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Pigeon pea grain physical characteristics and resistance to attack by the bruchid storage pest

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A b s t r a c t. Five grain physical traits comprising grain length, breadth, hardness, testa thickness and 1000-grain mass (TGM) were evaluated for their relative influence on the susceptibility of six pigeon pea genotypes to the bruchid (*Callosobruchus maculatus* F.). Correlation studies and path analysis were employed to assess the interrelationships and contributions of the traits studied. Heritability in broad sense, H^2 (bs) of selected trait(s) was also studied. Results showed that some of the genotypes differed as to their grain physical characteristics. Genotypes ICPL 87 and ICPL 161 had low susceptibility indices and were classified as having moderate levels of resistance. Resistant genotypes were, in addition to low susceptibility indices, characterized by low oviposition count, grain damage and grain mass loss. Correlation studies showed that testa thickness was the only physical character having strong correlation with susceptibility index (r = -0.753, P<0.01). However, the low heritability estimate of the trait suggests that selection of pigeon pea genotypes through this trait may be unreliable. Path coefficient analysis revealed that TGM had the highest direct effect of +1.369 with susceptibility index, although, their total correlation coefficient was low (+0.215). There were opposing influences of the four negative indirect effects of the other traits which resulted in the low total correlation value observed. The high heritability estimate of TGM indicated a better prospect for the improvement of the crop species through selection of the trait. TGM and testa thickness were therefore considered to be the most important factors responsible for resistance to bruchid, but TGM was more reliable for use in the selection of pigeon pea for improvement. All the traits assessed expressed higher magnitude of phenotypic coefficient of variation (PCV) relative to the genotypic coefficient of variation (GCV).

K e y w o r d s: *Cajanus cajan, Callosobruchus maculatus*, host-plant resistance mechanism, susceptibility index, path coefficient analysis

INTRODUCTION

Bruchids, especially members of the genus *Callosobruchus* (*Coleoptera: Bruchidae*), are major sources of loss in pigeon pea (*Cajanus cajan* L. Millsp) in storage (Rao and Willey, 1980; Singh and Jambunathan, 1990). Infestation starts from the field, before getting into the store (Brink and Belay, 2006). The larvae usually bore into the pulse grain, rendering it unsuitable for human consumption and resulting in poor seed viability (Garcia-Lara *et al.,* 2004). Bruchids are important storage pests of pulse crops in Asia and Africa as they can multiply quickly in infested stores and can migrate to infest separate lots (Anonymous, 1991).

Pigeon pea lines with grain resistance, pod-wall resistance or a combination of both have been bred through joint efforts of breeders and entomologists (Murdock *et al.,* 1997). Developing varieties that could combine both grain and pod resistance may result in an effective approach to achieving a high and durable level of resistance to bruchid attack. Some characteristics associated with resistance have been identified, such as reduction in insect oviposition and adult insect emergence due to the physical and chemical characteristics of the plant host (Fitzner *et al*., 1985; Suleherie *et al.,* 2003). A lot of these traits have been identified by several workers (Bamaiyi *et al*., 2000; Khokhar and Gupta, 1974; Singh *et al*., 1974), but there have been difficulties in delineating the most important physical traits responsible for such resistance.

Developing countries are adapting the use of resistant grain varieties to control stored grain weevils as a popular alternative to the use of chemicals (Gharib, 2004). Part of the major objective is to obviate attendant risk problems of death, environmental pollution and costs associated with pesticide usage. The present study was aimed at identifying important measurable physical or seed trait(s) that will be important in the selection and breeding for pigeon pea genotypes resistant to *C. maculatus* insect attack and damage. The trait(s) would aid in further screening of some varieties recently developed, for resistance to the bruchids.

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MATERIALS AND METHODS

The study was carried out between May and October, 2006, which was the yearly peak period of greater pest activity of *Callosobruchus maculatus* in Nigeria (Caswell, 1980).

The study was conducted at the Department of Crop Science, University of Nigeria, Nsukka, Nigeria. Nsukka is located at latitude 06°52'N and longitude 07°24'E and at an elevation of 447.26 m above sea level. The prevailing mean temperature and relative humidity during the experimental period were 28±2°C and 75±5%, respectively. The area is characterized by typical tropical climate with clearly distinguished wet and dry seasons. Wet seasons are bi-modally distributed with peaks in July and September of each year.

Test grains comprised five improved pigeon pea (*Cajanus cajan)* genotypes supplied by Institute for Agricultural Research (IAR) and International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Nigeria, breeding programme together with a local land race commonly grown by rural farmers around Nsukka in Nigeria. The improved genotypes were ICPL 87, I CPL 85063, ICP 7120, ICPL 161 and ICPL 87119. All the varieties were uniformly sized and wholesomely filled.

Samples of the test grain were separately fumigated using aluminium phosphide (phostoxin) in an air-tight polyethylene bag. Fumigated seed samples were left in the sealed container for four days and thereafter aired for another four days before use. The moisture content (m.c.) of the test grains was standardized at 16% moisture level before the application of treatments.

Adult stock of bruchids, *Callosobruchus maculatus,* was obtained from cowpea dealers in Nsukka main market in Nigeria. Cowpea cultivar (cv. Ife brown) known to be susceptible to bruchids was used to maintain the culture. Culture was maintained in a 500 ml transparent plastic container and placed inside a laboratory cupboard (29±2°C and 70±3% of relative humidity). Upon application of treatments, the insects were sexed into males and females using the key of Anonymous (1991).

Sample of 30 grains (m.c. 16%) was taken from each test line. The sample was used for the measurement of grain breadth, length, testa thickness and hardness. The grain breadth, length and thickness were measured using vernier calipers. Grain breadth was taken as the mean girth measured across the two broadest points of the grain along east-west axis with the helium facing the researcher. Grain length was adjudged as the length between the two polar regions with the helium facing the researcher. The testa thickness was measured by scooping the coat with a scalpel and measuring with a vernier caliper the thickness around the helium. Grain hardness was assessed at the Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka, Nigeria, using a grain hardness tester machine (30 Kgf) model 174886 of Ogawa Seiki Company Ltd.; Japan. Hardness was assessed by placing each of the 30 grain samples per genotype on the platform rack of the tester machine. A pressure was exerted on the grain upon switching the machine on, until the grain began to crack. The beginning of grain cracking was marked by the production of a crisp sound. At this point, the metre oscillation of the machine stopped momentarily and the pointer reading was noted and recorded. The mean grain hardness for 30 grains per genotype was later calculated and recorded. TGM for each of the pigeon pea genotypes was measured using a sensitive electronic balance.

Transparent plastic containers were used, each of diameter of 12 and 11 cm depth. Three ventilation holes equidistant to one another were made around the curved surface of each plastic container. Both the side holes and the lids were covered with a muslin cloth held in place with a rubber band for the lid and with 'evostick' gum for the side holes. To each plastic container was introduced 30 g of the previously fumigated grains plus 10 freshly emerged adults of *C. maculatus* (5 females: 5 males) before covering finally with the muslin cloth. The plastic containers were each replicated three times and laid out on the laboratory bench in a completely randomized design (CRD) arrangement. The introduced insects were removed 10 days after infestation (DAI) when they would have laid their eggs. Counts of eggs laid were made and calculated as number per 20 grains. Insect emergence was monitored from 20 DAI to 45 DAP when the first filial generation (F_1) would have emerged. Emerged adults were counted and discarded to prevent overlap with the first filial generation. Index of susceptibility (SI) was calculated from the insect counts based on the formula by Howe (1971) and modified by Dobie (1977) as follows:

$$\mathrm{SI} = \frac{Log\ F_1}{D} 100,$$

where: F_1= total number of F_1 progeny that emerged, D = mean developmental period (days), estimated as time from the middle of the oviposition period to the emergence of 50% of the F_1 progeny.

The treated grains were later sun-dried for 2-3 h to adjust the grain mass after the frass and the dust were carefully removed and the remnant of the grain weighed for quantitative determination of mass loss. Net percentage mass loss (PGML) was determined.

Grain with perforation was considered damaged and was separated from undamaged (whole some grains), counted and recorded with a view to obtaining percentage damaged grains in each treatment.

On the basis of susceptibility indices (SI), the varieties were later grouped according to their level of resistance, after Mensah (1986):

SI of between 0.0 and 2.5 = resistant,
SI of between 2.6 and 5.0 = moderately resistant,
SI of between 5.1 and 7.5 = moderately susceptible,
SI of between 7.6 and 10.0 = susceptible,
SI of greater than 10.0 = highly susceptible.

The data collected were subjected to analysis of variance procedure and the mean difference was compared by use of LSD as outlined by Obi (2002). Counts of insects, eggs as well as percentage grain damage were transformed to approximate a normal distribution using square root and arc-sine transformations, respectively. Correlation matrix was performed between all the variables assessed. Cause and effect relations of the variables in space and time were determined using path coefficient analysis (Dewey and Lu, 1959) on grain length, breadth, testa thickness, TGM and hardness as the causal components of grain susceptibility to bruchid attack. Heritability in broad sense, H^2(bs) was estimated for the principal grain characters studied after calculating their genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) using the procedure outlined by Uguru (2005) and Allard (1960).

RESULTS

Generally, all the genotype grains differed significantly ($P< 0.05$) as to the physical and susceptibility parameters assessed (Table 1). Grains of the local genotype (17.5 Kgf) were significantly harder ($P< 0.05$) than grains of other genotypes except those of ICPL 87 (15.6 kgf) and ICPL 85063 (17.9 kgf). Similarly, both the grain length (6.4 mm) and breadth (5.1mm) of the local variety were significantly higher than those of other genotypes which in turn did not differ from one another statistically. Genotypes ICPL87 and 161 recorded the highest testa thickness of 7.33 x 10^{-1}mm each. This was significantly higher ($P< 0.05$) when compared with other genotypes, but not significantly higher than ICPL 85063 and Nsukka local of 6.5 x10^{-1}mm and 6.8 x 10^{-1} mm, respectively. TGM of the local variety (113.1 g) was significantly heavier ($P< 0.05$) than those of other genotypes with grains of ICPL 87119 recording the least grain mass (78.9 g). Masses of other genotypes were comparable to one another as no statistical difference was detected amongst them. Genotypes ICP 7120 and ICPL 8119 did not differ from each other statistically as to the number of eggs deposited on them but significantly allowed higher egg deposition than the other genotypes. The number of eggs deposited on ICPL 87 (4.72 per 20 grains) was significantly ($P< 0.05$) the least, but was not significantly lower than counts recorded on the local (5.27 per 20 seeds). Both the grain damage (26.9%) and grain mass loss (24.7%) were consistently and significantly lower in ICPL 161. The percentage of grain damaged ranged from 26.9% in ICPL 161 to 41.4% in ICPL 87119, while the grain mass loss ranged from 24.7% in ICPL 161 to 38.5% in ICPL 8119. Accessions ICPL 87, ICPL 85063 and ICPL 161 did not differ significantly in their susceptibility indices but had indices that were significantly higher ($P <0.05$) than other accessions.

The correlation results showed that only testa thickness had a significant correlation with the index of susceptibility amongst the grain physical traits assessed (Table 2). A significant negative correlation ($P< 0.05$) was obtained between testa thickness and the number of eggs oviposited ($r= -0.867$), grain damaged (%) ($r= - 0.871$), grain mass loss (%) ($r = - 0.802$) and index of susceptibility ($r = - 0.753$). Conversely, a significant positive correlation ($P<0.05$) was established between testa thickness and grain length ($r = 0.518$).

Path coefficient analysis taking all the grain physical characters as the causal component of the susceptibility index (Tables 3 and 4) revealed that the traits varied in their contributions to the susceptibility index. Grain length had a negative and a very low direct effect on the index of susceptibility. Its correlation with the index was equally very low and of no significant effect. Grain hardness and breadth had a moderate direct effect on the susceptibility index, but

Table 1. Seed physical characteristics and relative susceptibilities of six pigeon pea (*Cajanus cajan)* genotypes to *Callosobruchus maculatus attack*

Genotypes	Grain physical characteristics					Susceptibility to *C. maculatus* attack			
	Hardness (kgf)	Length (mm)	Breadth (mm)	Testa thickness (x10^{-1} mm)	TGM (g)	Oviposition count	Grain damage (%)	Grain loss (%)	Susceptibility index
ICPL 87	15.6	6.2	4.4	1.3	89.6	4.7	31.5	29.7	1.8
ICPL85063	17.9	5.8	4.3	6.5	89.5	6.8	39.1	34.5	2.0
ICP7120	13.6	5.9	4.2	5.3	89.4	8.4	41.4	31.8	4.2
ICPL161	14.6	5.9	4.2	7.3	81.5	6.3	26.9	24.7	1.6
ICPL87119	14.7	5.8	4.2	4.7	78.9	8.0	41.4	38.5	3.1
Nsukka Local	17.5	6.4	5.1	6.8	113.1	5.3	35.3	27.1	3.1
Mean	15.7	6.0	4.4	6.3	90.3	6.6	35.9	31.1	2.6
LSD (5%)	2.3	0.3	0.2	1.5	12.2	1.7	7.2	7.4	0.9

T a b l e 2. Simple correlation coefficient between grain characters of six pigeon pea genotypes

Variables	GH	OVP. No.	PGD	PGML	SI	GL	GB	GTT	TGW
GH	–	-0.520*	-0.007	-0.026	-0.365	0.422	0.664**	0.393	0.610
OVP. No.		–	0.698**	0.611**	0.622**	-0.813	-0.646**	-0.867**	-0.510*
PGD			–	0.827**	0.737**	-0.340	-0.172	-0.871**	-0.005
PGML				_	0.326	-0.509*	-0.441	-0.80**	-0.402
SI					–	-0.064	0.019	-0.753**	0.215
GL						–	0.873**	0.518*	0.813**
GB							_	0.408	0.950**
GTT								_	0.314
TGW									–

GH – grain hardness, OVP. No. – egg number, PGD – % grain damage, PGML– percentage grain mass loss, SI – susceptibility index, GL – grain length, GB – grain breadth, GTT – grain testa thickness, TGM – 1000-grain mass. Correlation coefficient exceeding 0.456 and 0.575 are significant at the 0.05 and 0.01 levels, respectively. * $P < 0.05$; ** $P < 0.01$.

their negative correlations were also low and of no effect. The direct effect of TGM on the index of susceptibility was the highest (+1.369), but the positive correlation with the index was low and of no significant effect. The only character with a significant ($P < 0.05$) correlation was grain testa thickness with a negative total correlation coefficient of -0.753 and a high direct effect of -0.699. The negative correlation with the index of susceptibility appeared to be mainly due to its negative indirect effects through grain breadth and hardness. The coefficient of determination (R^2) which determines how best the causal factors accounted for the variability of the susceptibility index was 99.9% (Table 4). The residual factor which includes all the variables not in the models and the sampling error was computed as 0.036. The double arrowed lines in the path diagram (Fig. 1) indicated mutual association measured by correlation coefficient, while the single line represented direct influences as measured by path coefficient.

Phenotypic variance was found to be generally higher than the genotypic variance in all the attributes studied (Table 5). The phenotypic variances varied from 0.06 for grain length to 175.93 for TGM. Genotypic variances ranged from 0.04 for grain length to 130.87 for TGM. Also, there was a higher magnitude of the phenotypic coefficient of variation (PCV) relative to the corresponding genotypic coefficient of variation (GCV) in all the attributes. Both PCV and GCV were generally low for all the traits. Heritability in broad sense was high for grain breadth and TGM but moderately high for grain hardness, length and testa thickness.

DISCUSSION

Wide variability in grain characteristics has been found useful in the selection of ideotypes for insect resistance. Some cowpea grain physical characteristics associated with bruchid resistance have been identified (Kitch *et al.,* 1991; 1992).

In the present study, the significant differences in the grain physical traits amongst the pigeon pea accessions were attributed to their genetic make-up. The strong negative correlation coefficient between testa thickness and susceptibility index or oviposition count suggests that an increase in seed testa thickness will result in a decrease in grain susceptibility to bruchid attack. This inverse relationship could be attributed to the difficulty in larval penetration of thick grain coat barriers. To confirm the value of physical characteristics of hosts in the development of resistance to insect pests, Semple (1992) reported that the rate of insect population increase could be adversely affected when a resistant variety is used which causes a reduction in oviposition rate through physical or mechanical barrier. The barrier is said to either deter access into the grains or make it unsuitable for oviposition. This unsuitability of barriers to ovipositon was suggested to be caused either by barriers that are too hard for species that prefer smooth substrates to adhere their eggs or to the difficulty in penetrating such barriers by larvae after hatching from eggs. The difficulty in host tissue penetration is what Murdock *et al*., (1997) described as prestablishment larval mortality (PreM) as against death after penetration which was called post-establishment larval mortality (PostM). However, in selecting parents for their breeding programme,

T a b l e 3. Path coefficient analysis showing the direct and indirect effects of the grain physical characters on susceptibility index

S/NO	Pathway	Path analysis	Correlation coefficient
	Grain hardness and susceptibility index		
1	Direct effect, P_{16}	-0.500	
	Indirect effect via grain length, $P_{26}r_{12}$	-0.043	
	Indirect effect via grain breadth, $P_{36}r_{13}$	-0.382	
	Indirect effect via grain testa thickness, $P_{46}r_{14}$	-0.275	
	Indirect effect via TGM, $P_{56}r_{15}$	0.835	
	Correlation, r_{16}		-0.365
	Grain length and susceptibility index		
2	Direct effect, P_{26}	-0.101	
	Indirect effect via grain hardness, $P_{16}r_{21}$	-0.211	
	Indirect effect via grain breadth, $P_{36}r_{23}$	-0.503	
	Indirect effect via grain testa thickness, $P_{46}R_{24}$	-0.362	
	Indirect effect via TGM, $P_{56}r_{25}$	1.113	
	Correlation, r_{26}		-0.064
	Grain breadth and susceptibility index		
3	Direct effect, P_{36}	-0.576	
	Indirect effect via grain hardness, $P_{16}r_{31}$	-0.332	
	Indirect effect via grain length, $P_{26}r_{32}$	-0.088	
	indirect effect via grain testa thickness, $P_{46}r_{34}$	-0.285	
	Indirect effect via TGM, $P_{56}r_{35}$	1.300	
	Correlation, r_{36}		0.019
	Grain testa thickness and susceptibility index		
4	Direct effect, P_{46}	-0.699	
	Indirect effect via grain hardness, $P_{16}r_{41}$	-0.197	
	Indirect effect via grain length, $P_{26}r_{42}$	-0.052	
	Indirect effect via grain breadth, $P_{36}r_{43}$	-0.235	
	Indirect effect via TGM, $P_{56}r_{45}$	0.430	
	Correlation, r_{46}		-0.753
	1000-grain mass and susceptibility index		
5	Direct effect, P_{56}	1.369	
	Indirect effect via grain hardness, $P_{16}r_{51}$	-0.305	
	Indirect effect via grain length, $P_{26}r_{52}$	-0.082	
	Indirect effect via grain breadth, $P_{36}r_{53}$	-0.547	
	Indirect effect via grain testa thickness, $P_{46}r_{54}$	-0.219	
	Correlation, r_{56}		0.215

T a b l e 4. Direct and indirect effects of grain physical characters on susceptibility index based on path coefficient analysis

Characters	Hardiness	Length	Breadth	Thickness	TGM	Genotypic correlation with susceptibility index
Grain hardness	(-0.500)	-0.043	-0.382	-0.275	0.835	-0.365
Grain length	-0.211	(-0.101)	-0.503	-0.362	1.113	-0.064
Grain breadth	-0.332	-0.088	(-0.576)	-0.285	1.300	0.019
Testa thickness	-0.197	-0.052	-0.235	(-0.699)	0.430	-0.753**
TGM	-0.305	-0.082	-0.547	-0.219	(1.369)	0.215
Residual						0.036
R^2						0.999

** P<0.01.

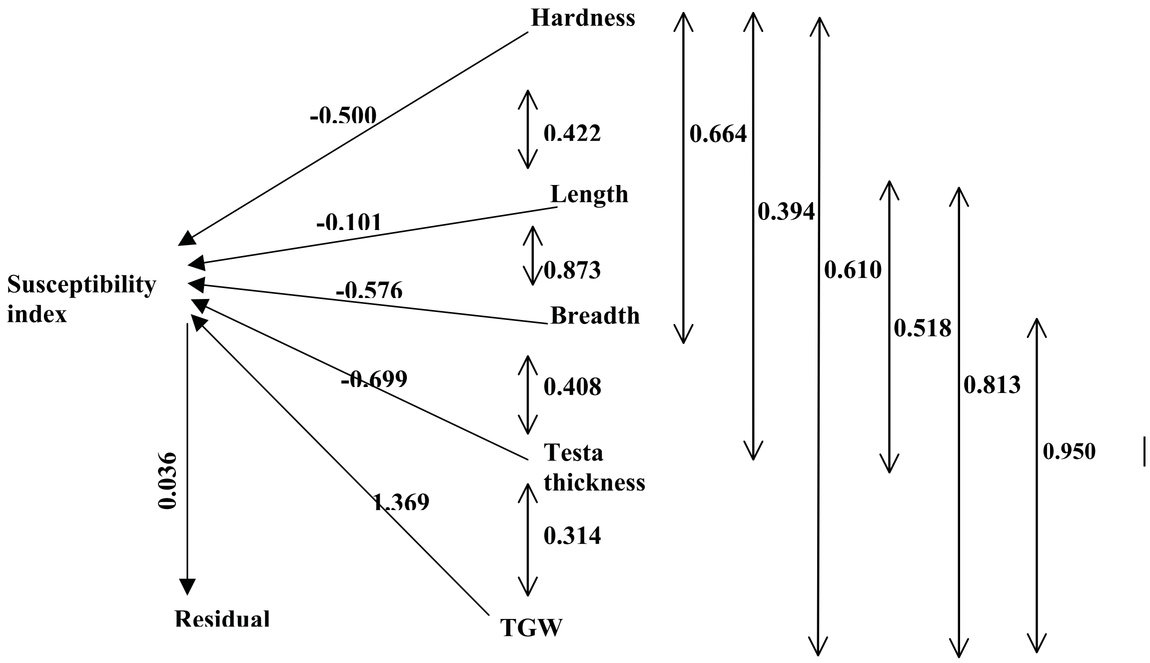

Fig. 1. Path diagram showing causal relationship between susceptibility index and five other grain physical characters. While the residual shows the undetermined traits, the double arrowed lines illustrate mutual association as measured by correlation coefficient, and the single arrowed lines represent direct influence as measured by path analysis.

the workers used the total percentage mortality (TM) which comprises both the PreM and PostM to make their selections. Based on their results, characteristics such as grain coat texture and thickness were found to significantly correlate with PreM (r = 0.843, P< 0.001). More eggs were deposited on susceptible grains, which makes our results agree with those ascertained by Khokhar and Gupta (1974).

The result of the present work further showed wide variability between the varieties with respect to the susceptibility index and grain physical traits studied. These, combined together, reflect the innate potentials of a particular variety to overcome pest attack which may be attributable to varietal physical characteristic variations. Based on Mensah, (1986) categorisation, accessions ICP 7120 and ICPL 87119 were classified as moderately resistant. These accessions allowed high egg deposition and supported high grain damage and mass loss. They also possessed thinner grain coat with reduced grain hardness. Conversely, accessions ICPL 87 and ICPL 161 were classified as resistant, being unsuitable for egg deposition and prone to damage and mass loss. The resistant accessions were also considerably hard, with thicker testa.

Table 5. Estimate of the genetic parameters for grain characters studied

Character	Environmental variance	Phenotypic variance	Genotypic variance	Phenotypic coefficient of variation (%)	Genotypic coefficient of variation (%)	Heritability in broad sense (%)
Grain hardness	1.64	3.97	2.34	12.73	9.80	58.83
Grain length	0.02	0.06	0.04	4.23	3.43	65.81
Grain breadth	0.01	0.12	0.11	7.95	7.69	93.68
Testa thickness	0.71	1.70	0.99	20.66	15.81	58.53
TGM	45.06	175.93	130.87	14.96	12.67	75.39

From the path coefficient analysis results, only TGM and testa thickness with high direct effects make for useful discussions. The low and positive simple correlation between TGM (grain size) and susceptibility index suggests that an increase in TGM might result in a small increase in susceptibility. A partition of this relationship into its components when the testa thickness, breadth, length and hardness were held constant indicated that TGM was a major factor influencing susceptibility, the direct effect being +1.369. The indirect effects played an important part and masked the direct influence. The net effect in the system being that the opposing influences of the four negative indirect effects outweighed the single positive direct effect and resulted in a small positive correlation between TGM and the susceptibility index (+0.215). Furthermore, the strong and negative simple correlation between testa thickness and the susceptibility index suggests a strong indirect or inverse relationship between the two variables. A partition of the relationship while holding other parameters constant showed that susceptibility to infestation could be reduced directly by increasing testa thickness, the direct effect being -0.699. The testa thickness was therefore considered another major factor influencing grain damage by the bruchids. While the indirect effect via TGM was low and positive, those via grain hardness, length, and breadth were also low and positive.

A close interrelationship was therefore found between TGM and other traits like grain hardness, length and breadth (grain size) following the strong positive correlation established between them. Such interrelationship was also confirmed between testa thickness and length (grain size) by the strong positive correlation obtained between them. These interrelationships suggested that TGM and testa thickness were independently and indirectly acting *via* grain hardness. Many authors have attributed grain resistance to differences in grain size and asserted that the larger grains supply more food and space for insect growth (Khare and Agrawal, 1963; Singh *et al.,* 1974). Our result agree with the results of Russell (1996) who reported that the smaller and harder the sorghum grains the more resistant the grains and vice versa. Results of other workers, both in the temperate and tropical regions of the world, directly selected grain hardness as an important factor of grain resistant to *Sitophilus oryzae* (Bamaiyi *et al.,* 2000; Davey, 1965). Adesuyi (1979) pointed out that among the factors known to be responsible for the resistance of stored products to attack by insects, grain coat characteristics discourage oviposition, digestive enzyme inhibitor and kernel hardness.

The higher phenotypic variance than the genotypic variance in the coat thickness and TGM indicated high environmental interactions with the genetic expression. This was further expressed in the higher magnitudes of the phenotypic coefficient of variation (PCV) relative to the corresponding genotypic coefficient of variation (GCV) in all the attributes. The coefficient of variation compares the relative amount of variability amongst the attributes. It also measures the potential for favourable advance in selection (Abu and Uguru, 2006). Low heritability estimate for testa thickness indicates that selection of pigeon pea genotypes in the confines of this study, through testa thickness, may be unreliable. This is because low heritability estimate is an attribute of high environmental effect on the trait. Burton and DeVane (1953) noted that heritability measures the efficiency of a selection system. The high heritability of TGM, therefore, indicated a better prospect for improvement of the trait through selection.

CONCLUSIONS

1. Some of the pigeon pea genotypes differed significantly as to their grain physical characteristics and susceptibility parameters.

2. The genotypes ICPL 87 and ICPL 161, pigeon pea collections from Institute for Agricultural Research (IAR) and International Crops Research Institute for Semi-Aid Tropics (ICRISAT), Nigeria, possessed traits related to moderate levels of resistance to bruchid (*Callosobruchus maculatus)* attack and damage.

3. The total correlation between pigeon pea grain testa thickness and susceptibility to bruchid was the highest when compared with other traits, but the heritability estimate of

the trait was low; hence, selection of pigeon pea genotypes through testa thickness alone may be unreliable. Conversely, the total correlation between 1000-grain mass and susceptibility index was low while the direct effect was the highest. Similarly, the heritability estimate of was also high, indicating a better prospect in the selection of genotypes through this trait.

4. 1000-grain mass and testa thickness were considered the most important factors responsible for resistance to bruchid attack but 1000-grain mass was more reliable for use in the selection of pigeon pea for improvement.

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