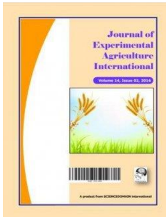

Journal of Experimental Agriculture International

20(1): 1-20, 2018; Article no.JEAI.22115
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Impact of Plant Density and Planting Dates on the Population of Major Pod Sucking Bugs in Relation to Damage and Yield of Improved Pigeonpea Cultivar in Owerri Rainforest Zone, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author SAD wrote the manuscript. All the authors were involved in all the field work such as land preparation, planting and pest sampling, in gathering literatures and analysis of the data collected from the field. All the authors read the final manuscript and approved it before submission for publication.

Article Information

DOI: 10.9734/JEAI/2018/22115
Editor(s):
(1) Mirza Hasanuzzaman, Assistant Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Bangladesh.
Reviewers:
(1) Tuneera Bhadauria, Feroz Gandhi College, C. S. J. M. University, India.
(2) Augustine Niba, Walter Sisulu University, South Africa.
Complete Peer review History: http://www.sciencedomain.org/review-history/22756

Original Research Article

Received 18th September 2015
Accepted 23rd November 2015
Published 16th January 2018

ABSTRACT

Field study was undertaken to determine the population of three major pod sucking bugs namely *Riptortus dentipes* Fab. (Hemiptera: coreidae), *Clavigralla tomentosicollis* Stall (Hemiptera: coreidae), *Anoplocnemis curvipes* Fab (Hemiptera: coreidae) and their effect on damage, yield (kg ha^{-1}) and yield components under varying plant densities and planting dates. The experiment was carried out at the Postgraduate Teaching and Research Farm, Department of Crop Science and Technology, Federal University of Technology, Owerri Imo State. Experiment was laid out in a 3 x 4 factorial and treatments comprised of four plant density of 190,474 plants ha^{-1}, 125,000 plants ha^{-1}, 80,000 plants ha^{-1}, 55,556 plants ha^{-1} and three planting dates, April (early season), July (Mid-season), and October (late season), 2009 and 2010. The results, show that there was significant

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($p<0.05$) population of the pod sucking bugs on pigeonpea flowers and pods at high plant density and low on plants at low plant density. There was significant ($p<0.05$) population of *C. tomentosicollis* and *A. curvipes* in October while April and July planting seasons showed absence of *C. tomentosicollis* and *A. curvipes* The population of *R. dentipes* occurred throughout the season with peak population in April which decreased as planting was delayed till October. Also plants at high density recorded high pod and seed damage resulting in low values of seed yield (147.90 kg ha^{-1}) in 2009, (168.80 kg ha^{-1}) in 2010 when compared with pigeonpea planted at low density which had low pod and seed damage with high seed yield of 223.33 kg ha^{-1} in 2009, and 268.83 kg ha^{-1} in 2010. Also yield components like 100 pod/seed weight (g), pod/seed yield (g) per plant, number of seeds per pod were low on plants at high density, but high on plants at low density. July planting season recorded the lowest pest loads, pods/seed damage, with resultant high pod/seed yield and yield components compared with April and October planting seasons. Therefore, for high seed yield with minimal damage by pod sucking bugs, planting the early maturing pigeonpea in July at low density should be incorporated into farming systems in this zone as integrated Pest Management alternative.

Keywords: Improved pigeonpea; Riptortus dentipes; Clavigralla tomentosicollis; Anoplocnemis curvipes; population; plant density; planting dates; seed damage; seed yield.

1. INTRODUCTION

The pigeonpea, *Cajanus cajan* (L.) Millsp, also known as red gram is found throughout tropical and subtropical areas of the world from about 30 N to about 30 S of the equator. Pigeonpea is believed to have originated in India [1]. Pigeonpea is widely grown in the semi-arid tropics particularly in the Indian subcontinent where it accounts for about 70% of the production and coverage [2], hence greater use of pigeonpea as food is made in India than in most other parts of the world. Southern and Eastern Africa particularly Kenya, Malawi, Mozambique, Tanzania and Uganda constitute the second largest pigeonpea growing areas [3]. Other growing regions include West Africa particularly in South eastern, Nigeria [4], Southeast Asia, Central Africa and America [5]. Appropriately therefore, a great majority of research in pigeonpea production and utilization occur in the Indian sub-continent comprising universities and institutes such as the International Crops Research Institute for Semi-Arid Tropics (ICRISAT). Pigeonpea is a rich source of carbohydrates, minerals and vitamins. The seeds contain a range of 51.4-58.8% carbohydrate, 1.2-8.1% crude fibre and 0.6-3.8% lipids [6]. Also [7], observed that the green pigeonpea had 64.95% moisture content, 6.7% protein, 2.9% crude fibre, 7.83% carbohydrate, and 181.47% Energy (kcal). Pigeonpea contains more minerals, ten times more fat, five times more vitamin A and three times more vitamin C than ordinary peas [8].

In India, dehulled and split pigeonpea seeds called Dhal is relished as excellent food. In West Africa, the mature seeds are soaked in water, cooked or eaten alone or it can be eaten with rice, yam, dried cocoyam chips, maize or sorghum flour or a variety of vegetables [4]. Pigeonpea is considered to have great potentials as an important grain legume for human nutrition. Because pigeonpea has great potential as a protein supplement to cereal based foods in many protein deficient tropical countries, the protein Advisory group (PAG) of the United nations recommended that urgent attention be paid to research into the production and nutritional evaluation of the pigeonpea and seven other grain legumes [9]. In fact, most researches on pigeonpea have been concentrated on breeding and other aspects of legumes [10]. Although cowpeas and other beans are the legumes of choice, pigeonpea has the potential to become an important dietary legume because of its relatively cheaper price in comparison with cowpea. This is indeed happening in South eastern, Nigeria, where the urban and the rural poor have turned to pigeonpea for part of their dietary protein requirements, [4].

Despite the importance of pigeonpea to dietary needs of people, insect pest incidence, use of local materials, inappropriate plant spacing and time of sowing, has been the major problems militating against production of pigeonpea especially in this part of south eastern Nigeria. Inappropriate plant spacing for optimum plant density and choice of time for planting predispose pigeonpea to harsh ecological imbalance with consequent yield reduction. Among all these factors pigeonpea destruction by insect pests mostly at flowering and podding stages by pod sucking bugs *C. tomentosicollis* Stall, *A. curvipes* [11] among other pests such as blister beetles (*Mylabris pustulata*

Thunberg) [12] and thrips [13] are the major production constraints.

Adoption of appropriate sowing time and plant spacing is paramount to sustainable food production through controlling of pre- harvest losses due to pests. It is compatible with the environment and safe to the health of plants and humans. Considerably, less research attention has however been paid to improved pigeonpea in Nigeria. Therefore, this study was undertaken to assess the interactive effect of plant densities and planting dates on the population of three major pigeonpea pod sucking bugs comprising *R. dentipes*, *C. tomentosicollis, A. curvipes* and their impact on pod/seed damage and yield (kg ha^{-1}) /yield components of improved pigeonpea in Owerri, representing the rainforest zone of Southeastern, Nigeria.

2. MATERIALS AND METHODS

2.1 Experimental Site

Field research was carried out at the Postgraduate Teaching and Research Farms, Department of Crop Science and Technology, Federal University of Technology, Owerri, Imo State Nigeria. Experiment was carried out in the months of April, July, and October, 2009 and repeated in 2010. The research field was located in the rain forest belt, longitude 7° 12′ E and latitude 5° 27′ N of equator. Plate 1, show the Map of Imo State. The annual monthly temperature, rainfall, and relative humidity of the study area prevalent in Owerri in the year 2009 and 2010 were obtained from Federal Ministry of Aviation Owerri Meteorological Station, Imo State (Table 1).

2.2 Variety of Pigeonpea Used

An improved pigeonpea cultivar, ICRISAT pigeonpea lines (ICPL 84023) was used for the research and was procured from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) India under phyosanitary certification.

2.3 Land Preparation

An area of land measuring 11.0 m × 10.0 m (110 m^2) was mapped out in the Postgraduate Teaching and Research Farms, Department of Crop Science and Technology, Federal University of Technology, Owerri during each sowing time in April, July, and October 2009 and repeated same time in 2010. The area was cleared, tilled manually and measured with tape.

2.4 Experimental Design and Treatment Allocation

The area was divided into 3 replications with 1m pathways between replications. Each replication comprised of 4 plots of uniform sizes 3.0 m × 3.6 m (10.8 m^2), with different plant spacing of 15 cm x 35 cm, 20 cm x 40 cm, 25 cm x 50 cm, 30 cm x 60 cm and separated by 1 m pathway between plots. Three seeds (3) were sown per hole on 7th April 2009 and 2010, 7th July 2009 and 2010 and 7th October 2009 and 2010. Each plot contained 5 ridges with 12 rows of pigeonpea per plot to give a total of 60 plants per plot. The improved pigeonpea cultivar (ICPL 84023) used was seed-dressed with Apron-star before sowing at the rate of 2 kg of seeds per a sachet, to control fungal diseases. Planting was done using 3 seeds per hole at each sowing time and later thinned down two weeks after planting (WAP) to one stand per hole to give the plant population per hectare for different crop arrangement as shown below:

> 55,556 plants ha^{-1} at spacing of 30 cm x 60 cm, 80,000 plants ha^{-1} at spacing of 25cm x 50 cm, 125,000 plants ha^{-1} at spacing of 20 cm x 40 cm , 190,474 plants ha^{-1} at spacing of 15 cm x 35 cm.

2.5 Methods of Pest Sampling

The experimental Design was a 4 x 3 factorial laid down in a Randomized Complete Block Design (RCBD) with (3) replications. All the treatments were randomly allocated in the plots.

The major pod sucking bugs (PSBs), were counted visually during podding phase using four (4) plants each selected at random from three middle ridges following the method as described by [14]. A total of 12 plants per plot were sampled till pod maturity. The pod sucking bugs were also collected with a sweep net, killed with ethyl acetate, and identified using preserved laboratory samples from the Department of Crop Science and Technology, Federal University of Technology Owerri. The identification of specimens was confirmed at the Insect Museum of the Institute of Agricultural Research, (IAR) ABU, Zaria, and also by the use of pigeonpea and chickpea insect identification Handbook by [15]. The collection and counting was done at weekly intervals each time between 6.30 a.m to 7.30 a.m when the insects were less mobile. Counts were also expressed as the number of *R. dentipes*, *C. tomentosicollis*, and *A. curvipes* per 12 plants within each plot.

Plate 1. Map of Nigeria showing location of Imo State (arrowed)

2.6 Assessment of Pods and Seeds Damage

At maturity the pigeonpea pods were harvested and manually threshed. The harvested pods and seeds were examined for insect damage and incidence of pod sucking pods damage assessed as the proportion of pods and seeds with shriveling, twisting, and constriction portions per 100. The proportion of damaged pods/seeds from 100 pods/seeds selected at random from each plot was counted, and expressed as percentage of the total weight (g) of pods /seeds assessed, according to [16] as shown below:

Pod/seed damage (%) =

$$\frac{\text{Wt. of damaged pods/seeds}}{\text{Total Wt. of pods/seeds examined}} \times \frac{100}{1}$$

2.7 Assessment of Yield and Yield Components

2.7.1 Pod and grain yields

The pod and seed yields were recorded from the harvested dried pods at 100% maturity from the three middle rows of each plot. The pods were oven dried at 40°C for five days and later hand threshed and winnowed. The pods (g) and seeds yield (g) per plot including 100 pod/seed weights (g) were weighed using a sensitive top loading balance at the Department of Crop Science and Technology laboratory, Federal university of Technology, Owerri. The pod and seed yield obtained from each plot was converted to yield per hectare (kg ha^{-1}). Other yield parameters measured were pod yield per plant, seed yield per plant, number of seeds per pod, 100 pod weight (g) and 100 seed weight (g).

2.8 Statistical Analysis

Data collected were subjected to analysis of variance using [17]. Data on *R. dentipes*, *C. tomentosicollis*, *A. curvipes* and pod/seed damage were subjected to square root transformation before analysis of variance was carried out, while treatment means was separated by the use of Least Significant Difference (LSD) at 5% level of significance.

2.9 Cultural Practices

Weeding was done manually with the use of hoe at two weeks and six weeks after planting. There was no application of either organic or inorganic fertilizers to the pigeonpea plots in all the experiments as the area was left fallow for over five years.

3. RESULTS

Results in Table 1, indicated the monthly climatic conditions prevalent during the 2009/2010 planting periods in Imo State. From the two year planting period's, rainfall pattern increased gradually from April planting reached its peak in August, declined in September, rose again in October and thereafter maintained very low rainfall till harvest. Temperature and relative humidity fluctuates in both years in relation to monthly rainfall. In 2010, there was increase in maximum/minimum temperature and relative humidity when compared with 2009 cropping season. The early season cropping (April) and late season cropping (October) across all the farming seasons suffer much set backs from inadequate rainfall either during establishment stage or at the reproductive phase of the crop. April suffered from water stress at the establishment stage while October suffered water stress during the reproductive phase. Hence plants in October planting were observed to be dwarfed with poor flower formation. Also the plants experienced scotched leaves and flowers which often shed off after 4-5 days.

Table 1, shows that there were high rainfall, relative humidity, and temperature in 2009 and 2010 planting seasons. There was low rainfall and high temperature in April in 2009 and 2010 planting seasons while there was high rainfall and relative humidity during October planting season. The establishment and reproductive phase of the plant during July planting received favourable rainfall, relative humidity and temperature across all the farming seasons with reduced pest loads.

The results of the effect of plant density and planting date on the population of *R. dentipes* during 2009 are presented in Fig. 1 (a and b). The population of *R. dentipes* on all the plant densities was low but higher plant densities of 190,474 plants^{-1} influenced higher population at 98 DAP. Plants at low density of 55,556 plants^{-1} had low population of *R. dentipes* at 77 DAP, 84 DAP and 91 DAP compared with other plant densities.

With respect to date of planting, April planting had significant (P<0.05) population of *R. dentipes* with peak population at 98 DAP followed by July planting with peak population at 105 DAP and 112 DAP. October planting recorded the lowest population of *R. dentipes* which were non-significant at 70 DAP to 91 DAP with April and July planting.

Fig. 2 (a and b) revealed the effect of plant densities and planting dates on the population of *R. dentipes* during 2010 planting season. High plant population of 190,474 plants^{-1} and 125,000 plants^{-1} had significant (P<0.05) population of *R. dentipes* which was peak at 77 DAP while plants at low density had low population of *R. dentipes* which decreased as days after planting increased. Highest population of *R. dentipes* was again noticed during April planting at 77 DAP followed by July planting while October planting had the least population of *R. dentipes*.

The result of the effect of plant densities and planting dates on *C. tomentosicollis* at podding phase of early maturing pieonpea cultivar during 2009 is presented in Fig. 3 (a and b). The result revealed that there was high population of *C. tomentosicollis* on high density plants (190,474 plants^{-1}) at 70 DAP, 84 DAP and 98 DAP while low density plants had significant low population of *C. tomentosicollis* at 77 DAP, 84 DAP and maintained zero levels of the pest from 91 DAP, 98 DAP and 105 DAP compared with other plant densities.

During October planting *C. tomentosicollis* descended on the pigeonpea pods with significant peak population at 70 DAP, 77 DAP and 84 DAP and decreased from 91 DAP to 105 DAP. There was absence of *C. tomentosicollis* during April and July planting.

Fig. 4 (a and b), presents the population of *C. tomentosicollis* as affected by plant densities and planting dates in 2010. High population of *C. tomentosicollis* was observed on all the plant densities at 77 DAP and 84 DAP. On the average the peak populations of *C. tomentosicollis* occurred on higher plant density of 190,474 plant ha^{-1} at 84 DAP. Thereafter there was a decline. Maximum population of *C. tomentosicollis* occurred in October planting at 84 DAP, decreased at 91 DAP and to zero level at 98 DAP and 105 DAP. April and July planting recorded zero population of *C. tomentosicollis.*

Fig. 5 (a and b) presents the effect of plant densities and planting dates on the population of *A. curvipes* on pigeonpea pods during 2009 planting season. The population of *A. curvipes* was significantly high on high density plants at 77 DAP, 91 DAP, 98 DAP and declined at 105 DAP. On the other hand, plants at low density maintained low population of *A. curvipes* from 77 DAP to 98 DAP and slightly increased at 105 DAP. Population of *A. curvipes* was significantly high in October at 91 DAP and 98 DAP, but sharply decreased to zero at 105 DAP. There was absence of *A. curvipes* during April and July plantings.

The result which shows the occurrence of *A. curvipes* on pigeonpea under different plant densities and planting dates during 2010 sowing season is presented in Fig. 6 (a and b). Significant population of *A. curvipes* on high density pigeonpea plants (190,474 plants ha^{-1}, 125,000 plants ha^{-1}) maximally occurred at 77 DAP, 91 DAP and 98 DAP while plants at low density of 55,556 plants ha^{-1}) maintained low population of *A. curvipes* from 70 DAP, 84 DAP, 91 DAP, 98 DAP and 105 DAP. At 84 DAP, population of *A. curvipes* on plants at low density of 80,000 plants ha^{-1} and 55,000 plants ha^{-1} was non-significant (P>0.05). The population of *A. curvipes* during October planting was highest at 91 DAP and 98 DAP. Again in 2010 planting season, there was absence of *A. curvipes* during April and July planting.

Table 2, presents the percentage pods and seed damaged by podsucking bugs, *R. dentipes*, *C. tomentosicollis* and *A. curvipes* (Plates 3, 4, 5) as well as percentage wholesome pods and seeds (Plate 2a, b, c, d) in 2009 and 2010 planting time. The results showed that pod and seed shriveled were significantly influenced by plant populations and planting dates at 5 % probability level. Plants at high density had more percentage pods and seeds damage compared with plants at low density during 2009 and 2010 planting seasons.

The damage decreases as plant density got decreased to 55,556 plants per hectare. Hence, plants at high density recorded poor wholesome pods and seeds.

Planting dates affected significantly (P<0.05) pods/seeds shriveled by pod sucking pods in 2009 and 2010 planting seasons. Generally, there was very high pest loads on the pigeonpea cultivar during April and October with consequent reduction in percentage wholesome pods and seeds. Planting in July 2009 and 2010 recorded the lowest percentage damage by pod sucking bugs with high percentage wholesome (Quality) pods and seeds, compared with April and October plantings. Result in Table 2 also revealed that interaction of plant populations and planting dates had significant influence on pods/ seed shriveled by pod sucking bugs damage as well as percentage wholesome (Quality) pods and seeds.

Table 3 presents data on yield and yield components, during 2009 and 2010 planting seasons. Plant population densities significantly (P<0.05) affected pod yield (kg ha^{-1} 2009), seed yield (kg ha^{-1}), and all the yield components. Also, planting dates significantly affected (P<0.05), all the yield and yield components observed in all the planting seasons.

Higher plant population gave higher pod yield (665.00 kg ha^{-1}) and pod yield per plant with reduced seed yield (147.90 kg ha^{-1}) while low plant density had lower pod yield (296.00 kg ha^{-1}) but gave higher seed yield (233.33 kg ha^{-1}) in 2009 and followed the same trend in 2010 planting time. With respect to 100 pod weight (g), and 100 seed weight (g), pigeonpea at higher plant population recorded low weights compared with plant population at lower plant population (wider spacing). Also seed yield per plant, and number of seeds per pod were higher at lower plant population compared with plants at higher plant density.

More pods were produced in April 2009 (444.00 kg ha^{-1}), July 2009 (525.00 kg ha^{-1}), and October 2009 (64.00 kg ha^{-1}), compared with 2010 pod yields of April (328.40 kg ha^{-1}), July (499.50 kg ha^{-1}), and October (60.40 kg ha^{-1}). With regards to seed yield (kg ha^{-1}), sowing pigeonpea within July produced more seed yield (kg ha^{-1}), followed by April while October had the poorest seed yield (kg ha^{-1}) in both cropping seasons therefore in all the planting seasons planting in July 2009 recorded the highest yields and yield components, followed by April planting and least with October planting.

Table 3 also shows that in both 2009 and 2010 planting seasons only pod yield (kg ha^{-1}), seed yield (kg ha^{-1}), pod yield (g), and seed yield (g), were significantly (P< 0.05), affected by interaction of planting dates and plant populations while other yield parameters were found not-significant (P> 0.05).

Plate 2. (a) Shriveled pods caused by pod sucking bugs

(b) Wholesome pods (undamaged pods)

(c) Shriveled seeds

(d) Wholesome seeds (undamaged seeds)

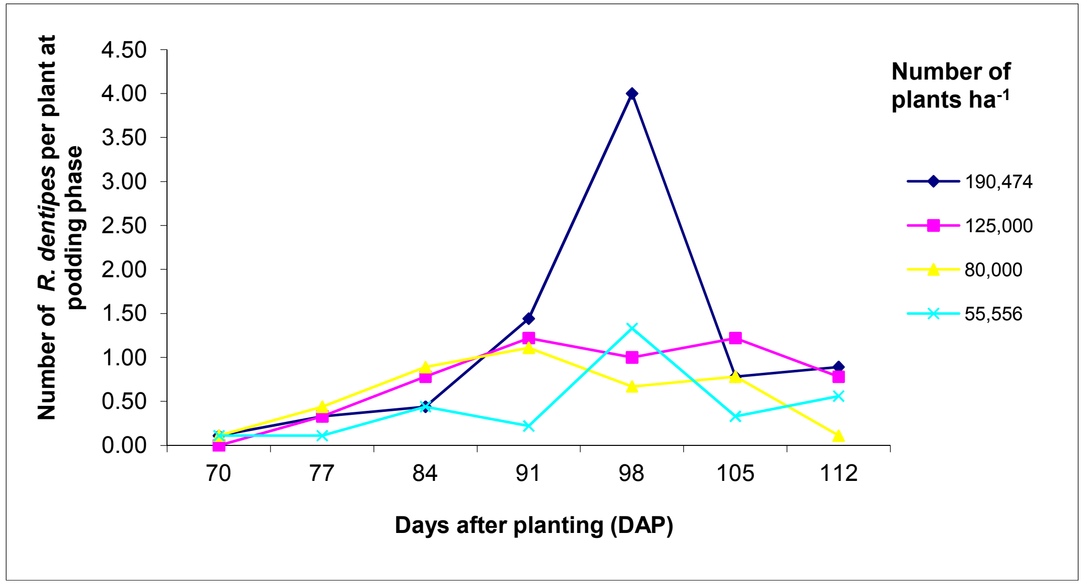

Fig. 1a. Effect of plant density on number of *R. dentipes* per plant at pigeonpea podding phase during 2009 season

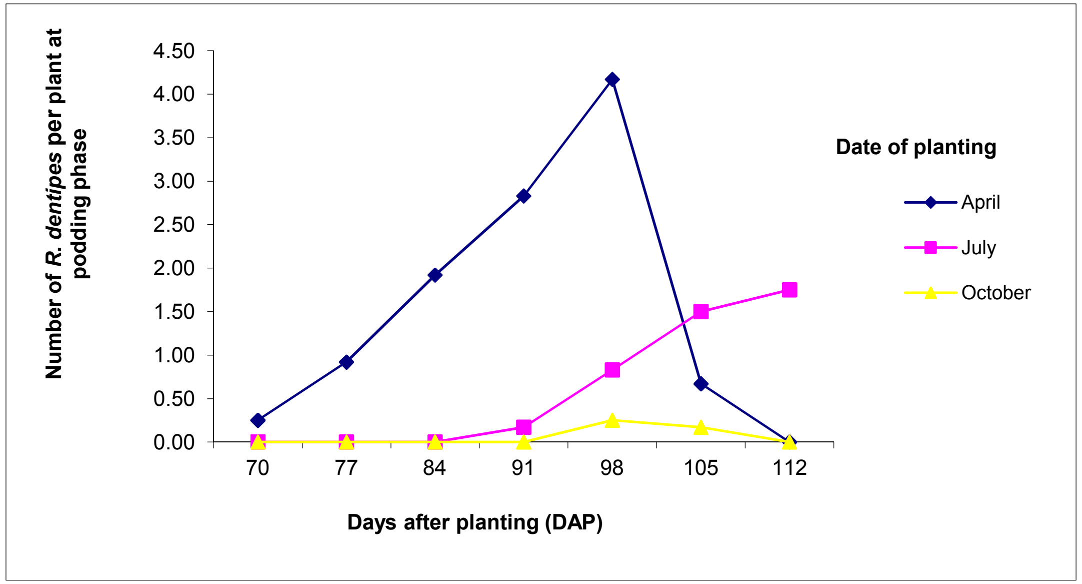

Fig. 1b. Effect of planting date on number of *R. dentipes* per plant at pigeonpea podding phase during 2009 season

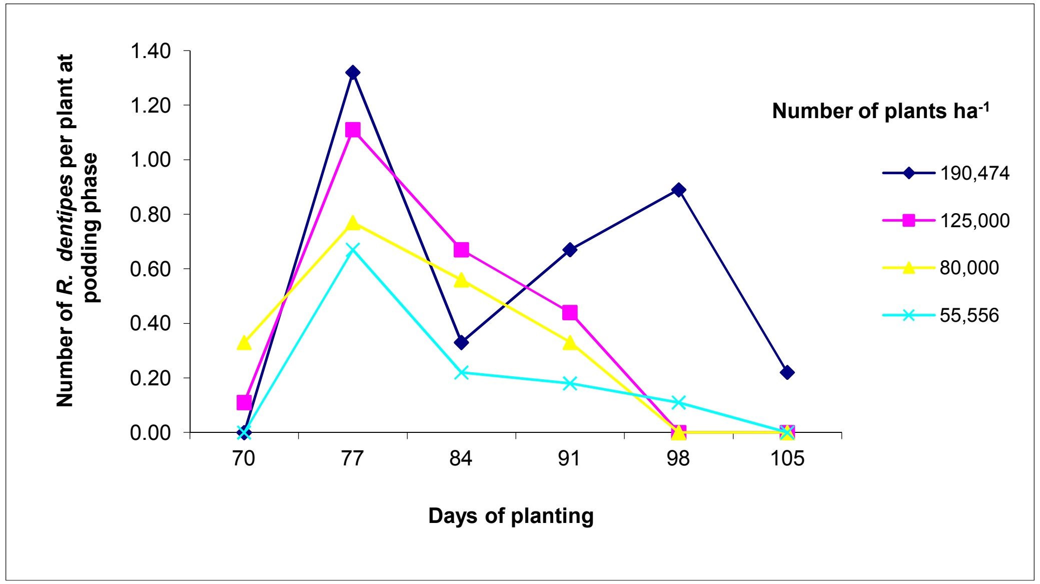

Fig. 2a. Effect of plant density on the number of *R. dentipes* per plant at pigeonpea podding phase during 2010 planting season

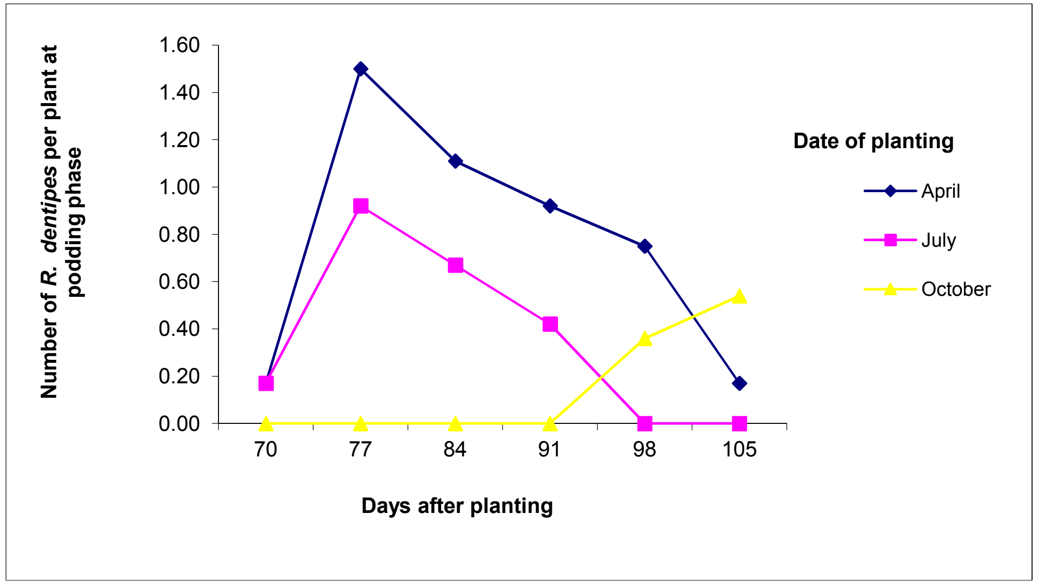

Fig. 2b. Effect of planting date on the number of *R. dentipes* per plant at pigeonpea podding phase during 2010 planting season

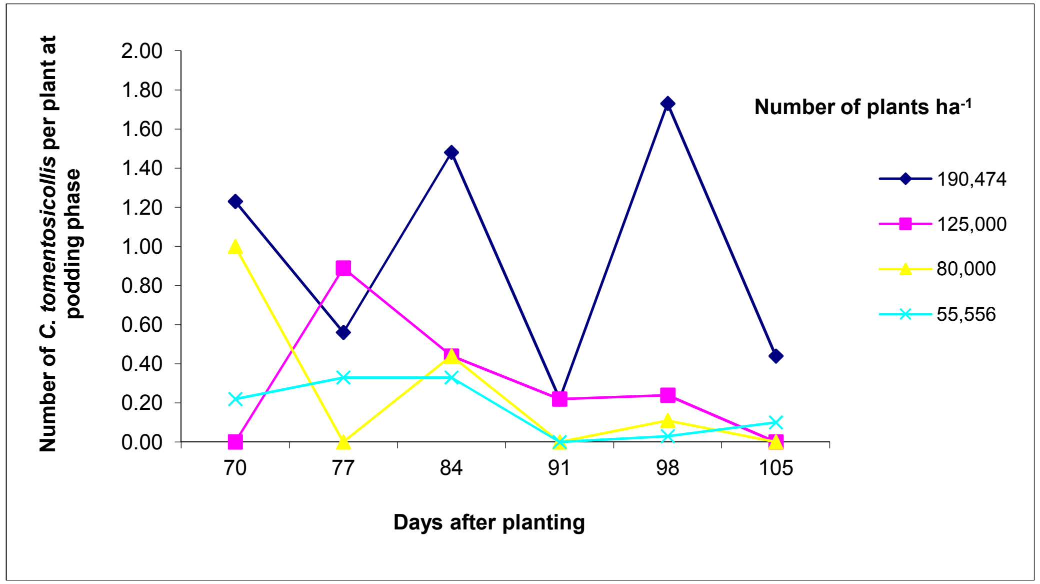

Fig. 3a. Effect of plant density on number of *C. tomentosicollis* per plant at pigeonpea podding phase during 2009 season

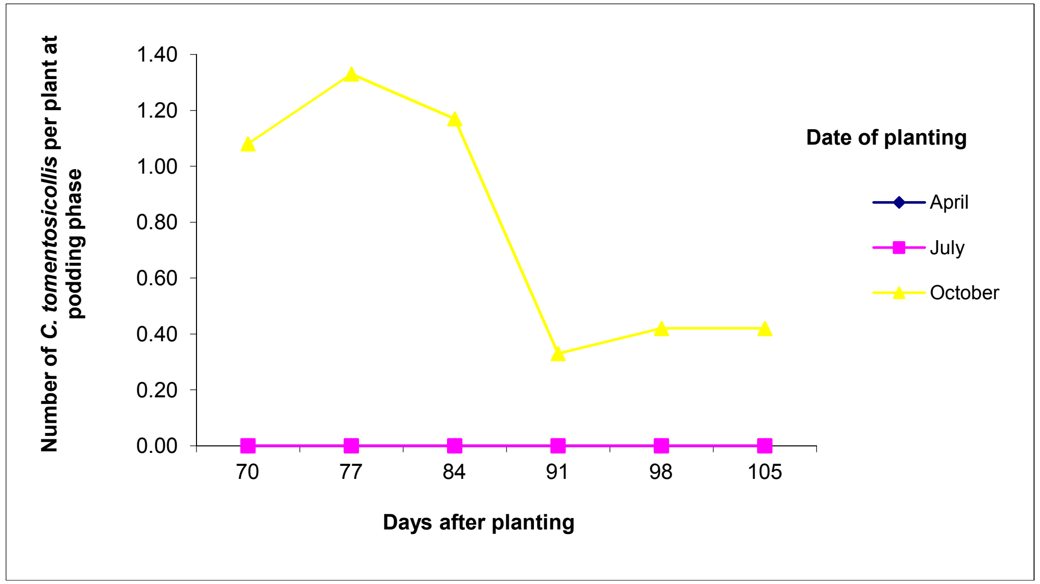

Fig. 3b. Effect of planting date on number of *C. tomentosicollis* per plant at pigeonpea podding phase during 2009 season

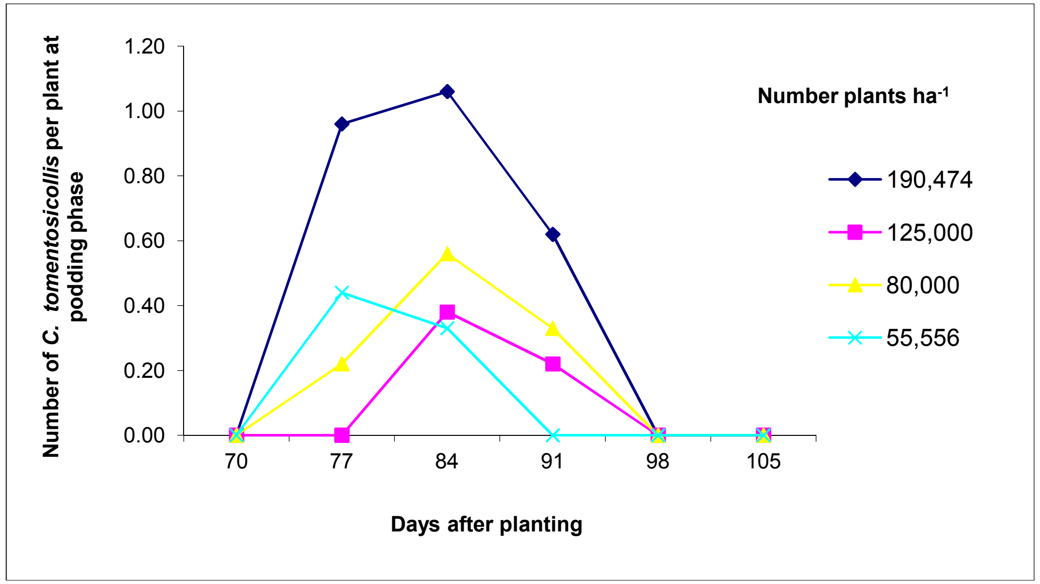

Fig. 4a. Effect of plant density on the number of *C. tomentosicollis* per plant at pigeonpea podding phase during 2010 planting season

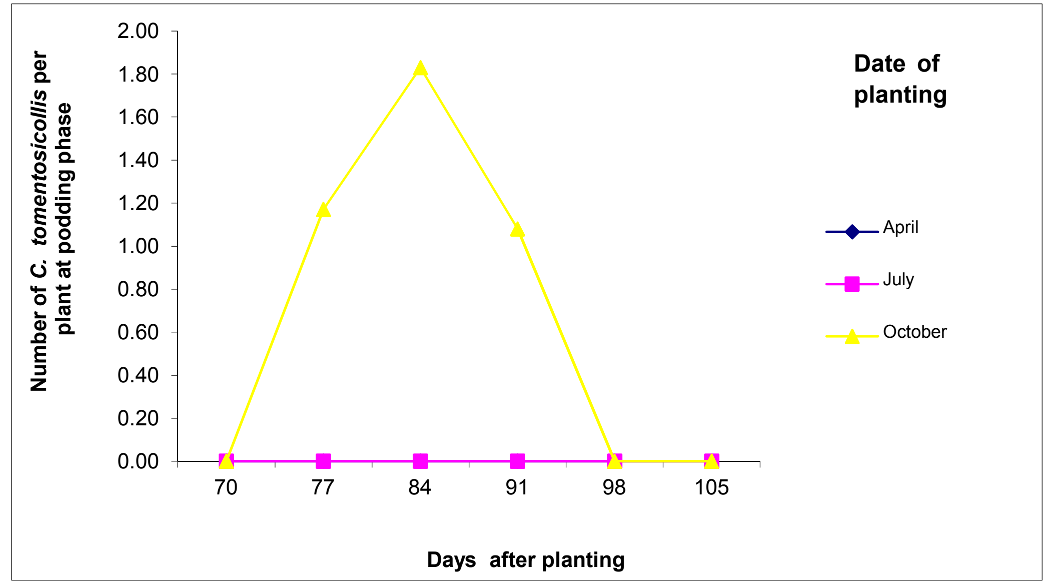

Fig. 4b. Effect of planting date on the number of *C. tomentosicollis* per plant at pigeonpea podding phase during 2010 planting season

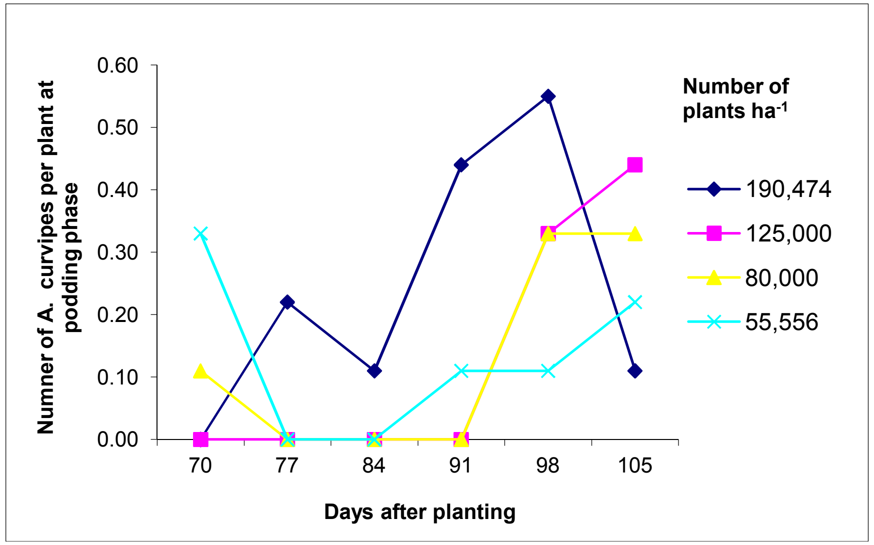

Fig. 5a. Effect of plant spacing on the number of *A. curvipes* per plant at pigeonpea podding phase during 2009 planting season

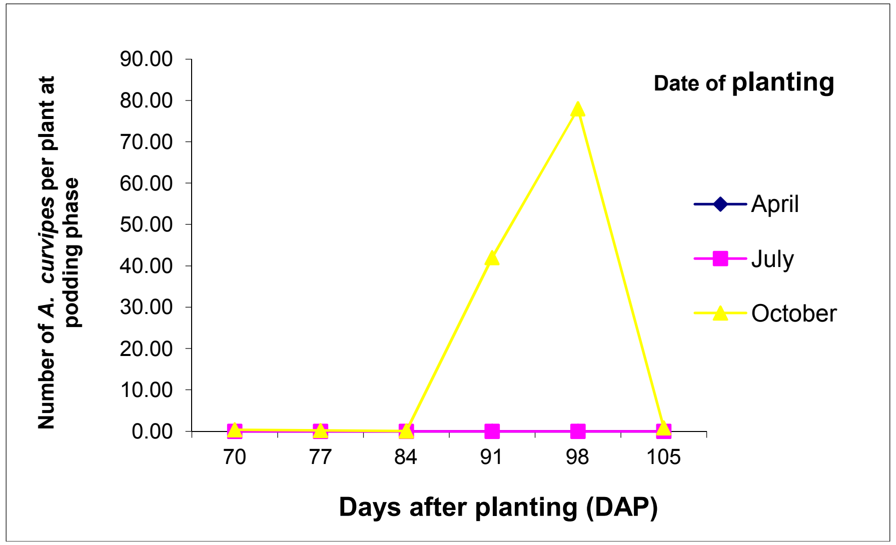

Fig. 5b. Effect of planting date on the number of *A. curvipes* per plant at pigeonpea podding phase during 2009 planting season

Table 1. Weather records from Federal Ministry of Aviation, Owerri Imo State, Nigeria

Year 2009	**Jan.**	**Feb.**	**Mar.**	**April**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Relative												
Humidity (%)	76	78	76	80	79	80	87	89	83	79	78	77
Total Rainfall (mm)	39	5.8	81.5	237.8	250	209	486	489	207.2	558	98.5	0
No. of Rain Days	3	3	3	12	12	10	20	23	12	18	5	0
Max. Temp. (°C)	34	35	35	34	34	36	33	33	37	32	33	30
Min. Temp. (°C)	15	15	15	14	15	17	18	18	21	20	18	18
Year 2010	**Jan.**	**Feb.**	**Mar.**	**April**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Relative												
Humidity (%)	72	71	85	84.2	87	90	91	89	89	79	79	85
Total Rainfall (mm)	0	78.7	26.9	141.7	220	352	428	745	360.4	399	67	0
No. of Rain Days	0	3	2	7	12	13	12	15	15	18	4	0
Max. Temp. (°C)	37	36	35	34.6	33	32	32.5	31.6	36.7	39	33	34
Min. Temp. (°C)	17	19	24	24	22	21.4	21	21	21.1	18	9	21

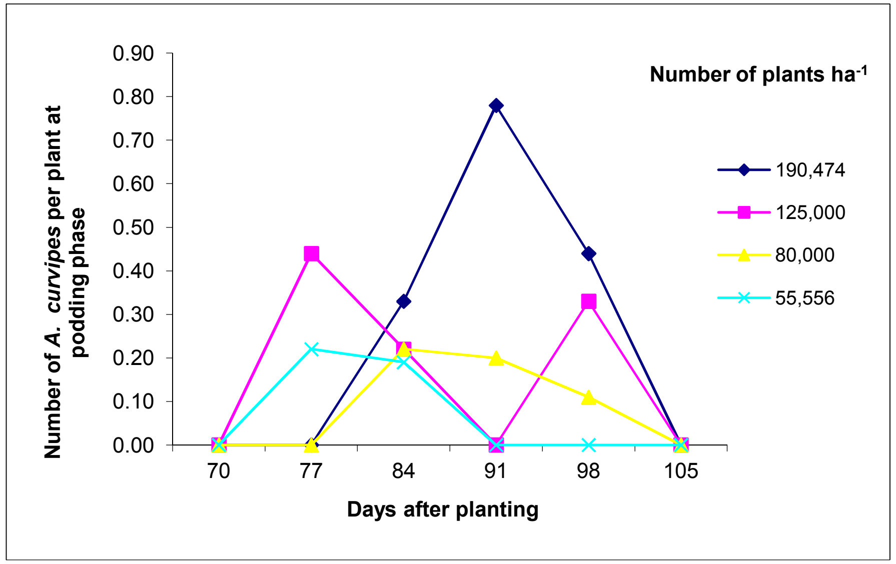

Fig. 6a. Effect of plant spacing on the number of *A. curvipes* per plant at pigeonpea podding phase during 2010 planting season

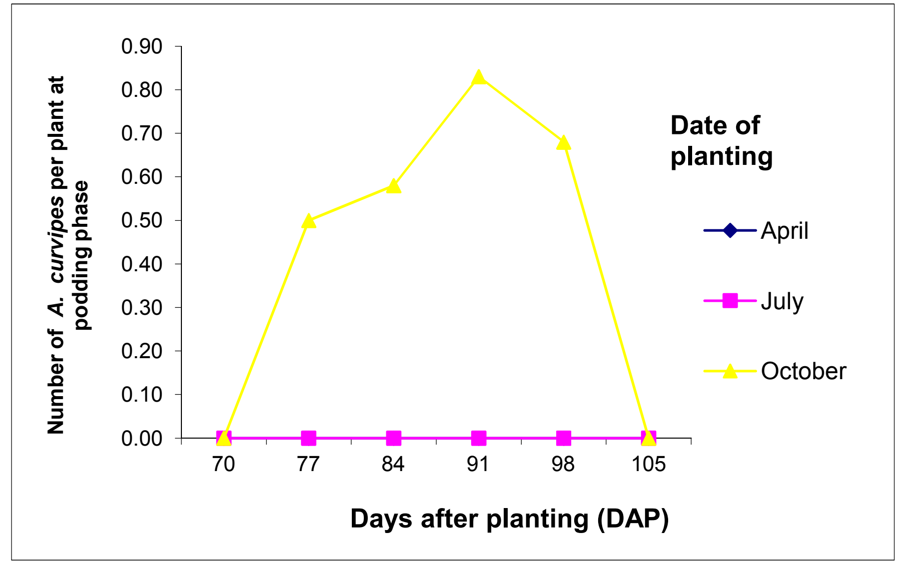

Fig. 6b. Effect of planting date on the number of *A. curvipes* per plant at pigeonpea podding phase during 2010 planting season

Table 2. Comparison of plant densities and planting dates on percentage damage of improved pigeonpea cultivar by major pod sucking bugs in Owerri, Imo State, Nigeria

Plant Pop. (PP) ha^{-1}	2009				2010			
	% pods shriveled by pod sucking bugs 100 pods^{-1}	% seeds shriveled by pod sucking bugs 100 seeds^{-1}	% wholesome pods 100 pods^{-1}	% wholesome seeds 100 seeds^{-1}	% pods shriveled by pod sucking bugs 100 pods^{-1}	% seeds shriveled by pod sucking bugs 100 seeds^{-1}	% wholesome pods 100 pods^{-1}	% wholesome seeds 100 seeds^{-1}
190,474	67.40	94.00	11.22	4.90	60.40	89.56	11.67	9.67
125,000	63.60	91.40	16.11	8.10	49.60	84.00	25.00	15.78
80,000	61.50	81.40	20.22	18.10	42.90	77.67	35.44	21.89
55,556	48.60	71.70	35.33	28.00	36.80	69.89	43.78	29.89
LSD 0.05	7.62	7.05	4.57	6.89	9.57	5.45	5.39	5.39
Planting dates								
(PD) April	76.00	93.40	14.08	5.90	45.80	95.50	25.33	3.58
July	48.20	63.70	47.25	35.50	35.00	47.08	61.58	52.67
October	56.60	96.80	0.83	2.90	61.60	98.25	0.00	1.67
LSD 0.05	6.60	6.11	4.28	5.96	8.29	4.72	4.67	4.67
Interaction								
PP × PD	13.19	12.22	1.14	11.83	16.57	9.43	9.33	9.33

Table 3. Effect of plant densities and planting dates on the yield and yield components of improved pigeonpea cultivar in Owerri, Nigeria (Dialoke et al. 2017)

Plant pop. ha^{-1} (PP)	2009							2010						
	Pod yield kg^{-1}	Seed yield kg^{-1}	100 pod weight (g)	100 seed weight (g)	Pod yield plant^{-1} (g)	Seed yield plant^{-1} (g)	Seeds pod^{-1}	Pod yield kg^{-1}	Seed yield kg^{-1}	100 pod weight (g)	100 seed weight (g)	Pod yield plant^{-1} (g)	Seed yield plant^{-1} (g)	Seeds pod^{-1}
55,556	296.00	223.33	14.05	3.99	4.64	4.87	3.92	277.10	268.83	17.34	5.00	3.24	5.09	4.04
80,000	343.00	198.70	12.89	3.30	5.76	3.70	3.57	322.30	238.44	14.46	3.91	4.23	3.78	3.68
125,000	475.00	173.88	12.44	2.67	5.00	3.90	2.91	468.90	196.26	12.27	3.57	4.12	3.32	3.00
190,474	665.00	147.90	8.91	2.61	5.94	3.10	2.14	586.00	168.80	9.91	3.18	4.35	3.07	2.19
LSD 0.05	105.00	19.48	3.18	0.87	0.79	0.42	0.68	47.94	25.24	4.72	1.14	0.83	0.69	0.62
Planting date (PD)														
April	444.00	295.30	13.21	2.35	6.71	4.57	3.31	328.40	287.9	9.24	2.87	5.05	4.47	3.13
July	525.00	353.20	19.6	5.77	7.95	5.86	3.59	499.50	368.00	29.85	8.00	7.62	6.13	4.12
October	64.00	57.50	3.40	1.31	0.99	0.87	2.51	60.40	56.60	1.4.0	0.87	0.91	0.85	2.43
LSD 0.05	90.90	16.87	2.76	0.75	1.18	0.36	0.58	41.94	21.86	4.09	0.99	0.72	0.60	0.54
Interaction														
PP × PD	181.9	33.73	N.S	N.S	N.S	0.72	N.S	83.04	43.72	N.S	N.S	1.36	1.19	N.S

Plate 3. *R. dentipes* Fab mating

Plate 4. *C. tomentoscicollis* stall

Plate 5. *A. curvipes* Fab. (adult) damaging pigeonpea flower buds

4. DISCUSSION

In both 2009 and 2010 seasons the high population of pod sucking bugs, *R. dentipes*, *C. tomentosicollis* and *A. curvipes* on plants at high densities of 190,474 plants ha^{-1} which decreased with decreased plant density of 55,556 plants ha^{-1} could be due to plant competition for growth resources. This struggle for survival must have compelled plants at high density to produce succulent pods faster at enough quantity than plants at low plant density. The succulent pods are liable to easy entry by bugs mandibles modified for piercing and sucking plant juice. In his work on early maturing pigeonpea [11] reported that there were high population of *A. curvipes* on plants at high density (closer spacing) than plants at low density (wider spacing). Also [18] on cowpea in Uganda reported that, close and irregularly spaced plants (higher density plants) had significantly higher pod sucking bug populations the first and second seasons of 2000 and 2001. This variation in time and quantity of pod production probably had direct effect on the population of nymphs and adults of *R. dentipes*, *C. tomentosicollis* and *A. curvipes* observed on early duration pigeonpea at different plant densities. This finding is in agreement with [19] and [20], who recorded high population of pod sucking bugs on plants at close spacing (high density) than at wide spacing (low density).

There was absence of *C. tomentosicollis* and *A. curvipes* during April and July planting and this could be due to the moderate rainfall in April planting season and high rainfall in July planting season which probably discouraged mating, oviposition and multiplication of the pest species. The significant population of *C. tomentosicollis* and *A. curvipes* during October planting coincided with the emergence of the nymphs of the bugs, hence sudden cessation of rainfall produced dry spell which probably favours feeding, mating, and multiplication of the bugs. This finding agreed with [11] who reported abundant population of *A. curvipes* on early maturing pigeonpea in the months of October. Also [21], who worked on cowpea earlier, observed in Ibadan high infestation of pod sucking bugs in the late season. [22], equally observed high population of *Nezera viridula* on pigeonpea flowering and podding stage in the months of October to December. [23], on rice also observed high population of stinkbug on rice planted late in a season.

A non- significant population *R. dentipes* on plant densities at some points within days after planting, indicates that *R. dentipes* is highly mobile and therefore spread evenly among the plant densities. *R. dentipes* is an active flyer and easily moves from one plant to another.

Maximum population of *R. dentipes* occurred in April 2009 than in April 2010 followed by July planting. October planting had the least population of *R. dentipes* in 2009 and 2010 planting seasons. At high temperature and reduced rainfall prevalent in April, population of *R. dentipes* increased. This finding is in agreement with [24], who also noted high population of *R. dentipes* on early maturing variety of pigeonpea (T-21). Also [25], recorded high relative abundance of *R. dentipes* (35.3% 2009 and 33.3% 2010) in April which decreased as planting was delayed till October. Higher population of grasshoppers (*Zonocerus variegatus* Fab.) was also observed on short duration pigeonpea cultivars at Nsukka derived savanna zone [26]. Invariably the impact of heavy rainfall and relative humidity put restriction to the fecundity and survival of the nymphs and adults of *R. dentipes*; hence the population was low during July planting season. During October planting, the impact of rainfall and sudden cessation of rainfall also affected the population of *R. dentipes* resulting again to reduced population compared with April and July plantings. This finding indicates that the amount and distribution of rainfall determine the population of *R. dentipes* on early maturing pigeonpea in this locality.

The greater percentage pod and seed damage at high plant population could be due to high infestation pressure of pod sucking bugs and cluster nature of pigeonpea plants brought about by high density of pigeonpea. Plants at low plant density have wide spaces in between them and this condition might put impediment/restrictions to feeding, movement, and oviposition of podsucking bugs resulting to low percentage insect damage. [27] in pigeonpea reported that a large number of pod sucking bugs, mainly, *R. dentipes, C. tomentosicollis, A. curvipes*, and *Mirperus* spp. feed on pigeonpea extensively at higher plant densities than at lower densities.

With regards to sowing dates the highest pods and seed shriveled was observed when pigeonpea was planted in October followed by April planting and least with July planting. Most of the unshedded pods were wrinkled without filling. The maximum pods and seed shriveled in October could be due to high pest infestation load of pod sucking bugs coupled with the cessation of rainfall at the onset of reproductive phase. Plants under environmental stress are struggling to survive and often are more attractive to insect pests and less tolerant of feeding damage. [28], reported in pigeonpea that late sowing encounters increase damage by pod suckers. Percentage pod and seed shriveled were low in July probably because of high rainfall and relative humidity (R.H) which probably caused the reduced activities of pod sucking bugs. Adults and nymphs feed on pigeonpea by piercing through the pod wall and extracting nutrients from the developing seeds [29]. Shriveled seeds do not germinate, carry very poor weight and are not acceptable as food for human consumption [29]. In cropping seasons (2009 and 2010), *R.dentipes* Fab.dominated the hemipteran species observed in April and July planting while *C. tomentosicollis* and *A. curvipes* dominated the species observed in October [30]. Damaged seeds were dark and shriveled, and may not germinate nor acceptable for human consumption.

Low percentage wholesome pod and seed were obtained from plants at higher plant densities compared to plants at lower plant densities. These differences in wholesome pod and seed could be related to high pest activities on plants at high plant densities compared with low or moderate pest loads on plants at low plant densities. [31] studied pigeonpea pests in different parts of Africa and reported that high quality grains were obtained from pigeonpea plants grown at lower plant densities.

Low pests loads in July, could have been responsible for the high percentage wholesome pod and seed while high pests loads in midst of water stress could be responsible for the total crop failure in October. [32] observed in pigeonpea that in coastal province Kenya, with low temperature and cold condition pigeonpea pod and seed damage was low due to reduced insect pests activities, but in Eastern province with high temperature and relative humidity the highest pod and seed damage was caused by pod sucking bugs followed by pod fly (*Melanagromyza obtusa)*. Therefore, high population of pests at podding stage could lead to total crop loss, especially where there is little or no rain to trigger new flushes or re-growth [33].

More pod yield at higher density might be due to increased plant population per unit area and taller plants under high plant density. [34,35,36, 37], found that improved varieties of cowpea that are erect in nature could be grown at a higher plant population to maximize yield. Low density pigeonpea plants had increased seed yield (kg ha^{-1}) probably due to reduced volume of pest population on pigeonpea which encouraged pod filling with high quality seeds. [38,39,40] reported increased seed yield (kg ha^{-1}) at lower density of pigeonpea.

Planting the early maturing cultivar in July produced the highest seed yield probably because the period received less insect pest infestation compared with April and October plantings with high insect pest infestation and lower pod and seed yield (kg ha^{-1}). A significant effect of sowing dates on pigeonpea was earlier reported by [41].

In late sown (October) pigeonpea, sudden cessation of rainfall affected the plants growth with less pod setting. [42] in his work in India, earlier recorded that moisture deficiency adversely affected the yield of early maturing pigeonpea cultivar (ICPL 88039), and followed by chickpea (ICCV 2) in post rainy season (October-February). Delayed and reduced flowering observed during October planting must also have contributed to the low yield values obtained [28]. These conditions (cessation of rainfall delayed and reduced flowering) coupled with high population of pod sucking bugs, infestation probably resulted to the poor pod and seed yield (kg ha^{-1}) observed. This result agreed with [43] and [44] who reported in pigeonpea that increased yield losses due to pod borers were higher on crops flowering and maturing during warm weather than on crops maturing during cool weather.

In the early sown (April), inadequate rainfall at seedling stage stunted the plant growth and development with high thrips, *M. usitatus*, flower blister beetles, *M. pustulata*, podsucking bugs, *R. dentipes*, resulting to moderate yield observed [29]. These findings were agreed with [45] who recorded lower grain yield (kg ha^{-1}) of Mungbean during early and late sown crops due to high pest infestation while the mid-sown crops produced appreciable yield due to less pest infestation.

The lower plant population (55,556 plants ha^{-1}) produced the highest pod and seed yield (g) per plant compared with the yields of plant population at higher density (190,474 plant ha^{-1}). These findings indicated that the increase in pod and seed yield per plant at lower plant density might be as a result of availability of better growth resource to the individual plant compared with plants at higher plant density. These results were quite similar to the findings of [46] and [40] who reported higher number of pods per plant, seeds per plant on pigeonpea at lower plant population than at higher population. [47], in mungbean, [37] in cowpea and [48], who worked on Chickpea (*Cicer arietinum*), also reported that the number of pods per plant decreased in highest planting density. The decreased pod production per plant with increasing plant population of 190,474 plants ha^{-1} was presumably due to plant to plant competition for growth resources.

Generally, greater values of the yield components, seed yield per pod, 100 pod and seed weight were noticed at lower plant population of 55,556 plants ha^{-1} as compared with the lower values obtained from 190,474 plants ha^{-1}. This could be due to the ability of 55,556 plants ha^{-1} to produce more seeds per pod through exhibition of better vegetative growth and increased reproductive growth phase which favoured the number of seeds per pod. This result agreed with the finding by [49], in soybean and [40], who observed increased number of seeds per pod at lower plant density and lower values at higher plant density.

With respect to 100 pod and seed weight (g), short vegetative growth period and comparatively longer reproductive and grain filling period significantly raised 100 pod and seed yield. This result was similar to the observation made by [50] in pigeonpea, [51], on mungbean who observed significant influence of plant pattern on 100 seed yield.

July sown crops produced the highest values in all the yield components, followed by April sown crops while October sown plants had the poorest values resulting to total crop failure. This agrees with [52] who worked on short duration pigeonpea cultivars at Nsukka and reported low percentage seed damage by pod borer (22.72% in 2008 and 27.24% in 2009) and podsucking bugs (33.75% in 2008 and 32.74% in 2009) in June with high seed yield (809.93 kg ha^{-1} in 2008 and 840.84 kg ha^{-1} in 2009) compared with April and August planting seasons. Favourable climatic conditions and less pest loads on early maturing pigeonpea plants might be responsible for the better performance observed during July sown crops compared with April and October plantings. This observation was supported by [53], who observed climatic effects on pod sucking bugs in Kenya with regards to pigeonpea pods and seeds damage in different locations.

5. CONCLUSION AND RECOMMENDATIONS

The population of *R. dentipes* occurred throughout the planting seasons while the population of *C. tomentosicollis* and *A. curvipes* occurred only during October planting seasons mostly at high plant density (190,474 (kg ha^{-1}) than at low density (55,556 kg ha^{-1}). Yields (kg ha^{-1}) of pigeonpea were low with high pest damage at high plant density (190,474 (kg ha^{-1}) during October and April planting seasons. July planting had the best pod and seed yield (kg ha^{-1}) with minimal pest populations at low plant density (55,556 kg ha^{-1}) than at high plant density (190,474 (kg ha^{-1}).Therefore, in Nigeria and with particular reference to Imo State, for efficient production, it should be practically wise to plant the early maturing duration pigeonpea cultivar (ICPL 84023) in the month of July at low plant density (55,556 kg ha^{-1}). Efforts should be made by relevant Agency of Federal Government to support further research on production, breeding and pest management of short duration pigeonpea in different localities as this move will ensure sustainable food security in Nigeria and national income through export promotion programmes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Van der Maesen LJG. Pigeonpea: Origin, history and evolution, taxonomy. In: Y. L. Nene, S.H. Hill, and V. K. Sheila. The pigeonpea, Cab international, Wallingford, U.K. 1990;15-46.
2. Food and Agricultural Organization (FAO); 2007. Available:http:// www.faostat.fao.org
3. Singh L. Overview of pigeonpea improvement research: Objectives, achievements, and looking ahead in the African content. In: Laxman S, Silim SN, Ariyanayagam RP, Reedy MV, (eds). Proceedings of the first Eastern and Southern Africa regional legumes (pigeonpea) workshop. 25-27 June 1990, Nairobi, Kenya. East Africa Regional Cereals and Legumes (EARCAL) Programme. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 1991;5-8.
4. Dialoke SA, Agu CM, Ojiako FO, Onweremadu E, Onyishi GO, Ozor N, et al. Survey of insect pests on pigeonpea in Nigeria. Journal of SAT Agricultural Research 8, ICRISAT, India; 2010.
5. Nene YL, Sheila VK. Pigeonpea: Geography and importance. In: Y.L. Nene, S.H. Hill, and V.K. Sheila. The Pigeonpea. CAB International Wallingford, U.K. 1990; 1-14.
6. Faris DG, Singh U. Pigeonpea: Nutrition and products. In: Nene, Y. L., Hall, S. D., Sheila, V. K (eds). The pigeonpea Wallingford, U.K. CAB International; 1990.
7. Kabuo NO, Dialoke SA, Onuegbu N, Nwosu JN, Peter-Ikechukwu AI Ogbu IR. Utilization of tender pigeonpea (*Cajanus cajan* (L.) Millsp. in Nigeria. Journal of Food Science and Quality management, International Institute for science, Technology and education (IISTE). 2015; 37:110-115.
   Available:www.iiste.org
   ISSN: 2224-6088 (Paper)
   ISSN: 2225-0557 (Online)
8. Foodnet, R-Directory of commodities. Pigeonpea; 2002.
   Available:http//:www.foodnet.cgiar/market, http://www.fao.org/fileadmin/templates/ess/documents/food_security_statis Tics/FoodConsumptionFoodGroups_en.xls (includes all food pulses as defined by FAO food category "pulses") (dry bean, chickpea, cowpea, lentil, pigeon pea, faba bean, pulses, nes, bambara beans, lupins, green peas).
9. Protein Advisory Group (PAG). Nutritional improvement of food legumes by breeding. Proceedings of Protein Advisory Group (PAG) symposium. Food and Agricultural Organization of the United Nations, Rome. 1972;3-5.
10. Sharma D, Green JM. Pigeonpea. In: Hybridization of crop plants, by Fehr, Walter R. 1980;471-481.
11. Dialoke SA. Egho EO., Bosah BO., Enujeke EC. Population dynamics of podsucking bug (*Anoplocnemis curvipes* Hemiptera: Coreidae) on improved pigeonpea pods under different plant spacing and time of sowing in Owerri, Rainforest Tropical Environment, Nigeria. Advances in Life Science and Technology, International Institute for science, Technology and education (IISTE). 2013a; 10:12-16.
    Available:www.iiste.org
    ISSN: 2224-7181 (Paper)
    ISSN: 2225-062X (Online)
12. Dialoke SA, Ojiako FO, Bosah BO, Peter-Onoh CA. Influence of plant densities and planting dates on the population of pigeonpea flower blister beetles (*Mylabris pustulata* Thunberg) in Owerri, Imo State, Nigeria. The Bioscan, An international quarterly Journal of life Sciences India. 2014a;9(1):41-44.
    Available:www.thebioscan.in
13. Dialoke SA. The population of leaf beetles (*Leptualaca fassicollis* thoms Coleoptera: Chrysomelidae and flower thrips (*Megalurothrips usitatus* Bagnall, Thysanoptera: Thripidae) on pigeonpea under the influence of plant density and planting date in a rain forest Zone, Nigeria. Journal of Biology, Agriculture and Healthcare, International Institute for

Science, Technology and Education (IISTE) U.S.A. 2013;8:81-86.
Available:www.iiste.org
ISSN: 2224-3208 (Paper)
ISSN: 2225093X (Online)

14. Amatobi CI. Field evaluation of some insecticides for the control of insect pests of cowpea, *Vigna unguiculata* (L.) Walp in the Sudan savannah of Nigeria. Intl J. Pest Manage. 1994;40:13-17.
15. Reed W, Lateef SS, Sithanantham, Pawar CS. Pigeonpea and chickpea insect identification Handbook Information bulletin No. 26. Patancheru, Andhra Pradesh 502 324. International Crops Research Institute for the Semi-Arid Tropics; 1989.
16. Manisha J, Rasmi U, Lata D. Evaluation of effect of different pesticides on pigeonpea using statistical tools in field experiment. IOSR Journal of environmental Science, Toxicology and food Technology. 2014; 8(1):24-27.
17. Genstat Release Edition 3. 2009; Free version of Statistical package. Available:http://www.discovery.genstat.co.uk
18. Nabirye J, Namapala P. Ogenga-Latigo MW, Kyamanywa S, Wilson H, Odeke, et al. Farmer participatory evaluation of cowpea integrated pest management (IPM) technologies in Eastern, Uganda. Journal of Crop Protection. 2003;22:31-38. Available:www.elsevier.com/locate/cropro
19. Akhilesh K. Parasnath D. Pest complex and their population dynamics on an early variety of pigeonpea UPAS-120 at varanesi. Ind. J. Ent. 2003;65(4):453-460.
20. Rao RGV, Saxena KB, Yang Shiying P. Wagisan G. Insect pests problems of pigeonpea in Gangeni and Hainsan province of China. International Chickpea and Pigeonpea Newsletter. 2002;48.
21. Dina SO. Interactions between rate, spraying intervals, and number of applicationof the synthetic pyrethroid Decis in cowpea (*Vigna unguiculata*) pest control. J. Agric. Camb. 1982;99:471-478.
22. Srilaxml K, Ravinda P. Diversity of insect pests of pigeonpea (*Cajanus cajan* (L.) Millsp) and their succession in relation to crop phenology in Gulbarga, Karnataka. The Ecascan. 2010;4(4):273-276.
23. Foster RE, Chery RH, Jones DB. Spatial distribution of the rice stinkbug *Oebalus pugnax* (F.) (Heteroptera: Pentatomidae) I Florida rice. Journal of Econ. Entomol. 1986;86(2):507-509.
24. Subharani S, Singh TK. Insect pest complex of pigeonpea (*Cajanus cajan*) in agro-ecosystem of Manipur. Indl. J. Ent. 2004;66(3):222-224.
25. Dialoke S A, Peter-Onoh CA, Ibeawuchi II, Ngwuta AA, Kabuo NO, Cookey CO, et al. The insect orders and relative abundance (R.A) of major pests species on early maturing pigeonpea cultivar (*Cajanus cajan* (L.) Millsp. in Imo State, Nigeria. International Journal of Agric. and Rural Dev. (IJARD). 2013b;16(1):1437-1444. ISSN: 1595-9716.
26. Dialoke SA, Ezueh MI. Population dynamics of insect pests on short duration pigeon pea cultivar at three planting dates Under Nsukka agro-ecological zone of Nigeria. Journal of Agriculture, Forestry and the Social Sciences (JOAFSS). 2003; 1(1):6-16.
ISSN: 1597-0906.
27. Singh HK, Singh HN. Some major pest incidence on certain late maturing pigeonpea *Cajanus cajan* L. during half pod formation stage. Indl. J. Ent. 1991; 53(2):298-303.
28. Lateef SS, Reed W. Insect pests of pigeonpea. Pages 193-242 In: insect pests of tropical legumes (Singh, S.R., Eds.). Chichester, U.K. Wiley; 1980.
29. Kyamanywa S, Akonga T, Rubaihayo PR. Past and current studies on ecology and management of insect pestsof pigeonpea. In: Silim, S.N., Mergeai, G., and Kimani, P.M., (eds) (2000). Status and potential of pigeonpea in Eastern and Southern Africa; Proceedings of a Regional Legume workshop, 12-15 September 2000, Nairobi Kenya. ICRISAT; 2001.
30. Dialoke SA, Emosairue SO, Egho EO, Ogoke IJ. Insect species associated with early maturing pugeonpea in Nigeria. Indian Journal of Entomology. 2014b; 76(4):330-336
31. Materu MEA. Damage caused by *Acanthomia tomentosicollis* stal. and *A. horrida* Germ. (Hemiptera: Coreidae). East African Agricultural and Forestry Journal. 1970;35(4):429-435.
32. Minja EM, Shanower TG, Songa JM, Ong'aro JM, Kawonga WT, Mviha PJ, et al. Studies of pigeonpea insect pests and their management in Kenya, Malawi, Tanzania, and Uganda. African Crop Science Journal. 1999;7:59-69.

33. Omanga PA, Singh L, Shakoor A. Pigeonpea production systems, insect pest damage and grain characteristics of pigeonpea landraces in kenya. In: Singh Lexman, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., (eds.). Proceedings of the first Eastern and Southern African Regional Legumes (Pigeonpea) workshop, 25-27 Jan. 1990, Nairobi, Kenya. P. O. BOX 39063, Nairobi, Kenya: Eastern African Regional Cereals and Legumes (EARCAL) programme, ICRISAT; 1990.
34. Dzemo WD, Niba AS, Asiwe JAN. Effect of insecticide spray on insect pest infestation and yield of cowpea (*Vign unguiculata* (L.) Walp in the Transkei, South Africa. African Journal of Biotectnology. 2010;9(11):1673-1679.
35. Okeleye KA, Ariyo OJ, Olowe VI. Evaluation of crop cultivars for stability and performance in humid environment. Nigerian Agricultural Journal. 1999;30:12-17.
36. Shetty SVR, Ntare BR, Batiano A, Renard C. Millet and cowpea in mixed farming of the Sahel. A review of strategies for increased productivity and sustainability, In: Livestock and sustainable nutrient cycling in mixed farming systems of Sub-Saharan Africa. Powell J.M., Fernendez R.S., Williams T.O., Renard C., Eds. Proceedings of International conference, International livestock centre of Africa, Addis Ababa, Ethiopia. 1995;293-304.
37. Tarawali S, Singh BB, Peters M, Blade SF. Cowpea haulms as fodder, In: Advances in cowpea Research Singh B.B., Mohan, Raj D.R., Dashiell K.E., Jackai L.E. N Eds. International Institute of Tropical Agriculture/Japan International Centre for Agricultural Sciences. 1997;313-425.
38. Ali B, Izge AU, Odo PE, Aminu D. Varietal performance of Dual purpose dry season cowpea (*Vigna unguiculata* L. Walp) under varying plant spacing in the Fadama in North Eastern, Nigeria. American Eurasian, Journal of Sustainable Agriculture. 2009;3(1):13-18.
39. Obuo JE, Okurut-Akol FA, Silim SN. Effect of spacing on yield of two pigeonpea cultivars in Uganda. In: Improvement of pigeonpea in Eastern and Southern Africa: Annual Research planning meeting 1995, 11-12 October 1995, Lilongwe, Malawi. Silim, S.N., and Tuwafe, S. (Eds.). International Crops Research Institute for the Semi-Arid Tropics: Southern and Eastern Region, Bulawayo, Zimbabwe. 1996;101-100.
40. Okurut-Akol FH, Silim SN, Opio C. Pigeonpea on-farm research and demonstration in Northen, Uganda. In: Improvement of pigeonpea in Eastern and Southern Africa: Annual Research planning meeting 1995, 11-12 October 1995, Lilongwe, Malawi. Silim S.N., and Tuwafe, S. (Eds.). International Crops Research Institute for the Semi-Arid Tropics: Southern and Eastern Region, Bulawayo, Zimbabwe. 1996;101-100.
41. Rubaihayo PR, Osiru DSO, Okware P. Performance of pigeonpea and its finger millet and sorghum intercrops. African Crop Science Journal. 2000;1:49-62.
42. Rati JK, Shekhon HS. (1975). Response of pigeonpea to dates of planting and phosphorus levels. Indian Journal of Agronomy. 2000;20:376-377.
43. Rupela OP, Gowda CLL, Wani, SP, Ranga Rao. Lessons from nonchemical input treatment based on scientific and traditional knowledge in a long term experiment. In the proceedings of the international conference on Agricultural heritage in Asia, 6-8 Dec., 2004, Asian Agri. History Foundation, Secundrabad, International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, 502 324, Andhra Pradesh, India. 2004; 184-186.
44. Minja EM. Insect pests of pigeonpea and yield losses in Eastern and Southern Africa: a preliminary Report. In: Improvement of pigeonpea in Eastern and Southern Africa: Annual Research planning meeting, 1995,11-12 Oct. 1995, Litongwe, Malawi. Silim, S.N., and Tuwafe, S., (Eds), International Crops Research Institute for the Semi-Arid Tropics, Southern and Eastern, Region,Bulawayo, Zimbabwe. 1996;14-23.
45. Hossain MA, Prodhani MZH, Sarker MA. Sowing dates: A major factor on the incidence of major Insect pests and yield of Mungbean. J. Agric. Rural Dev. 2009; 7(1- 2):127-133.
46. Biswas DK, Haque MM, Hamid A, Ahmed JU, Rahman MA. Influence of plant population density on growth and yield of two black gram varieties. Agron. 2002;1: 83-85.
47. Gebologlue N, Ecc A, Yazgan A. The effect of different sowing periods on the agronomic characteristics of mungbean

(*Vigna radiate* L.) in the ecological conditions of Tokat (Turkey). Act Hort. J. 1996;1(462):259-264.

48. Jettner RJ, Siddique KHM, Loss SP, French RJ. Optimum plant density of desi Chickpea (*Cicer arietinum* L.) increasing yield potential in South Western Australia. Aust. J. Agric. Res. 1999;50:1017-102.
49. Kil KY, Mira K, Nimks C, Yangmun P. Effect of planting date and plant density on growth and yield of soybean in Cheju Island. Korean J. Crop Sci. 1987;43(1):44-48.
50. Singh A, Prasad R, Saraf CS. Effect of variety, row spacing and phosphate fertilization on yields and moisture extraction pattern in pigeonpea. Indian Journal of Agronomy. 1973;28:33-36.
51. Asgher Malik M, Farrukh Saleem M, Ashar Ali, Rana Faraz Ishaq. Effects of sowing dates and planting patterns on growth and yield of mungbeans *Vigna radiata*, (L.). J. Agric., Res. 2006;44(2).
52. Dialoke SA, Ngwuta AA, Kabuo NO, Ofor MO, Tom CT. Effect of time of planting on major insect pests and yield performance of three short duration pigeonpea (*Cajanus cajan* (L.) Millsp.) cultivars in Nsukka agro-ecological zone, Nigeria. SAT e. Journal. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 2014c; 12:1-6.
    Available:ejournal.ecrisat.org
53. Omanga PA, Singh L, Shakoor A. Pigeonpea production systems, insect pest damage and grain characteristics of pigeonpea landraces in kenya. In: singh Lexman, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V., (eds.). Proceedings of the first Eastern and Southern African Regional Legumes (Pigeonpea) workshop, 25-27 Jan. 1990, Nairobi, Kenya. P. O. BOX 39063, Nairobi, Kenya: Eastern African Regional Cereals and Legumes (EARCAL) Programme, ICRISAT; 1990.

Peer-review history:
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