RESISTANCE AND QUALITY PARAMETERS OF SOME COWPEA VARIETIES INFESTED WITH COWPEA WEEVILS (*Callosobruchus maculatus* Fabricus).

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CERTIFICATION

This is to certify that this research work, "Resistance and Quality Parameters of Some cowpea varieties infested with Cowpea weevil (*Callosobruchus maculatus*) Fabricus" was carried out by Uba, Chinyere Peace (20144911298) in partial fulfillment of the requirement for the award of the degree of Masters of Science (M.Sc) in the Department of Crop Science and Technology, School of Agriculture and Agricultural Technology of Federal University of Technology, Owerri.

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DEDICATION

This work is dedicated to Almighty God, my family, my lecturers and all those that encouraged me during the period of study.

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ABSTRACT

This study evaluated the level of resistance in seven breeding lines of cowpea seeds from the Institute of Agricultural Research, Samaru, Zaria, Nigeria and three landraces collected from Agbani market, Enugu, Nigeria and conducted at the Centre for Agricultural Research and Extension laboratory of the Federal University of Technology, Owerri in 2015/2016 Academic session. All data were subjected to Analysis of Variance (ANOVA) and mean separation was done using least significant difference at 5% level of probability. The seeds were infested with cowpea weevils (*Callosobruchus maculatus*) in five repetitions. Proximate analysis, sensory, organoleptic and germination tests were carried out in the laboratory to evaluate the effect of bruchid infestation on the breeding lines and landraces of cowpea seeds in storage. 50g of each seeds were stored in plastic container covered with calico material. The proximate analysis for the seeds was to determine if infestation influenced the percent of crude protein, fat, fibre, ash, moisture and carbohydrate contents of the seeds. There was reduction in protein and carbohydrate content of the seeds (SAMPEA-1 from 23.53% to 18.17% and 21.72% protein then carbohydrate from 58.80% to 46.53% and 42.22%). In the first and second trial the results showed similarity. For the germination test among the seeds, SAMPEA-8 showed higher percent (35.0 and 45.0 % for field germination while 61.7 and 70.0 % for laboratory germination) than other seeds. Seed damage percent recorded lowest in SAMPEA-8 (10 and 14 %) than the other cultivars. In order to reduce postharvest losses of cowpea, the result from this research shows that planting of resistant variety such as SAMPEA-8 may reduce infestation and damage to seeds by cowpea weevils (*Callosobruchus maculatus*), enhance the shelf life and also boost food security programme in Nigeria.

Keywords: *Callosobruchus maculatus,* breeding lines, cowpea weevil, landraces, cowpea, cultivar.

CHAPTER ONE

1.0 INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is a warm weather crop that is well adapted to dryer regions of the tropics like Nigeria where other food legumes do not thrive well. It is one of the most economically and nutritionally important indigenous African grain legumes produced throughout the tropical and subtropical areas of the world (Abate *et al.*, 2011). Nigeria is the largest producer and consumer, accounting for 45 % of world's production (Lowenberg-DeBoer and Ibro, 2008; Ndong *et al.*, 2012) while Africa accounts for about 75 % (Brisibe *et al.*, 2011). Vegetable cowpea called *'akidi'* among the Igbos is botanically known as *Vigna unguiculata* sub-specie *sesquipedalis* in the legume family leguminosae and subfamily *papallionoidae* (Udensi *et al.*, 2007). It has two genotypes that exist in the farming system of South-East Nigeria, namely; those with climbing habit called *Vigna unguiculata* subspecies *sesquipedalis* commonly called *"Akidi enu"*; and other with prostrate habit referred to as *Vigna unguiculata* subspecies *denkintians* and known as "*Akidi ani"* (Redden, 1987; Ano and Ubochi, 2008).

Ghaly and Alkoaik (2010) reported that cowpea seed, pods and leaves are consumed in fresh form as green vegetables in some African countries, while the rest of the cowpea plant, after the pods has been harvested, serves as a nutritious fodder for livestock (Abebe *et al.*, 2005) and also a source of cash income when sold to farmers who use them as livestock feed (Dugje *et al.*, 2009).

Cowpea nutritive value makes it an extremely important protein source to vegetarians and people who cannot afford animal protein (Adeyemi *et al.*, 2012). The seeds are rich sources of mineral. Cowpea seed contains 23.4 % protein, 1.8 % fat, 60.3 % carbohydrate and is also a good source of vitamins and phosphorus (Adeyemi *et al.*, 2012).

The chemical composition and nutritional properties of cowpeas vary considerably according to cultivar. For effective utilization of newly developed cowpea cultivars for human nutrition, the removal or reduction of antinutritional factors and evaluation of their nutritional properties are necessary (Giami, 2005). It is known that some antinutritional factors interfere with digestion and also make cowpea seeds unpalatable when consumed. These factors are divided into protein and non- protein factors (Duranti and Gaius, 1997; Sharma and Thakur, 2014). The non proteins include alkaloids, tannins, phytic acid, sapponins and phenols while lectin, antifungal peptides, trypsin and chymotrypsin inhibitors are protein antinutritional factors (Duranti and Gaius, 1997).

The qualities of staple crops such as cowpea in West Africa have been greatly impaired by the attack of insect pests in storage. The major storage pest of cowpea is *Callosobruchus maculatus* (Brisibe *et al.,* 2011) with infestations on stored grains may reach 50 % within 3-4 months of storage (Dugje *et al.,* 2009). Perforations by these bruchids reduce the degree of usefulness and make the seeds unfit either for planting or human consumption (IITA, 1989; Ali *et al.*, 2004). Similar to other stored product insect pests, oviposition, development and survival of these pests are influenced to a large extent by temperature and humidity (Lale *et al*., 1996). *Callosobruchus maculatus* (Coleoptera: Bruchidae) are tropical and subtropical agricultural pests which are extremely easy to manipulate, maintain and has a very rapid life cycle (Beck and Blumer, 2007). The attack on these crops begins in the field and continues in storage, which is liable to degradation with rapid increase in population of the pest. (Agboola, 1982; Ivbijaro *et al*., 1985; Lale, 1992). Losses of crops during storage, processing and marketing may be as high as 50 % (Okunola *et al*, 2007).

However, in the production and storage of this important food crop, cowpea, has faced so many constraints, such as diseases and the unlimited use of fertilizers and irrigation inputs but insect pest are one major constraint (Brisibe *et al.,* 2011). If cowpea seeds are to be stored for longer periods, it is advisable to treat the seeds with recommended insecticides such as dust, aluminium phosphide (Asare *et al.,* 2011).

Synthetic insecticides are widely used, and misused, to control storage insects, as evident in several literature reports. Sudden deaths, blindness, and skin irritation are among the problems attributed to use of inappropriate storage chemicals in Nigeria (Magaji *et al.,* 2005). Control of insect with chemical insecticides has serious disadvantages such as the development of resistant strains, toxic residue, worker's safety and increasing costs (Ofuya *et al.,* 2008). Therefore, a modest way of increasing food availability to cope with the Nigerian ever-increasing population at low cost is to protect what has been produced and to achieve this, plant materials that are inexpensive, safe to the environment, and to users and consumers alike, need to be exploited as suitable alternatives to the expensive, toxic and environmentally unsafe synthetic insecticides eg diclorvos, chlorpyrifos, trichlorphon etc.

Sensory analysis is one of the oldest means of quality control. It is an essential part of the mandatory assessment of food quality, while also examining the deeper study of the interdependence between physiological and psychological phenomena in the very process of perception of sensory qualities. Sensory analysis, allow manufacturers to identify, understand and respond to consumer preferences more effectively (Fanatico *et al*., 2007; Saha *et al*., 2009). Additionally, the identification of sensory characteristics and consumer preferences, help manufacturers to increase competition in the market for other producers (Ponte *et al*., 2004; Young *et al*., 2004).

JUSTIFICATION.

The production of cowpea is restricted by a number of biotic and abiotic factors both in the field and in storage. Among the constraining biotic factors are insect pests. Storage of cowpea grain over long periods, especially at small scale farming levels, is limited due to attack by cowpea bruchids (*Callosobruchus maculatus* F.). This study is an attempt to determine and evaluate the effect of quality and nutritional parameters, through sample analyses, viability and organoleptic tests, on the resistance of these seeds to *Callosobruchus maculatus* infestation. The result should aid local farmers and researchers alike in choosing cowpea seeds for planting and breeding purposes.

OBJECTIVES

The objectives of this study are to;

1) investigate the physical and organoleptic characteristics of cowpea as to whether they aid or deter bruchid infestation.
2) determine if the screened cowpea land races or breeding lines are resistant to bruchids.
3) assess the effect of infestation on the physical and organoleptic characteristics of infested cowpea seeds.
4) determine the damage and weight loss on the infested cowpea.

CHAPTER TWO

2.0 Literature Review.

2.1 Brief History on Origin, Distribution and Production of Cowpea.

Cowpea (*Vigna unguiculata* L. Walp.) is a member of the Phaseoleae tribe of the Leguminosae family. Members of the Phaseoleae include many of the economically important warm season grain and oilseed legumes, such as soybean (*Glycine max*), common bean (*Phaseolus vulgaris*), and mungbean (*Vigna radiate*) (Timko *et al.,* 2007). The name cowpea probably originated from the fact that the plant was an important source of hay for cows in the southeastern United States and in other parts of the world (Timko *et al.*, 2007). Some important local names for cowpea around the world include "ewa" (Yoruba), Agwa (Igbo) in much of West Africa and "caupi" in Brazil. In the United States, other names used to describe cowpeas include "southernpeas," "blackeyed peas," "field peas," "pinkeyes," and "crowders." These names reflect traditional seed and market classes that developed over time in the southern United States (Timko *et al.,* 2007).

Vigna unguiculata L. Walp most certainly evolved in Africa, as wild cowpeas only exist in Africa and Madagascar (Steele, 1976). Interestingly, while West Africa appears to be the major center of diversity of cultivated forms of cowpea (Ng and Padulosi, 1988) and was probably domesticated by farmers in this region (Ba *et al.*, 2004), the center of diversity of wild *Vigna* species is southeastern Africa (Padulosi and Ng, 1997). Some evidence that domestication occurred in northeastern Africa, based on studies of amplified fragment length polymorphism (AFLP) analysis, has also been presented (Coulibaly *et al.*, 2002). The wild cowpea *Vigna unguiculata* sp. *Unguiculata* var. *spontanea* is the likely progenitor of cultivated cowpea (Pasquet, 1999).

It is estimated that the annual world cowpea crop is grown on 12.5 million hectares, and the total grain production is about 3 million metric tons, although only a small proportion enters the international trade (DPP, 2011). West and Central Africa are the leading cowpea producing regions in the world; these regions produce 64 % of the estimated 3 million metric tons of cowpea seed produced annually. Nigeria is the world's leading cowpea producing country, followed by Brazil (DPP, 2011). Other countries in Africa; Senegal, Ghana, Mali, Burkina Faso. Ghana, Niger, and Cameroon are significant producers (DPP, 2011). Dry grain yields above 7000 kg ha^{-1} have been achieved in large field plots with guard rows in the southern San Joaquin Valley of California, where growers often obtain yields; above 4000 kg ha^{-1} (Sanden, 1993).

2.2 Botany, characteristics and Ecological Requirements.

Cowpea is one of the most widely adapted, versatile, and nutritious of all the cultivated grain legumes (Ehlers and Halla, 1997). They are adapted to a wide variety of soils from heavy to light textured and from the humid tropics to the semi-arid tropics. Cowpea also has considerable adaptation to high temperatures (68–95° F, 20–35° C) and drought compared to other crop species (Valenzuela and Smith, 2002; Hall *et al.*, 2002; Hall, 2004).

Several types of cowpea may be distinguished. Broadly, there are the trailing types that may also climb and twine around other vegetation. These are usually indeterminate in growth habits, and may possibly grow over one or two seasons. Breeding and crop improvement efforts have resulted in "erect" non-trailing and determinate types. The duration of cowpea growth varies widely in different genotypes, but environmental conditions also seem to affect it. Most cowpeas are, in general, photoperiodically sensitive. According to Wien and Summerfield (1980), they are generally quantitative short day plants with a tendency to flower as the days become shorter. The day length above which flowering is delayed considerably may vary with variety but lies close to 13.5 hours.

Cowpea is more tolerant of low soil fertility, due to its high rates of nitrogen fixation (Elawad and Hall, 1987), effective symbiosis with mycorrhizae (Kwapata and Hall, 1985). It grows well on a wide range of soil textures, from heavy clays, if well drained, to sands. It grows best in slightly acid to slightly alkaline soils (pH 5.5– 8.3) and has little tolerance of salinity but is somewhat tolerant of soils high in aluminum. Like most legumes, it does not withstand waterlogged or flooded conditions but has the ability to better tolerate soils over a wide range of pH when compared with other popular grain legumes (Fery, 1990). Cowpea performs well in agroecological zones where the rainfall range is between 500 and 1200 mm/year (Dugje *et al*., 2009; Valenzuela and Smith, 2002).

According to Timko *et al*, (2007), cultivated cowpea seed weighs between 8 and 32 mg and ranges from round to kidney shaped. Pods are cylindrical and may be curved or straight, with between 8 and 15 seeds per pod. The seed coat can be either smooth or wrinkled and of various colors including white, cream, green, buff, red, brown, and black. Seed may also be speckled or patterned. Seeds of well-known cowpea types, such as “blackeye pea” and “pinkeye,” are white with a round irregular-shaped black or red pigmented area encircling the hilum, giving the seed the appearance of an eye.

Cowpea is a short day plant, and many cowpea accessions exhibit photoperiod sensitivity with respect to floral bud initiation and development, while others are day neutral (Ehlers and Hall 1996; Craufurd *et al.*, 1997).

2.3 Cultivars of Cowpea.

Cultivated cowpeas have been divided into five cultivar groups based mainly on pod and seed characteristics (Pursglove, 1968; Pasquet, 1999). The unguiculata group, is the largest and includes most medium and large-seeded African grain and forage-type cowpeas. Melanophthalmus cultivar group includes “black eye pea” type cowpea with large, somewhat elongated seeds with wrinkled seed coats and fragile pods (Pasquet, 1998). Members of cultivar group, Biflora, (also known as “catjang”) are common in India and characterized by their relatively small smooth seeds, borne in short pods that are held erect until maturity. Textilis, another cultivar group is a rather rare form of cowpea with very long peduncles that were used in Africa as a source of fiber. Sesquipedialis, (known as “yardlong bean,” “long bean,” “Asparagus bean,” or “snake bean”) is widely grown in Asia for production of its very long (40 to 100 cm) green pods that are used as “snap” beans (Timko *et al.*, 2007).

2.4 Sowing and spacing for sole cowpea

Erect cowpea variety is planted at a spacing of 50 cm between rows and 20 cm within rows, especially for extra-early maturing varieties (60–70 days). For semi-erect varieties, spacing is 75 cm between rows and 25–30 cm within rows. For prostrate varieties, planting is done at a spacing of 75 cm between rows and 50 cm within rows. For all recommended plant spacings, sow 3 seeds/hill and thin to 2 plants/stand at 2 weeks after planting. Cowpea is planted either on ridges or on flat beds, depending upon the field preparation. Planting is usually manual, since mechanical planters are not readily available. Cowpea seeds are sown at a depth of 2.5 to 5 cm for most varieties; planting seeds more than 5 cm deep delays emergence. The seeds may rot and plant stand will be uneven (Dugje *et al.*, 2009).

2.5 Economic Importance of Cowpea.

Cowpea plays a critical role in the lives of millions of people in Africa and other parts of the developing world, where it is a major source of dietary protein that nutritionally complement staple low-protein cereal and tuber crops, and is a valuable and dependable commodity that produces income for farmers and traders (Singh, 2002; Langyintuo *et al.*, 2003). Cowpea is a valuable component of farming systems in many areas because of its ability to restore soil fertility for succeeding cereal crops grown in rotation with it (Carsky *et al.,* 2002; Tarawali *et al.,* 2002; Sanginga *et al.,* 2003).

In developed countries, cowpea is expected to become increasingly important as consumers seek interesting and healthy “new” foods and rediscover “traditional” foods that are low in fat, high in fiber, and that have other health benefits. Fat contents of 100 advanced breeding lines from IITA showed a range in fat contents from 1.4 to 2.7 % (Nielson *et al.,* 1993), while fiber content is about 6 % (Bressani, 1985). Besides being low in fat and high in fiber, the protein in grain legumes like cowpea has been shown to reduce low-density lipoproteins that are implicated in heart diseases (Phillips *et al.*, 2003). The seeds contain high level of protein (about 25 %) making it extremely valuable where many people cannot afford protein foods such as meat and fish (Akpapunam and Sefa-Dedeh, 1997). The protein has a well-recognized deficiency of the essential sulphur-bearing amino-acid, methionine and cystine, but are comparatively rich in lysine; therefore, a combination of cereal protein and legume protein such as cowpea, comes very close to providing an ideal source of dietary proteins for human beings (Ihekoronye and Ngoddy, 1985). Its grain is also a rich source of minerals and vitamins and it has one of the highest levels of any food of folic acid, a crucial B vitamin that helps prevent spinal tube defects in unborn children (Hall *et al.,* 2003). Cowpea is known as an excellent source of other trace elements in the diet of most rural populace (Bressani and Elias, 1984) and can be used at all stages of growth as a vegetable crop. The leaves are of significant nutritional value (Ahenkora *et al.,* 1998; Nielson *et al.,* 1993). The tender green leaves are an important food source in Africa and are prepared as a pot herb, like spinach. Immature green pods are used in the same way as snap beans, often being mixed with cooked dry cowpeas or with other foods. Nearly mature "fresh-shelled" cowpea grains are boiled as a fresh vegetable or may be canned or frozen. Dry mature seeds are also suitable for boiling and canning. In many areas of the world, cowpea foliage is an important source of high-quality hay for livestock feed (Tarawali *et al.,* 2002).

In Nigeria, cowpea is mainly prepared and eaten as whole or part of a meal. The most common dishes being cowpea porridge or boiled cowpea eaten with stew, moi-moi (steamed bean cake), akara (fried bean balls) and apapa (steamed cake with bitter pepper). In the developed world, cowpea is technologically processed into flour and used in various preparations such as protein concentrate and isolates for the formulation of animal feed (Chinma *et al.,* 2008).

2.6 Insect Pests and Diseases of Cowpea.

2.6.1 Field pests

Adipala *et al* (2000) have reported more than 100 field pests of cowpea that can be found in most of the crop production agroecologies in Africa but four of these – aphids (*Aphis craccivora* Koch), flower thrips (*Megalurothrips sjostedti* Trybom), legume pod borer (*Maruca vitrata* Fab. Syn. *Maruca testulalis* Geyer) and pod sucking bugs are commonly encountered and are of economic importance.

2.6.2 Storage pests

The major insect pests of stored cowpea in tropical Africa are *Callosobruchus maculatus* (Fab.) and *Bruchidius atrolineatus* (Pic). *C. maculatus* attack usually starts with females laying eggs on ripening cowpea pods in the field (Caswell, 1976). In northern Nigeria, less than 5 % of pods are infested (Booker, 1967). During eclosion, the larvae burrow through the chorion of the egg directly into the pod wall, and then into the seed, where the larvae develop and pupate. Store infestation is frequently derived from harvested field-infested pods or seeds (Alzouma, 1981) but may also come from hidden infestation in the store as source of initial infestation. The founder population consists of relatively few individuals that can breed and proliferate to pest proportions in a relatively short time (Messina, 1989).

Bruchidius atrolineatus (Pic). commonly infests and damages seeds of cowpea and is sympatric in the distribution with C. maculatus in the West African Sahel (Ofuya and Credland, 1995). *B. atrolineatus* is primarily a field pest (Booker, 1967). In the West African Sahel, adults are seen in cowpea fields at the flowering and podding phases and the females lay eggs on mature and ripening pods, and at harvest about 80-90% of the pods are infested (Alebeek, 1996). Average egg loads in the field are about ten eggs per pod, but may be higher (Huignard *et al.,* 1985). Cowpea pods taken into storage are infested with *B. atrolineatus* eggs and the larvae at different stages of development (Bawa *et al.*, 2012).

2.6.3 Description of *Callosobruchus maculatus*

Bean beetles, *Callosobruchus maculatus* (Coleoptera: Bruchidae), are tropical and subtropical agricultural insect pests. Females lay their eggs on the surface of beans (seeds in Family Fabaceae). Eggs are deposited singly and 8-10 days after oviposition, a beetle larva (maggot) burrows directly from the egg into the bean. At 25°-30° C, pupation and emergence of an adult beetle occurs 25-35 days after an egg was deposited. Adults mature 24-36 hours after emergence and they do not need to feed. Under these circumstances, adults may live for an average of 12-14 days during which time mating and oviposition occurs. Adult sexes can be distinguished by means of readily observed morphological differences that are easily seen with the naked eye. Females have dark stripes on each side of the posterior dorsal abdomen that is not found in males (Bandara and Saxena, 1995; Beck and Blummer, 2007). Adults have an average mass of 4-6mg and an average body length of 4-6mm. The entire life cycle can be readily and successfully completed without the provision of water or any food source other than the dried beans upon which the eggs are laid. Females have a lifetime egg production ranging from 30 –100 in laboratory cultures. Adults will readily mate under laboratory conditions and males inseminate females with spermatophores that represent a substantial proportion of total body mass, as much as 20 % of his body mass (Beck and Blumer, 2007).

2.6.4 Control of pests

The diverse cowpea pest complex dictates that a single control strategy is unlikely to produce satisfactory control. Earlier field studies done in Uganda demonstrated that close spacing (30 x 20 cm) effectively reduces aphid infestation (early season pest) but seems to promote thrips, legume pod borers and pod bugs infestation. An option for management of early season pests and nematodes is seed dressing, especially with carbofuran (Furadan 3G). Late season pests are more effectively controlled by the use of foliar sprays, the type of pesticide depending on the pest profile (Adipala *et al*., 2000).

Intercropping also offers remedial control, but the crop combination must consider the pest profile. Cowpea- sorghum intercrop being effective against aphids and thrips while cowpea-greengram against legume pod borers and pod sucking bugs. Selected combinations of agronomic, chemical and cultural control measure (Integrated Pest Management) especially when combined with early planting, offer better management option than the use of sole treatments (Adipala *et al*., 2000).

2.6.5 Diseases of cowpea and their control.

Root rot and damping off are caused by three different fungi. Symptoms vary and include rapid death of young succulent plants, discoloration of tap roots, longitudinal cracks of the stems, stunting, wilting and poor yields. These diseases can be controlled by treating high quality seeds with fungicides, planting certified seeds of resistance varieties, controlling weeds and removal of virus affected plants (Davis *et al*., 1991)

2.7 Harvesting and storage of cowpea.

2.7.1 Harvesting.

Cowpea can be harvested at three different stages of maturity; green snaps, green mature and dry. Depending on temperature, fresh market (green mature) peas are ready for harvest 16 to 17 days after bloom (60 to 90 days after planting) (Davis *et al*., 1991). *V. unguiculata* vary in growth habit from erect or semi-erect types with short (<100 days) growth duration, grown mostly for grain, to longer (>120 days) duration in semi-erect to trailing plants which are normally grown primarily for forage. At maturity, leaves will dry down but may not drop off completely. They need to be harvested when seed moisture content is 14 to 18 %, depending on the consumer's requirement. In cowpeas grown for vegetable purposes, the leaves are picked 4 weeks after planting, and this continues until the plants start to flower (DPP, 2011).

2.7.2 Storage.

The storage life of cowpea depends on its moisture content before storage. The lower the moisture content, the better the quality of seeds in storage. In developed countries; one alternative is the use of cold storage. An exposure to 18 ^{o}C during 6 to 24 hours can reduce pest numbers by more than 99 %. The grain can be stored short term at around 12 % moisture or less, with 8 to 9 % recommended for long-term storage. Cowpea leaves are dried to store them for the dry season. Sun-dried leaves may store for up to a year because dried, cooked leaves are not damaged as much by insects as dried seeds (DPP, 2011).

In cowpea storage, ash is also used to preserve the grains. This is applicable to only small quantities due to it required more labour and a lot of people considers ash as dirty and refuse to consume food stored in ash. Other storage methods include metal drums, this has been widely used in Northern Senegal and South Benin (Boys *et al.*, 2007). According to Moussa (2006), he reported that farmers used insecticides when storing cowpea in single or double layer plastic bags. Adoption studies conducted at the village level in West and Central Africa revealed that growers were interested in hermetic storage for cowpea, but they lack appropriate containers and information about proper storage (Moussa, 2006; Boys, 2005).

Purdue Improved Cowpea Storage (PICS) Technology, is an improved storage technique which involved the use of hermetic storage without insecticides. This three-layer plastic bagging technology is effective because, insects respire in aerobic environment and thus utilize the oxygen in the airtight container while also raising the Co_2 levels. Once the oxygen level in the container falls sufficiently low, the insect cease feeding and become inactive (Margam, 2009).

CHAPTER THREE

3.0 Materials and Methods.

3.1 Laboratory Culture of Insects.

Adult *Callosobruchus maculatus* were collected from infested cowpea seeds from Eke-ukwu market in Owerri Municipal Area of Imo state, Nigeria. The insects were cultured in breeding containers containing susceptible cowpea seeds and kept under ambient temperature 28 ± 3^0 C and relative humidity of 75±5 %. Temperature and relative humidity are the most important variables influencing generation times when beetles are raised on preferred host beans (Howe and Currie, 1964; Lale *et al.*, 1996; Cope and Fox, 2003). The seeds were air dried in the laboratory to avoid mouldiness and later placed in plastic containers covered with calico cloth. Rubber bands were used to hold the calico cloth to prevent escape of bruchids and allow good aeration. The sexes of C. *maculatus* were determined by examining the elytral pattern (Southgate *et al.*, 1957; Beck and Blummer, 2007). The females usually are dark in colour and possess spots on their elytra, while the males are pale brown with less spots. Males also have shorter abdomen while the females possess longer abdomen (Bandara and Saxena, 1995; Beck and Blummer, 2014).

Plate 1. Insect culture (picture scale 1x)

3.2 Sources of Seed Varieties.

Different cowpea varieties that comprise of three land races (One “Akidi ala and two Akidi elu”) and seven breeding lines (SAMPEA-1, SAMPEA-2, SAMPEA-7, SAMPEA-8, SAMPEA-9, SAMPEA-10 and SAMPEA-11) were collected. The local varieties (“Akidi enu and akidi ani”) were obtained from Agbani market in Enugu State, Nigeria, while the breeding lines were sourced from the Institute for Agricultural Research, Amadu Bello University, Samaru, Zaria, Nigeria. The breeding lines and land races were fumigated by wrapping Aluminum phosphide with tissue paper and placed in airtight container and later aired for 24 hours to disinfect them of any incipient infestation.

3.3 Treatment / Experimental design.

The treatment comprised three land races (one akidi ani and two akidi enu) and seven breeding lines (SAMPEA-1, SAMPEA-2, SAMPEA-7, SAMPEA-8, SAMPEA-9, SAMPEA-10 and

SAMPEA-11) of cowpea. These ten (10) treatments were repeated five times (Including the control) in a completely randomized design (CRD), in the laboratory. The grains were properly selected to ensure they were smooth, without wrinkles and blemish on their seed coats. Small, shriveled and broken seeds contain fewer nutrients (Anonymous, 2016). Fifty gram (50 g) of each variety was placed in a 100 ml container and infested with bruchids (5 males and 5 females). Calico cloth was used to seal each container to aid proper ventilation and preclude exit or entry of insects.

Plate 2. Breeding lines and landraces of cowpea seeds. (from top left to down right: “Akidi enu” 2, SAMPEA-1, “Akidi ani”, SAMPEA-7, “Akidi enu” 1, SAMPEA-8, SAMPEA-2, SAMPEA-9, SAMPEA-7 and SAMPEA-11. Scale: -2x)

3.4 Germination Tests.

These were carried out in two phases (Laboratory and field trial). The laboratory trial was carried out in Crop Science Laboratory while the field trial was carried out at the Centre for Agricultural Research and Extension (CARE) of the Federal University of Technology, Owerri. For the first trial, 30 seeds of cowpea were selected from each variety. 10 seeds each were placed in three petri dishes whose bases were lined with whatman's No 44 filter paper moistened with water. The experiment was left for seven days to ensure that all the viable seeds germinate.

Another set of viability tests were carried out at the end of the experiment in same manner as explained above. This was done to know the effect of bruchids infestation on the germination rate of the cowpea seeds. The germination percent was calculated with this formular;

$$\text{Percent germination} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds planted}} \times \frac{100}{1}$$

Plate 3. Laboratory germination test of cowpea seed. (Scale: -1x)

Plate 4. Field germination test of the seeds (Scale: -2x)

3.5 Organoleptic Evaluation.

Fifty gram (100 g) from each variety were washed and cooked with clean water in a clean pot for 60minutes. No extraneous flavor was added to the cooking. The cooked cowpea grains were served on panelists with questionnaires administered to rate the sensory evaluation of the seeds (Larmond, 1977).

Cryptic labeling was employed to eliminate bias among the panelist. Samples were labeled alphabetically. The cooked grains were served on a panel of ten judges in a tasting room devoid of environmental interference of extraneous odour and noise. Questionnaires were drawn to determine the parameters being sought after, which were; taste, odour, texture and overall acceptability. This was done using a five-point hedonic scale (Amerine *et al.*, 1965) with scores ranging from 0 to 4, where 0 is bad and 4 excellent.

Organoleptic evaluation was assessed with damaged and whole seeds to know panelists reaction and acceptability.

Plate 5. Organoletic evaluation of cowpea seeds before bruchid infestation.

(Scale: -1x**)**

Plate 6. Organoleptic evaluation of cowpea seeds after infestation with bruchids.

3.6 Mortality and Oviposition count

Mortality count involves the counting of dead bruchids. It was assessed 24, 48, 72 hours and 7 days after infestation. This was to know if the seed's physical and chemical characteristics influenced mortality (Silim, 1995). The percent mortality was calculated as described by Niber (1994).

$$\text{Percent mortality} = \frac{\text{Number of dead insects}}{\text{Total number of insects}} \times \frac{100}{1}$$

Oviposition count was assessed by counting the number of eggs on ten (10) randomly selected grains per treatment on the 7th day after infestation. The seeds were placed back into their respective containers. This count was carried out using a magnifying lens.

Plate 7. Oviposition on a land race of cowpea. (scale: -3x)

Plate 8. Oviposition on a breeding line of cowpea. (Scale: -1x)

3.7 Emergence.

Emergence was assessed by counting the number of adults that emerged 24, 48, 72 hours and 7 days as the first filial generation and for second filial generation.

Plate 9. Bruchid emergence on sampling container. (scale:+1)

3.8 Damage assessment

Damage assessment was achieved by counting the number of exit holes on the seeds.10 seeds were randomly selected on 7th day after emergence and same for second filial generation. The percentage seed damage was calculated according to Enobakhare and Law-Ogbomo (2002).

$$\text{Percentage seed damage} = \frac{\text{Number of damaged seeds}}{\text{Total number of seeds used}} \times \frac{100}{1}$$

3.9 Properties' evaluation.

3.9.1 Seed coat colour: Seed coat colour was assessed using the five hedonic scale method as described by Amerine *et al.* (1965).

3.9.2 Seed size: Seed sizes were assessed using venier calipers as described by IBPGR (1983).

3.9.3 Seed texture: Seeds were assessed as smooth, smooth to rough, rough, rough to wrinkled and wrinkled (coarse fold on the testa) as described by IBPGR (1983).

3.9.4 Mouldiness: Infested seeds from all samples were compared to determine seed mouldiness, using Amerine *et al.* (1965).

3.9.5 Seed weight loss assessment.

Seed weight percentage was achieved by weighting 100 randomly selected grains of cowpea from each container before infestation (initial weight) and at the end of experiment (final weight). Using the formular,

$$\text{Weight loss percent} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \times \frac{100}{1}$$

3.10 Proximate Analysis: The determination of proximate components; moisture content, crude fat, crude protein and ash was achieved by standard methods of AOAC (2016). This was done before and after the experiment, to know the effect of infestation on the seeds nutritional properties.

3.11 Statistical Analysis:

All the data obtained were analyzed using analysis of variance. The means were separated using Fisher's least significant difference at a 5 % level of significance as described by Wahua (1999).

CHAPTER FOUR

4.0 RESULTS.

4.1 Field and laboratory germination tests for uninfested and infested cowpea seeds at 7days after planting.

Table 1 shows the germination tests of uninfested and infested seeds at 7 days after planting. Statistically, field germination for the uninfested seeds was not significant whereas laboratory germination tests for uninfested cowpea seeds showed significant difference. The result was not significant for field and laboratory germination of infested seeds for the first and second trial. The coefficient of variation in the field and laboratory viability tests for first and second trials recorded low variation between the seeds meaning that the variations between the seeds were not much.

Visually, it was observed, however that sampea 1 and 11 had higher seed germination than sampea 2, 7, 8, 9, 10 and the land races in field viability test of uinfested seeds. The laboratory germination test for uninfested seed showed that sampea 2 recorded highest percent (96.7) followed by sampea 1 (91.7) while the lowest germination percent was recorded in akidi enu 1 (61.7). General observation shows that after infestation sampea 8 recorded higher germination percent than the other seeds while the land races recorded low percent germination. The conclusion, the breeding lines showed higher germination percent than landraces in the first and second trials.

Table1: Field and laboratory germination tests for uninfested and infested cowpea seeds at 7days after planting

Treatment	Field germination (Uninfested)	Laboratory germination (Uninfested)	Field germination (infested)		Laboratory germination (infested)	
			(1st trial)	(2nd trial)	(1st trial)	(2nd trial)
SAMPEA-1	56.7	91.7	31.7	35.0	58.3	56.7
SAMPEA-2	73.3	96.7	30.0	36.7	61.7	50.0
SAMPEA-7	55.0	85.0	30.0	36.7	55.0	50.0
SAMPEA-8	41.7	90.0	35.0	40.0	70.0	61.7
SAMPEA-9	51.7	81.7	28.3	33.3	46.7	53.3
SAMPEA-10	51.7	83.3	33.3	30.0	51.7	58.3
SAMPEA-11	65.0	90.0	28.3	31.7	53.3	53.3
Akidi enu 1	41.7	61.7	31.7	33.3	50.0	46.7
Akidi enu 2	40.0	66.7	25.0	30.0	40.0	45.0
Akidi ani	63.3	90.0	30.0	26.7	50.0	46.7
Mean	54.0	83.7	30.0	33.3	53.7	52.2
LSD $_{(0.05)}$	NS	11.74	NS	NS	NS	NS
Coefficient of variation (cv%)	14.4	2.8	7.8	6.9	18.6	16.7

4.2 Percentage mortality of infested cowpea breeding lines and landraces for first trial at 24, 48 and 72 hours after infestation with *Callosobruchus maculatus*.

Percentage mortality of infested cowpea breeding lines and landraces for first experiment at 24, 48 and 72 hours after infestation with *Callosobruchus maculatus* is represented in Table 2. The highest mortality count was recorded in SAMPEA-8 (38%) while SAMPEA-7 and The result at 24 hours was significant between the seeds. SAMPEA-11 had the lowest mortality (22%) at 24 hours. Observation showed that apart from SAMPEA-8 which recorded highest mortality, the landraces followed suit. The result of mortality counts at 48 and 72 hours was not significant statistically. SAMPEA-8 recorded highest mortality at 48 hours while SAMPEA-7 and 10 had the least percent mortality. At 78 hours, the landraces: “akidi enu” 1 and 2 recorded highest mortality (86%) while SAMPEA-10 had the least mortality percent (76%). Generally, it was observed that there was slight difference in mortality between the breeding lines and land races. For this reason, the coefficient of variation was low for both the breeding lines and landraces.

Table 2: Percentage mortality of infested cowpea breeding lines and landraces for first trial at 24, 48 and 72 hours after infestation with *Callosobruchus maculatus*.

Treatment	**Mortality count**		
	24 hour(%)	48 hour(%)	72 hour(%)
SAMPEA-1	30.0	52.0	82.0
SAMPEA-2	26.0	52.0	78.0
SAMPEA-7	22.0	50.0	80.0
SAMPEA-8	38.0	66.0	84.0
SAMPEA-9	28.0	62.0	78.0
SAMPEA-10	26.0	50.0	76.0
SAMPEA-11	22.0	54.0	82.0
Akidi enu 1	36.0	62.0	86.0
Akidi enu 2	34.0	62.0	86.0
Akidi ani	30.0	58.0	80.0
Mean	29.2	56.8	81.2
LSD $_{(0.05)}$	9.04	NS	NS
Coefficient of variation (CV%)	24.2	19.1	15.3

4.3 Percentage mortality of infested cowpea breeding lines and landraces for second trial at 24, 48, 72, 96, 120 and 144 hours after infestation.

The percentage mortality of cowpea seeds for second experiment at 24, 48, 72, 96, 120 and 144 hours are presented in Table 3. The result at 24 and 72 hours were not significant. But at 48, 96, 120 and 144 hours the results showed significant difference between the breeding lines and landraces. The mortality counts at 24 and 48 hours recorded highest in SAMPEA-8 while the least mortality was recorded in SAMPEA-11. Also, the results at 72 hours showed that SAMPEA-8 recorded higher than other breeding lines and the landraces. The least percent mortality was recorded in "akidi enu" 2. At 72 hours, the breeding lines had higher mortality than the landraces except SAMPEA-1. The results at 96, 120 and 144 hours showed that SAMPEA-7 had the highest mortality while "akidi ani" recorded the least mortality. In general, the coefficient of variation at 24 hours was slightly high while at 48, 72, 96, 120 and 144 hours, there were lower variations.

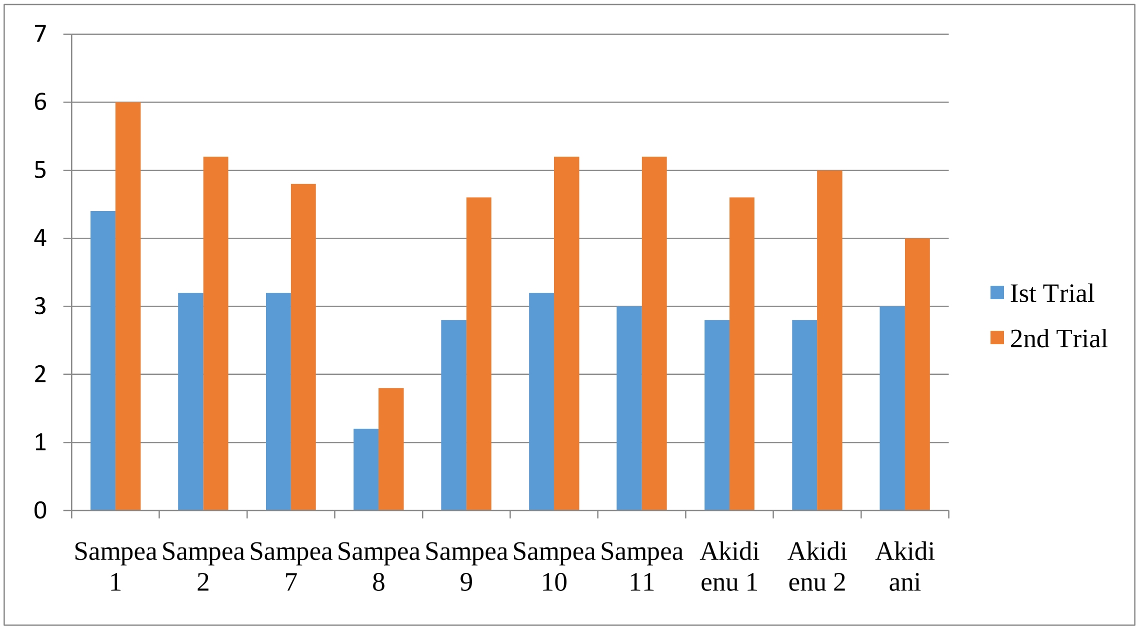
Table 3: Percentage mortality of infested cowpea breeding lines and landraces for second trial at 24, 48, 72, 96, 120 and 144 hours after infestation with *Callosobruchus maculatus*.

Treatment		**Mortality**	**count**			
	24 hr(%)	48 hr(%)	72 hr(%)	96 hr(%)	120 hr(%)	144 hr(%)
SAMPEA-1	32.0	60.0	78.0	94.0	94.2	94.6
SAMPEA-2	28.0	60.0	82.0	94.0	94.4	94.4
SAMPEA-7	30.0	56.0	82.0	100	100.0	100.0
SAMPEA-8	48.0	78.0	94.0	96.0	96.4	96.4
SAMPEA-9	30.0	66.0	84.0	98.0	98.6	98.2
SAMPEA-10	34.0	56.0	80.0	94.0	94.6	94.6
SAMPEA-11	22.0	50.0	80.0	88.0	88.6	89.0
Akidi enu 1	34.0	54.0	76.0	90.0	90.2	90.6
Akidi enu 2	34.0	62.0	74.0	88.0	88.8	89.0
Akidi ani	28.0	58.0	78.0	86.0	87.0	87.6
MEAN	32.0	60.0	80.8	92.8	93.2	93.44
LSD $_{(0.05)}$	NS	14.46	NS	7.12	6.67	6.49
Coefficient of variation (CV%)	32.6	18.9	11.4	6.0	5.6	5.4

4.4 The mean number of eggs laid on some breeding lines and land races of cowpea seeds.

The results of mean number of eggs laid on the seeds are presented in Figure 1. The number of eggs per 10 seeds in the first and second trials, showed statistical difference among the breeding lines and land races. In the first trial, SAMPEA-l had the highest number of eggs per 10 seeds (4.4) while SAMPEA-8 recorded the least (1.2). The breeding lines recorded higher eggs than the landraces except SAMPEA-8 and 9. The second trial has similar result as the first. SAMPEA-8 recorded the least number of eggs while SAMPEA-1 had the highest number of eggs per 10 seeds. Also, the breeding lines had more oviposition than the landraces except for SAMPEA-8 and 10.

Figure 1. Mean number of eggs laid on some breeding lines and landraces of cowpea seeds.



4.5 The mean number of emerged *Callosobruchus maculatus* from the cowpea seeds for the first trial.

Table 4 shows the number of emerged *Callosobruchus maculatus* from the breeding lines and landraces at 24, 48, 72 and 168 hours for the first trial. The result of adult emergence at 24, 48, 72 and 168 hours showed significant difference with low coefficient of variation between them. This indicated that the variability between the seeds was low. It was observed that at 24 and 72 hours, SAMPEA-1 recorded highest number of emergence while the lowest number of emerged *Callosobruchus* was recorded in SAMPEA-8 (1.4). The breeding lines had more emergence than landraces except for SAMPEA-8 and 11. At 48 hours, SAMPEA-8 also recorded the least emergence while the highest number of emerged bruchid was recorded in SAMPEA-1 (25.8). The number of emerged *Callosobruchus maculatus* at 168 hours, recorded highest in SAMPEA-2 while SAMPEA-8 had the lowest emergence. Moreso, total emergence recorded the highest number of emerged *Callosobruchus maculatus* in SAMPEA-1 (93.4) while the least number of emerged adult was recorded in SAMPEA-8 (7.2). Furthermore, observation showed the breeding lines: SAMPEA-1, 2, 7, 9 and 10 recorded more emergence than the landraces.

Table 4: Mean number of emerged adult *Callosobruchus maculatus* for first trial.

	Number of Emerged Insects				
Treatment	24Hrs	48Hrs	72Hrs	168Hrs	**Total emergence**
SAMPEA-1	24.0	25.8	17.2	26.4	93.4
SAMPEA-2	19.2	16.0	14.2	27.8	77.2
SAMPEA-7	15.0	13.6	11.8	16.8	57.2
SAMPEA-8	1.4	1.2	1.4	3.2	7.2
SAMPEA-9	12.4	12.0	10.0	21.2	55.6
SAMPEA-10	13.0	13.4	11.2	19.8	57.4
SAMPEA-11	10.8	10.4	8.6	19.8	49.6
Akidi enu 1	10.8	11.6	9.4	18.0	49.8
Akidi enu 2	9.2	11.2	8.8	20.0	49.2
Akidi ani	10.2	10.2	9.4	18.0	47.8
MEAN	12.6	12.54	10.2	26.4	54.4
$LSD_{(0.05)}$	4.228	4.378	3.201	4.659	13.11
Coefficient of variation (CV%)	14.8	16.3	15.1	9.7	18.9

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4.6 The mean number of emerged bruchid at 24, 48, 72, 96, 120 and 168 hours and second filial generation for second trial.

Presented in Table 5 are the mean numbers of emerged adult *Callosobruchus maculatus* at 24, 48, 72, 96,120, 144, 168 and second filial generation for second trial. The result between the treatments at 24 hours was not significance. At 48 hours, the result of emerged bruchid between the treatments was significantly different. This result is similar at 72, 96, 120, 168 and second filial generation except for 144 hours which was not significant. Observation showed that at 48 and 72 hours, SAMPEA-10 recorded highest number of emerged *Callosobruchus maculatus* while the least emergence was recorded in SAMPEA-8. Furthermore, the results at 96 and 120 hours took a different direction. The landraces had more emerged adults than the breeding lines except for SAMPEA-10 and 11. At 96 and 120 hours “akidi enu” 2 had the highest number of emerged *Callosobruchus maculatus* while sampea 8 recorded the lowest adult emergence. Also, in same manner, “akidi enu” 1 and 2 recorded the highest adult emergence while the least number of emergences was recorded in SAMPEA-9. The result at 168 hours is similar to that of 96 and 120 hours where SAMPEA-8 had the lowest number of emerged *Callosobruchus maculatus,* while “akidi enu” 2 recorded the highest bruchid emergence. For the second filial generation, the result of the number of emerged bruchid showed significant difference. It was observed SAMPEA-11 recorded the highest emergence while the lowest number of bruchid emergence was recorded in SAMPEA-8 (0.8).

Table 5: The mean number of emerged adult *Callosobruchus maculatus* at 24, 48, 72, 96, 120,144 and 168 hours and second filial generation for second trial.

	Number of Emerged Insects								
Treatment	24Hrs	48Hrs	72Hrs	96Hrs	120Hrs	144Hrs	168Hrs	second filial generation.	**Total emergence**
SAMPEA-1	16.0	10.4	5.2	3.8	4.0	5.0	3.0	11.4	58.8
SAMPEA-2	9.6	6.2	4.2	2.6	2.8	3.6	2.2	6.0	37.2
SAMPEA-7	8.2	7.8	6.2	5.0	4.2	3.4	3.8	10.0	52.6
SAMPEA-8	0.6	1.2	1.6	0.2	0.2	3.2	0.2	0.8	8.0
SAMPEA-9	9.0	5.6	5.0	4.0	3.8	2.4	4.6	18.4	42.8
SAMPEA-10	10.0	11.6	11.4	8.0	5.8	5.4	4.4	17.8	74.4
SAMPEA-11	8.2	8.4	6.6	5.8	6.0	5.6	5.4	27.0	73.0
Akidi enu1	11.6	15.0	10.8	5.4	7.0	6.4	4.6	25.2	86.0
Akidi enu2	7.0	12.4	8.8	10.4	8.0	6.4	5.8	20.4	79.2
Akidi ani	5.2	6.0	7.4	8.4	4.8	5.6	3.2	12.2	52.8
MEAN	8.5	8.46	6.72	5.36	4.66	4.7	3.72	14.9	57.5
LSD $_{(0.05)}$	NS	7.283	3.844	4.007	3.031	NS	2.325	11.28	23.01
Coefficient of variation(CV %)	18.0	29.7	19.3	24.7	23.4	31.3	21.0	33.4	44.7

4.7 Damage assessment of the breeding lines and landraces of cowpea seeds.

The result of damage assessment between the breeding lines and landrace is presented in Table 6. In the first and second trial, number of holes per 10 seeds and seed damage percent showed significant differences. However, the number of holes per 10 seeds in the first trial recorded highest in SAMPEA-1 (6.2), followed by SAMPEA-2 (4.8). The least mean number of holes per 10 seed was recorded in SAMPEA-8 (1). The result showed significant differences. In the second trial, SAMPEA-1 had higher mean number of holes per 10 seeds (6.4) while SAMPEA-8 had the lowest number of hole per seeds (0.4). The seed damage percent in the first trial revealed SAMPEA-1 recorded the highest (46%) while SAMPEA-8 recorded the least seed damage percent (14%). Damage percent in the second trial had similar percent range, where SAMPEA-1, 9, 10 and “Akidi enu” 2 recorded (44%) which is the highest percent damage. It was also observed that sampea8 recorded the lowest damage percent (10). The effect of infestation on the seeds which resulted to seed damage showed significant difference ($P>0.05$).

Table 6: Damage assessment of the breeding lines and landraces.

Treatment	No. of holes per 10 seeds (1st trial)	No. of holes per 10 seeds (2nd trial)	Seed damage (%) (1st trial)	Seed damage (%) (2nd trial)
SAMPEA-1	6.2	5.4	46.0	44.0
SAMPEA-2	4.8	3.8	42.0	38.0
SAMPEA-7	3.8	4.0	38.0	32.0
SAMPEA-8	1.0	0.4	14.0	10.0
SAMPEA-9	4.0	4.6	32.0	44.0
SAMPEA-10	3.8	4.8	34.0	44.0
SAMPEA-11	3.6	4.2	32.0	42.0
Akidi enu 1	3.6	4.4	32.0	40.0
Akidi enu 2	3.6	4.6	32.0	44.0
Akidi ani	3.2	4.0	32.0	38.0
MEAN	3.76	4.02	33.4	37.6
$LSD_{(0.05)}$	1.137	1.010	12.03	11.88
Coefficient of variation(CV%)	9.7	14.8	8.9	16.4

4.8 The result of organoleptic ratings of cooked uninfested breeding lines and landraces of cowpea.

In Table 7, is presented the organoleptic ratings of cooked uninfested breeding lines and landraces of cowpea. Result of grain appearance was significantly different statistically. However, the result showed that sampea1 had higher ratings in appearance where “akidi enu” 2 recorded the lowest grain appearance. Also, the results for odour, texture, taste and overall acceptability showed significant difference between the treatments. It was observed that odour rating showed that SAMPEA-1 had highest rating (3.7) while “akidi ani” recorded the lowest odour rating (1.8). The rating results for texture and tastes of the uninfested cowpea seeds showed that the highest rating was recorded in SAMPEA-1 while the least rating was recorded in “akidi enu” 2. It was observed that the overall acceptability was highest in SAMPEA-1 while “akidi enu” 2 had the lowest overall acceptability. Generally, the organoleptic rating had the breeding lines to be preferred more than landraces, with low coefficient of variation between the seeds.

Table 7. Organoleptic ratings of cooked uninfested breeding lines and landraces of cowpea.

Treatment	Appearance	Odour	Texture	Taste	**Overall acceptability**
SAMPEA-1	3.7	3.6	3.7	3.6	3.7
SAMPEA-2	3.2	3.0	3.6	3.0	3.0
SAMPEA-7	1.8	1.8	2.3	1.5	2.0
SAMPEA-8	3.0	2.9	2.7	3.0	2.9
SAMPEA-9	2.9	2.7	3.2	3.0	3.0
SAMPEA-10	3.5	2.9	3.2	3.2	3.3
SAMPEA-11	2.9	2.7	3.3	2.8	3.1
Akidi enu 1	1.5	2.0	1.5	1.4	1.4
Akidi enu 2	1.0	1.7	1.0	0.9	1.0
Akidi ani	1.3	1.3	1.1	1.0	1.2
MEAN	2.48	2.46	2.56	2.34	2.46
LSD $_{(0.05)}$	0.7622	0.7757	0.7669	0.7553	0.7181
Coefficient of variation (CV%)	16.3	17.5	13.8	16.3	13.0

SCORING SCALE
0 = Bad (Dislike, definitely), 1 = Poor (Dislike, slightly), 2 = Average (Neither like nor dislike), 3 = Good (Like, slightly), 4 = Excellent (Like, definitely).

4.9 Organoleptic ratings of cooked infested cowpea for first and second trial.

The results for organoleptic ratings of cooked infested cowpea seeds for first and second experiment are represented in Table 8. The rating for appearance showed significant difference in the first and second trial. SAMPEA-2 had the highest appearance rating (3.2) while “akidi enu” 2 had the lowest appearance rating (0.4) in the first trial. For the second trial, appearance values recorded the least rating in “akidi enu” 1 and 2 (0.9) while the highest was recorded in SAMPEA-10 (3.4). The result recorded low coefficient of variation for the first and second trial. Ratings for odour in the first and second trial also showed significant difference ($p<0.05$) with low coefficient of variation. This result showed that the variability between the treatments were not high. At the first trial, odour rated highest in SAMPEA-10 (3.3) while “akidi ani” had the least odour preference (1.5). For the second trial, “akidi enu” 2 recorded the lowest odour rating while the highest rating was recorded in SAMPEA-10 (3.4). The result for texture rating the first and second trial differed significantly. Through observation, SAMPEA-2 and 10 recorded the highest texture rating for the first and second trial while “akidi enu” 2 showed the lowest texture rating. Taste rating showed highest preference in SAMPEA-1 (2.9) in the first trial while “akidi enu” 2 recorded the lowest (0.7) taste rating. For the second experiment, the least taste rating was recorded in “akidi enu” 1 (0.9) after which SAMPEA-10 had the highest taste rating (2.9). The overall acceptability of the cooked seeds, SAMPEA-9 had the highest rating while the least acceptability rating was recorded in “akidi ani”. The second experiment for overall acceptability recorded highest rating in SAMPEA-11 while “akidi enu” 1 had the lowest acceptability rating. Generally, observation showed that the breeding lines had higher ratings than the landraces in the organoleptic rating of the seeds.

Table 8. Organoleptic ratings of cooked infested cowpea for first and second trial.

Treatment	Appearance		Odour		Texture		Taste		**Overall acceptability**	
	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial
SAMPEA-1	1.8	2.1	2.8	2.7	1.9	2.2	2.9	2.1	2.2	2.4
SAMPEA-2	3.2	2.7	1.9	2.8	3.2	2.6	2.7	2.5	2.9	2.8
SAMPEA-7	2.3	2.3	2.5	1.9	2.3	2.6	1.8	2.0	2.1	2.4
SAMPEA-8	2.6	2.7	2.5	2.5	2.7	2.9	3.1	2.4	3.1	2.8
SAMPEA-9	3.0	3.2	3.1	3.2	2.8	3.1	3.2	2.8	3.3	3.2
SAMPEA-10	2.9	3.4	3.3	3.4	2.4	3.2	2.5	2.9	2.7	3.3
SAMPEA-11	1.4	1.8	2.8	2.9	2.5	2.6	3	2.5	2.7	2.6
Akidi enu 1	0.9	0.9	1.9	1.2	1.4	0.8	1.3	0.9	1.0	0.9
Akidi enu 2	0.4	0.9	2.0	1.6	0.9	0.7	0.7	1.4	0.7	1.3
Akidi ani	0.6	1.6	1.5	2.2	1.1	1.6	1.2	2.3	0.6	2.0
Mean	1.91	2.16	2.43	2.44	2.12	2.23	2.24	2.18	2.13	2.37
LSD $_{(0.05)}$	0.7646	0.895	0.7791	0.8617	0.995	0.6842	0.8042	0.7414	0.6698	0.6624
Coefficient of variation (CV%)	31.7	28.1	18.1	21.0	21.2	21.4	40.3	29.0	25.8	25.2

SCORING SCALE

0 = Bad (Dislike, definitely), 1 = Poor (Dislike, slightly), 2 = Average (Neither like nor dislike), 3 = Good (Like, slightly), 4 = Excellent (Like, definitely)

4.10 The results of Morphological properties of the breeding lines and landraces of cowpea seeds.

Table 9 represents the morphological properties of some breeding lines and landraces of cowpea. The result for seed size, 100 seed weight, seed texture, colour preference and moldiness of infested seeds for first and second trials shows significant difference between the treatments. Seed size recorded highest in SAMPEA-11 (5.05) while “akidi enu” 2 had the least seed size (3.09). The seed weight, “akidi enu” 1 had the lowest seed weight while the highest seed weight was recorded in SAMPEA-7. The texture property of the seeds recorded highest in SAMPEA-1 and 9 while the lowest seed texture was recorded in “akidi ani”. Colour preference of the cowpea seeds recorded highest in SAMPEA-10, followed by SAMPEA-9 while “akidi ani” had the lowest colour preference (0.5). The result of seed moldiness after infestation for the first trial recorded higher in SAMPEA-2 (2.3) while SAMPEA-8 had the lowest seed moldiness (0.1). Also, SAMPEA-8 recorded the least seed moldiness in the second trial while “akidi enu” 1 had the highest seed moldiness (3.7). In general, it was observed that morphological properties such as seed size, 100 seed weight, colour preference had higher mean values in the breeding lines than landraces.

Table 9. Morphological properties of some breeding lines and landraces of cowpea

Treatment	Seed size (mm)	100 seed weight	Texture	Colour preference	Moldiness of infested seeds (1st trial)	Moldiness of infested seeds (2nd trial)
SAMPEA-1	4.54	17.52	2.90	3.20	1.40	0.60
SAMPEA-2	4.11	15.85	0.50	2.30	2.30	2.40
SAMPEA-7	4.11	18.05	0.70	2.40	2.00	1.60
SAMPEA-8	4.32	16.17	2.60	2.90	0.10	0.10
SAMPEA-9	4.74	15.53	2.90	3.50	1.60	0.60
SAMPEA-10	4.91	16.81	2.30	3.70	1.90	1.70
SAMPEA-11	5.05	17.33	2.10	3.00	1.50	1.60
Akidi enu 1	3.11	8.85	1.30	2.00	0.50	3.70
Akidi enu 2	3.09	9.31	1.00	1.20	0.50	1.40
Akidi ani	3.87	11.97	0.30	0.50	4.00	1.70
MEAN	4.19	14.74	1.66	2.47	1.58	1.54
LSD $_{(0.05)}$	0.510	0.859	1.166	0.839	0.605	0.666
Coefficient of variation(CV%)	6.2	1.0	29.0	20.7	17.3	33.7

SCORING SCALE

0 = Bad (Dislike, definitely), 1 = Poor (Dislike, slightly), 2 = Average (Neither like nor dislike), 3 = Good (Like, slightly), 4 = Excellent (Like, definitely

4.11 Seed weight loss assessment of the breeding lines and landraces of cowpea.

The weight (g) loss assessment of the seeds is presented in Table 10. Results of the initial and final weight of seeds in the first and second trial showed significant difference ($p<0.05$). The treatments recorded low coefficient of variation. The initial and final seed weight of the seeds in the first trial showed that SAMPEA-7 had the highest seed weight while the lowest initial and final weight was recorded in “akidi enu” 1. Similar to the first trial, the initial seed weight in the second trial had higher weight in SAMPEA-7 (17.14) while “akidi enu” 2 recorded the least weight (9.69). Also, the final seed weight in the second trial showed that the least weight (8.68) was recorded in “akidi enu” 1 while the highest seed weight (16.56) was recorded in SAMPEA-1. The weight loss percent in the first trial showed that SAMPEA-1 had the lowest percentage weight loss while “akidi ani” had the highest weight loss percent. In the second trial, SAMPEA-9 had the lowest weight loss percent while SAMPEA-11 recorded the highest weight loss percent. Generally, it was observed that the initial and final seed weight as well as the weight loss percent had low coefficient of variation.

Table 10. Seed weight loss assessment of some breeding lines and landraces of cowpea

Treatment	Initial seed weight (g) (1st. trial)	Initial seed weight (g) (2nd trial)	Final seed weight (g) (1st trial)	Final seed weight (g) (2nd trial)	Weight loss (%) (1st trial)	Weight loss (%) (2nd trial)
SAMPEA-1	17.88	17.08	17.32	16.56	3.15	3.04
SAMPEA-2	17.07	17.00	15.8	15.14	7.23	10.94
SAMPEA-7	18.5	17.14	17.53	16.26	5.21	5.13
SAMPEA-8	17.27	17.04	16.17	15.57	6.36	8.63
SAMPEA-9	16.65	16.65	15.53	16.26	6.09	2.34
SAMPEA-10	17.28	16.79	16.57	15.3	5.02	8.87
SAMPEA-11	18.12	16.61	17.13	11.11	5.48	33.11
Akidi enu 1	9.69	9.69	8.85	8.68	8.59	10.42
Akidi enu 2	10.75	10.75	9.28	8.98	13.16	16.47
Akidi ani	15.48	14.88	11.72	10.3	22.29	30.78
MEAN	15.87	14.76	14.59	14.02	8.26	12.97
LSD $_{(0.05)}$	1.538	2.571	0.927	1.094	8.141	0.92
Coefficient of variation(CV%)	2.8	3.2	0.9	1.5	23.1	5.7

4.12 The result of proximate analysis for uninfested cowpea seeds.

Presented in Table 11, is the proximate analysis for uninfested cowpea seed. The results indicate that the breeding lines and landraces differed statistically ($P<0.05$) on fat, fibre, moisture, protein and carbohydrate respectively. The sample analyses between the seeds showed low coefficient of variation. Fat content of the seeds recorded highest in "akidi ani" (5.41%) after which the lowest fat content was recorded in SAMPEA-11 (0.83%). The result of ash content was not significant ($p<0.05$). It was observed that ash content had highest percent in "akidi enu" 1 while "akidi ani" showed the lowest ash content percent. Furthermore, the fibre and moisture content showed the land races had higher percent than breeding lines. The fibre content showed that "akidi enu" 2 had highest percent (4.70) while SAMPEA-2 recorded the least percent (1.50%). Also, moisture content percent was highest in "akidi ani" (13.05) while SAMPEA-11 recorded the lowest (9.02%). The protein content had highest percent in SAMPEA-1 while SAMPEA-10 showed the least protein content. It was observed that the carbohydrate content of the seeds showed higher percent in the breeding lines than landraces. The highest carbohydrate content was recorded in SAMPEA-10 (70.47%) while "akidi ani" had the least percent (56.17%).

Table 11: Proximate analysis for uninfested cowpea seeds.

Treatment	% Fat	% Ash	% Fibre	% Moisture	% Protein	% Carbohydrate
SAMPEA-1	1.33	3.53	3.50	9.31	23.53	58.80
SAMPEA-2	1.40	3.34	1.50	9.18	15.35	69.23
SAMPEA-7	1.64	3.48	1.80	9.18	16.47	67.43
SAMPEA-8	2.23	3.21	2.15	9.88	16.53	66.00
SAMPEA-9	1.54	3.36	2.37	9.14	15.07	68.52
SAMPEA-10	0.91	3.42	2.25	9.62	13.30	70.47
SAMPEA-11	0.83	3.14	2.35	9.02	14.38	70.39
Akidi enu 1	4.36	3.70	3.60	11.44	21.21	55.69
Akidi enu 2	3.21	3.69	4.70	10.33	14.84	63.13
Akidi ani	5.41	3.01	4.55	13.05	17.81	56.17
MEAN	2.29	3.39	2.88	10.02	16.85	64.58
LSD $_{(0.05)}$	0.341	NS	0.374	0.601	1.155	1.343
Coefficient of variation(CV%)	8.8	9.2	7.6	3.5	4.0	1.2

4.13 The result of proximate analyses for infested cowpea seeds of first and second trial.

Proximate analysis of the infested cowpea seeds for first and second trial is represented in Table 12. In this result, the fat, ash, fibre, moisture, protein and carbohydrate of the first and second trial showed significant differences among the seeds. The fat content of the seeds after infestation showed that “akidi ani” had the lowest fat content (6.82%) while SAMPEA-2 recorded the highest (10.92%) in the first trial. Also in the second trial, SAMPEA-2 had the highest fat content while “akidi enu” 2 and “akidi ani” recorded the lowest respectively. These results had low coefficient of variation. Ash content in the first trial recorded highest in SAMPEA-11 (3.88%) while SAMPEA-8 recorded the lowest ash content percent. In the second trial, ash content recorded highest percent in “akidi enu” 2 (3.30%) while the least percent was recorded in SAMPEA-10 (1.33%). Fibre content in the first experiment showed that SAMPEA-8 recorded the highest fibre content then SAMPEA-10 had the least percent. The second trial showed that SAMPEA-7 had the lowest fibre content while the highest (13.15%) was recorded in SAMPEA-10. In the first trial for moisture content percent of the seeds, “akidi ani” had the highest percent (15.77%) while SAMPEA-10 recorded the lowest moisture percent (14.00%). The second experiment showed that SAMPEA-11 had the highest moisture content percent (17.55 %) while the lowest moisture content was recorded in SAMPEA-8. Result for protein content percent in the first and second trial showed that SAMPEA-1 had the highest percent (18.10 and 21.72 %) while SAMPEA-10 had the least protein content (11.18 and 10.30 %) respectively. The carbohydrate content of the seeds in the first experiment revealed that the lowest percent was recorded in SAMPEA-2 and the highest carbohydrate content was recorded in SAMPEA-10 (57.92 %). In the second trial, “akidi enu” 2 had the highest carbohydrate content after infestation while SAMPEA-1 recorded the lowest percent carbohydrate. It was also observed in this result that the coefficient of variation between the treatments was low in the first and second trials.

Table 12: Proximate analyses for infested cowpea seeds of first and second experiment.

Treatment	% Fat		% Ash		% Fibre		% Moisture		% Protein		% Carbohydrate	
	1st trial	2nd trial	1st trial	2nd trial	1st expt	2nd trial	1st trial	2nd trial	1st trial	2nd trial	1st trial	2nd trial
SAMPEA-1	10.57	9.62	3.68	2.34	6.50	7.85	14.62	16.16	18.10	21.72	46.53	42.22
SAMPEA-2	10.92	11.43	3.18	2.97	10.25	8.45	15.55	16.37	15.10	11.18	45.93	49.45
SAMPEA-7	10.11	10.07	3.31	3.18	4.95	7.00	14.84	16.50	14.50	11.25	50.55	52.00
SAMPEA-8	9.96	7.18	2.82	2.30	12.50	13.00	14.62	15.39	12.56	15.28	46.58	46.85
SAMPEA-9	6.98	10.12	3.18	3.16	6.90	13.15	15.15	16.31	14.21	12.07	53.58	45.19
SAMPEA-10	7.46	7.84	2.89	1.33	6.55	12.35	14.00	16.52	11.18	10.30	57.92	51.66
SAMPEA-11	7.93	9.23	3.88	1.14	4.30	12.65	15.10	17.55	12.89	13.18	55.90	46.25
Akidi enu 1	7.56	9.64	3.76	2.97	9.90	8.40	14.18	16.83	14.50	14.66	49.81	47.30
Akidi enu 2	7.60	7.16	3.45	3.30	6.45	8.75	14.60	15.81	13.61	11.32	54.09	53.63
Akidi ani	6.82	7.16	2.87	3.11	10.10	10.75	15.77	16.27	16.00	13.53	48.44	49.18
MEAN	8.59	8.95	3.30	2.59	7.84	10.24	14.84	16.37	14.27	13.45	50.93	48.37
LSD $_{(0.05)}$	0.519	0.374	0.410	0.318	0.427	0.599	0.906	0.525	1.020	0.386	2.233	0.524
Coefficient of variation(CV%)	3.6	2.5	7.3	7.2	3.2	3.4	3.6	1.9	4.2	1.7	2.6	0.6

4.2 DISCUSSION

The treatment materials (breeding lines and landraces) gave different responses when subjected to *Callosobruchus maculatus* infestation. Some seeds were susceptible (SAMPEA-1, 2, 7, 9, 10 and 11) while sampea-8 was tolerant to bruchid attack. This may be as a result of the varied characteristics possessed by the seeds (coat texture). Variability in grain characteristics has been found useful in the selection of cultivars for insect resistance. Due to the fewer number of insects observed in SAMPEA-8, the breeding line may possess different characteristics from the others. This result is in agreement with Laphale *et al* (2012) who reported that some characteristics, including seed size, testa thickness and hardness in the genotypes may influence cowpea seed response to bruchid attack. Lale and Kolo, (1998); Dasbak *et al*., (2009) and Asante and Mensah, (2007) had opined that the susceptibility of stored seeds to damage by insect pests is dependent on numerous factors including variety, seed size, environment and physical and chemical composition of the seed coat.

Resistance being genetic is a potential option to reduce losses caused by *C. maculatus* during storage. Most of the cowpea cultivars showed high percent seed damage except sampea 8 which had the least seed damage. This indicates its resistance to bruchid and could be attributed to its genetic characteristics. Singh *et al.*, (2002) reported that most cowpea varieties have combined resistant ability not only to *Callosobruchus maculatus* but also to other insect pests and weeds.

Seed resistance can also be attributed to seed texture. In this study, Sampea 1, 8 and 9 showed high rating values than the other seeds. This agrees with Amusa *et al.,* (2013) that one important resistant character is seed texture which may interfere with the larval establishment stage of insect pest. Rosemond and khan (2013) reported that the larval penetration and entry into the seed is in part dependent on the seed coat toughness.

The rate of oviposition and bruchid emergence on the seeds showed that some seeds possess barrier that hinders larval penetration. Some of the breeding lines and landraces were prone to insect oviposition. With exception of SAMPEA-8; all other cultivars and the Akidi cultivars also recorded oviposition and emergence rates. Semple (1992) had earlier noted that the rate of insect population is affected by the resistance a particular cultivar or variety offers which may or may not cause reduction in the rate of oviposition through physical or mechanical barriers. The barrier may either limit access into the grain or make it unsuitable for oviposition. The oviposition deterrence may be due to the difficulty eggs have in adhering to the seed surface or the prevention of larval penetration after hatching.

Seed germination after infestation was expectedly low. This could be as a result of the destruction of the germ cells in the seed. This agrees with Santos *et al*., (1990) that insects feed on the endosperm causing loss of weight and quality, while other species feed on the germ, resulting in poor seed germination and less viability. The exit holes made by *Callosobruchus maculatus* have an indirect effect since these holes becomes entrance points for fungi that attack seed and also reduce the amount of energy available for germination. This agrees with Melo *et al* (2011) that seed damage by *C. maculatus* was associated with any resulting adverse effects on germination. Nahdy (1995) reported that reduction in germination of bambara groundnut land races and breeding lines was due to bruchid infestation. Infestation of paddy rice seeds by insects resulted to low seed germination percent compared to the uninfested seeds (Mulungu *et al.,* 2011) whilst

Canepple *et al.*, (2011) reported insect infestation affects seeds physiological quality and reduce germination. Thus, even if the insect damage does not affect germination, the seed might not produce a healthy seedling. Wagner *et al* (1991) had observed that, insects nevertheless play a significant role in reducing the availability of viable seeds in many parts of Africa. The variation between the field and laboratory viability test was a bit high. This could be as a result of some biotic factors in the soil that hamper germination. Also the laboratory experiment was in a controlled environment.

The effect of *C. maculatus* infestation on the weight of the seed revealed reduction irrespective of the variability in seed size. The result showed wide variation with respect to seed weight. For the initial seed weight, it was observed that, those cowpea seeds that had high seed damage generally had reduced final weight and higher weight loss. This agrees with Laphale *et al* (2012) which reported that cultivars with reduced seed damage gets higher residual seed weight, reduced weight loss and increased percentage pest tolerance. Umezor (2005) reported that as the number of exit hole of bruchid increased, the weight of the cowpea seed decreased.

The breeding lines had bigger seed size than the land races. Singh *et al* (1974) had reported that attributed grain resistance to differences in grain size and asserted that the larger grains supply more food and space for insect growth whilst the smaller grains offer more resistance to pest attack than larger grains. However, this is true to some extent with some breeding lines used for the experiment. SAMPEA-1 and Akidi cultivars, especially "Akidi ani" (which were small in size) recorded more infestation of *Callosobruchus maculatus* than others. Contrarily, SAMPEA-8, which had larger seed size than the landraces, recorded very small number of insects both in the first and second experiments. Messina and Renwick (1985) agrees that physical characteristics of seeds can determine the acceptability for oviposition but may not be related to the antibiotic nature of the seed. Seed texture and colour preferences varied with the breeding lines and played an important role in *C. maculatus* infestation. Seeds were either smooth, rough or wrinkled. SAMPEA-1, 2, 9, 10, 11 were smooth while SAMPEA-8 was not. The rough texture of SAMPEA-8 could have served as a hindrance to oviposition. It was observed that *C. maculatus* preferred to lay egg on seeds with smooth surface. This is agreeing with Nwanze *et al* (1975) that rough seeds were less acceptable to *C. maculatus* than smooth ones. Amusa *et al.,* (2013) reported that more eggs were laid on smooth coated seeds than the rough coated seeds, consequently resulted more bruchid emergence on smooth coated seed.

The proximate composition of the breeding lines and landraces of cowpea used, showed that protein content decreased with infestation (SAMPEA-1 decreased in both first and second experiments), respectively. The decrease in the protein content could be attributed to the utilization of these nutrients by the infesting bruchids (Ojimelekwe, 2002; Mbah and Silas, 2007; Owolabi *et al.*, 2012). Also, it could be stated that crude protein reduces with time in storage. It has been noted that Water melon seeds (*Citrullus lanatus*) stored for six months had reduced crude protein (Lawal, 2012). Osunde and Orhevba (2009) had earlier observed that yam tubers (*Dioscorea rotundata*) stored for 3 months had significantly reduced crude protein content. These results are consistent with the later findings of Gupta *et al.*, (2013) which reported 10% crude protein decrease after 2-3 months and 22.6%after 6 months of storing wheat. A decreasing value was also noticed in the carbohydrate content after insect infestation. The decreasing value of carbohydrate content may be attributed to the feeding activities of the bruchids (Owolabi *et al.,* 2012). There were increases in moisture, fat and ash content after infestation. The moisture content increased in both the breeding lines and landraces and could be ascribed to the humidity of the storage facility that promotes infestation. This agrees with the reports of Silas (2007) that storage conditions, variety, geographical location and time of the year affect moisture contents. The increase in ash content could be attributed to storage condition. Ojiako and Kayode (2014) had earlier noted that storage alone increased the total ash content of stored seeds. The increase in fat and fibre contents of the seeds (breeding lines and landraces) may be as a result of excretions and other secretions by the insects (Mbah and Silas, 2007; Owolabi *et al*., 2012). Similarly, the result for fibre content gained after infestation both in the breeding lines and land races.

The organoleptic tests of the cowpea seeds showed that uninfested seeds had higher overall acceptability than infested seeds. Also, the breeding lines had higher rating than landraces. The depreciation in appearance, odour, texture, taste and overall acceptability was as a result of infestation. This agrees with Odejayi and Aina (2016) that bruchid infestation resulted to high depreciation in taste, aroma and texture of processed infested cowpea products. For the sensory tests of the breeding lines and landraces, SAMPEA-8 recorded the lowest moldiness. This was as a result of little infestation recorded in the breeding line which explains that other seeds were susceptible to bruchid attack.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study shows that of the breeding lines and landraces of cowpea used in this study, SAMPEA-8 had more tolerance to bruchid infestation. Seed germination was greatly affected by *Callosobruchus maculatus* infestation. SAMPEA-8, however, had higher viability due to little or no insect emergence recorded unlike other breeding lines and Akidi cultivars which had higher insect emergence consequent lower percent seed germination.

Bruchid infestation had significant effect on the organoleptic ratings of the seeds. In similar manner, the cowpea seeds weight recorded reduction after infestation which also was significant from the un-infested seeds. The highly infested had reduced final weight and higher percentage weight loss. Proximate analysis of the seed after infestation observed decrease in value of protein and carbohydrate content while total ash, crude fibre, moisture and fat recorded increase. The evaluation of these seeds proved SAMPEA-8 to be more tolerant to infestation

Seed resistance is a valuable tool against bruchid infestation, but must be carefully deployed to avoid the rapid development of a virulent cowpea bruchid biotype. Periodic evaluation should therefore be conducted on resistant genotypes to ascertain the durability of their resistance.

5.2 RECOMMENDATION

This study recommends the need to continue research studies on resistant varieties of cowpea. SAMPEA-8 breeding line should be the focus of Ministries of Agriculture, Agricultural Institutes, Departments and Faculties in tertiary institutions in Nigeria. The availability of this breeding line could help in subsistence and commercial production of insect resistant's seeds.

5.3 CONTRIBUTION TO KNOWLEGE

The contribution to knowledge of this work is that, SAMPEA-8 which was less susceptible to cowpea weevils, should be made readily available so that it can get to the commercial and subsistence farmers. Due its high rate of tolerance to *Callosobruchus maculatus,* seed breeders can develop more resistant breeding lines using SAMPEA-8.

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APPENDIX

Field germination test results of cowpea seeds for first trial

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	111.67	55.83	0.58	
Cultivar	9	213.33	23.70	0.25	0.981
Residual	18	1721.67	95.65		
Total	29	2046.67			

Field germination test of cowpea seeds for second trial

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication stratum	2	106.7	53.3	0.44	
Cultivar	9	416.7	46.3	0.38	0.930
Residual	18	2193.3	121.9		
Total	29	2716.7			

Laboratory germination test of cowpea seeds for first trial

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	1863.33	207.04	2.09	0.082
Residual	20	1983.33	99.17		
Total	29	3846.67			

Laboratory germination test of cowpea seeds for second trial

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	817.50	90.83	1.20	0.349
Residual	20	1516.67	75.83		
Total	29	2334.17			

Proximate analysis for uninfested cowpea seeds

%Fat

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	64.87403	7.20823	179.97	<.001
Residual	20	0.80107	0.04005		
Total	29	65.67510			

%Protein

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	279.1078	31.0120	67.49	<.001
Residual	20	9.1905	0.4595		
Total	29	288.2983			

%_Ash

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	1.37208	0.15245	1.57	0.191
Residual	20	1.93980	0.09699		
Total	29	3.31188			

%_Carbohydrate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	903.5517	100.3946	161.35	<.001
Residual	20	12.4446	0.6222		
Total	29	915.9963			

%_Fibre

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	34.64700	3.84967	79.65	<.001
Residual	20	0.96667	0.04833		
Total	29	35.61367			

%_Moisture

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	45.4874	5.0542	40.63	<.001
Residual	20	2.4878	0.1244		
Total	29	47.9752			

Proximate analysis results for first trial of infested seeds

%Fat

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	68.99579	7.66620	82.42	<.001
Residual	20	1.86020	0.09301		
Total	29	70.85599			

%Protein

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	99.7498	11.0833	30.90	<.001
Residual	20	7.1743	0.3587		
Total	29	106.9242			

%_Ash

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	3.98148	0.44239	7.64	<.001
Residual	20	1.15820	0.05791		
Total	29	5.13968			

%_Carbohydrate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	484.255	53.806	31.29	<.001
Residual	20	34.387	1.719		
Total	29	518.642			

%_Fibre

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	192.10200	21.34467	340.15	<.001
Residual	20	1.25500	0.06275		
Total	29	193.35700			

%_Moisture

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	8.4988	0.9443	3.34	0.012
Residual	20	5.6621	0.2831		
Total	29	14.1609			

Proximate analysis results of infested seeds for second trial.

%Fat

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	61.61448	6.84605	141.67	<.001
Residual	20	0.96647	0.04832		
Total	29	62.58095			

%Protein

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	298.75868	33.19541	644.86	<.001
Residual	20	1.02953	0.05148		
Total	29	299.78822			

%_Ash

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	16.59688	1.84410	52.93	<.001
Residual	20	0.69687	0.03484		
Total	29	17.29375			

%_Carbohydrate

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	328.00654	36.44517	384.44	<.001
Residual	20	1.89600	0.09480		
Total	29	329.90254			

%_Fibre

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	154.8758	17.2084	139.34	<.001
Residual	20	2.4700	0.1235		
Total	29	157.3458			

%_Moisture

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	8.90174	0.98908	10.42	<.001
Residual	20	1.89893	0.09495		
Total	29	10.80067			

Number of insect emergence for first experiment

Emergence at 24Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	1643.60	182.62	13.77	<.001
Residual	40	530.40	13.26		
Total	49	2174.00			

Emergence at 48Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	6497.22	721.91	19.34	<.001
Residual	40	1492.80	37.32		
Total	49	7990.02			

Emergence at 72Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	11627.22	1291.91	20.70	<.001
Residual	40	2496.00	62.40		
Total	49	14123.22			

Emergence at 96Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	22135.7	2459.5	23.40	<.001
Residual	40	4204.8	105.1		
Total	49	26340.5			

Number of insect emergence for second experiment

Emergence at 24Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	726.42	80.71	1.67	0.128
Residual	40	1928.00	48.20		
Total	49	2654.42			

Emergence at 48Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	2402.4	266.9	1.86	0.087
Residual	40	5741.6	143.5		
Total	49	8144.0			

Emergence at 72Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	4139.7	460.0	2.43	0.026
Residual	40	7562.4	189.1		
Total	49	11702.1			

Emergence at 96Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	5946.9	660.8	3.00	0.008
Residual	40	8823.6	220.6		
Total	49	14770.5			

Emergence at 120Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	8192.8	910.3	3.65	0.002
Residual	40	9971.2	249.3		
Total	49	18164.0			

Emergence at 144Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	9543.9	1060.4	3.57	0.002
Residual	40	11878.8	297.0		
Total	49	21422.7			

Emergence at 168Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	11393.1	1265.9	4.02	0.001
Residual	40	12583.2	314.6		
Total	49	23976.3			

Mortality rate of bruchid at first trial.

%Mortality_at 24_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	1368.00	152.00	3.04	0.007
Residual	40	2000.00	50.00		
Total	49	3368.00			

%Mortality_at 48_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	1568.0	174.2	1.48	0.190
Residual	40	4720.0	118.0		
Total	49	6288.0			

%Mortality_at 72_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	528.0	58.7	0.38	0.939
Residual	40	6200.0	155.0		
Total	49	6728.0			

Mortality rate of bruchid for second experiment

%Mortality_at24_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	2040.0	226.7	2.08	0.055
Residual	40	4360.0	109.0		
Total	49	6400.0			

%Mortality_at48_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	2680.0	297.8	2.33	0.033
Residual	40	5120.0	128.0		
Total	49	7800.0			

%Mortality_at72_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	1368.00	152.00	1.79	0.101
Residual	40	3400.00	85.00		
Total	49	4768.00			

%Mortality_at96_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	968.00	107.56	3.47	0.003
Residual	40	1240.00	31.00		
Total	49	2208.00			

%Mortality_at120_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	869.12	96.57	3.54	0.003
Residual	40	1090.00	27.25		
Total	49	1959.12			

%Mortality_at144_Hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Cultivar	9	798.32	88.70	3.43	0.003
Residual	40	1034.00	25.85		
Total	49	1832.32			