RESEARCH

FIELD INSECT PESTS AND CROP DAMAGE ASSESSMENT OF PIGEON PEA (*Cajanus cajan* [L.] Huth) GROWN UNDER RATOON AND IN MIXTURE WITH MAIZE

Madang A. Dasbak[1], Bonaventure C. Echezona[1*], and Jerry E. Asiegbu[1]

The widespread adoption of cropping systems that are sustainable and environmentally friendly is vital for the macroeconomic survival of civilization. Intercropping could ensure stability of insect populations in a system. A 3-yr (2005-2007) field trial was therefore carried out in Nigeria under regular and ratoon crops to evaluate five recently developed pigeon pea (*Cajanus cajan* [L.] Huth) genotypes (ICPL 87, ICPL 161, ICPL 85063, ICP 7120, and ICPL 87119) from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) and one local variety for their relative performance and susceptibility to insect pests. The pigeon pea genotypes were in a mixture with two maize genotypes (*Zea mays* L., open-pollinated and hybrid) in regular crops for 2 yr (2005-2006) followed by a ratoon crop for 1 yr (2007). Termites (*Odontotermes badius*), crickets (*Gymnogryllus lucens*), and variegated grasshoppers (*Zonocerus variegatus*) were the crop's seedling pests and caused minimal damage. *Clavigralla* spp. infestations were high at the reproductive stage causing 24% and 29% seed damage in regular and ratoon pigeon pea crops, respectively. Maize slightly suppressed insect pest incidence and damage to pigeon pea pods and seeds but significantly ($P < 0.01$) reduced grain yield in the regular pigeon pea crops in 2005 and 2006, although not in the 2007 ratoon. The pigeon pea genotypes differed significantly ($P < 0.05$) in pest incidence at the podding stage in both the regular and ratoon crops and in grain yield ($P < 0.01$) for the regular crop. Grain yield of the pigeon pea ratoon crops was about 60% of the regular crop. Farmers were recommended to adopt the ICPL 161 and ICPL 87 genotypes based on pest tolerance and high grain yield or as idiotypes in pigeon pea hybridization programs.

Key words*:* *Cajanus cajan*, *Clavigralla* spp., cropping system, ratoon crops, regular crop.

Pigeon pea (*Cajanus cajan* [L.] Huth) is an important legume crop belonging to the Fabaceae family. It is a short-lived perennial shrub grown either as an annual or perennial. The green seeds serve as vegetables and the dry grains serve as food for humans and livestock. Dried split peas are an export commodity to North America and Europe for some Eastern and South African countries (Boringer *et al*., 1995). Extracts of pigeon pea seeds have exhibited antisickling action on red blood cells (Brink and Belay, 2006). This activity was attributed to the presence of phenylalanine and hydroxybenzoic acid contained in their seeds.

Pigeon pea is one of the mandate crops of the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), which has released improved genotypes to farmers (Guy *et al*., 2001) and holds about 13 544 accessions (ICRISAT Newsletter, 2003). The Consultative Group on International Agricultural Research (CGIAR, 2005) report indicated that world production in 2005 was about 3.5 million Mg. Africa accounted for 317 862 Mg and Asia for 3 million Mg. According to El-Titi (1995), the genotype of a plant species has many different implications for crop production. It determines yield potential under a given environment, product quality, and its resistance to pests and diseases. Davis and Woolley (1993) reported that plant varieties can respond differently to their environment, the climate, soil, and crop management. The most important aspect to consider is the degree of competition between crops and the variation in competitive ability among cultivars. Where the variation in competition among cultivars is large, it is likely that a highly significant genotype × cropping system interaction will occur. Willey (1979) states that crop genotypes should be selected to minimize intercrop competition and maximize complementary effects.

Pigeon peas are frequently inter-planted with other short-term crops, including cereals and other grain legumes, for higher productivity per unit land area and reduced risks associated with some crop failures. Andrew and Kassam (1976) defined intercropping as growing two or more crops simultaneously on the same field, i.e., farmers manage more than one crop at the same time in the field. The cropping

[1]University of Nigeria, Department of Crop Science, P.O. Box 28 Nsukka, Nigeria.
[*]Corresponding author (chezbon2001@yahoo.co.uk).
Received: 23 March 2011.
Accepted: 3 January 2012.

system was also defined by the cropping patterns used on a farm and their interaction with farm resources, other farm enterprises, and available technology, all of which determines their make-up. The cropping pattern is defined as the yearly sequence and spatial arrangement of crops and fallow on a given area. Ratoon cropping is the maintenance of crop regrowth from living stumps after harvest. It is a form of continuous cropping. These systems are all used with pigeon pea and have practical benefits. There has been little research about intercropping pigeon pea and maize (*Zea mays* L.) and it will be very important and benefit farmers economically. Much of the intercropping work done in ICRISAT, India, has been mostly with pigeon pea, millet (*Pennisetum glaucum* L.), and sorghum (*Sorghum bicolor* L.). It would be very advantageous to evaluate these recently released pigeon peas with differing growth patterns and duration with maize, especially under humid tropical lowland conditions where maize is more popular and more widely grown than millet or sorghum. Snapp *et al*. (2003) reported that the long duration pigeon pea cultivars are generally planted simultaneously as an intercrop with a cereal at the beginning of the rainy season. Cereals are generally harvested toward the end of the rainy season, and pigeon pea develops rapidly on the residual moisture after harvesting the companion crop. Intercropping has also been recorded as reducing the incidence and spread of diseases and pests (Davis and Woolley, 1993). Intercrop components are often less damaged by pests and disease organisms than when grown as sole crops (Sastawa *et al*., 2004). Snapp *et al*. (2003) also recognize that a ratoon system is used in some areas after the stems are cut back to facilitate regrowth and a second crop is harvested in the subsequent season.

Shanower *et al*. (1999) and Kooner and Cheema (2006) reported damage caused by insect pests as a major factor responsible for low crop yield where several insect pests attack from the seedling stage until harvest. Two major yield limitations that can be manipulated genetically are the susceptibility to diseases and pests. Reed and Lateef (1990) noted that the pod-sucking bugs (*Clavigralla* spp.) are one of the major insect pests of pigeon pea in the field. In a survey, Ajayi *et al*. (1995) documented a list of insect pests of pigeon pea that included thrips, leaf hoppers, leaf-eating caterpillars (*Spodoptera exempta*), pod-sucking bugs (*Clavigralla tomentoscicollis*), flower beetles, pod borers (*Maruca testulalis*), ants, and spittle bugs. Minja (2000) indicated that the most important insect pests of pigeon pea in tropical and subtropical regions are those that attack the crop at the reproductive stage and during storage. Pod-sucking bugs suck developing seeds through the pod wall causing shriveled seeds with dark patches. Affected seeds often do not germinate and are unfit for human consumption. Minja *et al*. (1999) recorded that insect pests caused considerable seed damage from 14% to 69% in the humid regions of Kenya. Ajayi *et al*. (1995) indicated that there are relatively few published accounts of insect damage to pigeon pea in Africa.

Ratoon cropping in pigeon pea is a practice where the stems are cut back after harvest to facilitate re-growth and a second crop is harvested in the subsequent season. This practice has a minimal production cost since ratoon crops are simply maintained so as to yield in the second year. However, it could be associated with pest build-up that needs to be assessed. There is a lack of information on insect pest damage to pigeon pea under sole and intercropping systems in Nigeria. This study was therefore carried out to identify the field insect pests associated with pigeon pea and to assess the damage to the genotypes under sole and intercrop mixtures with maize and in the ratoon crop with a view to recommending to farmers the most suitable genotypes to adopt.

Therefore, the specific objectives of this study were: i) to test the effect of genotype × cropping system interaction on recently released pigeon pea genotypes in a mixture with two maize varieties; ii) to test genotype × cropping system effects on insect pest infestation on pigeon pea component crop; and iii) to ascertain the residual effects of intercropping maize with pigeon pea on the performance and insect pest infestations on the ratoon pigeon pea crop.

MATERIALS AND METHODS

This study was carried out at the Teaching and Research Farm of the Department of Crop Science, University of Nigeria, Nsukka, during the 2005 and 2006 cropping seasons, while the ratoon crops were maintained in 2007. Nsukka is in a humid tropical area (06°52’ N, 07°24’ E; 447.26 m a.s.l.). Detailed meteorological records and physico-chemical properties of the experimental site are shown in Tables 1 and 2, respectively. Soil type was a dark reddish-brown loamy Ultisol (Obi and Salako, 1995). Conditions at Nsukka show that pigeon pea is one of the population’s staple foods and a major crop cultivated as both regular and ratoon crops in the area. Five high-yielding (improved) pigeon pea genotypes, ICPL 87, ICPL 161 (short-duration), from a consultative group of the International Crops Research Institute for the Semi-Arid Tropics ICRISAT/IAR Zaria in Nigeria, ICPL 85063, ICP 7120, and ICPL 87119 (medium-duration) intercrop treatment combinations, as well as a large popular brown-seeded Nsukka Local genotype (long-duration) were combined with two maize genotypes: ‘Oba super II’ (hybrid) and ‘New Kaduna’ (open-pollinated). There were also sole crops of each genotype that were arranged in a factorial experiment and laid out in a completely randomized block design (CRBD) with three replicates.

Each plot was 5.0 × 3.0 m (15 m^2) with a 1.0 m pathway in a ploughed, harrowed, and ridged field. Representative soil samples were taken at the study site with an auger at 0-30 cm depth. The samples were combined and analyzed for physical and chemical properties. Pigeon pea seeds

Table 1. Meteorological records for 2005, 2006, and 2007 in Nsukka, Nigeria.

Year	Records	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
2005	Total rainfall, mm						323.8	246.2	125.4	208.0	304.2	10.1	1.2
	Rain days						18	20	17	19	16	1	1
	Max. temp., °C						29.4	28.3	27.3	28.7	30.1	32.4	22.4
	Min. temp., °C						21.8	20.9	20.3	21.5	21.1	21.3	20.7
	RH, %						74.8	76.9	76.9	76.9	73.8	66.2	63.1
2006	Total rainfall, mm	36.3	4.0	103.1	51.0	243.8	259.6	213.8	195.5	190.5	313.9	1.5	0.0
	Rain days	1	2	4	5	16	16	21	19	25	19	1	0
	Max. temp., °C	33.1	33.6	33.1	35.5	30.5	29.9	28.6	27.8	28.1	29.9	31.7	32.6
	Min. temp., °C	23.0	23.2	22.8	23.3	21.3	21.2	21.5	20.8	21.3	21.2	18.9	17.9
	RH, %	66.5	67.8	67.6	68.2	74.4	74.9	76.8	77.4	76.7	74.8	60.8	50.0
2007	Total rainfall, mm	0	9.9	39.1	122	193.5	327.6	62.9	323.6	169.6	267.2	55.1	0
	Rain days	0	1	4	8	11	16	14	17	19	18	4	0
	Max. temp., °C	33.2	35.0	35.1	32.6	31.1	29.3	28.5	27.6	28.2	29.5	30.4	31.6
	Min. temp., °C	20.8	22.6	23.1	22.9	21.8	21.8	21.2	21.8	21.3	20.7	21.3	20.0
	RH, %	57.5	64.3	67.1	69.2	73.9	74.8	76.9	76.9	76.9	73.8	66.2	67.2

RH: relative humidity.

Table 2. Soil physical and chemical features before planting at the experimental sites in Nsukka, Nigeria.

Mechanical properties	2005	2006
Clay, %	19.76	21.04
Silt, %	9.28	10.56
Fine sand, %	46.56	50.04
Texture class	Sandy clay loam	Sandy clay loam
Chemical properties		
pH in H_2O	5.2	5.1
pH in KCl	4.5	4.9
Organic matter		
C, %	0.93	0.63
N, %	0.070	0.068
Na, meq 100 g^{-1}	0.57	0.66
K, meq 100 g^{-1}	0.23	0.37
Ca, meq 100 g^{-1}	1.60	0.80
Mg, meq 100 g^{-1}	1.20	0.96
CEC, meq 100 g^{-1}	2.24	1.12
P, mg kg^{-1}	44.78	26.87

CEC: cation exchange capacity.

were planted on the sides of the ridges with 0.5 × 0.5 m spacing, while maize was planted on their crest with 1.0 × 0.25 m spacing. Each crop was maintained at one plant per stand for a total plant population of 40 000 plants ha^{-1} for both maize and pigeon pea. The same plant populations were maintained under intercrop and sole crop conditions in additive series intercropping. Planting was done in July of each year at two seeds $stand^{-1}$ and later thinned to one plant $stand^{-1}$ 3 wk after planting to maintain the stipulated plant population. Weeds were manually controlled by hoeing at 21 and 45 d after planting (DAP). Fertilizer was applied by the band method at the rate of 120 kg N, 60 kg P and 80 kg K per hectare.

Observations on major insect pests of the pigeon pea plants were recorded from planting to harvest. The dominant insect pests at the flowering and podding stages of pigeon pea were identified and counted at 50% flowering and 50% podding on the plots. Five sampled pigeon pea and maize plants on the central ridges were manually harvested at maturity in each plot for yield assessment and the remaining plants harvested per plot. Maize cobs were harvested on 18 October 2005 (2005 planting) and 21 October 2006 (2006 planting). Picking of pigeon pea pods started on 6 November 2005 and continued through May 2006 for the 2005 planting and 8 November 2006 through June 2006 for the 2006 planting. Harvested maize cobs were dehusked, sun-dried, shelled, cleaned, and grains weighed for yield assessment at a 13% moisture level. Harvested pigeon pea pods were dried, threshed, cleaned, and grains weighed for yield assessment. Damaged (shriveled) pods were separated from wholesome pods and their number was recorded to obtain percentage damaged pods for each plot. Harvested pods were later threshed and carefully cleaned. Seeds damaged by insect pests (shriveled) and wholesome seeds were separated, counted, and recorded.

The number of insect pests at the flowering and pod formation stages of pigeon pea and the percentage of pods and seeds damaged by insect pests were subjected to square root and arcsine transformations, respectively, before ANOVA was carried out. Data obtained were analyzed with the Genstat Discovery (3) statistical analysis package. Differences between treatment means were compared for significance by Duncan's New Multiple Range Test in accordance with the procedure outlined by Gomez and Gomez (1984).

RESULTS

Rainfall during the 2005, 2006, and 2007 production periods was generally high from July to October, but dropped sharply in November and December of each year (Table 1). The maximum air temperatures ranged between 22 and 32 °C, whereas the minimum air temperature was between 17 and 21.8 °C during these periods (Table 2). The relative humidity was high and ranged from 73% to 77% in the rainy months, July to October, and dropped between 50% and 66% in November and December. Soil on this site had a sandy clay loam texture and was slightly acidic in reaction. According to Black's (1975) classification, organic matter content of the experimental sites was low and had very low N content in both years. With the same ratings by Black (1975), Na was also moderately low in the experimental sites for 2005 and 2006. Although K was low in 2005, it was moderate in 2006. In both 2005 and 2006, Ca was generally low in the two fields. The 2005 experimental field had moderate Mg content, but it was low in 2006. The CEC (cation exchange capacity) was low in both years, while P was high in 2005 and moderately low in 2006 according to Landon's (1991) ratings.

Few pigeon pea plants were affected at the seedling stage by variegated grasshoppers (*Zonocerus variegatus*), crickets (*Gymnogryllus lucens*), and termites (*Odontotermes badius*) (Table 3). White flies (*Bemisia* spp.) were observed on the plants at the vegetative stage without any visible plant damage. Insect pest infestation was high at the reproductive stage because of the pod flies (*Melanagromyza* spp.), blister beetles (*Mylabris* spp.), pod-sucking bugs (*Clavigralla* spp.), and pod borers (*Helicoverpa armigera*) which inflicted damage to pigeon pea flowers and pods. The pod-sucking bug (*Clavigralla* spp.) was noted as a major crop pest for its preponderance and severe damage.

The pigeon pea genotypes did not differ significantly ($P < 0.05$) in the number of *Clavigralla* spp. per plant at the flowering stage in both the 2005 and 2006 plantings (Table 4). On the other hand, pigeon pea genotypes of ratoon crops differed significantly ($P < 0.01$) in their pest density during the two growth stages. In the ratoon crops, the ICPL 161 genotype had a significantly lower number of *Clavigralla* spp. per plant compared with those of the ICRISAT genotypes. There was a significant ($P < 0.05$) variation among pigeon pea genotypes in their number of *Clavigralla* spp. per plant in both the 2005 and 2006 regular crops and in the 2007 ratoon crops. The Nsukka Local ratoon genotype had a significantly ($P < 0.05$) lower number of *Clavigralla* spp. per plant compared with those of the ICRISAT genotypes. The ICPL 85063 and ICPL 87119 genotypes maintained high mean values of insect pests plant^{-1} at the flowering and podding stages in the regular production seasons and ratoon crops. The number of *Clavigralla* spp. per plant at both the flowering and podding stages were generally slightly higher in the ratoon crops compared with those in the regular 2005 and 2006 production seasons. The pigeon pea genotypes differed significantly in their percentage of damaged seeds in both 2005 and 2006. The ICPL 161 and Nsukka Local genotypes had a significantly lower percentage of damaged seeds compared with other genotypes in both 2005 and 2006. In 2005, ICPL 87119 and ICPL 85063 had ($P < 0.01$) higher percentages of damaged seeds compared with ICPL 87 and ICP 7120, which had similar values. The pigeon pea genotypes also did not differ ($P > 0.05$) in their percentage of damaged pods plant^{-1}. However, the Nsukka Local genotype had the lowest mean percentage of damaged pods and seed values compared with those of the ICRISAT genotypes. The percentage of damaged pods was 24.3% in the ICPL 87119 genotype and 31.1% in the ICPL 87 genotype. The percentages of damaged pods and seeds were generally higher in the ratoon crops compared with those in the regular 2005 and 2006 production

Table 3. Field insect pests on pigeon pea in Nsukka, Nigeria.

S/N°	Common name	Scientific name	Order: Family	Occurrence (WAP)	Crop stage attacked	Type of damage
1	Variegated grasshopper	*Zonocerus variegatus*	Orthoptera: Pyrgomorphidae	4-10	Seedling Vegetative	Leaf defoliation
2	Crickets	*Gymnogryllus lucens*	Orthoptera: Gryllidae	3-10	Seedling	Stand reduction
3	Termites	*Odontotermes badius*	Isoptera: Termitidae	4-10	Seedling	Stand reduction
4	White flies	*Bemisia tabaci*	Homoptera:Aleyrodidae	8-11	Vegetative	No obvious damage
5	Pod fly	*Melanagromyza* spp.	Diptera: Melanogromyzidae	> 14	Vegetative/Reproductive	Larvae feed on developing seeds
6	Blister beetles	*Mylabris* spp.	Coleoptera:Meloidae	> 14	Reproductive	Adults feed on flowers
7	Pod-sucking bugs	*Clavigralla* spp.	Hemiptera: Coriedae	> 14	Reproductive	Causes shriveled/wrinkled seeds
8	Pod borer	*Helicoverpa armigera*	Lepidoptera: Noctuidae	> 14	Reproductive	Larvae feed on flower buds and developing seeds in the pod

WAP: weeks after planting.

Table 4. Main effects of pigeon pea genotypes on *Clavigralla* spp. counts and percentage pigeon pea pod and seed damage per plant in both regular (2005 and 2006) and ratoon (2007) crops.

Pigeon pea genotype	*Clavigralla* spp. count						Pigeon pea pod and seed damage per plant (%)					
	Regular crop				Ratoon crop		Regular crop (% damaged)				Ratoon crop (% damaged)	
	Flower stage		Pod stage		Flower stage	Pod stage	Pods		Seeds		Pods	Seeds
	2005	2006	2005	2006	2007	2007	2005	2006	2005	2006	2007	2007
ICPL 87	2.35a	1.90a	2.11a	1.65b	2.90b	2.44c	2.11a	2.54a	23.53a	21.32b	31.1a	22.0a
ICPL 161	2.28a	1.84a	2.10a	2.08c	2.80a	2.35b	2.10a	2.90a	23.29a	15.50a	30.1a	23.8a
ICPL 8503	2.48a	2.18a	2.36b	2.48d	2.97c	2.56d	2.36a	2.51a	24.98a	19.01ab	29.2a	23.1a
ICP 7120	2.42a	1.92a	2.38b	2.03c	2.87a	2.43c	2.38a	2.64a	27.30b	18.59ab	29.6a	23.1a
ICPL 8719	2.34a	1.96a	2.63c	2.65d	3.01c	2.44c	2.63a	2.76a	25.81a	18.72ab	28.8a	24.3a
Nsk Local	2.48a	1.93a	1.97a	1.30a	2.85ab	2.24a	1.97a	2.13a	23.22a	11.03a	27.5a	20.8a
Mean	2.39	1.95	2.26	2.03	2.90	2.41	2.26	2.58	24.69	17.36	29.4	22.8

Means followed by the same letters in a column do not differ significantly according to Duncan's New Multiple Range test ($p < 0.05$).

seasons. There was no significant interaction between cropping systems and pigeon pea genotypes in either the number of insect pest plant^{-1} or pest damage on pods and seeds in both the regular and ratoon pigeon pea crops.

The number of *Clavigralla* spp. per plant at the flowering and podding stages in pigeon pea were not significantly ($P < 0.05$) affected by maize intercropping in 2005 and 2006 (Table 5). A previous intercropping effect of maize on the pigeon pea ratoon crop plants did not affect ($P > 0.05$) their percentage of damaged pods plant^{-1} and seeds plant^{-1}. The interaction between the cropping system and the pigeon pea genotypes was not significant for both percentages of damaged pods plant^{-1} and seeds plant^{-1}.

However, the number of insect pests plant^{-1} was consistently slightly lower, although not significant, under the intercropping system as compared with sole pigeon pea systems at both the flowering and podding stages in 2005 and 2006. Intercropping maize with pigeon pea also did not significantly ($P > 0.05$) affect the percentage of damaged pods in both the 2005 and 2006 regular crops (Table 5). On the other hand, the percentages of damaged pods were slightly lower under the intercropping system compared with the sole cropping system. Hybrid maize intercropping ($P < 0.01$) reduced the percentage of damaged seeds plant^{-1} compared with those under sole cropping in 2005, although the reduction was not significant ($P > 0.05$) in 2006.

Intercropping maize with pigeon pea significantly ($P < 0.01$) reduced grain yield (kg ha^{-1}) in pigeon pea in both 2005 and 2006, while the 2007 ratoon crops did not differ significantly ($P < 0.05$) in grain yield (kg ha^{-1}) (Table 6). The pigeon pea genotypes differed significantly ($P < 0.01$) in grain yield in the 2005 and 2006 regular production (Table 7). In 2005, the Nsukka Local genotype produced a significantly ($P < 0.05$) lower grain yield compared with the ICRISAT genotypes. Among the ICRISAT genotypes, ICPL 87 yielded significantly ($P < 0.01$) higher than the other genotypes. In 2006, ICPL 85063 grain yield was highly significant ($P < 0.01$) compared with other genotypes. In the ratoon crops, ICPL 85063 and ICP 7120 produced significantly ($P < 0.05$) higher grain yields compared with other genotypes. However, the Nsukka Local genotype had a lower grain yield compared with the ICRISAT genotypes. Among the ICRISAT genotypes, ICP 7120 had the highest yield compared with other genotypes. There was no significant interaction between the cropping system and the pigeon pea genotypes for grain yield. The ratoon crop grain yield was 60% of the mean grain yield for the main crop.

Table 6. Effect of maize intercropping on pigeon pea grain yield for both regular and ratoon cropping systems.

Cropping system	Pigeon pea grain yield (kg ha^{-1}) Regular cropping 2005	Regular cropping 2006	Ratoon cropping 2007
Pigeon pea + Hybrid maize	983.0a	895.0a	640.0a
Pigeon pea + Open-pollinated maize	1079.0a	936.0a	658.0a
Pigeon pea sole-crop	1493.0b	1345.0b	723.0a
Mean	1185.0	1059.0	674.0

Means followed by the same letters in a column do not differ significantly according to Duncan's New Multiple Range test ($P < 0.05$).

Table 7. Pigeon pea genotype grain yield for both regular and ratoon cropping.

Pigeon pea genotype	Pigeon pea grain yield (kg ha^{-1}) Regular cropping 2005	Regular cropping 2006	Ratoon cropping 2007
ICPL 87	1560.0c	1053.0b	640.0a
ICPL 161	1335.0b	1001.0a	623.0a
ICPL 85063	1160.0b	1293.0c	726.0b
ICP 7120	1225.0b	1151.0b	807.0b
ICPL 87119	990.0a	1045.0b	673.0a
Local	842.0a	808.0a	574.0a
Mean	1185.0	1059.0	674.0

Means followed by the same letters in a column do not differ significantly according to Duncan's New Multiple Range test ($P < 0.05$).

DISCUSSION

High rainfall of between 125.4 and 313.9 mm and a relative humidity of not less than 70% from July to October during the cropping periods was adequate for both maize and pigeon pea components. For sweet corn, Braunworth (1987) reported optimum yield between 311and 604 mm water, while Costa *et al*. (1988) recorded between 111 and 600 mm to achieve the best grain yield. Similarly, Marin *et al*. (2004) reported that water stress appears to be the critical limiting factor for germination

Table 5. Main effects of cropping systems on *Clavigralla* spp. counts and percentage pigeon pea pod and seed damage per plant in both regular (2005 and 2006) and ratoon (2007) crops.

Cropping system	*Clavigralla* spp. count: Regular cropping, Flower stage 2005	Flower stage 2006	Pod stage 2005	Pod stage 2006	Ratoon cropping, Flower stage 2007	Pod stage 2007	(%) Pigeon pea pod and seed damage per plant: Regular cropping (% damaged), Pods 2005	Pods 2006	Seeds 2005	Seeds 2006	Ratoon cropping (% damaged), Pods 2007	Seeds 2007
PP + HM	2.35a	1.95a	2.17a	1.92a	2.92b	2.42b	2.17a	2.68a	23.33a	18.12a	22.8a	30.7a
PP + OM	2.31a	1.91a	2.23a	1.99a	2.89a	2.42b	2.23a	2.54a	25.42b	17.45a	22.6a	29.2a
Sole PP	2.51a	2.01a	2.37a	2.18a	2.90b	2.39a	2.27a	2.51a	25.30b	16.52a	23.1a	28.3a
Mean	2.39	1.95	2.26	2.03	2.90	2.41	2.26	2.58	24.69	17.36	22.8	29.4

PP: Pigeon pea; HM: Hybrid maize; OM: Open-pollinated maize.
Means followed by the same letters in a column do not differ significantly according to Duncan's New Multiple Range test ($P < 0.05$).

and seedling establishment in pigeon pea. The drop in rainfall and temperature in November and December were essential for pigeon pea since they coincided with pod maturation and drying. Patel *et al*. (2001) noted that water use efficiency during the reproductive phase in pigeon pea decreased with increasing plant age. The slightly acidic sandy clay loamy soil of the experimental sites was within the tolerable range by both maize and pigeon pea crops. Brink and Belay (2006) recommended these climatic conditions for maize and pigeon pea for their good development both in the field and at harvest. The minimal plant destruction by variegated grasshoppers, crickets, and termites at the seedling and early vegetative growth stages in the pigeon pea regular crops was attributed to the low population of these insects observed in the field. The lack of destruction or disease symptoms associated with the observed large number of white flies at the vegetative growth stage of the pigeon pea was attributed to the high rainfall recorded during that period, which tends to incapacitate the vector activities of leaf hoppers. This agrees with the report by Stewart (2005). The large number of insect pests observed during the flowering and podding stages in the pigeon pea agreed with earlier reports by Night and Ogenga-Latigo (1994) and Minja (2000). The large number of pod-sucking bugs (*Clavigralla* spp.) and the associated damaged pods and seeds agreed with Minja (2000) and Dialoke *et al*. (2010), who reported high damage from pod-sucking bugs regardless of weather conditions.

The lower number of insect pests observed in the maize intercropped pigeon pea plants compared with the sole pigeon pea crop was attributed to the maize intercropping effect and the availability of unlimited host supply in sole cropping over intercropping. The maize plants are probably physical barriers that impede insect movement and/or visibility. In their review, Hooks and Johnson (2003) attributed the mechanisms accounting for herbivore responses to a mixture of plants to include reduced colonization, reduced adult tenure time, and ovipositional interference. Bastos *et al*. (2003) also recorded fewer insect phytophagous incidence on beans cultivated in an intercropping system with maize. The consistently lower number of *Clavigralla* spp. plant^{-1} on 'ICPL 161' pigeon pea (although not significant) in both the 2005 and 2006 seasons indicated some levels of resistance traits that could be harnessed in further breeding programs. Similarly, the lower number of *Clavigralla* spp. plant^{-1} at the podding stage in the Nsukka Local genotype further confirmed its resistance trait, which could be due to its lengthy adaptation to the local environment given its long production history in the locality. The lower number of *Clavigralla* spp. at the podding stageon 'ICPL 87' and the significantly higher number on 'ICPL 87119' in both 2005 and 2006 implied differential resistance to the insect pest among the ICRISAT pigeon pea genotypes; this agrees with El-Titi (1995) and Kooner and Cheema (2006), who reported that the genetic constitution of genotypes could determine the levels of their susceptibility to pests and diseases. Furthermore, the previous short duration must have evaded infestation by an escape mechanism unlike the later medium duration. The nonsignificant effect of the cropping system on the *Clavigralla* count plant^{-1} at both pigeon pea flowering and podding stages implied that the maize component did not impede the movement or visibility of such a large insect and thus only minimally reduced the insect pest population.

The significant difference among pigeon pea genotypes on the *Clavigralla* count plant^{-1} at the flowering and podding stages of the regular 2005 and 2006 crops and ratoon crops was attributed to genotypic differences. The higher number of insect pests on 'ICPL 87119' and 'ICPL 85063' compared with those of other genotypes in both regular production periods and in the ratoon crops implied higher susceptibility to insect pest infestation in the two genotypes, while the low number of pests plant^{-1} on 'ICPL 161' and 'Nsukka Local' implied the presence of some resistance traits. The higher number of insect pests plant^{-1} in the ratoon plants and the associated higher percentage of damage to pods and seeds compared with the regular pigeon pea plants was attributed to pest buildup and reduced plant vigor in the ratoon plants.

The nonsignificant effect of maize intercropping on the percentage of damaged pods in both the 2005 and 2006 cropping seasons was attributed to its nonsignificant difference in the number of insect pest plant^{-1} at both the flowering and podding stages in this study. The increased reduction in the percentage of damaged pigeon pea seeds plant^{-1} in 2005 and a lower (but not significant) percentage of seed damage plant^{-1} in 2006 suggest that assessing seed damage could be done better by assessing *Clavigralla* in pigeon pea. The significant differences among pigeon pea genotypes for the percentage of damaged seeds in both 2005 ($P < 0.01$) and 2006 ($P < 0.05$) confirmed the differences in resistance to seed damage by the field insect pests among the pigeon pea genotypes; Kooner and Cheema (2006) reported similar results.

The lower percentage of damaged seeds in 'ICPL 161' and 'Nsukka Local' in 2005 and 2006 confirms that they have some levels of resistance. The higher percentage of damaged seeds and pods in the ratoon crops compared with those of regular pigeon pea crops was attributed to the absence of the maize crop during the 2007 ratoon crop production season and the high pest buildup as a result of a continuous supply of the host plant. The lowest mean percentage of damaged pods and seeds in the Nsukka Local genotype compared with the ICRISAT genotypes implied higher resistance that was attributed to its lengthy adaptation to the environment. The overall mean of damaged seeds by pests in both 2005 and 2006 was 24% in regular production and 29% in ratoon crops, which was due to the higher pest buildup. These values were within the range of 14% and 69% reported by

Kooner and Cheema (2006) in a humid region of Kenya. In addition to unquantified damaged flowers and pods destroyed by insect pests, this clearly implies that field insects are a big threat to crop production and could enhance yield if adequately controlled. Identification of genotypes with resistance to field insect pests will reduce costs and provide a yield advantage to resource-poor farmers. Moreover, it will provide a more ecological approach to insect pest management and reduce public concern over the socio-economic consequences of using pesticides.

Pigeon pea grain yield in intercropping systems was significantly reduced compared with 2005 and 2006 sole crops and was attributed to the intercropping effect of maize on pigeon pea. In a study conducted by Bottenberg *et al*. (1997), severe yield losses occurred in cabbage planted in rye, *Secale cerale* L. This occurred although lower populations of various lepidopteran and aphid species. However, if intercropping were to increase pest loads, it is still possible that further yield reductions would have been possible. The significant difference in grain yield among pigeon pea genotypes in the regular 2005 and 2006 production seasons was attributed to genotypic differences. The lower grain yield in pigeon pea ratoon crops compared with regular crops was attributed to the higher insect pest infestation and low plant vigor of the ratoon plants because of senescence. The nonsignificant difference in grain yield among pigeon pea ratoon crops was attributed to the generally low yield in the ratoon plants. The lowest yield in the Nsukka Local genotype under both regular and ratoon cropping was a demonstration of the low-yielding ability of the local genotype in spite of its higher resistance levels to insect pests compared with the improved genotypes. Therefore, the local variety should be replaced by more productive genotypes with more promising levels of insect resistance to encourage the farmers.

CONCLUSIONS

Pigeon pea was found to be associated with termites (*O. badius*), crickets (*G. lucens*), and variegated grasshoppers (*Z. variegatus*) at the seedling stages, but the insects were considered minor pests. Field insect pest infestation on pigeon pea was more critical at the reproductive stage where damage was mainly caused by pod-sucking bugs (*Clavigralla* spp.), pod borers (*Helicoverpa*), pod flies (*Melanogromyza* spp.), and blister beetles (*Mylabris* spp.) Damage by *Clavigralla* spp. in this study led to 24% seed damage in regular crops and 29% seed damage in ratoon crops. The ICPL 161 genotype recorded the lowest *Clavigralla* count and damage to pods and seeds. Based on low insect pest infestation and high grain yield production, it is recommended ICPL 16 and ICPL 87 be adopted by farmers or as idiotypes in pigeon pea hybridization programs.

Evaluación de campo de insectos pestes y daño del cultivo de gandul (*Cajanus cajan* [L.] Huth) creciendo bajo rebrotes o en mezcla con maíz. La extendida adopción de sistemas de cultivo que son sustentables y benignos para el medio ambiente es vital para la supervivencia macro-económica de la civilización. El intercultivo podría asegurar la estabilidad de población de insectos en un sistema. Un ensayo de campo de 3 años (2005-2007) fue realizado en Nigeria bajo condiciones de cultivo regular y ratoon para evaluar cinco genotipos de poroto gandul (*Cajanus cajan* [L.] Huth): ICPL 87, ICPL 161, ICPL 85063, ICP 7120, e ICPL 87119 desde International Crops Research Institute for Semi-Arid Tropics (ICRISAT) y una variedad local, por sus rendimientos y susceptibilidades relativas a insectos plaga. Los genotipos de poroto gandul estaban en mezcla con dos genotipos de maíz (*Zea mays* L., de polinización abierta e híbrido) en cultivos regulares por 2 años (2005-2006) seguido por un ratoon por 1 año (2007). Termitas (*Odontotermes badius*), grillos (*Gymnogryllus lucens*) y saltamontes variegado (*Zonocerus variegatus*) fueron las plagas de plántula del cultivo, causando daño mínimo. Infestaciones con *Clavigralla* spp. fueron altas en el estado reproductivo causando 24% y 29% de daño seminal en cultivos regular y de poroto gandul ratoon. El maíz suprimió la incidencia de la plaga y el daño a las vainas y semillas de poroto gandul pero redujeron significativamente (P < 0,01) el rendimiento de grano en los cultivos de poroto gandul en 2005 y 2006, pero no en ratoon en 2007. Los genotipos de poroto gandul difirieron significativamente (P < 0,05) en incidencia de la plaga al estado de vaina en cultivos regular y ratoon y en rendimiento de grano (P < 0,01) bajo el cultivo regular. El rendimiento de granos de los cultivos de poroto gandul ratoon fue aproximadamente 60% de aquel del cultivo regular. Los genotipos ICPL 161 e ICPL 87 se recomendaron para adopción por los agricultores basados en tolerancia a las plagas y alto rendimiento de granos o como idiotipos en programas de hibridación de poroto gandul.

Palabras clave: *Cajanus cajan*, *Clavigralla* spp., sistema de cultivo, rebrotes de cultivo, cultivo regular.

LITERATURE CITED

Ajayi, O.M., M.I. Ezueh, R. Tabo, J.E. Asiegbu, and L. Singh. 1995. Pigeon pea production and utilization in Nigeria. International Chickpea and Pigeon Pea Newsletter 2:47-49.

Andrew, D.J., and A.H. Kassam. 1976. The importance of multiple cropping in increasing world food supply. *In* Papendick, R.I., P.A. Sawches, and G.B. Triplett (eds.) Multiple cropping. American Society of Agronomy (ASA Special Publication) N° 27. ASA, Madison, Wisconsin, USA.

Bastos, C.S., J.C.C. Galvao, M.C. Picanco, P.R. Cecon, and P.R.G. Pereira. 2003. Insect phytophagous and predators incidence on maize and bean cultivated in exclusive and intercropped systems. Ciencia Rural 33:391-379.

Black, C.A. 1975. Methods of soil analyses. Agronomy Journal N° 9. Part 2. American Society of Agronomy, Madison, Wisconsin, USA.

Boringer, A., D.E. Leihner, and R. Bocker. 1995. Cut dry matter productivity of perennial pigeon pea genotypes on an Acrisol in sub-humid West Africa. International Chickpea and Pigeon Pea Newsletter 2:61-63.

Bottenberg, H., J. Masiunas, C. Eastman, and D. Eastburn. 1997. Yield and quality constraints of cabbage planted in rye mulch. Biological Agriculture and Horticulture 14:323-342.

Braunworth, W.S. 1987. Irrigation scheduling methods and water use of sweet corn. Dissertation Abstract International B 47(8):3168B.

Brink, M., and G. Belay (eds.) 2006. Plant resources of tropical Africa. 1. Cereals and pulses. 298 p. PROTA Foundation, Wageningen/Backhuys Publishers, Leiden/CTA, Wageningen, The Netherlands.

CGIAR. 2005. Research and impact: Pigeon pea 2004-2005. Consultative Group on International Agricultural Research (CGIAR). Available at http://www.cgiar.org/impact/research/pigeonpea.html (accessed 23 October 2010).

Costa, J.O., L.G.R. Ferreira, and F.D. Souza. 1988. Yield of maize under different levels of water stress. Pesquisa Agropecuaria Brasileira 23:1255-1261.

Davis, J.H.C., and J.N. Woolley. 1993. Genotypic requirement for intercropping. Field Crops Research 34:407-430.

Dialoke, S.A., C.M. Agu, G.O. Ojiako, E. Onwurah, C.C. Onyishi, N. Ozor, *et al*. 2010. Survey of insect pests on pigeon pea in Nigeria. An Open Access Journal published by ICRISAT. Journal of SAT Agricultural Research 8:1-8.

El-Titi, A. 1995. Ecological aspects of integrated farming. *In* Glen, D.M., M.P. Greeves, and H.M. Anderson (eds.) Ecological and integrated farming systems. Proceedings of the 13th Long Ashton International Symposium. IACR Long Ashton Research Station, University of Bristol, UK. John Wiley & Sons Publishers, London, UK.

Gomez, K.A., and A.A. Gomez. 1984. Statistical procedure for agricultural research. 680 p. 2a ed. John Wiley & Sons, New York, USA.

Guy, M.P., A. Kimani, O. Mwang, F. Olubayo, C. Smith, P. Audi, *et al*. 2001. Survey of pigeon pea production systems, utilization and marketing in semi-arid lands of Kenya. Biotechnology, Agronomy and Social Environment 5:145-153.

Hooks, C.R.R., and M.W. Johnson. 2003. Impact of agricultural diversification on insect community of cruciferous crops. Crop Protection 22:223-238.

ICRISAT Newsletter. 2003. Crop improvement and management. International Crops Research for the Semi-Arid Tropics (ICRISAT) Newsletter October 2003.

Kooner, B.S., and H.K. Cheema. 2006. Evaluation of pigeon pea genotypes for resistance to pod borer complex. Indian Journal of Crop Science 1:194-196.

Landon, J.R. (ed.) 1991. Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. 474 p. John Wiley and Sons, New York, USA.

Marin, A., D.M.M. dos Santos, D.A. Banzatto, and A.S. Ferraudo. 2004. Seed germination of pigeon pea (*Cajanus cajan* (L.) Millsp.) under water stress and aluminum sublethal doses. Bragantia 63:13-24.

Minja, E.M. 2000. Yield losses due to field pests and integrated pest management strategies for pigeon pea- a synthesis. p. 48-53. *In* Silim, S.N., G. Mergeai, and P.M. Kimani (eds.) Status and potential of pigeon pea in Eastern and Southern Africa: Proceedings of a Regional Workshop, Nairobi, Kenya. 12-15 September. B-5030 Gembloux, Belgium: Gembloux Agricultural University; and Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi- Arid Tropics (ICRISAT).

Minja, E.M., T.G. Shanower, J.M. Songa, J.M., Ong′aro, W.T. Kawonga, P.J. Mviha, *et al*. 1999. Studies of pigeon pea insect pests and their management in Kenya, Malawi, Tanzania and Uganda. African Crop Science Journal 7:59-69.

Night, G., and M.W. Ogenga-Latigo. 1994. Range and occurrence of pigeon pea pests in Central Uganda. African Crop Science Journal 2:105-109.

Obi, M.E., and F.K. Salako. 1995. Rainfall parameters influencing erosivity in southeastern Nigeria. CATENA 24:275-280.

Patel, N.R., A.N. Mehta, and A.M. Shekh. 2001. Canopy temperature and water stress quantification in rainfed pigeon pea (*Cajanus cajan* (L.) Millsp.) Agriculture and Forest Meteorology 109:223-232.

Reed, W., and S.S. Lateef. 1990. Pigeon pea pest management. *In* Nene, Y.L., S.D. Hall, and V.K. Sheila (eds.) The pigeon pea. CAB International, Wallingford, Oxon, UK.

Sastawa, B.M., M. Lawan, and Y.T. Maina. 2004. Management of insect pests of soybean: Effects of sowing date and intercropping on damage and grain yield in the Nigerian Sudan savanna. Crop Protection 23:155-161.

Shanower, T.G., J. Romeis, and E.M. Minja. 1999. Insect pests of pigeon pea and their management. Annual Review of Entomology 44:77-96.

Snapp, S.S., R.B. Jones, E.M. Minja, J. Rusike, and S.N. Silim. 2003. Pigeon pea for Africa: A versatile vegetable and more. HortScience 36:1073-1078.

Stewart, A.J.A. 2005. The conservation of grassland leafhoppers. Journal of Insect Conservation 9:227-374.

Willey, R.W. 1979. Intercropping: its importance and research needs. Part 1. Competition and yield advantages. Field Crops Abstract 32:1-10.