response of sand treatment as indicated by Javaid and Ramatlakapela (1995). The farmer’s practice of storage is to use either gunny bags or metallic storage bins and more importantly these are kept at a place i.e. not shifted or disturbed. Under such situation, the sand will definitely play a role in protection of such stored grains.

Many workers while testing the effectiveness of non-chemicals have also tested the effect of the treated materials on the seed germination. They have mostly reported that there is no negative impact of the treatments on the germination. In the present study, some interesting results have been found.
The most effective results obtained in the study are in the treatments with 2 cm layer of fine sand, Neem oil (.5 and 1%), Karanj oil (1%) and the Malathion treatment (.1 and .5%), which showed absolute protection of stored seeds in terms of oviposition and seed damage with zero WPI. The percent germination in these treatments came out as 100% in 2 cm layer of fine sand, 83.33% in Neem Oil 0.5%, 79.33% in Neem Oil 1.0%, 57.33% in Karanj Oil 1.0%, 78.33% Malathion 0.1%, 73.66% in Malathion 0.5% as against 87.33 in untreated control. This is indicated that there is some adverse effect on germination % because of the treatments in all except in sand treatment wherein it is far better then the control.

If we compare the performance of other treatments as far as germination is concerned, it is seen that germination is 87.33% in fine sand 20%, 89.66% in fine sand 40%, 99.33 in .1cm fine sand layer, 100.00 in 2 cm fine sand layer, 86.66 in 20% coarse sand, 82.33 in coarse sand 40%, 98.66 in coarse sand layer 1cm and 98.33 coarse sand layer 2cm. In all these cases is at par or superior then the control. This is one more advantage related to the storage with sand, which provides good protection.

The germination percentage in the treatment is worked out as Karanj oil 0.75% (67.66%), Inert dust 2.5% (71.33%), Neem Oil 0.5% (83.33%), Neem leaf powder 5% (71.66%), Inert dust 5% (73.66%), Fine sand 40% (81.66%), Neem leaf powder 10% (74.66%), De-oiled neem cake 2.5% (75.33%), Fine sand 20% (83.33%), Karanj Oil 1.0% (57.33%), Ipomea ash 20% (87.66%), Karanj Oil 0.5% (69.66%), Karanj Oil 0.25% (73.33%), Malathion 0.1%
(78.33%), Neem Oil 0.1% (81.33%), De-oiled neem cake 5% (73.33%), Malathion 0.5% (73.66%), Cow dung ash 10% (81.33%), Goat pallet ash 20% (79.66%), Malathion dust 0.7% (76.66%), Coarse sand 40% (82.33%), Goat pallet ash 10% (75.66%), Ipomoea ash 10% (85.33%), Cow dung ash 20% (86.66%), Coarse sand 20% (86.66%), Neem Oil 1.0% (79.33%), Neem Oil 0.25% (86.66%), Coarse sand layer 2 cm (98.33%), Coarse sand layer 1 cm (98.66%) and Control (87.33%). The final identification of non-chemicals to be recommended for use particularly for seeds should include in addition to its performance as protectant, the effect on germination also. The importance can be understood because of the fact that some of the protectants are seen to effect seed germination adversely. These may be good for other stored commodities but does not qualify as appropriate protectant for seeds in particular.

This study can be concluded as, there is vast scope for replacement of chemicals with those of non-chemical in nature for management of commonly occurring insect pests and other commodities under storage. Previous workers have already identified a large number of materials those can be used for this purpose. There could be other materials of plant origin (leaf, seed, bark, oils- fixed or essential, ash of plant/ animal origin etc.) available which need to be studied further for application/ packaging as technology. It would be important while making a recommendation, to ascertain the availability of that particular material locally. The ethnic knowledge at farmers’ level as well at household level needs to be properly documented, scientifically validated for use and integrated in different agricultural package
of practices. While doing so basic issues/mechanisms/modes involved also need to be explored/studied.