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Review

Environmental factors affecting growth and development of Banlangen *(Radix Isatidis)* in China

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Banlangen (*Radix Isatidis*) is an herbal medicine, and grows in various parts of China. It can be classified into North *Radix Isatidis* and South *Radix Isatidis*. With the rising demand of users all over the world, more and more popularly used herbal plants are now grown in agricultural fields. The natural force of supply and demand has encouraged the cultivation of Banlangen in China. However, the cultivation of Banlangen at a large scale does not always result in high yield and good quality, because many agronomic factors have an influence on the growth of Banlangen, such as variety, soil properties, climate and other environmental factors. This paper provides a brief review on the progresses of recent research regarding agronomic factors that affect the growth and quality of Banlangen in China and elsewhere.

Key words: Banlangen *(Radix Isatidis)*, agronomic factors, growth, quality.

INTRODUCTION

Nature of Chinese material is the nucleus in the theory of Chinese material medicine based on the recognition of traditional Chinese medicine, which is the character of the drug related to curative effect (Gao, 2012). Banlangen (*Radix Isatidis*) is an official herbal medicine with the part of anti-virus, anti-endotoxin, anti-inflammatory and improve immune system and grows in various parts of China (Chen et al., 2011; Du et al., 2013; Li and Yang, 2014). Studies have shown that the drawing material of *R. Isatidis* had a strong effect as antiviral, and which is often used in preventing virus or bacterial infection in clinical practice, and therefore, the *R. Isatidis* is considered to prevent diseases of pestilent maculae, fever headache, swollen-head infection, scarlet fever, pharyngitis, chicken pox, measles,hepatitis and flu (Huang, 2009; Guo et al., 2011; Xiao et al., 2014; Chen et al., 2015).

R. Isatidis can be classified into North *R. Isatidis* and South *R. Isatidis*. North *R. Isatidies* is the root of *Isatis indigotica* Fortune which belongs to Cruciferae family.

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South *R. Isatidies* is the root of *Strobilanthes cusia* (Ness) Bremek which belong to the Acathaceae family (Lou and Qin, 1995). Because of the differences between them in origin, trait, chemical composition, function and indications, it is common to distinguish between them in clinical application. Formation of Chinese material medical nature shows that the herbal plants receives the change of physical environmental factors, and resulted from the synthesis of the factors, including climate, soil, biology, and topography (Tang et al., 2010). Like other crops, growth and development of medicinal plants are affected by environmental factors (Yang and Tian, 2004). Previous studies showed that biological environment would have effect on plant morphology, especially blade size, texture, thickness and plant morphology (Huang et al., 2009).

CLIMATIC FACTORS

Climatic factors include light, temperature, moisture, and so on (Yang and Tian, 2004). They determine the processes of soil water and heat conditions, and are the primary factors for the development of Chinese herbal medicine (Yang et al., 2001). There are different requirements for environmental conditions between different varieties; wild species and cultivars from germination to its growth stage of *R. Isatidis*. Temperature and moisture are two important factors for the germination of *I. indigotica* seeds, and 30°C is the optimum germination temperature (Bai et al., 2009; Dong et al., 2006). The optimal growth temperature for *I. indigotica* fort is 18 - 23°C during the day and 13 -18°C at night and the optimal humidity is 80 - 90% (Ma and Lian, 2005). But appropriate low temperature stress will increase content of indirubin (Duan, 2006). *Baphicacanthus cusia* (Nees) is mainly distributed in Jiangsu, Zhejiang, Fujian, Taiwan, Guangdong, Guangxi, Guizhou and Yunnan of China. It also likes sunshine and warm temperature. *B. cusia* (Nees) grows well at temperature of 15 - 30°C and humidity of 70% or more (Du, 2008). Different condition of slight temperature and humidity may result in difference in yield and quality of *R. Isatidis* (Yang et al., 2001).

Light is one of the most important environmental factors that affect plant survival, growth, reproduction and distribution of *R. Isatidis*, although, it had no significant effects on seed germination (Bai et al., 2009) and adequate illumination time is conducive to increase plant height, number of branches,_dry matter weight and indirubin content (Du, 2008). Adequate illumination can improve the yield and quality of *B. cusia* (Nees); light intensity affects photosynthesis and different plant species respond differently to light intensity (Anjana and Pramod, 2010). The strength of illumination will bring different actions on the growth and development of traditional Chinese medicine for different varieties (Yang et al., 2001). Under given environmental conditions, net photosynthetic rate (Pn) and water use efficiency of *R. Isatidis* leaves increased with photosynthetically active radiation (PAR), but when the PAR reaches certain threshold, the net photosynthetic rate and water use efficiency decline (Zhang et al., 2004), which may be caused by excess light photoinhibition (Powles, 1984).

SOIL FACTORS

Soil factors include soil texture, physical and chemical properties, field holding capacity, nutrient and so on (Yang et al., 2004). *R. Isatidis* plants generally have no strict soil requirements, with soil pH from slightly acidic to slightly alkaline. However, it is conducive to growth of *R. Isatidis* in loose and fertile sandy loam or light sandy, with soil temperature around 18°C and soil moisture at 60 - 80% (Ma et al., 2005). For *B. cusia* (Nees), in the optimal soil conditions are acidic or neutral sandy soil or loam, soil moisture at 22 - 33% (Du, 2008). If *R. Isatidis* plants are subjected to severe water stress (the lack of soil water or too much), their growth and development will be negatively affected. Studies showed that the water demand critical period of *Isatis tinctoria* L. is in July when accumulation of the indirubin decreased with increasing degree and length of drought stress (Tan et al., 2008); water stress also reduced root activity and biomass production. However, water use efficiency increased (He, 2008). Studies also showed that with the increasing of drought stress, chlorophyll content, photosynthesis, transpiration rate and biomass yield were reduced. Adequate yield and quality of *I. tinctoria* L. were obtained when soil moisture was maintained at 60 - 80% of field holding capacity (Ma et al., 2005; Tan et al., 2008). Root growth is closely related to soil moisture; excessive soil moisture is conducive to the growth of stems and leaves, but reduces the accumulation of the root dry matter (Zhang and Ke, 2010). Meanwhile, alcohol dehydrogenase activity of the roots was induced under excessive soil moisture, which helps alleviate the damage to *R. Isatidis* (Tang et al., 2011).

Soil nutrients and fertilizers

These play a very important role in the formation of yield and quality of herbal plants. The content of the epigoitrin in *R. Isatidis* plants was negatively correlated with total and nitrate nitrogen while the contents of the uridine and adenosine were negatively correlated with soil available potassium and affected by soil pH and total P (Pan and Liu, 2001; Chu et al., 2007).

Though no systematic studies were conducted on fertilization effects on *R. Isatidis*, the importance of fertilization for the yield and quality of medicinal plants has been increasingly recognized. Studies have shown that nitrogen fertilizer is beneficial to improve the yield of *R. Isatidis*, organic manure and chemical fertilizer combination is more advantageous to improve the yield of *R. Isatidis* (Qin et al., 2015). Appropriate amounts of phosphorus and organic fertilizers were reported to reduce arsenic accumulation in *R. Isatidis* (Gao, 2012). Application of nitrogen (N) and phosphorus (P) together improved soluble protein content of *I. indigotica* fort, but single N application reduced the root to shoot ratio while single P fertilizer increased the root to shoot ratio. Iron, manganese and zinc play a catalytic role in the synthesis of indigo in *I. indigotica* fort leaves and Isatis root (Wu, 2008). The concentrations of N, K and P in *B. Cusia* Bremek plants varied with organs and growth periods: decreasing in the order of leaves > stems > roots. The content of N is highest in 7- 8 months after germination, P is highest in June and July and K is highest in August. *B. Cusia* Bremek plants have four major nutrition periods: planting and sprouting, young shoot, vigorous growth and harvest period (Wei et al.,, 2004).

Combinations of different NPK formulation have a significant effect on the yield and polysaccharide content in *I. indigotica* (Wang et al., 2007). They also influence plant height, leaf number, leaf size, root weight, leaf weight, chlorophyll, soluble protein and soluble sugar content (Zhang and Ke, 2010). In order to harvest more leaves and roots, the optimal ratio of N:P is 1.99:1.91 (Wu, 2008). A combination of organic and mineral fertilizers was reported to improve the yield and quality of banlangen. An optimal proportion of N: P_2O_5: K_2O: organic fertilizer was found to be 1:0.68:0.90:0.82. This combination may vary with field conditions and herbal variety. In other experiments of *I. indigtica* fort, the optimal NPK application ratio was reported to be 2.5:1:4 (Ma and Lian, 2005), the different ratio may be caused by different varieties, but there is a common trend, that is, there are more demand for nitrogen and potassium than for P. The ratio of nitrogenous-phosphatic fertilizer was considered to be important for the prevention and cure of some diseases (Wei and Han, 2006).

Trace elements also play an important role in the yield and quality of *R. Isatidis*. Studies showed that during the vegetative growth spraying of Zn and Fe could promote chlorophyll synthesis of *I. indigtica* Fort. Spraying Fe, Mn and Zn promoted indigo synthesis in the leaves and roots (Wu, 2008). Copper inhibits indigo synthesis in the leaves and roost (Wu, 2008); spraying Fe and Mn improved the accumulation of indirubin in the leaves and roots, but Zn and Cu application is the opposite (Wu, 2008). Spraying ferrous sulfate, zinc sulfate and borax was reported to improve root diameter and root production of *I. indigtica* fort, whereas spraying ferrous sulfate, zinc sulfate improved the yield of leaves (He, 2008). The forms of nutrients also affect physiological characteristics, yield and quality of herbal plants (Tian et al., 1999; Ma et al., 2003; Li et al, 2007). For *I. indigotica*, increasing NH_4-N proportion was conducive to the accumulation of indirubin in the leaves and the polysaccharide in the root, while the accumulation of phosphorus, P, K and Mg was enhanced if NO_3^-N proportion was higher than NH_4^-N (Yan et al., 2010).

Soil heavy metals

Control of heavy metals is important for the quality of medicinal plants. Poisonings associated with the presence of heavy metals in some herbs were reported in Asia, Europe and the United States (Dunbabin et al., 1992; Markowitz et al., 1994; Olujohungbe et al., 1994). These heavy metals were mainly from the soil, water, or air (Mclaughlin, 1999; Caldas et al., 2004). Pollution of cadmium in soil is multi-faceted. It not only changed soil biological properties, such as microbial and enzyme activities, but also reduced nutrient cycling and soil fertility (Xia, 1997). Studies showed that high levels of Cadmium (Cd) reduced soil ammonification rate, with severe Cd pollution, microbial functional diversity and various enzyme activities that involve N and S cycle in the soil were significantly reduced (Kandeler et al., 1997). The activities of SOD and POD in *R. Isatidis* were also reported to decrease by soil Pb pollution (Meng et al., 2012), indicating that reactive oxygen radicals are produced beyond the plant's ability to scavenge. With increasing Cd concentration in soil, cumulative amount of Cd in *R. Isatidis* increased, and plant height, number of branches, number of leaves and other biomass indicators declined, and N, P, K content in the plants also decreased (Zhang et al., 2011). The content of indirubin, a major medicinal ingredient also decreased. Cadmium accumulated mainly in the roots, seldom delivered to above ground parts (He, 2007). Low concentrations of Cd (<5mg L^{-1}) may stimulate germination rate, germination index, and germination potential of *R. Isatidis* (Fu, 2007).

BIOLOGICAL FACTORS

Biological factors include planting density, weeds, diseases and pests, soil microbes and so on (Yang and Tian, 2004).

Sowing time

Sowing time should be also regarded as a biological factor, as it has a significant effect on contents of some chemical ingredients in the medicinal plants (Jiang et al., 2008; Qi et al, 2008; Wang et al., 2005). Studies have shown that chemical ingredients of European Isatis tended to decrease when sowing time was delayed (Sales et

Table 1. Environmental factors of affecting growth and development of Banlangen *(Radix Isatidis)*.

Environmental factors		Growth indicators	Active ingredient	References
Climatic	Light	plant height, number of branches	indirubin	Du (2008)
	Temperature		indirubin	Duan (2006)
	Moisture	root dry matter	Alcohol dehydrogenase	Zhang et al. (2010), Tang et al. (2011)
Soil	pH		Adenosine	Pan et al. (2001)
	Fieldholding capacity	root and biomass production, alcohol dehydrogenase	Indirubin	He (2008), Tan et al. (2008), Tang et al. (2011)
	nutrients	Epigoitrin, yield, chlorophyll soluble protein, and sugar	Adenosine Polysaccharide Indigo	Pan et al. (2001), Chu et al. (2007), Qin et al. (2015), Wang et al. (2007), Zhang et al. (2010), Du (2008)
	heavy metals	SOD and POD, oxygen radicals, biomass, germination index	Indirubin	Meng et al. (2012), He (2007), Zhang et al. (2011), Fu (2007)
Biological	Sowing time	Vegetative stage	Chemical ingredients	Chen et al. (2009), Sales et al. (2006)
	Density of planting	Plant growth		Chen (2011)

al., 2006). With the sowing time constantly delayed, soil temperature increased, the vegetative stage of *I. indigotic* Fort was shortened. As a result, the time for plants to expose light is insufficient and ultimately led to declining of active ingredient content in the plants (Chen et al., 2009). Sowing time varies with geographical location. Studies showed that the optimal sowing time was from April 15 to 25 in Yutian county of Hebei province (Ke et al., 2005).

Density of planting

Like other medicinal plants, appropriate density of planting is important for *R. Isatidis.* It affects the growth of leaves and roots, and yield. 25 cm × 7 cm is generally considered as an optimum planting density (Chen et al., 2009). Different variety of *R. Isatidis* requires different density of planting. The optimal space of *R. Isatidis* plants was 10 - 20 cm between plants, and 30 cm between rows (Ke et al., 2005). For *B. cusia* (Nees) Bremek, wide line spacing and narrow plant spacing can ensure the effective number of trees per unit area and promote plant growth. Therefore, it's appropriate planting density is 20 cm × 45 cm (Chen, 2011). Planting *B. cusia* (Nees) Bremek between banana forest or mandarin trees was reported to improve biological yield and adenosine content (Lin, 2011). The mechanisms are not fully understood. Inter-cropping with trees may provide more scattered light, which is beneficial to the growth of the herbal plants. Good management practices are also important for the growth of *B. cusia* (Nees) Bremek. For instance, pruning or multiple cuttings can effectively improve the production of the herbs (Chen, 2011).

CONCLUSIONS

With rising demand for herbal medicine worldwide, particularly in Asia, wild source of herbal plants is rapidly depleted. *R. Isatidis*, one of the most extensively used herbal medicines, has been increasingly grown in agricultural fields in the last two decades. Many factors are involved in the formation of active components in *R. Isatidis*. They include cultivars of *R. Isatidis*, climate conditions, soil fertility, and management practices. Light texture soil with pH near neutral is favorable to the growth of *R. Isatidis*. Combination of organic and inorganic fertilizers with balanced macro- and micronutrients enhances the yield and quality of this herbal plant, thus, it can be seen that environmental factors affect the growth and quality of *R. Isatidis* from different aspects, as is shown in Table 1. Further studies are needed to develop best management practices to warrant profitable production of herbal plants like *R. Isatidis* in agriculture and a more thorough and comprehensive research should be further expanded on important environmental factors and how to affect the growth and development of *R.*

Isatidis.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Poultry litter management in Lagos and effects of its soil application on the growth of okra (*Abelmoschus esculentus*)

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Poultry litter constitutes one of the animal wastes that are produced in large quantity. Information on the quantity generated may enhance planning for its utilisation. Quantification of poultry litter (PL) generated and its utilisation is rare in Nigeria. This study was designed to investigate PL management in Lagos, Nigeria and possible utilisation potential. Questionnaires were distributed to poultry farmers in Lagos to evaluate poultry waste generation and management practices. Additionally, PL was also quantified from selected farms. Greenhouse experiments were conducted to evaluate the agronomic effects of raw and composted PL (each applied at 0, 5, 10 t/ha and replicated four times) on the growth and heavy metals uptake of *Abelmoschus esculentus* (okra). Poultry farms were situated in the residential, non-residential and industrial areas with non-residential areas housing a larger percentage. About 53% of the farms were located near rivers or streams. A few of the poultry farmers treated and utilised PL using chemical and physical methods before disposal. Also, no record of waste utilization was found in 72.3% of the farms. About 87.4% of the farmers quantified the PL generated. About 89.3% of the farmers disposed PL in open dumpsites. Mean poultry litter generated from four farms per bird/day was 0.11 ± 0.001 kg. The HMs contents in plants grown on the poultry treated soils were below the permissible levels in soil. The heavy metals concentrations in the leaves and fruits (which are usually the edible parts of okra plants) for all the treatments fall within WHO/FAO permissible levels. Overall, soil amended with 5 t/ha composted poultry litter performed best in terms of fruit production and reduction in HMs uptake. The use of composted poultry litter as fertiliser at calculated quantity will increase PL management.

Key words: Poultry litter management, heavy metals, Lagos, *Abelmoschus esculentus.*

INTRODUCTION

Poultry farming is one of the largest and fast growing agricultural businesses worldwide. This is due to its economic and health benefits. There is high demand for poultry products in form of meat and eggs which

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makes poultry business to be lucrative and high source of income (Aklilu et al., 2008). This demand stems from the fact that poultry products serve as sources of animal protein as well as micronutrients like iron, selenium and zinc (Pereira and Vicente, 2013; Demirbas, 1999). Protein originating from poultry meat has been categorised as complete protein which consists of all the essential amino acids required by man for healthy functions of the body. Additionally, in terms of value to human health, eggs have a high digestibility score. According to Protein Digestibility-Corrected Amino Acid Scores (PDCAAS), a higher PDCAAS of 1.00 has been attributed to egg white when compared with PDCAAS of 0.92 for meat (Pereira and Vicente, 2013). However, among major environmental issues facing the poultry industry is the huge accumulation of waste, particularly poultry litter and its management. For instance, based on 18 billion meat chickens slaughtered in the USA and Europe in 2009, 25 million tons of litter was estimated per annum (Lynch et al., 2013), about 2 M tons of poultry waste/year were reported in Jordan (Abu-Ashour et al., 2010).

Poorly managed PL may have grave consequences for the environment. The possible environmental consequences include air, surface water and soil contamination. Air may be contaminated with emission of greenhouse gases (CH_4 and CO_2) and ammonia due to microbial action on the litter (Martinez et al., 2009). Most of the environmental problems associated with improper handling of PL are contamination of surface water with nitrogen and phosphorus (Sims et al., 2005). The contamination may be caused by leaching and run-off from open-dumping of PL on land or through direct disposal in water bodies. The leaching of phosphorus and nitrogen from the litter could result in eutrophication, while decomposition of the litter may possibly cause bad odour. Potentially toxic trace elements, such as As, Cd, Cu, Mn, Pb and Zn have been reported in poultry litter (Subramanian and Gupta, 2006).

Economical and environment friendly recycling methods are required to reduce the potential environmental impacts posed by poultry farms. Physical and chemical characteristics of PL have been modified for its utilisation as animal feeds, bioenergy source and activator among others (Martinez et al., 2009; Stephenson et al., 1990). These types of treatment and recycling options could be unaffordable by poultry farmers in the developing countries. Recycling of regulated amount of composted poultry litter as fertiliser may be a viable option. Poultry litter generally contains nutrients and trace elements such as N, P, K, S, Ca, Mg, B, Cu, Fe, Mn, Mo and Zn which can be beneficial for plant growth (Subramanian and Gupta, 2006). It also contains HMs which are toxic. Application of PL in its raw state to agricultural soils may lead to accumulation of these elements in soil with potential effects on plant uptake and washing off into water bodies. In order to salvage these associated environmental problems, the elements can be stabilised in the litter through treatment by composting. Composted PL has been reported to yield a stabilised product which improved physical, chemical and biological properties of soils (Martinez et al., 2009; Sistani et al., 2003; Guerra-Rodriguez et al., 2001).

Comprehensive studies on poultry litter management practices, quantification and utilisation in Nigeria are scanty in literature. The available studies focused mainly on complementary use of NPK fertiliser and poultry litter to improve soil properties and enhance plant growth (Agbede, 2010; Agbede and Ojeniyi, 2009). In this study, practices relating to farm siting and management, PL generation, storage, collection, treatment, utilisation and disposal methods were examined. Information regarding these areas is necessary for improvement on Nigeria environment, awareness raising on both wrong and right PL management practices among poultry farmers and on the part of the appropriate government regulatory authorities to enact and enforce environmental measures regarding PL management. Therefore, this research has the following objectives: (1) Information and generation of data on the PL management practises and PL generation in Lagos state, (2) determination of heavy metal concentrations of raw poultry litter, (3) utilisation as fertilizer to grow okra (*Abelmoschus esculentus*) plant, and (4) comparison evaluation of plant uptake of heavy metals into root, leaves and fruit from the soils treated with raw and composted poultry litter.

MATERIALS AND METHODS

Questionnaire administration

In order to evaluate poultry waste generation and management practices in Lagos, Nigeria, 150 questionnaires were distributed to poultry farmers, out of which only 104 were filled and returned. This means 69.3% of the farmers responded. The questionnaire was designed to obtain information on the farm location, poultry system and poultry waste management. The data were statistically analysed using descriptive statistics.

Study area, sample collection and quantification

The locations of the farms were determined with the use of Geographical Position Sensing (GPS) as shown in Figure 1. On-site quantification of PL generated per day from four selected poultry farms was carried out. The selection was based on the areas (residential, industrial, non-industrial) where the farms were located and the willingness of the famers to participate in the quantification. The quantification was done by collecting PL from a known number of chickens (not less than 30) in a pre-weighed sack spread under the poultry cage. The litter was weighed on daily basis for a week, collected inside polythene bags and transported to the laboratory.

Sample pre-treatment

The collected samples were pooled together to make a composite sample. This was dried, ground, homogenised and sieved to size <

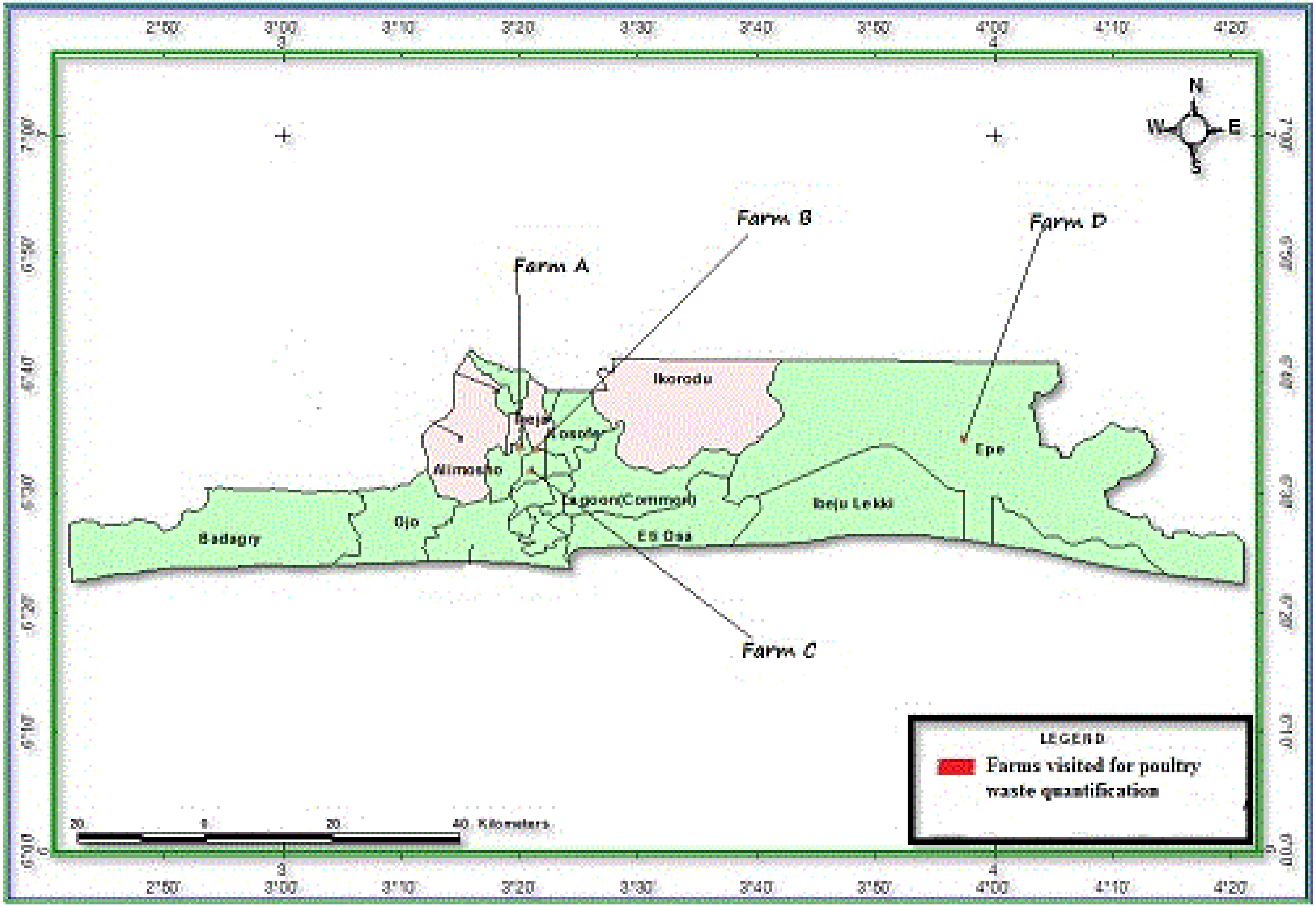

Figure 1. Map of Lagos State showing the four farms where poultry litter quantification was carried out.

Figure 2. Dried raw and composted poultry litter.

2 mm.

Composting of litter

A portion of the composite PL was composted with sunflower at the ratio of 1:3 (poultry litter : sunflower). A polyethene sheet was spread under a shed, then 50 kg of the poultry litter was weighed and 150 kg of sunflower was added to it and covered with perforated polyethylene to allow for the exchange of gases, using partially aerated composting technology. This was left for a period of three months with continuous mixing of the litter and sunflower at a regular interval (Figure 2).

Greenhouse study

A greenhouse experiment was carried out at the Department of Crop Protection and Environmental Biology, University of Ibadan. Top soil used for the experiment was collected at 0 -15 cm depth from the departmental garden. The soil was air-dried, sieved and weighed into each plastic

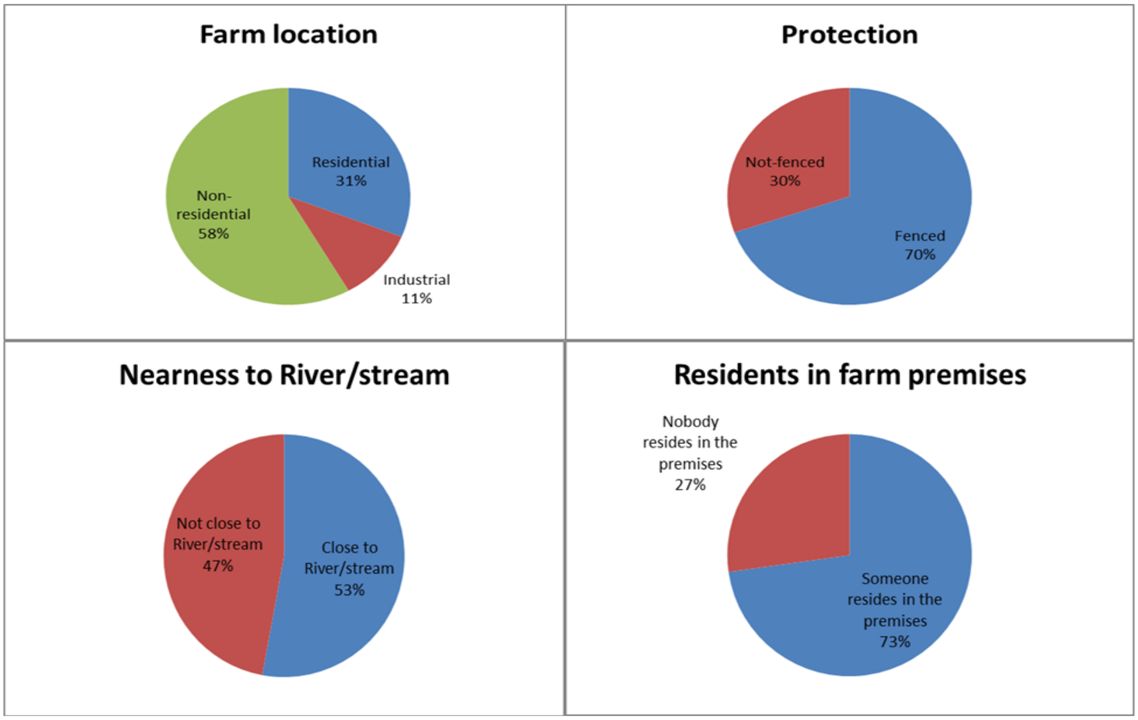

Figure 3. Characteristics of farm sites.

pot. Five treatments were used with each replicated four (4) times. The treatments used were: Treatment 1 (control-0 t/ha); Treatment 2 (soil amended with 5 t/ha composted manure); Treatment 3 (soil amended with 10t/ha composted manure); Treatment 4 (soil amended with 5 t/ha raw manure); Treatment 5 (soil amended with 10 t/ha raw manure). A week before planting, the manure was thoroughly mixed with the soil in each pot and watered to allow for proper equilibration with the soil. After which okra seeds (*A. esculentus*) were planted into each of the treatment pots, and they were watered every two days. Okra was chosen since it requires short time to grow into fruit production and also eaten by many in the South-Western Nigeria. The plants in each pot were thinned out, two weeks after emergence. Growth parameters such as plant height and number of leaves were taken fortnightly while fruit yield was taken at maturity.

Analytical procedures

Physicochemical properties of the poultry litter and soil were determined. These included pH values, total nitrogen, extractable potassium, available phosphorus and heavy metals (Cr, Cu, Mn, Pb and Zn). The pH of soil and litter was determined in the supernatant liquid of the mixture of soil and water (1: 1) using pH meter. Organic carbon content was determined by Walkley-Black method. Total nitrogen was determined by the Kjeldahl method. Phosphorus was determined using the Vanado-Molybdenum method. Potassium was determined with a flame photometer (Jenway, PFP7). The concentrations of Cr, Cu, Mn, Pb and Zn in the litters and soil samples were determined with the use of atomic absorption spectrophotometer (Buck scientific model 205A) with air-acetylene flame after 2 M nitric acid digestion for 2 h at 90-100°C (Ogundiran and Osibanjo, 2009).

Heavy metal determination in plant roots, leaves and fruits

Okra roots, leaves and fruits for each treatment were analysed for Cr, Cu, Mn, Pb and Zn. The samples were washed under a running tap to remove the attached soil. The samples were then dried in the oven at 105°C, ground, sieved and digested (Ogundiran and Osibanjo, 2008). A spiked recovery was used to validate the method of acid digestion. Data were analysed statistically using ANOVA and Duncan's multiple range test was used to separate the means at a $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

Current poultry litter management practices

Information obtained from the poultry farmers on farm system and PL management practices were grouped into five categories: Farm location, system and management, animal care, poultry litter collection and disposal methods, poultry litter treatment and utilisation.

Farm siting

The results on the information about the farm sites are shown in Figure 3. Poultry farms are situated in the residential, non-residential and industrial areas with non-residential areas housing a larger percentage, followed by residential areas. Majority of the farms are protected

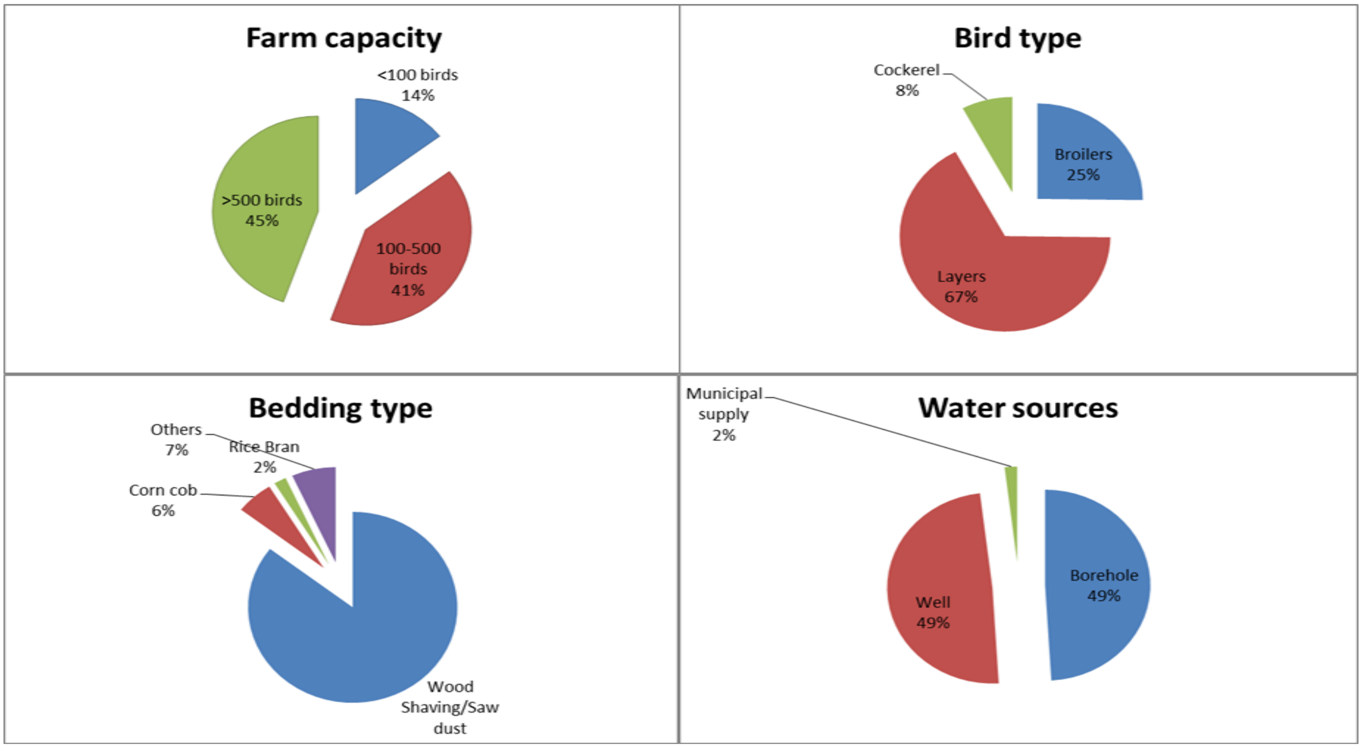

Figure 4. Farm system and management.

while only about 30% are not shielded from access. The current practice of siting and fencing the farms mainly in non-residential areas used by most of the farmers is a right attempt to reduce contact between human beings and the farms. Nevertheless, about 53% of the farms were located near rivers or streams. This raises a concern about the possibility of leaching of PL into the water bodies, which may pose risks of eutrophication and health of those who depend on the river for domestic purposes. Seventy three percent (73%) of the farms have people, including gardeners, security men and farm owners residing in the vicinity. These observations imply that site selection should be considered as a component of effective PL management strategy.

Farm system and management

The results of survey on farm system and management are illustrated in Figure 4. Greater percentage of the farms (44.7%) have farm capacity of more than 500 birds while 40.8 and 14.6% rear 100-500 birds and less than 100 birds, respectively. Based on the type of birds, layers (67.0%) were found to be most commonly reared by the farmers, followed by broilers (25.2%) and cockerels (7.8%). Battery cage system (64.4%) was found to be the most dominant poultry system used followed by deep litter system (35.6%). Among those that practised the deep litter system, majority used wood shaving/sawdust as bedding materials followed by corncob and rice bran. Borehole and well are the main sources of water supply to the farms.

Poultry care pattern

Many farmers feed the poultry with commercial feeds (top and vital feeds) while a few others used self-formulated feeds (Figure 5). Birds were fed twice daily in 91.1% of the farms, others three times daily. The use of vaccine and antibiotics were found to be common in the farms. The use of vaccines and antibiotics in a large number of the farms is an indication of good poultry care and management practices. However, there is need for another study to investigate the residues of these chemicals in poultry litter.

Poultry litter collection and disposal methods

The results of type of waste generated, PL collection methods, collection frequency, disposal methods and distance of the poultry farms to the disposal sites are presented in Figure 6. The results revealed that a larger proportion (88.1%) of the farms generate solid waste, mainly PL. This is supported by Moore et al. (1996) who reported that most broiler operations result in the production of solid poultry manure.

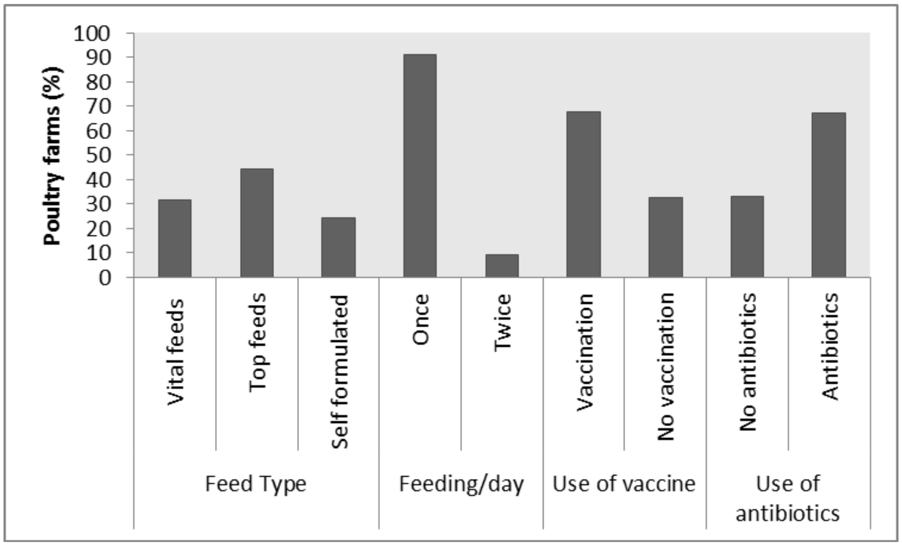

Figure 5. Poultry care pattern.

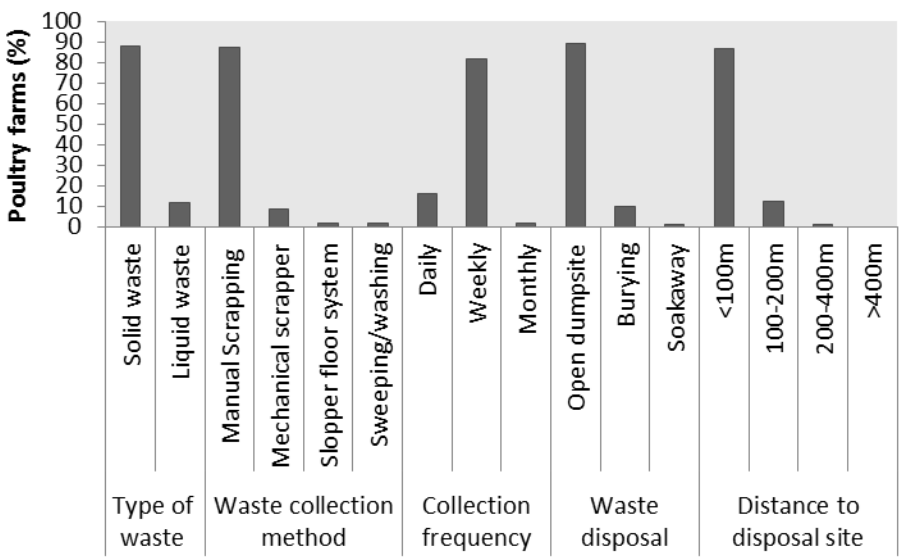

Figure 6. Waste collection and Disposal methods practiced in the poultry farms.

Manual scraping with shovel, which accounts for 87.1% of the responses is the commonest collection method while others include mechanical scraping, slopper floor system, sweeping and washing. Majority of the farmers collected the litter weekly. About 89.3% of the farms practised open-air dumping since it is at little or no cost. These unofficial disposal sites were some metres away from the poultry farms (Figure 6). About 86% of the farmers have their disposal sites located at an estimate of 100 m away from the farms. This disposal method is inappropriate since it can lead to varieties of environmental and human health problems. Consequently, open-air dumping should be discouraged. Poultry litter has been shown to contain high levels of phosphorus and nitrogen, which can be washed off into nearby streams leading to eutrophication (Edwards and Daniel, 1992). Microbial decomposition of PL can lead to emission of methane, which contributes to greenhouse effects (Bhattcharya et al., 1997). Besides potential to releasing hazardous chemical substances, breeding of pathogens and harmful bacteria in the open dumpsites are also possible effects of improper disposal of PL. Flies can be attracted to the open dumpsites, and thereby possibly transferring deadly diseases to humans. For these reasons, there is need for proper guidelines and legislative intervention to regulate management of wastes from

Table 1. Current poultry litter treatment and utilisation methods.

PL treatment and utilisation		Poultry farms (%)
Waste Treatment	No treatment	82.5
	Chemical treatment	4.90
	Physical treatment e.g. drying	3.90
	Burning	8.70
Waste utilisation	No utilisation	72.3
	Fish feeding	5.90
	Manure/composting/fertiliser	21.8
	Biogas generation	Nil
	Electricity generation	Nil
Constraint to waste utilisation and disposal	Lack of utilisation skill	75.0
	Irritation and labour scarcity	4.20
	Difficulty of burning during raining season	3.10
	High cost of Disposal	8.30
	Lack of vehicle or transportation cost	8.30
Estimation of Poultry waste generation	Estimate known	12.6
	No known estimate	87.4

Table 2. Amount (kg) of poultry litter generation per day by four poultry farms.

Farm	No of birds	Day							Total/week	Average daily litter per farm	Average daily litter /bird/farm
		1	2	3	4	5	6	7			
A	50	5.3	5.2	5.4	5.6	5.1	5.3	5.3	37.2	5.31±0.06	0.11
B	58	6.2	6.3	6.1	6.3	6.2	6.2	6.1	43.4	6.20±0.03	0.11
C	65	6.9	6.1	6.8	6.6	6.8	6.7	6.9	46.8	6.69±0.11	0.10
D	45	4.8	4.8	4.7	4.6	4.7	4.8	4.7	33.1	4.72±0.03	0.11

Mean daily litter per bird/day (kg/bird/day) 0.11 ± 0.001

poultry farms in Nigeria.

Poultry litter treatment and utilisation methods

The results of the current poultry litter treatment and utilisation methods practised by the farmers are presented in Table 1. Few of the poultry farms treat PL using chemical and physical treatments, while a greater percentage (82.5%) of the farms do not treat the litter before disposal. Also, no record of waste utilisation was found in 72.3% of the farms. Fish feeding (5.9%) and manure/fertiliser (21.8%) are the current PL recycling methods. It is worth noting that none of the farms generated biogas or electricity from the litter. A majority of the poultry farmers (75.0%) attributed non-utilisation of PL to lack of utilisation skill, irritation, labour scarcity, difficulty of burning during raining season, high cost of disposal and lack of vehicle or transportation cost. About 12.6% of the farmers quantified PL generated while 87.4% did not estimate the quantity of waste generated in the farms. There is need for awareness and training on quantification and utilisation of PL. The developed countries can provide information on the annual generation of PL, which makes it easier to plan for the utilisation of the waste (Lynch et al., 2013; Abu-Ashour et al., 2010). Considering the rate at which the population of Nigeria increases, there is high probability that the production of poultry litter will continue to rise; therefore, there is urgent need for research into various ways that PL can be used.

Quantification of poultry litter generation

The quantity of poultry litter generated daily for a week by a known number of birds is shown in Table 2. The quantity of average daily litter generation was found to correspond approximately proportional to the number of birds. For instance, in Farm C, 6.69 ± 0.11 kg of poultry litter was generated by 65 birds, 58 birds produced 6.02 ± 0.03 kg in Farm B, 50 birds in Farm A have average daily litter weight of 5.31 ± 0.059 kg while 45 birds in Farm D

Table 3. pH, organic carbon, nutrients and heavy metal contents of soil, raw and composted poultry litters.

Parameter	Soil	Raw poultry manure	Composted poultry manure
pH	5.70	6.90	8.00
Organic carbon (%)	4.89	74.9	76.7
N (g/kg)	36.4	12640	8710
P (g/kg)	26.4	11640	5970
K (g/kg)	19.8	1450	1630
Pb (mg/kg)	12.9	42.5	51.4
Cr (mg/kg)	2.45	6.95	10.4
Cu (mg/kg)	22.5	21.6	24.5
Zn (mg/kg)	98.9	83.8	80.0
Mn (mg/kg)	200	170	250

generated 4.72 ± 0.03 kg of litter. However, this may also be a direct indication of the feeding rate. Factors such as body size, type of feed, and level of nutrition have been associated with amount of manure produced by animals per day (Bhattcharya et al., 1997). The mean daily poultry litter per bird estimated from the result of daily measurement from the four farms was 0.11 ± 0.001 kg/bird. This result can be used as supporting information for estimating the amount of poultry litter generated annually in Lagos State and in Nigeria, if the number of birds raised is known. Estimates of poultry litter generated per annum using the data obtained for a certain number of bird have been reported (Lynch et al., 2013; Abu-Ashour et al., 2010).

Chemical analysis

Physicochemical parameters of the soil, raw and composted poultry litter

The results of the physicochemical parameters, and heavy metal contents of the soil, raw and composted poultry litter, are shown in Table 3. The pH of the soil sample was acidic while that of raw litter was about neutral and composted was alkaline. Both raw and composted litter were rich in carbon content. The N, P and K contents of the poultry litter were comparable with a previous report (Sistani et al., 2003). No substantial difference in heavy metals concentrations of the raw and composted poultry litter was observed.

Heavy metal content of the soil, raw and composted poultry litters

The results show that soil, raw and composted poultry litter contained Cr, Cu, Mn, Pb and Zn but not at elevated concentrations (Table 3). Concentrations of heavy metals in poultry litter have been reported to vary, depending on poultry production and management practices (Subramanian and Gupta, 2006; Kunkle et al., 1981).

Plant growth performance parameters

The parameters of plants that were grown on the soil samples, amended with varying quantity of the raw poultry litter and composted litter are shown in Figure 7. There was no significant difference ($p \geq 0.05$) in the plant height among the treatments, however the number of fruits of the plants grown on control soil were significantly lower ($p \leq 0.05$) as compared to the number of fruits obtained from other treatments. Soil amended with 5 t/ha of composted poultry litter produced okra plants with the highest mean number of fruit (6), while others produced the same number of fruit (4). This implies that 5t/ha composted litter increased the yield of okra by 83.3% while others increased by 75% as compared to the control. Kogram et al. (2002) also reported increase in yield of cassava with composted manure when compared with the control.

Accumulation of heavy metal in the plant parts

The results of Pb, Cr, Cu, Mn and Zn accumulation in the okra plants for various treatments and WHO/FAO guidelines are presented in Table 3. The highest concentrations of the HMs were found in the root followed by the leaves and fruit of the okra plant (Table 4). Distribution of heavy metals in the plant parts for all the treatments followed the same trend for all the HMs. The result of HMs accumulation in the okra plants showed that the content of HMs in plants grown using treatment 1 was significantly lower than those grown using treatments 2, 3, 4, and 5. The highest HMs accumulation was found in plants grown with treatment 5, that is, treatment with higher amount of raw manure and this was significantly different ($P < 0.05$) from those grown using treatments 2, 3 and 4. The composted PL had high reduction capacity on plant HMs uptake when compared with the raw litter. There was no considerable accumulation of Pb and Cr in

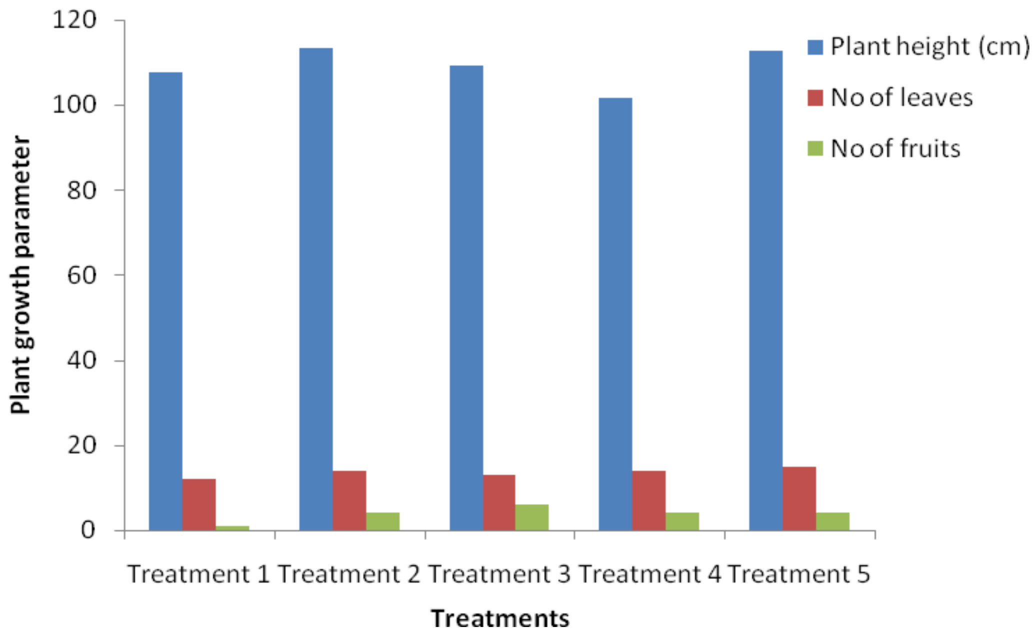

Figure 7. Growth performance parameters of okra plant on the soil sample amended with varying quantities of the raw and composted poultry litter.
Treatment 1: Soil sample only (control-0 t/ha), Treatment 2: Soil sample amended with composted manure (5 t/ha composted manure), Treatment 3: Soil sample amended with 10 t/ha composted manure Treatment 4: Soil sample amended with raw manure (5 t/ha raw manure), Treatment 5: Soil sample amended with raw manure (10 t/ha raw manure)}.

Table 4. Heavy metals concentration (mg/kg) in the roots, leaves and fruits of the okra plants in the pot experiment.

Treatments	Plant parts	Pb	Cr	Cu	Mn	Zn
	Root	5.72±0.005^{a}	0.11±0.00^{a}	14.27±0.08^{a}	109±0.03^{a}	67.7±0.05^{c}
Treatment 1	Leaves	0.35±0.005^{a}	0.003±0.00^{a}	7.86±0.05^{a}	120±0.00^{a}	57.3±0.03^{a}
	Fruit	0.00±0.000^{a}	0.001±0.00^{a}	1.72±0.05^{a}	6.06±0.01^{a}	16.3±0.03^{a}
	Root	5.89±0.005^{b}	0.21±0.00^{b}	14.50±0.10^{b}	109±0.00^{a}	69.1±0.01^{d}
Treatment 2	Leaves	0.54±0.015^{b}	0.001±0.01^{b}	8.55±0.05^{b}	120±0.13^{a}	58.2±0.50^{b}
	Fruit	0.00±0.000^{a}	0.001±0.00^{b}	1.87±0.01^{b}	6.30±0.05^{a}	41.7±0.08^{e}
	Root	6.28±0.025^{c}	0.25±0.01^{c}	20.23±0.03^{c}	143±0.04^{b}	69.8±0.00^{e}
Treatment 3	Leaves	0.88±0.010^{c}	0.001±0.01^{c}	8.65±0.05^{c}	121±0.00^{a}	75.1±0.04^{e}
	Fruit	0.05±0.000^{c}	0.002±0.00^{c}	1.93±0.02^{c}	7.91±0.09^{b}	24.4±0.00^{b}
	Root	8.84±0.030^{d}	0.35±0.01^{d}	25.96±0.01^{d}	144±0.00^{c}	58.4±0.00^{a}
Treatment 4	Leaves	0.92±0.005^{d}	0.002±0.01^{d}	8.84±0.01^{d}	140±0.63^{b}	62.0±0.00^{c}
	Fruit	0.02±0.045^{b}	0.002±0.00^{d}	2.22±0.15^{d}	31.2±0.07^{c}	25.1±0.65^{c}
	Root	13.7±0.065^{e}	0.42±0.00^{e}	29.42±0.02^{e}	149±0.13^{d}	61.3±0.01^{b}
Treatment 5	Leaves	1.54±0.020^{e}	0.002±0.01^{e}	9.16±0.055^{e}	143±0.13^{c}	65.9±0.03^{d}
	Fruit	0.01±0.000^{a}	0.002±0.00^{e}	2.43±0.15^{e}	40.3±0.20^{d}	26.1±0.19^{d}
WHO/FAO limits		5.00	5.00	40.0	-	60

Each value is a replicate determination of Mean ± SEM (n=4). Means with the same letter in the same column are significantly different ($p < 0.05$) using Duncan's multiple range test.

the fruit of the plants grown on all the soils. The heavy metal concentrations in the leaves and fruit, which are usually the edible parts of okra plants for all the treatments, still fall within the permissible consumption level according to WHO/FAO as cited by Yang et al. (2011). Overall, soil amended with 5 t/ha composted litter performed best in terms of fruit production and reduction in HMs uptake. Considering heavy metals reduction in uptake by plants, composted poultry litter performed better than raw poultry litter. This supports the recommendation for the use of poultry litter as a good source of fertiliser, if treated through composting and applied at a regulated quantity to farm soil.

Conclusion

Evaluation of poultry waste generation and management practices among selected poultry farms in Lagos State, Nigeria was carried out. It has been ascertained that currently there is no best poultry litter management practice in Nigeria, due to poor waste disposal and treatment methods, lack of utilization and insufficient education in utilization skills. The locations of poultry farms encourage pollution of surface water. About 53% of the farms were located near rivers or streams. A few of the poultry farms treat and utilize PL using chemical and physical treatments while a greater percentage (82.5%) of the farms do not treat the litter before disposal. Poultry litter is yet to find full utilization by the poultry farmers and the public. A few current applications include fish feeding (5.9%) and manure/fertilizer (21.9%). Quantification of the litter generated was uncommon in a majority of the farms (12.6%). Open-dumping of the litter at some meters away from the farms is the common method of disposal (89.3%). Mean poultry litter generated from four farms per bird/day was 0.11 ± 0.001 kg. The HMs content in plants grown on control soil was significantly different ($P < 0.05$) from the content in plants grown on treated soils. However, they are still within their background levels. The heavy metal concentrations in the leaves and fruit, which are usually the edible parts of okra plants, are generally low for all the treatments and fall within the WHO/FAO permissible level. Considering heavy metal reduction in uptake by *A. esculentus*, composted poultry litter performed better than raw litter.

Overall, soil amended with 5 t/ha composted poultry litter performed best in terms of fruit production and HMs uptake. This supports the use of poultry litter as a good source of fertiliser if a controlled quantity of it is applied to soil. Based on the results of this study, the use of poultry litter in the form of compost at a regulated quantity may be recommended for use as soil amendment in crop production. It is also recommended that there should be regulation and legislation on the disposal and treatment of poultry litter by the relevant authorities. The poultry farmers should be trained on the merits of different utilisation skills for best management of poultry wastes. A national database should be established to document and monitor the quantity of poultry litter generated.

Conflict of Interest

The authors have not declared any conflict of interest.

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Planting date and cultivar effects on growth and yield performance of cowpea (*Vigna unguiculata* (L.) Walp)

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Genotype by environment interaction results in significant differences in the performance of cultivars when tested in diverse environments. Nine improved cowpea (*Vigna unguiculata* (L.) Walp) cultivars obtained from International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria and a local check were evaluated for growth, reproductive and grain yield components in a non-traditional cowpea growing region of south eastern Nigeria with the aim of identifying high yielding genotypes and optimum planting date. The study was conducted in two locations namely Mgbakwu (06°17'N, 07°04'E; 83 masl) and Ishiagu (05°58'N, 07°34'E; 197 masl) across two years and two seasons in each year. A split-plot design was used with three replications. The results indicated that early planting date gave significantly higher yield and yield components than late planting date in both years and locations. IT 98K-131-2 produced mean grain yield of 1220 kg ha^{-1} in early planting date and 732 kg ha^{-1} in late season planting in Ishiagu, while in Mgbakwu, it produced 921 and 326 kg ha^{-1} in early and late planting dates, respectively. IT 97K-556-4 on the other hand produced mean grain yield of 1154 and 424 kg ha^{-1} in early and late planting dates, respectively in Ishiagu; while in Mgbakwu, the mean grain yield were 1594 and 251 kg ha^{-1} for early and late planting dates, respectively. IT 98K-131-2 exhibited the highest mean grain yield attributes in all the environments, indicating broad adaptation; while IT 97K-556-4 was the next highest grain yielder with specific adaptation to early season in Mgbakwu. The two cultivars are therefore recommended to farmers for multiplication and general cultivation in south eastern Nigeria.

Key words: Cowpea, growth and yield components, planting date.

INTRODUCTION

Cowpea is cultivated on at least 12.5 million hectares, with an annual production of over 3 million tonnes. Cowpea is widely distributed throughout the tropics, but Central and West Africa accounts for over 64% of the area (Singh et al., 1997). Cowpea is mostly grown in the drier northern parts of the country; however, advances in crop development have opened up opportunities for its production in wetter agro-ecologies (Nwofia et al., 2006).

Cowpea is an important component of the food intake of the less developed countries of the world because of its high protein content (Jaritz, 1991). It is consumed by humans in many forms; the young leaves, green pods

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and green seeds which are used as vegetables; dry seeds are used in various food preparations; and the haulms including pod walls are fed to livestock as nutritious supplement to cereal fodder (Barrett, 1987). Nigeria is the largest consumer of cowpea in the world (Nnanyelugo et al., 1985; McWatters et al., 1990). The bulk of the diet of rural and urban poor African people consists of starchy food made from cassava, yam, cocoyam, millet, sorghum and maize. The addition of even a small amount of cowpea ensures the nutritional balance of the diet and enhances the protein quality by the synergistic effect of high protein and high lysine from cowpea and high methionine and high energy from the cereals. The nutritious and balanced diet ensures good health and enables the body to resist infectious diseases and slow down their development (Nielsen et al., 1993). Similarly, Carper (1988) pointed out that a cup of cooked dry beans every day should lower the low-density lipid cholesterol, regulate blood sugar and insulin, lower blood pressure, regulate the bowels, and prevent gastrointestinal troubles, even hemorrhoids and cancer of the gut. It is estimated that cowpea supplies about 40% of the daily protein requirements to most of the people in Nigeria (Muleba et al., 1997). Cowpea improves soil fertility fixing atmospheric nitrogen and some varieties fix 46 to 103 $kgNh^{-1}$ annually (Sanginga et al., 2003). This can reduce the need for application of nitrogenous fertilizers that are detrimental to the environment. Biological nitrogen fixation is environmentally friendly and ideal for sustainable agriculture (Cheng, 2008).

Cowpea is usually grown under rain fed conditions. Both quality and quantity of cowpea seed are affected by the amount and distribution of rainfall, which is affected by the period of planting (Morakinyo and Ajibade, 1998). Identification of the appropriate timing of sowing of a crop in any particular location is an important agronomic requirement needed for high and sustained productivity (Akande et al., 2012).Year, location, planting dates and climatic factors of a place often affect crop production by interacting with cultivar and its traits (Akande, 2007). Multi-environment trials are evaluated to identify superior and stable cowpea genotypes and to understand the effects of genotypes and environments on cowpea performance. The interaction between genotype and environment results in significant differences in performance of genotypes when tested in various environments (Gauch and Zobel, 1997). The genotype by environment (GE) interactions plays a major role in the performance of any genotype and in identification of adaptable genotypes to varying environments. Interactions between genotype and environment affect both quantitative and qualitative traits. Due to varying effects of climate change and divers ecological conditions in Nigeria, it is important to select suitable cultivars for adaptability to specific as well as across environments.

Use of improved cultivars and alteration of crop planting dates have been reported by many researchers as effective strategies for reducing pest damage and improvement of crop productivity (Ekesi et al., 1996; Karungi et al., 2000). Studies conducted in Kano (Northern Guinea Savanna of Nigeria) showed that elite cowpea lines performed better in terms of grain yield when planted between mid-June and mid-July without insecticide protection, whereas a local variety included in the study produced higher grain yield when planted between late July and early August (Asante et al., 2001). The value of manipulating the planting date as a package for optimizing cowpea productivity have been confirmed, thus giving scientific credence to the traditional practice of planting early in the season than late planting (Jackai et al., 1985). Experiment conducted in monomodal climates had shown that early planting, as soon as rains become well established in mid to late June, to be associated with high grain yield (IITA-SAFGRAD, 1983). Kamara (1981) reported that plant height, pod number and seed yield of cowpea planted in September were significantly greater than those from other planting dates in Sierra Leone. Late season planting was recommended as the most appropriate planting period in southern Nigeria based on distinct variations observed in the growth and reproduction of cowpea planted at different times (Morakinyo and Ajibade, 1998). Asio et al. (2005) observed higher grain yield of the best yielding variety when planted in the late season in Uganda as compared to early season planting, and this was attributed to different weather conditions that prevailed in the two seasons. The first season was associated with heavy rains which promoted excessive vegetative growth, fewer pods and thus lower grain yields.

Climate change has caused significant modification of the cropping seasons in different regions, and the effect of this alteration is variation in performance of crop species grown in different environments. The objectives of this study were to determine the effects of planting season on cowpea cultivars and to identify cultivars with high agronomic values. The study was also meant to identify optimum sowing date so that farmers could be advised on the appropriate planting date that will stimulate higher cowpea production.

MATERIALS AND METHODS

Experimental sites

The study was conducted across two locations and over two years within derived savanna agro-ecology of southeastern Nigeria, considered as non-traditional cowpea growing region. In each year, early and late season sowing dates were utilized to assess the agronomic potentials of the cultivars. The two locations experiences bimodal rainfall pattern and they include Mgbakwu (06° 17'N, 07° 04'E; 83 m asl) and Ishiagu (05° 58'N, 07° 34'E; 197 m asl). Mgbakwu location experienced an average daily temperature and relative humidity of 31°C and 74, respectively with a total annual precipitation of 1571 mm in 2007 and 1638.1 mm in 2008. Ishiagu witnessed an average daily temperature and relative humidity of 31.5°C and 81, respectively with a total annual precipitation of

1677.5 mm in 2007 and 1954.1 mm in 2008. The soils of Mgbakwu are predominantly sandy and acidic (pH 4.6) while that of Ishiagu are sandy loam soils with alkaline pH of 6.0.

Cultivars

Nine improved cowpea cultivars collected from IITA, and a local cultivar (check) were used in this study. The improved cultivars consisted of extra early (IT 93K-452-1), early (IT 84S-2246-4, IT 90K-82-2, IT 97K-558-18) and medium maturing cultivars (IT 90K-277-2, IT 97K-499-35, IT 97K-556-4, IT 98K-131-2, IT 98K-205-8) (Dugje et al., 2009) while local check falls within long duration category.

Experimental procedures

The experimental plot was ploughed, harrowed and manually ridged. Prior to ridging, a basal dose of 100 kg NPK 15-15-15 per hectare plus 1000 kg per hectare of well cured cow dung was broadcasted uniformly and later incorporated into the soil before ridging. Seed was dressed with fungicide (seed-plus) at the rate of one sachet (10 g) to 2 kg of seed. Inter-row spacing was 75 cm while intra row spacing was 25 cm; 2-3 whole-seeds per hill were sown at 3-5 cm depth. Plants were thinned down to two stands per hill two weeks after crop emergence. Weeds were manually controlled as regularly as they appeared while other agronomic practices were carried out as recommended. Early and late season sowing dates were observed for the two years and in the two locations. In 2007, the experiments were established on July 23 for early season sowing and September 4 for late season sowing in Mgbakwu while in Ishiagu location, sowing was done on July 31 and September 12 for early and late season sowing, respectively. In 2008, the experiment was established in Mgbakwu on July 21 and September 15 while sowing in Ishiagu was carried out on July 24 and September 12 for early and late season sowing, respectively. Planting done before the month of August was considered early planting date while planting done after August was regarded as late planting date. The experiment was a split-plot arranged in a randomized complete block design (RCBD), replicated three times on a four row plots of 2 m long. Insect pests were managed with the application of full dose of 100 ml of insecticide, cypermethrin and dimethoate mixture containing 30 and 250 g active ingredients respectively, using 15 L knapsack sprayer.

Data collection

The data were collected from the inner two rows in each replicate. Observation were recorded on growth components (dry fodder weight, number of internodes, number of leaves, number of nodules, number of plant stand, peduncle length, taproot length and vine length) and reproductive and grain yield components (bloom, duration of grain filling period, 100 seed weight, number of pods per plant, number of seed per pod, pod length, grain yield, threshing percentage and harvest index). Days to 50% flowering/bloom was sampled when there was at least one flower in 50% of all plants in the plot. Duration of grain filling period was determined as days from 50% bloom to when the pods have reached physiological maturity (when the pods had reached their mature pod color). At the end of vegetative growth, the rest of the growth components were determined on five randomly selected plants while at maturity, the yield and yield components were sampled from five randomly selected plants. Dry fodder weight was determined from the net plot after harvest and sun drying while the weight of 100 seeds was recorded by weighing a random sample of 100 seeds.

Data analysis

The data collected were subjected to analysis of variance (ANOVA) using GENSTAT Discovery Edition 2 (GENSTAT, 2005) procedures as outlined for RCBD. Means of cultivars were separated using fishers least significant difference (F-LSD) (P = 0.05).

RESULTS

Results indicated that early planting date in Ishiagu location significantly increased growth components such as internode length, number of nodules, number of plant stand and vine length than in late planting date (Table 1). Response of cultivars to both planting dates differed for dry fodder weight, number of leaves, peduncle length and root length with local cultivar expressing significantly higher dry fodder weight, internode length, number of leaves, number of nodules and vine length. Conversely, local cultivar produced the least plant stands in both planting dates indicating poor plant establishment while IT 845-2246-4 produced significantly higher plant stand in both planting dates showing that the cultivar had good crop establishment probably due to its viability.

Table 2 shows that early season plating resulted in significantly higher reproductive and grain yield components except number of nodes per plant and pod length which differed among all the cultivars and across the two planting dates. In early season, local cultivar did not flower as expected and therefore could not produce any yield components, on the contrary it flowered and produced grains in late planting. IT 93K-452-1 was the earliest to bloom in both planting dates. The cultivar IT 98K-131-2 produced significantly higher grain yield per hectare of 1220 and 732 kg in both early and late planting dates, respectively. Similarly, IT 98K-131-2 produced significantly higher number of pods per plant, number of seed per pod, threshing percentage and harvest index in both planting dates. It also took relatively longer days to fill its pods. Local cultivar however expressed significantly lower 100 seed weight, number of pods per plant, number of seeds per pod, pod length, grain yield, threshing percentage and harvest index.

Response of cultivars to the growth parameters in Table 3 revealed similar trend to that shown in Table 1 with early planting dates expressing significantly higher dry fodder weight, internode length, number of nodules, number of plant stands and vine length. Local cultivar again produced significantly higher growth components for most traits except number of plant standand peduncle length. In both locations and planting dates, IT 93K-452-1 was the earliest to bloom making it an extra early flowering cultivar.

Early planting date in Mgbakwu location supported significantly higher reproductive and grain yield components across all the cultivars except 100 seed weight and planting dates Table 4). IT 97K-556-4 produced significantly higher grain yield per hectare (1394 kg) in early

Table 1. Effect of early and late planting dates on growth components of cowpea cultivars combined across 2007 and 2008 in Ishiagu.

Cultivar	DFWT (g)		Inter node		NLEAF		NNODULE		NSTAND		PEDLT(CM)		RTLENGTH (CM)		VINELTH (CM)	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
IT 84S-2246-4	554	625	6	5.58	24.1	21.58	1.17	5.58	39.5	39.17	29.29	30.67	22.75	22.12	43.7	35.1
IT 90K-277-2	952	842	12.O8	9.17	28.8	39.08	16.67	14.5	34.33	31.83	30.83	33.08	22.5	22.5	111.2	89.9
IT 90K-82-2	742	608	10.08	7.25	30	27.5	6.17	4.17	38.42	36.5	29.71	27.25	19.67	20.25	72.7	41
IT 93K-452-1	298	400	8.5	7.42	22.2	20.42	15.5	8.92	35.17	29.83	25.92	25.08	17.92	19.17	65.7	45.7
IT 97K-499-35	640	450	9	8	21.8	23.25	8.25	5.75	37	36.67	29.33	25.5	20.75	22.21	62	44.9
IT97K-556-4	771	875	7.42	4.92	27.8	23.75	17.5	10.58	38.17	34.42	27.58	26.33	20.08	19.58	72.4	31.8
IT97K-55568-8	696	600	9.92	8.83	29.3	32.33	14.67	4.33	30.75	26	29.75	29.67	20.5	21.42	97.2	75.6
IT98K-131-2	625	550	9.58	9.08	32.5	32.83	9.92	4.58	29.83	27.17	30.75	31.08	21.75	23.33	89.2	77.3
IT98K-205-8	642	458	9.25	7.75	26	20.5	10.83	4.92	34.58	32.5	30.75	31.08	21.75	23.33	83.3	54.7
LOCAL	853	569	20.42	15.75	83.5	68.25	17.25	9.5	14.08	20.33	0	22.75	18.08	16.42	185.7	168
MEAN	677.3	598	10.22	8.38	32.6	30.95	12.69	7.28	33.18	31.44	26.58	27.77	20.7	20.81	88.3	66.4
F-LSD(0.05)	191.9	136.8	2.459	2.448	18.72	7.175	5.467	3.218	3.362	4.087	5.1	4.32	3.922	3.398	34.06	24.69

P_1 =early planting date; P_2 = late planting date; DFWT (g) = Dry fodder weight; Internode = Number of internodes; NLEAF = Number of leaves; NNODULE = Number of nodules; NSTAND = Number of Plant Stands; PEDLT = Peduncle length; RTLENGTH = Roof length; VINELTH = Vine length.

Table 2. Effect of early and late planting dates on reproductive and grain yield components of cowpea cultivars combined across 2007 and 2008 in Ishiagu.

Cultivar	Bloom (days)		Podfill (days)		100 SWT (g)		NPOD/PLT		NSEED/POD		PODLT (cm)		GYD/ HA		Thresh (%)		HI	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
IT845-2246-4	51.67	43.25	16.67	14.17	11.92	7.5	17.08	19.08	10.25	8.25	14.58	14.08	892	455	58.94	32.2	52.9	20.1
IT90K-277-2	50.25	43.42	21.58	16.58	17.77	10.58	16.92	15.42	13	9.67	14.62	15	1072	581	54.61	36.4	31.07	26.3
IT90K-82-2	51.25	45.25	19.17	14	11.63	9.45	19.75	16.75	12.08	10	14.75	14.92	978	401	58.09	41	45.5	30.2
IT93K-452-1	40.25	38.92	20.25	14.33	16.33	12.41	14.5	14.08	11.75	9.83	13.38	13.73	807	492	63.09	47	70	39.2
IT97K-499-35	44	41.08	21	15.83	14.71	9.48	13.33	13	11.5	8.5	13.67	14.08	1114	341	65.02	37.6	50.4	38
IT97K-556-4	50.58	41.67	19.83	17.42	17.24	10.88	14.92	17.33	11.58	9.83	16.93	17.17	1154	424	62.94	32.5	50.9	15.6
IT97K-568-18	47	41.75	20.83	18.83	15.19	12.58	16.67	17.33	12	9.33	14.38	14.38	943	566	54.7	42.4	39.2	24.7
IT98K-131-2	50	41.58	21.67	18.67	15.43	11.5	17.58	20	12.58	10.08	14.88	14.84	1220	732	68.55	47.5	74.2	43.8
IT98K-205-8	43.33	40.33	2075	18.75	15.48	11.84	15.5	16.25	11.67	9.08	13.96	13.67	1023	408	64.18	44.8	59.9	33.8
LOCAL	0	49.08	0	27.42	0	8.33	0	6.33	0	4.92	0	7.83	0	145	0	28.4	0	8.8
MEAN	43.48	42.63	18.18	17.6	13.57	10.46	14.62	15.56	10.64	8.95	13.11	13.97	920	455	55.09	39	52.74	29.05
F-LSD(0.05)	5.857	4.645	2.494	4.259	0.515	3.466	5.183	4.907	1.729	2.325	0.841	2.316	230.7	191.3	6.458	14.52	24.1	15.8

P_1 =early planting date; P_2 = late planting date; Bloom = Days to 50% flowering; PODFILL = Days to pod filling; 100 SWT = 100 Seed Weight; NPOD/PLT = Number of pods per plant; NSED/POD = Number of Seeds per pod; PODLT = Pod length; GYD/HA = Grain Yield per hectare; Thresh % = Threshing percentage; HI = Harvest Index.

Table 3. Effect of early and late planting dates on growth components of cowpea cultivars combined across 2007 and 2008 in Mgbakwu.

Cultivar	DFWT (g)		Inter node		NLEAF		NNODULE		NSTAND		PEDLT(CM)		RTLENGTH (CM)		VINELTH (CM)	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
IT845-2246-4	608	284	8.17	6.5	18.5	14.5	8.83	3.88	43.33	36.67	33.58	31.36	30.38	30.58	47	26.7
IT90K-277-2	592	338	14.92	9.67	31.6	32.92	14.33	5.33	31.25	17.58	26.78	25.91	37.25	29.29	143.7	66.1
IT90K-82-2	331	321	10.5	8.25	24.4	20.42	8.08	4.08	37.75	33.5	24.1	28.38	32.25	28.54	40.7	37.5
IT93K-452-1	288	252	9.08	10	20.3	25.75	17.5	5.33	32.25	23.58	22.83	25.25	27.25	28.83	98.4	59.4
IT97K-499-35	250	252	10.17	7.17	17.2	21.42	7.5	4.29	36.33	33.75	25.77	22.23	29.58	30.38	68.9	29.9
IT97K-556-4	962	538	9.5	6.83	26.5	26.83	20.58	10.85	38.58	32.08	26.18	26.95	33.67	27.25	57.4	31.9
IT97K-568-18	312	226	14.75	9.92	22.6	21.29	14.25	5.54	28.5	22.92	26.44	25.18	31.46	27.54	117.4	67.5
IT98K-131-2	296	276	14.25	8.42	26.5	24.04	10.67	5.5	25.5	23.58	26.33	26.15	27.33	25.68	113	50.9
IT98K-205-8	588	247	10.67	9.25	21.9	19.67	7.08	4.54	34.58	28.75	28.76	22.96	29	25.62	86.9	43.1
LOCAL	1171	382	22.42	14.25	81	39.42	29.08	9.04	26.17	22.5	16.69	17.48	33.58	30.46	218.9	109.1
MEAN	550	312	12.44	9.03	29.1	24.62	13.79	5.84	33.42	27.49	25.75	25.19	31.18	28.42	99.2	52.2
F-LSD (0.05)	327.7	121.4	2.485	1.442	17.16	5.97	8.95	2.751	3.617	5.46	4.029	5.098	5.375	5.607	34.57	18.76

P_1 =early planting date; P_2 = late planting date; DFWT (g) = Dry fodder weight; Internode = Number of internodes; NLEAF = Number of leaves; NNODULE = Number of nodules; NSTAND = Number of Plant Stands; PEDLT = Peduncle length; RTLENGTH = Roof length; VINELTH = Vine length.

Table 4. Effect of early and late planting dates on reproductive and grain yield components of cowpea cultivars combined across 2007 and 2008 in Mgbakwu.

Cultivar	Bloom (Days)		PODFILL (days)		100 SWT (g)		NPOD/ PLT		NSEED/ POD		PODLT (cm)		GYD/ HA		THRESH %		HI	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
IT84S-2246-4	49.42	46.67	23.83	16.5	11.5	10.58	16.42	6	11.79	7.96	16.42	13.42	848	184	64.61	51.5	43.4	41.8
IT90K-277-2	50.5	45.58	24.92	20.92	18.12	15.52	15.25	10.92	11.29	8.29	16.61	14.18	750	149	58.64	51.3	60.3	18.9
IT90K-82-2	53.5	46.83	20.75	17.17	12.29	12.31	12.5	6.08	14.08	9.92	15.17	14.83	815	160	67.44	52.7	89	55.1
IT93K-452-1	41.58	41.33	22.25	19.5	16.3	16.68	17.83	12.5	11	7	14.42	14.87	864	216	66.65	50.3	95	30.6
IT97K-499-35	45.67	41	22.5	19.58	15.02	13.17	11.54	6.92	11.83	6.29	15.19	14.49	638	195	64.39	49.5	63.1	51.3
IT97K-556-4	49	42	22.33	24.33	18.67	12.03	13.04	9	11.79	6.79	19.02	15.63	1394	251	68.36	40.2	57.9	17.5
IT97K-568-18	49	44.33	23.83	21.75	16.3	14.35	20	11.42	12.46	8.92	15.38	14.72	792	216	67.93	53.6	81.4	83.4
IT98K-131-2	49.83	43.75	22.5	23	16.24	15.34	17.21	13.92	12.42	9	16.52	14.64	921	326	72.05	62.4	97.5	55.7
IT98K-205-8	44.75	41.58	23.17	21.5	15.78	13.48	14.33	6.5	11.75	6.54	15.19	13.63	758	134	66.37	47	51.5	60.1
LOCAL	0	61.17	0	23	0	11.15	0	3.33	0	3.87	0	7.17	0	64	0	32.7	0	6.3
MEAN	48.14	45.42	22.9	20.73	14.03	13.46	13.97	8.66	11.24	7.46	16	13.74	778	190	59.65	49.1	71	42.1
F.LSD (0.05)	2.186	1.583	4.826	3.667	0.918	3.473	4.741	3.491	1.637	2.345	1.433	1.81	446.1	93.7	4.271	15.54	28.91	48.19

P_1 =early planting date; P_2 = late planting date; Bloom = Days to 50% flowering; PODFILL = Days to pod filling; 100 SWT = 100 Seed Weight; NPOD/PLT = Number of pods per plant; NSED/POD = Number of Seeds per pod; PODLT = Pod length; GYD/HA = Grain yield per hectare; Thresh % = Threshing percentage; HI = Harvest Index.

Table 5. Interaction effect of cultivar and year on reproductive and grain yield components in early season, Ishiagu.

Cultivar	PODFILL (days)		100 SWT (g)		NPOD/PLT		NSEED/pod		PODLT (cm)		GYD/ HA		THRESH (%)		HI	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
IT 845-2246-4	16.5	16.83	12.17	11.67	14.2	20	10	10.5	14.08	15.08	482	1303	49.79	68.09	46.7	59.2
IT 90K-277-2	22.17	21	17.37	18.17	13.7	20.17	13.67	12.33	13.75	15.5	462	1682	39.99	69.24	26.3	37.2
IT 90K-82-2	18.33	20	11.1	12.17	15.7	23.83	12.83	11.33	14.83	14.67	624	1332	44.04	72.15	53	38
IT 93K-452-1	18.67	21.83	15.82	16.83	12.2	16.83	11.83	11.67	13	13.75	366	1249	49.76	78.03	68.6	95.6
IT 97K-499-35	18.67	23.33	14.42	15	10	16.67	12.67	10.33	13.67	13.67	494	1733	54.02	76.03	35.6	65.3
IT 97K-556- 4	18.67	21.5	17.32	17.17	11	18.83	11.5	11.67	16.7	17.17	689	1618	51.33	74.55	55.6	46.1
IT 97K-568-18	20.67	21	14.05	16.33	15.5	17.83	12.17	11.83	13.83	14.92	480	1406	37.35	72.04	39.2	39.3
IT 98K-131-2	21.17	22.17	14.52	16.33	14.2	21	13	12.17	14.5	15.25	799	1640	60.13	76.96	67.6	80.9
IT 98K-205-8	18.33	23.17	15.28	15.67	12.3	18.67	11.5	11.83	13.17	14.75	574	1473	54.41	73.95	49.1	70.8
LOCAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MEAN	17.27	19.08	13.2	13.93	11.9	17.38	10.92	10.37	12.75	13.48	497	1343	44.08	66.1	44.2	59.16
F-LSD (0.05)	3.409	3.409	0.737	0.737	6.85	6.846	2.539	2.539	1.442	1.442	297.2	297.2	8.453	8.453	33.53	33.53

Y_1 = Year 1; Y_2 = Year 2; PODFILL = days to pod filling; 100 SWT = 100 Seed Weight; NPOD/PLT = number of pods per plant; NSED/POD = number of Seeds per pod; PODLT = pod length; GYD/HA = Grain yield per hectare; Thresh % = Threshing percentage; HI = harvest Index.

planting while it gave the second highest grain yield in late planting date. The reverse is the case with IT 98K-131-2 which produced significantly higher grain yield per hectare (326 kg) in late planting date while it was the second highest grain yielder per hectare (921 kg) in early planting date.

The interaction effects of cultivar and year on reproductive and grain yield components in early (Table 5) and in late season (Table 6) in Ishiagu location are shown. The results revealed that in both early and late seasons, year two (2008) expressed significantly higher reproductive and grain yield traits. Cultivar IT 98K-131-2 again produced significantly higher grain yield per hectare in both year and season indicating that the cultivar is an ideotype cultivar possessing superior grain yielding ability with broad adaptation endowment.

The interaction effects of cultivar and year on reproductive and grain yield components in early (Table 7) and late season (Table 8) in Mgbakwu location are presented. In both early and late seasons, year one (2007) expressed significantly higher reproductive and grain yield components for most traits sampled. IT 97K-556-4 produced significantly higher grain yield in year one (1428kg) and year two (1360 kg) in early season while in late season, IT 98K-131-2 produced significantly higher grain yield in year one (488 kg) and year two (164 kg) revealing that IT 97K-556-4 was more adapted to early season than late season, while IT 98K-131-2 possess broad adaptation to both early and late seasons. Late season in Mgbakwu location supported the lowest expression of grain yield per hectare with grain yield range (136 and 488 kg) in year one while it ranged between 49 and 164 kg in year two. Pod length was minimally influenced by year effect in most cases. In both planting dates and locations, IT90K-277-2, IT 93K-452-1 and IT97K-556-4 produced significantly higher 100 seed weight. A similar trend was observed where IT97K-556-4 produced the longest pod in both planting dates and locations.

DISCUSSION

Early and late planting dates were utilized to evaluate some selected cowpea genotypes across two locations and over years. Results obtained indicated that yield and yield components were best expressed in early planting date but decreased in late planting date in all the environments. Ray et al. (2008) and Shegro et al. (2010) working on soybean reported that early planting date produced a higher seed yield than late planting. Javaid et al. (2005) and Akande et al. (2012) also obtained similar result on cowpea and attributed the yield differences to higher solar

Table 6. Interaction effect of cultivar and year on reproductive and grain yield components in late season, Ishiagu.

Cultivar	PODFILL (days)		100 SWT (g)		NPOD/ PLT		NSEED/ POD		PODLT (cm)		GYD/ HA		THRESH %		HI	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
IT 845-2246-4	10.5	17.83	5.67	9.33	11.5	26.67	6.5	10	13.92	14.25	111	799	18	46.4	9	31.2
IT90K-277-2	15.17	18	8.67	12.5	9	21.83	8	11.33	15	15	184	978	22.1	50.6	7.9	44.7
IT 90K-82-2	9.67	18.33	5.9	13	8.83	24.67	7.67	12.33	15	14.83	193	609	21.7	60.4	14.5	45.8
IT 90K-452-1	15.67	13	9.48	15.33	10.5	17.67	8.83	10.83	13.62	13.83	187	797	27.5	66.5	14.8	93.6
IT 97K-499-35	16.5	15.17	7.13	11.83	8.17	17.83	6.67	10.33	14.17	14	196	485	26.8	48.4	10.4	65.6
IT 97K-556-4	15.17	19.67	10.43	11.33	12.5	22.17	7.83	11.83	17.17	17.17	211	637	25.6	39.4	8.8	22.4
IT 97K-568-16	16.5	21.17	8.33	16.83	9.17	25.5	7.83	10.83	13.92	14.83	225	908	23.8	61.1	14.8	34.6
IT98K-131-2	17.83	19.5	7	16	13.17	26.83	9.5	10.67	14.85	14.83	333	1131	25.8	69.1	17	70.7
IT 98K-205-8	20.17	17.33	10.18	13.5	12.5	20	7.83	10.33	13.58	13.75	203	612	33.8	55.8	11.1	56.5
LOCAL	33.33	21.5	7	9.67	2.17	10.5	1.67	8.17	5.83	9.83	88	203	27.1	29.6	3.2	14.3
MEAN	17.05	18.15	7.98	12.93	9.75	21.37	7.23	10.67	13.71	14.23	193	716	25.2	52.7	11.1	47.9
F-LSD (8.05)	6.5	6.5	4.389	4.389	6.389	6.389	3.079	3.079	2.532	2.532	272.5	272.5	18.35	18.35	21.84	21.84

Y_1 = Year 1; Y_2 = Year 2; PODFILL = Days to pod filling; 100 SWT = 100 Seed Weight; NPOD/PLT = Number of pods per plant; NSED/POD = Number of Seeds per pod; PODLT = Pod length; GYD/HA = Grain yield per hectare; Thresh % = Threshing percentage; HI = Harvest Index.

Table 7. Interaction effect of cultivar and year on reproductive and grain yield components in early season, Mgbakwu.

Cultivar	PODFILL (days)		100 SWT (g)		NPOD/ PLT		NSEED/ POD		PODLT (cm)		GYD/ HA		THRESH (%)		HI	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
IT845-2246-4	25.33	22.33	11.5	11.5	21.17	11.67	13.83	9.75	16.08	16.75	1023	673	60.09	69.14	53.9	33
IT90K-277-2	27.83	22	18.52	17.83	15.33	15.17	12.83	9.75	17.42	15.8	618	882	46.54	70.73	61.6	59
IT 90K-82-2	21.83	19.67	12.25	12.33	13.67	11.33	14.33	13.83	15.42	14.92	827	803	62.51	72.36	66.4	79.2
IT 93K-452-1	22.67	21.83	16.27	16.33	21.17	14.5	12.17	9.83	14.25	14.6	746	981	63.01	70.29	96	83.4
IT97K-499-35	22	23	15.03	15	14.17	8.92	12	11.67	16.08	14.3	686	589	59.8	68.98	62.6	63.6
IT97K-556-4	23.83	20.83	18.67	18.67	14.83	11.25	12.67	10.92	19.92	18.13	1428	1360	67.61	69.12	65.2	50.6
IT97K-568-18	25.67	22	15.43	17.17	21.83	18.17	13	11.92	16.33	14.43	1002	581	63.95	71.92	73.7	89.1
IT 98K-131-2	23.17	21.83	15.65	16.83	20.33	14.08	12.5	12.33	16.42	16.63	999	843	69.76	74.34	95.67	91.2
IT98K-205-8	22.33	24	15.72	15.83	17.17	11.5	13	10.5	15.42	14.97	781	734	63.57	69.17	67.2	35.8
LOCAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MEAN	21.47	21.83	13.9	14.15	16.13	11.81	11.97	10.51	16.37	15.61	811	745	55.68	63.61	71.36	64.99
F-LSD (0.05)	6.629	6.629	0.918	0.918	6.472	6.472	2.19	2.19	2.107	2.107	390.8	390.8	6.884	6.884	44.62	44.62

Y_1 = Year 1; Y_2 = Year 2; PODFILL = Days to pod filling; 100 SWT = 100 Seed Weight; NPOD/PLT = Number of pods per plant; NSED/POD = Number of Seeds per pod; PODLT = Pod length; GYD/HA = Grain yield per hectare; Thresh % = Threshing percentage; HI = Harvest Index.

Table 8. Interaction effect of cultivar and year on reproductive and grain yield components in late season, Mgbakwu.

CULTIVAR	PODFILL (days)		100 SWT (g)		NPOD/PLT		NSEED/POD		PODLT (cm)		GYD/HA		THRESH (%)		HI	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
IT845-2246-4	14.67	18.33	8.45	12.67	8.33	3.67	9.67	6.25	15.33	11.52	234	134	42.7	60.2	11.4	72.3
IT90K-277-2	19.5	22.33	13.2	17.83	15	6.83	11.33	5.25	14.67	13.7	216	82	37.3	65.3	13.1	24.8
IT90K- 82-2	13.67	20.67	10.78	13.83	8.33	3.83	13.17	6.67	16.25	13.42	240	81	35.6	69.9	19.7	90.5
IT93K-452-1	17.67	21.33	15.7	17.67	19	6	9	5	15.67	13.68	282	151	44.4	56.1	22.4	38.7
IT97K-499-35	17	22.17	10.17	16.17	9.5	4.33	7	5.58	15.92	13.07	262	128	38.6	60.4	20	82.7
IT 97-556-4	22.33	26.33	11.73	12.33	14	4	10	3.58	18	13.27	418	84	42.3	38.1	22.3	12.7
IT97K-568-18	19.33	24.17	13.03	15.67	16.67	6.17	11.5	6.33	15.75	13.68	328	104	40.6	66.7	32.9	94.5
IT 98K-131-2	25.5	20.5	12.85	17.83	23.67	4.17	12.17	5.83	15.5	13.78	488	164	58.1	66.7	34.8	76.5
IT 98K-205-8	20	23	9.97	17	8.5	4.5	7.5	5.58	14.25	13.02	136	131	30.1	63.9	11.9	73.65
LOCAL	32.67	13.33	11.13	11.17	4.33	2.33	4.83	2.92	7.83	6.5	79	49	26.7	38.7	4.9	7.7
MEAN	20.23	21.22	11.7	15.22	12.73	4.58	9.62	5.3	14.92	12.56	268	111	39.7	58.6	19.3	57.41
F-LSD (0.05)	6.569	6.569	4.525	4.525	4.777	4.777	3.151	3.151	2.564	2.564	133.5	133.5	18.85	18.85	69.64	69.64

Y_1 = Year 1; Y_2 = Year 2; PODFILL = Days to pod filling; 100 SWT = 100 Seed Weight; NPOD/PLT = Number of pods per plant; NSED/POD = Number of Seeds per pod; PODLT = Pod length; GYD/HA = Grain yield per hectare; Thresh % = Threshing percentage; HI = Harvest Index.

radiation and leaf area index as well as lower pest pressure in early season. This result confirmed those findings except that differences in yield between the two seasons could also be attributed to rainfall, since the reproductive period was longer in the early season than late season owing to adequate moisture. This view was supported by Hall (1992), Ismaila and Hall (1998) who noted that early sowing enabled cowpea to escape high temperatures during the flowering stages when the crop was sensitive to heat and the crop would mature before the rains ceased. Higher grain yield in early season could therefore be attributed to longer duration of pod filling which was observed in early season in this study. This result was in line with that of Evans (1993) who reported that the longer the duration of growth period, the higher the potential photosynthates production and consequently the better the crop performance.

The result further showed that plant population was higher in early season than late season, indicating that lower soil temperatures at the time of late planting affected seed germination, and consequently resulted in lowered plant population. Lower cowpea grain yield as observed in this study in late season could be attributed to this phenomenon. Ismail et al. (1997) reported that warm season annual crop such as cowpea exhibited slow and incomplete emergence when subjected to cool soils.

The threshold soil temperature where cowpea exhibits incomplete emergence is about 19°C. Soil temperatures below 19°C often occur at the peak of rainy season. Craufurd et al. (1997) reported that with optimum soil moisture, the rate of seed germination increased linearly as temperature increased. Hall (1992) recommended that farmers should adopt early sowing at high soil temperature because such practice would result in higher plant population and better crop yield. The differences in yield pattern across these locations as observed in this study are as expected, and justified the evaluation of crop species in environments with distinct biotic and abiotic resources. A complete evaluation of crop genotypes cannot take place in one environment as use of the results of the evaluation would be limited only to that environment. However, even in one environment, evaluation should be carried out at least for two or more years and in different seasons (Baiyeri, 1998; Perrino and Monti, 1991).

In this study, season was found to exhibit significant effect on cowpea flowering. The non-photosensitive genotypes flowered and produced components of grain yields as expected in both seasons, while the local variety failed to flower and produced no yield in the first season owing to its sensitivity to photoperiod. This result is in conformity with Nangju et al. (1979), Singh et al. (2002)

and Kamara et al. (2009). The shortened days to flowering as observed in this study is in agreement with Summerfield and Roberts (1985) who noted that warmer temperature hasten the appearance of flower in both photoperiod sensitive and insensitive genotypes.

The result also showed that pod length, number of seeds per pod, number of branches and number of internodes were least influenced by seasonal changes. This result confirmed the observation made by Uguru and Uzo (1991) and Singh et al. (2002) that these traits are moderately to highly heritable.

Threshing percentage and harvest index were affected by season in a similar way it affected grain yield with early season favouring higher expression of both traits. Harvest index was directly related with some yield components. This finding is supported by Kwapata and Hall (1990) who noted that harvest index was positively correlated with yield and yield components in cowpea. This indicated that the yield potential of cowpea could be raised by selecting for high harvest index.

Local cultivar recorded significantly lower yield and yield components than improved cultivars. The higher yield of improved cowpea over local variety was supported by Singh et al. (2002) who showed that the use of improved varieties led to the realization of 4 tonnes per hectare. Local cultivars were found to be poor in resource capture and utilization. The local variety although had lower plant population, it nevertheless produced the highest fresh and dry fodder yield as well as other growth components especially in early season. This observation is supported by Singh et al. (1997) and Blade et al. (1992) who reported that while the traditional varieties do not yield as much grain, they do give large fodder yield. IT90K-227-2 and IT97K-556-4 exhibited dual-purpose characteristics in both seasons having produced high yield of both grain and fodder, while the rest of the genotypes were purely grain type. Earlier reports by Ajeigbe et al. (2005), Singh et al. (1997) and Kamara et al. (2010) were confirmed in this study as they also identified these cultivars as dual-purpose cowpea. IT98K-131-2 gave significantly higher yield and yield components. Its superior performance cut across seasons, locations and years indicating that the cultivar had broad and stable adaptation. Kamara et al. (2010) working in northern Nigeria also identified this cultivar as high yielding.

Most of the cultivars expressed similar I00 seed weight across different environments. For instance, the cultivars IT90K-277-2, IT98K-556-4, local and IT93K-452-1, produced significantly higher and more stable 100 seed weight while IT84S-2246-4 and IT 90K-82-2 consistently produced smaller seed size across all the environments. This result is corroborated by Karkannavar et al. (1991) who pointed out that seed size in cowpea is highly heritable and is less affected by environment. Drabo et al. (1984) concluded that the gene action controlling seed size is predominantly additive but they also noted that it could be modified by environment. This is in conformity with the findings in this study. IT90K-277-2, IT98K-556-4 and IT93K-452-1 were earlier identified by IITA (1995) as possessing large seed size.

The cultivar IT97K-556-4 expressed significantly higher grain and fodder yield attributes in early season, particularly in Mgbakwu location while its yield and yield components were significantly depressed in late season making it a cultivar with narrow adaptation to early season.

Conflict of Interest

The authors have not declared any conflict of interest.

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Influence of herbivorous insects on the production of *Lagenaria siceraria* (Molina) Standley (Cucurbitaceae)

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The production of indigenous cucurbits remains very low in tropical zones, mainly due to herbivorous insect damage. This study was conducted in Manfla located in the centre of Côte d'Ivoire at 400 km from Abidjan to evaluate the impact of herbivorous insects on foliar damage and agronomic parameters of *Lagenaria siceraria* (Molina) Standley (Cucurbitaceae). Our study revealed that nine insect species belonging to four families and three orders were responsible for foliar damage. The leaves were perforated, shredded and eaten away. The extent of foliar damage was estimated for each accession during three consecutive cropping seasons. For the oleaginous gourd accessions NI227, NI219 and NI180, over 75% of the leaf surface was regularly destroyed. For the bottle gourd accessions NI431 and NI432 and the oleaginous gourd accession NI354, leaf surface damage was less than 25%. Thirteen accessions were intermediate between the two groups of accessions cited above. There was no significant difference between fruits weight and seed weight for accessions NI431, NI432, NI354 and NI434, whether or not plants were treated with a broad spectrum cypermethrin based-insecticide (Cypercal 50 EC). However, these parameters differed significantly for accessions NI227, NI219 and NI180.

Key words: Herbivorous insect damage, agronomic parameters, damage on foliar surface, extent of foliar damage.

INTRODUCTION

In several areas of Africa, the production of numerous crops has declined sharply as the result of major pests and disease outbreaks (Gogi et al., 2009; Stoddard et al., 2010). Literature on sustainability often touches on pest

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and disease issues, but concern has been limited to major crops. Little attention has been paid to neglected and underutilized crops such as indigenous oleaginous gourd *Lagenaria siceraria* (Molina) Standley (Cucurbitaceae) cultivated for seed consump-tion. *L. siceraria* has been reported to have considerable agronomic and economic potential for small farm holders (Taffouo et al., 2008), and its leaves and flowers play an important role in traditional medicine (Edeoga et al., 2010; Achu et al., 2013). This species is composed of two varieties. The first called “egussi” is cultivated for their oleaginous seeds. The dried and slightly roasted kernels are transformed into a paste for consumption as soup thickener. The second called “bottle gourd” is grown for non-food used and the mature fruit can be used as bowls, utensils, and musical instruments. However *L. siceraria* production remains low (Zoro Bi et al., 2003; Achigan-Dako et al., 2008; Taffouo et al., 2008). The low production of *L. siceraria* may be due to several factors, among them are insect pests (Dhillon, 2005; Ayalew, 2006; Koch et al., 2004). Herbivorous insects are known to affect the fitness and dynamics of plant populations and strongly influence morphology, physiology, phenology, and seed production of individual host plants (Maron and Vila, 2001; Maron and Crone, 2006). According to Muro (1998), defoliation causes significant yield reduction on onion crops. In fact, leaves play an important role in the production of food substances through the process of photosynthesis; hence defoliation might be detrimental to plant growth, survival and crop production. Hoffmann (2000) showed that removal of 20% of the leaf area of *Cucurbita pepo* L. significantly reduced the weight of marketable fruit. Agunloye (1986) reported that foliar damage by the flea beetle *Podogrica* on *Abelmoschus esculentus* L. Moench in Nigeria led to as much as a 50% reduction in yield. Unfortunately quantitative data on yield loss in *L. siceraria* attributed to herbivorous insect damage is limited. Knowledge of the yield-loss relationships between a crop and its associated pest is an important aspect of any integrated pest management program (Pitan and Okoja, 2011). So ethology of insect pests could be necessary in order to understand their effect on plants (Fomekong et al., 2010). The aim of this study is to estimate the extent of foliar loss to herbivorous insects on *L. siceraria* and its conse-quences for reduction in yield. Such data would provide a basis to develop effective pest control methods and to improve the productivity.

MATERIALS AND METHODS

Study site

On farm experiments were conducted in 2008 and 2009 in the village of Manfla (6°49'34.38"N, 5°43'47.68"W). This village located 400 km North of Abidjan (Côte d’Ivoire) is characterized by high production of cucurbits. There are two rainy seasons separated by a short period dry (July-August) and a long dry season (December-February) at the target site. Annual rainfall varies from 800 to 1400 mm with a long-term mean of 1200 mm and the annual mean temperature is 27°C.

Over the experimental periods the mean monthly temperature was 32°C in 2008 for the first cropping season (March–June) and mean monthly rainfall was 138.88 mm. Mean relative humidity was 786.52%. In second cropping season (July–December), the mean monthly temperature was 31°C. Mean monthly rainfall and mean relative humidity were 76.91 mm and 83.04% respectively. In 2009, the mean monthly temperature, mean monthly rainfall and mean relative humidity were 32°C, 100.13 mm, and 81.52%, respectively for the only third cropping season.

The vegetation is a woodland savanna. Soil testing at 20 cm depth revealed the following characteristics: pH=6.45 with 57% sand, 36% Silt, 7% clay, 6% organic matter, 3.5 g/kg total N, 24.4 g/ kg of available P and 0.45 g / kg of K (Kouassi and Zoro Bi, 2009).

Plant material and experimental design

Plant material is composed of two varieties of *L. siceraria*: an oilseed type and a bottle gourd type. Nineteen open-pollinated accessions of *L. siceraria* were selected from the collection of the University Nangui Abrogua (Abidjan, Côte d'Ivoire), 13 accessions of oleaginous (oilseed) type and 6 of bottle gourd. Plants were collected from different areas of Côte d'Ivoire (Table 1). Genotypes used in this work resulted from three generations of in-breeding. A plot of 50 m x 30 m was established to evaluate herbivorous insect damage on leaves of *L. siceraria*. Plants were sown according to a completely randomized design with one replication per accession. Each accession is being represented by 5 plants. Three seeds were sown per hole at depth of 3 cm and thinned to one plant per hole at the two-leaf stage. The holes were arranged in rows at spacing of 3 m between and within rows. And the distance between the plot and edge was 1.5 m. A total of 95 plants were screening. The plot was weeded manually throughout the period of plant development.

Sampling of herbivorous insects

Sampling of herbivorous insects was carried out in vine creeping stage. Activities of herbivores were monitored daily on each plant during this vegetative stage. The type of damage caused by each insect species on leaves and their modes of attack was noted. Insects were sampled with sweet netting and those which only fed leaf were considered in this study. An inventory of insects was performed twice weekly. Insects captured were stored in a pillbox 2/3 filled with ethanol (70%) until they were identified. Defoliating insects were identified to the species level in the laboratory of Zoology and Entomology of National Polytechnic Institute Houphouët Boigny of Yamoussoukro (INP-HB). Identification keys adapted for insects from the tropical zones were used (Appert and Deuse, 1988; Michel, 1990; Poutouli et al*.,* 2011).

Intensity of foliar damage on accessions

The extent of foliar damage to each plant was scored based on visual inspection of insect damage on leaves. An estimate of the Severity of Damage on a plant (SeDa) was assigned to each plant. Five plants were used for each accession. The SeDa score consisted of 5 classes (1 – 25% or less of the leaf surface damaged, 2 – 26 to 50% damage, 3 – 51 to 75% damage, 4 – 76 to100% damage, and 5 indicating plant death) (Bubici and Cirulli,

Table 1. Collection zone and physical characteristics of *Lagenaria siceraria* accessions.

Accessions	Variety	Fruit shape	Collection site	Collection zone
NI219	Oleaginous	Round	Alépé	South
NI227	Oleaginous	Round	Alépé	South
NI252	Oleaginous	Oval	Alépé	South
NI180	Oleaginous	Oval	Bongouanou	Southeast
NI174	Oleaginous	Round	Bongouanou	Southeast
NI185	Oleaginous	Oval	Bongouanou	Southeast
NI354	Oleaginous	Round	Bondoukou	East
NI359	Oleaginous	Oval	Bondoukou	East
NI347	Oleaginous	Oval	Bondoukou	East
NI304	Oleaginous	Oval	Bondoukou	East
NI106	Oleaginous	Elongated	Gohitafla	Centre
NI421	Oleaginous	Elongated	Mankono	North
NI420	Oleaginous	Elongated	Mankono	North
NI425	Bottle gourd	Oval	Ouangolo	North
NI429	Bottle gourd	With sleeves	Ouangolo	North
NI430	Bottle gourd	With sleeves	Niéllé	North
NI431	Bottle gourd	Round	Niéllé	North
NI432	Bottle gourd	With sleeves	Ouangolo	North
NI434	Bottle gourd	With sleeves	Ouangolo	North

2008; Sobrinho et al., 2010).

Impact of foliar damage on agronomic parameters

Two plots (treated and untreated) were established to evaluate the impact of foliar damage on agronomic parameters of *L. siceraria*. Each plot was a 50 m × 30 m. One of the two plots was treated with a broad spectrum cypermethrin based-insecticide (Cypercal 50 EC) at a dose of 0.8 l/ha and the second was not treated. Three applications of insecticide were conducted on the treated plot to insure that most herbivorous insects were eliminated from the plot. The first application occurred when 50% of seedlings reached the stage of 2-3 leaves, the second application occurred when 50% of the plants began crawling, and the final application occurred when 50% of male flowers appeared (Goré Bi et al., 2011).

Four parameters were measured during each cropping seasons: the Plant Length (PL) was measured on main stem from the plant basis for the 5 estimates per accessions (95 plants of each plot were measured after 120 days), the Number of Fruits (FN), was the total number of fruits per plant at maturity in each plot. Fruit Weight (FW): 5 fruits where weighted with a scale after harvest for the 5 estimates per accessions (475 fruits in each plot). Seeds Weight (SW): total seeds from each fruit were weighted with an electronic scale after drying for the 5 estimates per accessions (475 fruits in each plot).

Comparison of agronomic traits between accessions from the treated and untreated plots allowed us to estimate the impact of pests on crop productivity. The estimation of seed weight loss (SWL) for each accession was done through the ratio of the difference of seed weight collected from the treated and untreated plots and was calculated as SWL (%) = $[(SW_{treated} - SW_{untreated})/SW_{treated}] \times 100$ according to Ahn (2005).

Statistical analysis

Statistical analyses were carried out using SPSS 16.0 (SPSS, 2007). To test for differences among accessions data on the severity of damage on leaf surfaces from each accession were subjected to Analysis of Variance (ANOVA). Following the ANOVA, when there were significant differences between accessions, means were separated using the Student Newman Keul Test (SNK). Student's – *t* test was carried out also to evaluate impact of foliar damage on agronomic parameters of *L. siceraria*. All tests were performed with an $\alpha = 0.05$.

RESULTS

Inventory of herbivorous insects and description of damage

Insects collected belong to three orders (Coleoptera, Lepidoptera and Orthoptera), four families (Chrysomelidae, Coccinellidae, Plutellidae and Pyrgomorphidae) and nine species (Table 2). A total of 1,388 herbivorous insects were collected during the three cropping cycles (512, 451 and 425 insects respectively for the first, the second, and the third cycle). The average number of herbivorous insects per plant was 5.39, 4.74 and 4.47 during the first, the second and the third cropping cycle respectively. Among these insects sampled on *L. siceraria*, *Lamprocopa occidentalis* (Coleoptera: Chrysomelidae), *Lilioceris livida* (Dalman) (Coleoptera: Chrysomelidae) and *Henosepilachna elaterii* (Rossi) (Coleoptera: Chrysomelidae) were present during the three cropping

Table 2. Number and percentages of herbivorous insects collected on *Lagenaria siceraria* per cropping cycle.

Herbivore collected			Individual record (%)		
Orders	**Families**	**Species**	**1st cropping cycle**	**2nd cropping cycle**	**3rd cropping cycle**
Coleoptera	Chrysomelidae	*Lamprocopa occidentalis*	207 (40.43)	291 (64.52)	114 (26.82)
Coleoptera	Chrysomelidae	*Ootheca mutabilis*	9 (1.76)	–	–
Coleoptera	Chrysomelidae	*Lilioceris livida*	104 (20. 31)	140 (31.04)	120 (28.23)
Coleoptera	Chrysomelidae	*Asbecesta cyanipennis*	60 (11.72)	–	37 (8.70)
Coleoptera	Chrysomelidae	*Aulacophora foveicolis*	27 (5.27)	–	59 (13.88)
Coleoptera	Coccinellidae	*Henosepilachna elaterii*	30 (5.86)	20 (4.43)	25 (5.88)
Coleoptera	Coccinellidae	*Henosepilachna reticulata*	33 (6.44)	–	21 (4.94)
Lepidoptera	Plutellidae	*Plutella xylostella*	13 (2.54)	–	–
Orthoptera	Pyrgomorphidae	*Zonocerus variegatus*	29 (5.67)	–	49 (11.53)

-: absent.

Lamprocopa occidentalis *Asbescesta cyannipennis* *Hennosepilachna elaterii*

a b c

Figure 1. Damage of host-specific herbivore.

Table 3. Mean values of the SeDa score of herbivorous insect damage for accessions per cropping cycle.

Accessions	*Defoliating damage on *Lagenaria siceraria*		
	First cropping cycle (March-July 2008)	**Second cropping cycle (August-December 2008)**	**Third cropping cycle (March-July 2009)**
NI227	5.000±0.000^{a}	4.666±0.577^{a}	4.750±0.500^{b}
NI219	5.000±0.000^{a}	5.000±0.000^{a}	4.750±0.500^{ab}
NI180	5.000±0.000^{a}	5.000±0.000^{a}	5.000±0.000^{a}
NI185	3.000±0.000^{c}	3.000±0.000^{c}	3.000±0.000^{c}
NI174	3.666±0.577^{b}	3.000±0.000^{c}	4.000±0.000^{bc}
NI252	3.666±0.577^{b}	3.000±0.000^{c}	3.333±0.577^{c}
NI106	2.333±0.577^{d}	3.000±0.000^{c}	-
NI304	2.000±0.000^{d}	2.000±0.000^{e}	3.000±1.000^{c}
NI347	2.000±0.000^{d}	2.000±0.000^{e}	3.250±0.500^{c}
NI354	1.333±0.577^{e}	1.250±0.500^{fg}	4.000±1.000^{bc}
NI359	2.333±0.577^{d}	2.000±0.000^{e}	2.666±0.577^{c}
NI420	2.666±0.577^{d}	2.333±0.577^{de}	1.666±0.577^{d}
NI421	2.333±0.577^{d}	3.000±0.000^{c}	3.000±0.000^{c}
NI425	2.000±0.000^{d}	3.000±0.000^{c}	2.666±0.577^{c}
NI429	2.000±0.000^{d}	3.000±0.000^{c}	3.000±1.000^{c}
NI430	2.000±0.000^{d}	3.000±0.000^{b}	3.000±0.000^{c}
NI431	1.000±0.000^{e}	1.000±0.000^{g}	1.500±0.577^{d}
NI432	1.333±0.577^{e}	1.333±0.577^{fg}	3.000±0.000^{c}
NI434	2.000±0.000^{d}	1.666±0.577^{ef}	3.000±0.000^{c}
F	32.990	51.180	9.070
P	<0.001	<0.001	0.001

*Mean values followed by the same superscript were not significantly different (p≥ 0.05).
-: absent

cycles. *L. occidentalis* was the most abundant with 40.43, 64.52 and 26.80% respect-tively in the first, the second, and the third cropping cycle. Injuring symptoms caused by herbivorous insects are characterized by round feeding holes on *L. siceraria* leaves (Figure 1a). Leaves were also shredded by herbi-vorous insects (Figure 1b) and eaten away (Figure 1c).

Intensity of foliar damage on accession

The insect feeding damage on the tested *L. siceraria* accessions varied from 1 to 5. The foliar damage of the three accessions NI354 (oleaginous gourd), NI431 and NI432 (bottle gourd) was less than 25% according to the classification scale adopted. On the other side, the accessions NI227, NI219 and NI180 presented more than 75% of foliar damage. Percentage of leaves destroyed was between 25 and 75% for thirteen accessions composed of 4 accessions of bottle gourd (NI425, NI429, NI430 and NI434) and 9 accessions of oleaginous gourd (NI185, NI174, NI252, NI106, NI304, NI347, NI359, NI420 and NI421) (Table 3).

Impact of damage plant production

Four parameters were measured to evaluate plant production. Among the nineteen accessions, seed weight (SW) did not differ significantly for only four accessions between treated and untreated plots: NI354, NI431, NI432 and NI434 respectively (Table 4). The loss of seed weight varies between 0.74% (NI431) to 18.97% (NI432) and high of 60% for NI227, NI219 and NI180 accessions. It varied from 26.03 to 44.92% for the other accessions. NI219 and NI434 were the only two accessions out of nineteen for which plant length (PL) and numbers of fruit (NF) were significantly influenced by the treatment. Fruit weight (FW) variation showed that 6 accessions (NI429, NI425, NI420, NI180, NI227 and NI219) of the 19 accessions were significantly influenced by insect feeding damage. Fruit weight of these accessions was lower in untreated plots compared to treated plots.

DISCUSSION

The present study revealed nine species of insects

Table 4. Agronomic parameters of *Lagenaria siceraria* from treated and untreated plots.

Accessions	Length of the plant				Number of fruits per plant				Fruit weight				Seed weight				Loss of seed weight Pg (%)
	Untreated	Treated	*t*	*P*	Untreated	Treated	*t*	*P*	Untreated	Treated	*t*	*P*	Untreated	Treated	*t*	*P*	
NI227	4.12±1.11	4.19±1.12	0.12	0.90	1.10±0.87	1.88±1.05	1.78	0.09	372.72±153.07	936.76±191.44	8.20	<0.01	6.98±4.46	20.24±9.25	4.41	<0.01	65.51
NI219	2.99±0.55	3.45±0.75	2.99	0.13	0.70±0.82	1.88±1.05	2.75	0.01	375.00±72.16	633.82±149.72	4.32	<0.01	6.38±4.20	16.62±5.68	4.28	<0.01	61.61
NI180	3.40±1.14	3.23±1.43	2.27	0.78	0.70±0.67	1.44±1.01	1.90	0.07	375.00±50.00	690.38±169.10	4.76	<0.01	6.91±5.10	20.24±7.78	4.05	<0.01	65.85
NI185	4.27±1.18	4.20±1.42	0.11	0.90	1.77±0.83	1.50±0.70	0.78	0.44	525.00±179.35	578.33±152.38	1.38	0.38	8.88±4.40	16.12±8.71	3.91	<0.01	44.92
NI174	4.38±2.17	4.28±2.27	0.09	0.92	2.00±0.86	2.00±1.18	0.00	1.00	623.68±219.29	715.27±214.22	1.28	0.20	13.75±6.77	22.78±9.92	3.26	<0.01	33.64
NI252	3.18±1.22	2.63±1.25	0.95	0.35	1.55±0.72	2.00±1.24	0.93	0.36	525.00±135.87	645.00±218.16	1.82	0.07	12.16±4.14	20.58±6.88	4.07	<0.01	40.91
NI106	6.16±0.90	5.99±0.95	0.31	0.75	1.83±0.75	1.66±1.21	0.28	0.78	963.63±252.5	1152.50±507.77	1.09	0.28	13.17±3.72	23.75±12.67	2.65	0.01	44.54
NI304	6.92±0.91	7.78±1.30	1.62	0.12	2.00±1.00	1.66±1.11	0.66	0.51	1431.94±349.45	1445.00±416.53	0.09	0.92	20.85±7.93	35.70±17.44	0.80	<0.01	41.59
NI347	7.54±0.68	7.89±1.53	0.65	0.51	2.10±0.73	2.22±0.97	0.31	0.75	1379.76±320.11	1461.25±497.32	0.62	0.53	17.63±10.68	31.56±13.08	3.74	<0.01	44.13
NI354	6.35±1.18	6.54±0.84	0.42	0.67	1.50±0.52	1.27±0.46	1.04	0.30	1731.61±729.96	1663.63±524.18	0.43	0.66	31.60±6.91	34.97±14.06	3.23	0.42	10.66
NI359	8.11±1.38	8.64±1.75	0.76	0.45	2.80±1.39	2.27±1.34	0.87	0.39	1336.60±343.96	1345.00±341.86	0.08	0.92	21.17±15.54	32.06±17.21	2.42	0.01	33.96
NI420	6.46±2.16	6.21±1.04	0.30	0.76	2.00±1.00	1.77±1.39	0.38	0.70	1208.33±492.96	1514.06±324.51	2.10	0.04	24.31±9.32	35.38±19.41	2.15	0.03	34.52
NI421	5.31±0.87	5.56±0.68	0.68	0.50	1.66±0.70	1.88±1.05	0.52	0.60	898.21±331.00	1063.23±165.15	1.80	0.08	19.66±10.02	26.58±6.76	2.28	0.02	26.03
NI425	4.78±1.53	4.63±1.49	0.20	0.84	2.77±1.48	2.33±0.86	0.77	0.44	275.00±102.06	366.66±88.85	3.21	<0.01	9.89±3.81	14.99±6.47	3.22	<0.01	34.02
NI429	6.57±1.19	5.88±1.41	1.14	0.26	1.44±0.52	1.30±0.48	0.62	0.54	873.07±146.65	1101.92±250.51	2.84	<0.01	12.62±5.89	19.25±7.18	2.57	0.01	34.44
NI430	5.87±0.74	5.37±1.48	0.91	0.37	1.44±0.52	1.30±0.67	0.51	0.69	840.38±295.19	913.46±194.08	0.74	0.46	15.37±7.38	25.19±5.76	3.77	<0.01	38.98
NI431	6.63±0.95	7.33±1.54	1.20	0.24	0.88±0.33	0.90±0.56	0.05	0.95	2480.55±951.05	2325.00±192.43	0.48	0.63	69.81±27.69	70.33±17.21	0.04	0.96	0.74
NI432	5.10±0.69	4.77±0.85	0.89	0.38	1.12±0.35	1.11±0.33	0.08	0.93	1347.22±447.81	1445.00±448.88	0.47	0.64	35.40±10.04	43.69±19.95	1.12	0.27	18.97
NI434	5.34±0.71	4.55±0.69	2.50	0.02	1.22±0.44	1.27±0.64	0.19	0.84	1395.45±374.13	1503.84±497.37	0.59	0.55	36.83±19.56	41.89±23.55	1.44	0.56	12.07

belonging to three orders and four families responsible for leaf damage. Chrysomelidae represents more than 50% of the herbivorous insects sampled. The same species of Chrysomelideae have been reported by Adja et al. (2014) on *L. siceraria*. Insects belonging to Coleoptera and specifically to Chrysomelideae family were also collected on *Cucurbita moschata* (Duchesne) (Koch et al., 2004), *Citrullus lanatus* (Thunberg) Nakai and Matsumara and *C. pepo* L. (Thapa and Neupane, 1992). Although Lepidoptera and Orthoptera have not been reported as pests of cucurbits to our knowledge, they were reported as defoliators of other plants (Vayssieres et al., 2000; Idowu and Akinsete, 2001). The damage caused by these insects on the cited plants was identical to those observed in the present study on the leaves of *L. siceraria*. The pests caused three types of damages. The leaves were perforated, shredded and eaten away. Insects belonging to Lepidoptera and Orthoptera were already present before the planting in a large number and were found on the leaves of *L. siceraria* during the vegetative and flowering stages. These insects cannot be host-specific to *L. siceraria*. *L. occidentalis*, *Lilioceris livida* and *Henosepilachna elaterii* were present during the three cropping cycles. They might be considered as host-specific to *L. siceraria*. *L. occidentalis* appeared as the most abundant respectively in the first, second and third cropping cycle. The damage caused by this insect on the leaves was very impressive. It could be seen as the most harmful to *L. siceraria*.

The present study is the first step of a program research on screening collection of *L. siceraria* to defoliating insects. The determination of visual damages on leaves by herbivorous insects in this study has been also used by other researchers (Jacas et al., 1997; Kumar, 1997). This study showed that *L. siceraria* accessions react differently to insect attacks. Some of these accessions were less attacked than others. Our results show that herbivorous insects preferred leaves of oleaginous gourd than bottle gourd. These results could be explained by the fact that the leaves of oleaginous gourd are tenderer than the bottle gourd leaves. On the other hand, bottle gourd is the wild form of *L. siceraria* which is known to be well resistant to pests (Mladenović et al., 2012; Morimoto et al., 2006). It was reported that wild types have a high level of genetic diversity (Given, 1994). They are well adapted to extremely divergent agro-ecosystems and pests (Chweya and Eyzaguirre, 1999). One accession of oleaginous gourd presented the least foliar damage (NI354). This accession was identified as large-seed cultivar of *L. siceraria* (Koffi et al*.,* 2009) which was characterized by larger leaves. Some authors have reported that plants can react through a mechanical process by increasing for example, the size of their leaves or by elaborating wax or hairs on the surface of leaves to protect themselves (Eigenbrode and Espelie, 1995; Li et al., 2000; Lucas et al., 2000; Tsumuki et al., 1989).

The impact of leaf destruction was observed on plant production. Significant decrease of seed weight of NI227, NI219 and NI180 was observed. It might be due to intensity of the defoliation (above 80%). Leaf destruction reduces photosynthetic activities (Muro et al., 1998) and consequently, decreases plant production. This study showed that the seed weight of four accessions NI431, NI432, NI354 and NI434 were similar when plants were from plot treated or plot not treated. These accessions could be used in breeding program to develop high yielding accessions of *L. siceraria.*

Conclusion

Nine herbivorous insects belonging to four families and three orders were identified as responsible for foliar damage on *L. siceraria*. *L. occidentalis*, *L. livida* and *H. elaterii* might be considered as host-specific to *L. siceraria*. The leaves were perforated, shredded and eaten away. During the three cropping cycle, three accessions (NI431, NI354 and NI432) were less attacked. These accessions should be used as parental genotypes to investigate tolerance to defoliating insect for uses in breeding program.

Conflict of Interest

The authors have not declared any conflict of interest.

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