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Research Article

Role of two Organic Fertilizers (Pig and Poultry Manures) Associated with Insects' Activities on Okra (*Abelmoschus esculentus*, Malvaceae) Yields at Ntambessi (Northwest Region-Cameroon)

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Abstract

Field surveys of okra plant plots were conducted during two seasons in 2021 and 2022 in Ntambesi (Northwest Region - Cameroon) aiming to contribute to the improvement of the yield of okra by combining two organic fertilizers and flowering insects. The main factor was pollination with two levels (flowers left free to pollination and flowers isolated from insects). The secondary aspect was fertilization with three points, namely poultry manure, pig manure and the control. The growth parameters, the diversity of the entomaufauna, the foraging activity, the influence of anthophilous insects on pollination and the produce according to organic fertilizers and insects were evaluated. The results showed that the plants located on the plots treated with poultry and pig manure showed significant growth on the various parameters studied irrespective of the year. In both years, a total of six insect's species have been identified where *Ceratina* sp. (21.43%) ranks first followed by *Apis mellifera* (18.63%). A*pis mellifera* harvested pollen (56.19%) and nectar (43.81%) while *Ceratina* sp. solely harvested pollen (100%). The fruiting rate, the ratio of normal seeds and mean number of seeds per pod of flowers left free pollination was greater compared to those isolated from insects. Fructification was higher in the lot having poultry manure (90.49%) compared to the lot having pig manure (79.68%) and the control lot (73.77%). The use of organic manure especially the poultry manure and the maintenance of insect nest around okra are recommended to improve crop yield.

Keywords: *okra, poultry manure, pig manure, insects, pollination, yield.*

Introduction

Veggies cultivation is among the leading enterprises in gardening which is fast gaining grounds due to the greater appreciation of their nutrient values (Gardner, 2004), vitamins and minerals (Adeboye, 1996). *Abelmoschus esculentus* (okra) is widely cultivated in both tropical and sub-tropical regions (Phlips,1997) for its immature green fruits, seeds, fresh leaves and buds which can be used in stew, soups and salads (Tiamiyu, *et al*., 2012). The average productivity of okra has remained low with less significant changes over the last decades (Adekiya, *et al*., 2020). The lesser returns obtained has been accredited to many factors such as low soil fertility and insufficiency in vital mineral nutrients, the utilization of local varieties, inappropriate doses of manure, (Anim, *et al*., 2006; Tiamiyu, *et al*., 2012; Elkhalifa, *et al*., 2021) and less knowledge on the pollinating insects. There is therefore a need to meet the increasing demands of the growing population in

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developing countries especially in Cameroon (72,661 tons annually with a yield of 3,027 tons per hectare) where obtaining high yields is amongst the main goals of agronomic research. This has led farmers to devising methods through which soil fertility can be improved, mainly through the application of different types of manure (Mathew and Karikari, 1995). Organic manure is naturally available and contains moderate amounts of essential nutrients needed by plants (Shaji and Mathew, 2021). Being a short duration vegetable crop, Okra growth, yield and quality are largely influenced by the application of fertilizers. Apart the beneficial use of organic fertilizers, the insufficient knowledge on the positive impact of anthophilous insect on plant yield is scarcey documented whereas the insects play a very important role in agricultural production (Klein, *et al*., 2007). The flowering insects in general and Apoides in particular are of great ecological and economic importance because they positively influence agro-food production (Mutsaers, 1991). The general objective of this research is to assess the influence of organic fertilizers (poultry and pig manures) associated with insect pollinators on okra development and yields for their optimal management in Ntambessi-Bamenda, specifically (a) to appreciate okra growth, (b) to investigate the activity of pollinating insects on flowers and (3) to assess the effects of organic fertilizers and flowering insects on the yields of this Malvaceae.

Materials and Methods

Study station

The experimental investigations were performed during two seasons from the 14th of March to the 4th of July in 2021 and from the 22th of February to the 16th of June 2022 at Ntambessi-Bamenda, Mezam division, Northwest Region of Cameroon (Figure 1) during the end of the dry season and the start of the rainy period. The field for investigation was a plot situated at flat stone, on a point of 5.97544, N 5*58'31.884 latitude, 10.16664 E 10*9'59.97 of longitude and 1241 m of altitude above sea level. Bamenda has a tropical savanna climate bordering on a tropical monsoon climate with the months of January to April having high temperatures 25.9 °C to 25.6 °C, low temperatures of 13.2 °C to 16.7 °C, rainfall from 11.6 mm to 178.1 mm (Ayonghe, *et al*., 2002). The important vegetation present are the savannah, mountain forest, lowland forest and the afro-alpine vegetation (Neba, 1999).

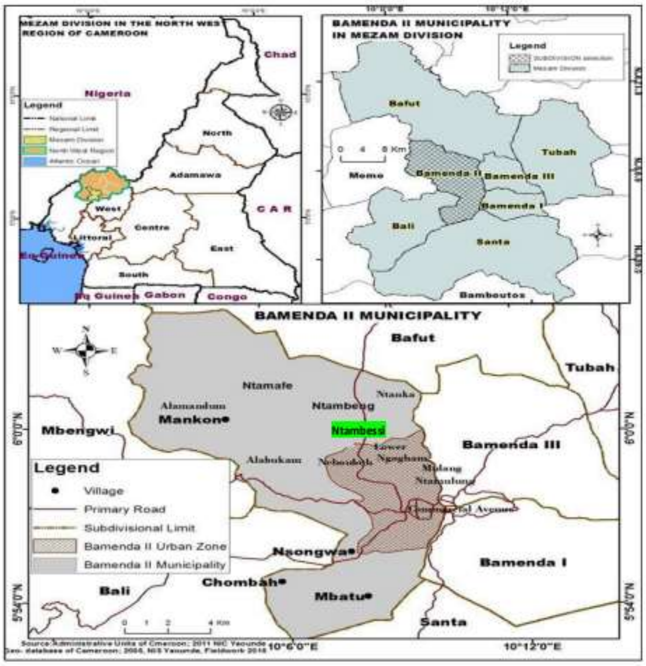

Figure 1: Location of study site

Biological Material
The animal material constituted of all insects naturally present in the environment of study station. Seeds of *A. esculentus* were supplied by an okra farmer based at Ntambessi. The pig and poultry manure was the organic manure used.

Preparation, Sowing and Tending of the Experimental Plot
The experimental field (6m X 7m) was cleared and cleaned using a cutlass on the l4th of March 202l and on the 27th of February 2022. Using a hoe, the soil was tilled forming three blocks. (B1, B2 and B3). Each block was subdivided into two ridges, giving a total of six ridges: lot 1 & lot 2 for B1; lot 3 & lot 4 for B2; lot 5 & lot 6 for B3; that were each 6 m long by 1m wide and 15 cm high.

Two weeks before planting, pig and poultry manure were added in block 1 and 2 respectively and mixed with the soil in holes destined for each okra plant. This gave time for the organic manure to decay, possibly countering the destruction of seeds by carbon dioxide released during decay (Ouda and Mahadeen, 2008). Okra seeds were sown at three grains per hole, 3 holes per line at a spacing of 30 cm by 30 cm between the lines. Fourteen days after germination, the plants were thinned by manual uprooting; leaving only one plant per hole (only the strongest foot of each hole was chosen for our investigations, based on physical observation). From germination on the 5th of April to the opening of the first flower on the 25th of May, the experimental farm was weeded and hoed, respectively, every two weeks. Plots were watered using a sprinkling can till rainfall was steady. Pesticides were not used on the farm land.

Determination of the Impact of Manure on the Growth of Okra
One week after the plants had emerged, on the 11th of April 2021 and the 15th of March 2022, 30 plants height was measured on each ridge from the ground line to the shoot tip using a measuring tape; the diameter of the root collar was measured using a vernier calliper and the number of leaves counted manually every week until the first flower appears. The weight of the okra pod was measured using a scale balance and the pod length using a ruler

Activity of Flowering Insects on the Flower of Okra
The experimental farm was divided into treatment A (lot 1, lot 3 and lot 5) which were bagged to prevent pollinators and treatment B (lot 2, lot 4 and lot 6) which were allowed free for insect visits (Figure 2).

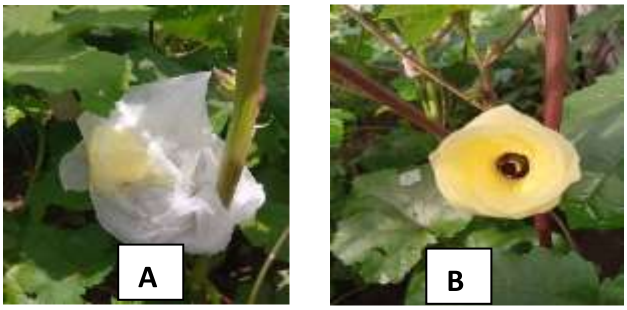

Figure 2: okra plants showing the different treatments (A: Protected flower with gauze bag; B: Unprotected flower)

Direct observations on free flowers were made every two days during four daily: 7am-9am, 10am-12pm, 1pm-3pm, 4pm – 6pm from the 25th of May in 2021 and from 21st of May 2022. During this period the numbers of insect's species on the blossomed flowers were counted and three to five specimens of each species were captured with an insect net and were preserved in a container made of 70% ethanol for future taxonomic identification except for Lepidoptera which were preserved in wrapper according to the Borror and White (1991) recommendations. Insects have not been marked; the cumulative results were expressed by the number of visits to determine the relative frequency (Fi) of each insect species in the anthophilous entomofauna of okra where, Fi ={[Vi/VI] * 100} With Vi = number of visits of the insect i on the flowers of the free treatment and VI the number of visits of all the insects on these same flowers (Tchuenguem, *et al*., 2001). Data on the relative frequency of visits to the various listed anthophilous insects will allow determining the place of each insect in the anthophilous fauna of the studied plant (Tchuenguem, 2005). Floral Products harvested by an insect were noted on flowers; it can be pollen, nectar or both based on the activity of the insect on the flower. The floral product being harvested was determined by the position of the insect on the plant: Insects that plunge their trunk into a flower are a nectar forager where as if it uses its mandibles and legs to scratch the anthers, it is a pollen forager. In this case, balls of pollen are observed in the baskets of the hind legs in Apidae, the collecting hairs of the legs in Halictidae and the ventral brush in Megachilidae (Borror and White, 1991). Pollen harvesting can be active (if pollen is collected) or passive (if by taking the nectar, the pollen accumulates on the insect's tegument and then collects it in its organs storage (Jousselin and Kjellberg, 2001). Also the duration of visit for each insect during the harvest of nectar or pollen was recorded. The floral products collected were systematically noted during the recording of the duration of the visits per flower.

For each year, this evaluation was based on the impact of insect visiting flowers on pollination, the impact of pollination on fructification of okra, and the comparison of fruiting rate of treatment A (bagged flowers) and treatment B (unprotected flowers).

1113 flowers of the studied plant at the bud stage were labelled (distributed over the ridges at the rate of 30 plants per ridge) and two treatments were made up: - Treatment A (lot 1, lot 3 and lot 5): 90 feet bearing 518 flowers delicately isolated using the gauze bags; - Treatment B (lot 2, lot 4 and lot 6): 90 feet bearing 595 free flowers. At maturity, fruits grown from each treatment were harvested and were individually tagged. Comparison was done on the fruit set rate between treatments. The fruiting rate, the percentage of the average number of seeds per pod and the percentage of normal seeds were calculated.

For each treatment, the fruiting index (Ifr) was determined based on the number of flowers and the number of actual fruits formed using the formula: Ifr = (Fr / Fl); where Fr is the number of fruit formed and Fl is the number of viable flowers initially borne. The percentage of the fruiting rate (Pf) was calculated according the following formula: Pf = {[(f1- f2) / f1] × 100}, where f1 and f2 represents the fruiting rate in each treatment. These data allow appreciate the influence of manure and flowering insects on fruiting rate (Tchuenguem, *et al*., 2014). The percentage of the average number of seeds per pod (Ps) was calculated using the following formula: Ps = {[(s1- s2) / s1] × 100}, where s1 and s2 represent the average number of seed by pod in each treatment. The percentage of normal seeds (Pn) was also determined using the formula: Pn = {[(ns1- ns2) / ns1] × 100}, ns1 and ns2 representing the percentages of normal seeds in each treatment.

Data Analysis

Data were analyzed using descriptive statistics, student's t-test for the comparison of means of two samples, correlation coefficient (r) for the study of the association between two variables, chi-square (χ^2) test for the comparison of two percentages using SPSS statistical software (version 19.0; SPSS, Inc., Chicago, Illinois, USA) and Microsoft Excel 2003.

Results

Efficacy of Amendment with two Organic Fertilizers (Pig and Poultry) on the Growth of Okra (Growth Parameters)

The plant height, the root collar diameter, the number of leaves and pod length increase with time in each of the treatments according to observation days. Figure 3 shows that, the plants present in the plots treated with poultry manure have a rapid growth with regard to the various parameters studied in relation to those of the plots treated with pig manure and those of the control plots.

Height: the average on the growth of okra plant height was 38.19 cm (n = 43; s = 5.69), 38.52 cm (n = 50; s = 4.71) and 32.51 cm (n = 42; s = 4.4) for poultry manure, pig manure and control respectively. The difference is highly significant between poultry, pig and control (Fpo-pi-co = 24.56; dof = 2; p = 0.0001).

Collar: the average on the growth of okra plant diameter was 0.51 cm (n = 34; s = 0.04), 0.49 cm (n = 34; s = 0.02) and 0.42 cm (n = 34; s = 0.14) for poultry manure, pig manure and control respectively. The difference is highly significant between poultry, pig and control (Fpo-pi-co = 9.13; dof = 2; p = 0.001).

Length: the average on the growth of okra leaves lenght was 13.76 cm (n = 47; s = 1.5), 13.04 cm (n = 47; s = 1.18) and 11 cm (n = 47; s = 1.49) for poultry manure, pig manure and control respectively. The difference is highly significant between poultry, pig and control (Fpo-pi-co = 43.70; dof = 2; p = 0.0001).

Abundance: the average on the leaves abundance of okra plant was 9.74 (n = 34; s = 2.27), 10 (n = 34; s = 2.24) and 8.13 (n = 34; s = 0.77) for poultry manure, pig manure and control respectively. The difference is high significant between poultry, pig and control (Fpo-pi-co = 29.16; dof = 2; p = 0.002).

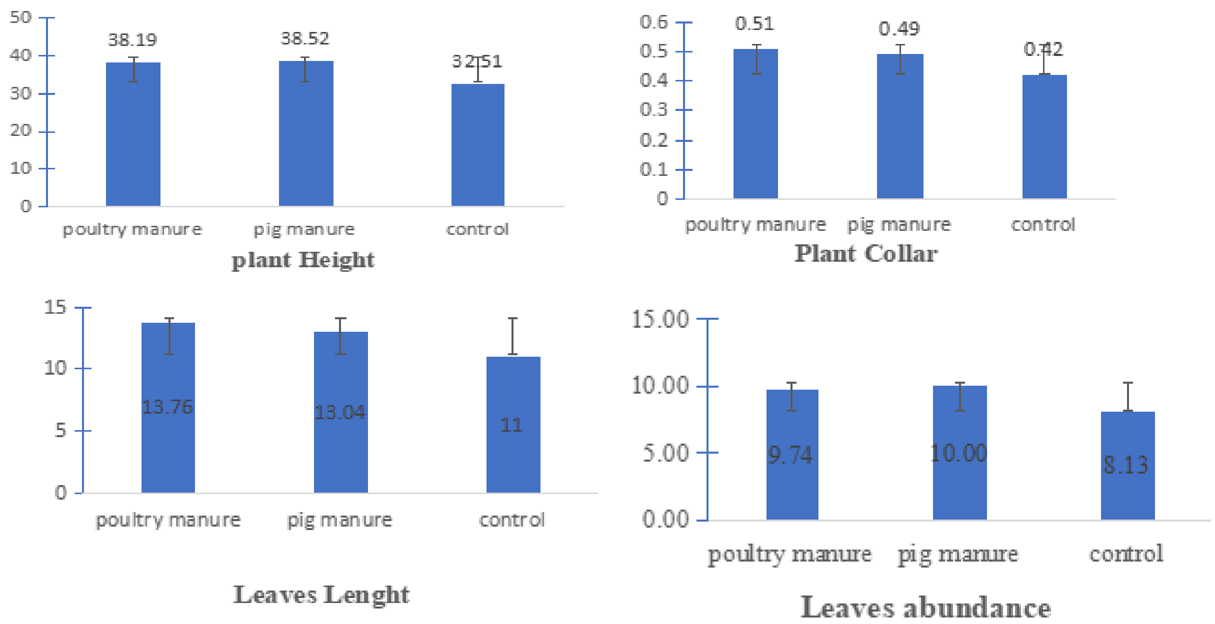

Figure 3: growth parameters of okra according to each treatment

Diversity and abundance of insects in the floral fauna of okra

In total, six insect's species belonging to three Families under two Orders visiting the okra plant were recorded during the two studied periods (Table 1). It appears that, Hymenoptera has the highest number of family and species. Among the families, the Apidae has the most representative species (four species) while the others (Vespidae and Hesperidae) have one species each. It appears that, for the two cumulative years, *Ceratina* sp. (21.43%) ranks first followed by *Apis mellifera* (18.63%) (Figure 4). We will not consider *Melipoluna* SP. because it has been seen only during the second year of investigation.

Table 1: Insect species recorded on okra flowers at Ntambessi in 2021 and 2022, number and percentage of visits of different insects.

Insects			**2021**		**2022**		**Total**	
Order	Family	Genus, Species	n_1	p_1 (%)	n_2	p_2 (%)	n_t	p_t (%)
Hymenoptera	Apidae	*Amegilla* sp.	185	23,60	-	-	185	2,62
		Apis mellifera	312	39,80	1005	15,99	1317	18,63
		Ceratina sp	275	35,08	1240	19,73	1515	21,43
		Meliponula sp	-	-	4022	63,99	4022	56,90
	Vespidae	*Belonogaster juncea*	3	0,38	18	0,29	21	0,30
Lepidoptera	Hesperidae	*Boaris* sp	9	1,15	-	-	9	0,13
Taxons	3	6	784		6285		7069	

n_1: number of visits on 1211 flowers in12 days; n_2: number of visits on 961 flowers in 12 days; n_t: Total number of visits for the two combined year on 2172 flowers in 24 days; p_1, p_2, p_t: percentages of visits; $p1 = (n1 / 784) \times 100$; $p_2 = (n_2 / 6285) \times 100$; $p_t = (n_t / 7069) \times 100$. Comparison of the percentage of *Apis mellifera* visits: 2021 / 2022: $\chi^2 = 260.57$ ($p < 0{,}001$; HS). Comparison of the percentage of *Ceratina* sp. visits: 2021 / 2022: $\chi 2 = 97.50$ ($p < 0{,}001$; HS).

Floral Products Harvested

Flowers of okra for the collection of pollen and/or nectar. The foraging behavior of these insect species varies with the food harvested. Nectar foragers were seen extending their proboscis to the base of the corolla while pollen gatherers scratched anthers with the mandibles or the legs. Out of 1317, *A. mellifera* visits recorded, 56.19% were devoted to the pollen harvest and 43.81% to the nectar harvest while all the 1515 visits (100%) of the *Ceratina* sp. were spent only to pollen harvest. The difference between the percentage of pollen harvest visits and the percentage of nectar collection of *A. mellifera* is significant ($\chi^2 = 8.03$; dof = 1; $p < 0.01$).

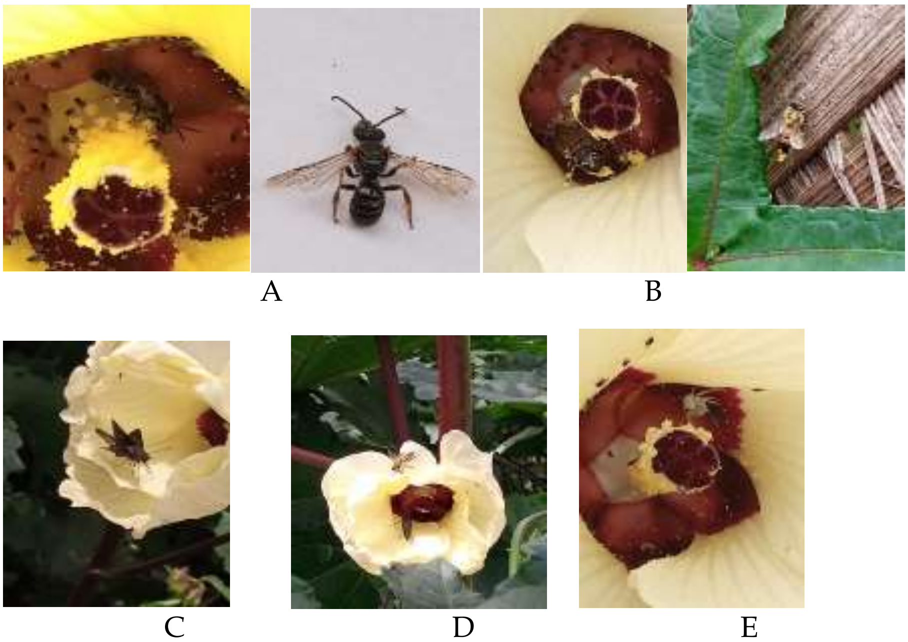

Figure 4: Some species of insects recorded on the flowers of okra from March to July 2021 at Ntambessi. (A): *Ceratina* sp. Collecting pollen (left) and a dorsal view of the species (right), (B): *Apis mellifera* collecting pollen on the okra flower (left) and the species in a resting position (right), (C): *Boaris* sp. (D): *Apis mellifera* and *Boaris* sp. as competing insects for the same floral product, (E): The predator, the white crap spider capturing *Ceratina* sp.

Duration of insect visits to okra flower

The duration of visits to a flower varies with the insect species. Table 2 shows that:

For *Ceratina* sp. the average duration of a visit to a flower for the collection of pollen was 38.81 sec.

For *A. mellifera*, the average duration of a visit to a flower was 32.88 sec for the collection of pollen and 26.09 sec for the collection of nectar.

The difference between these two means is highly significant. The average duration for both pollen and nectar collection is 29.49 sec. The difference is highly significant between the average duration of visit of *Ceratina* sp. and *A. mellifera*.

Table 2: Duration of nectar and pollen harvests from okra recorded for different insects in 2021 and 2022 at Ntambessi.

Insects	years		Harvest time per flower (sec)		
			n	*m*	*sd*
A. mellifera	2021	Pollen	148	23,53	13,49
		Nectar	148	21,49	11,89
	2022	Pollen	36	42,22	20,44
		Nectar	36	30,69	12,41
	total	Pollen	184	32,88	16,97
		Nectar	184	26,09	12,15
ceratina sp.	2021	Pollen	60	39,72	25,69
	2022	Pollen	42	50,36	34,02
	total	Pollen	102	45,04	29,86

n = number, m = mean, *sd*= Standard deviation. Comparison of the average duration of visit by *A. mellifera* devoted to the collection of pollen and nectar: t (nectar / pollen) = 42.21, dof = 366; $p < 0.001$, HS); Comparison of the average duration of visit by the two insect species: A. mellifera and *Ceratina* sp: t = 47.70, dof = 284, $p <0.001$, HS.

Yield evaluation of okra

Reproduction mode of okra

in 2021, the allogamy rate (AR) was 18.13% while the autogamy rate (AuR) was 81.87%; in 2022, the corresponding values are 15.50% and 84.50% respectively. For the two cumulated year, AR = 16.82% and AuR = 83.19% (Table 3). It emerges that okra has a mixed allogamous-autogamous reproduction regime, with autogamy being the principal one

Table 3: Reproduction mode of *Abelmochus esculentus* according to treatments

Year	Type of reproduction	% of reproduction		
		Poultry manure	**Pig manure**	**Control**
2021	Allogamy (AR)	8.17	24.43	21.80
	Autogamy (AuR)	91.83	75.57	78.20
Total	**AR = 18.13; AuR = 81.87**			
2022	Allogamy (AR)	5.72	18.70	22.08
	Autogamy(AuR)	94.28	81.30	77.92
Total	**AR = 15.50; AuR = 84.50**			

Determination of the Impact of Manure on Yields

Number of Pods Per Plant

The average number of pods per plant in uncovered plot that received poultry manure was 19.83 (n = 12; s = 5.89); that received pig manure, the average number of pods per plant was 19.17 (n=12; s= 7.63) and 12.25 (n= 12, s=3.47) in the control plot in 2021. In 2022, the corresponding value was 12.58 (n = 12; s = 5.89), 13.55 (n = 12; s = 4.52), 10.33 (n = 12; s = 2.15) for poultry, pig and control respectively.

The average number of pods per plant in covered plot that received poultry manure was 17.50 (n = 10; s = 8.86); that received pig manure, the average number of pods per plant was 11.70 (n=10; s= 4.57) and 10.33 (n= 11, s=4.73) in the control plot in 2021. In 2022, the corresponding value was 11.09 (n = 11; s = 4.95), 10.09 (n = 10; s = 2.63), 8.33 (n = 12; s = 2.71) for poultry, pig and control respectively. The difference between the number of pod produce in the different plots is significant in 2021(F_{2021} = 6.05 dof = 2, p = 0.006) and not significant in 2022 (F_{2022} = 2.40, df = 2, p = 0.11). The difference is significant between uncovered lot and covered lot that received pig manure (t_{2021} = 2.79; df = 20; p = 0.01; t_{2022} = 2.24; df = 21; p = 0.03) and not significant with lots that received poultry (t_{2021} = 1.06; df = 20; p = 0.304; t_{2022} = 0.66; df = 21; p = 0.52) and control (t_{2021} = 0.83; df = 21; p = 0.414; t_{2022} = 1.99; df = 22; p = 0.59). The plots treated with organic fertilizer produced more pods than the control treatment (Figure 5).

Number of Seeds Per Pod

The average number of seeds per pod was 46 (n= 206, s = 15.5) in the plot which received poultry manure, 42.5 (n= 206, s = 14) in the plot which received pig manure and 38 (n= 206, s = 15.5) in the control plot (Figure 5). The difference between the average number of seeds per pod in the different plots is significant (F = 4.93; dof= 2; P < 0.05).

Percentage of Normal Seeds

The percentage of normal seeds was 84.8% in the plot treated with poultry manure, 81.58% in the plot treated with pig manure and 69.27% in the control plot (Figure 5). The difference between the percentages of normal seeds in the different treatments is highly significant (χ^2 = 120.50; dof = 2; P < 0.05) (Table 4).

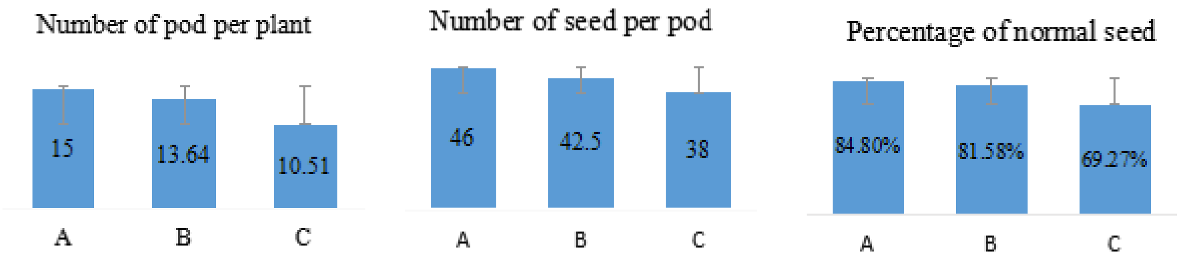

Figure 5: impact of the different manures on the okra yields in 2021 and 2022 at Ntambessi. A: Poultry manure, B: Pig manure, C: control.

Quantitative evaluation

- Poultry manure: The percentage of the number of pods per plant due to the action of poultry manure in the plot is 90.49%.
- Pig manure: The percentage of the number of pods per plant due to the action of pig manure in the plot is 79.68%.
- Control: The percentage of the number of pods per plant without any treatment is 73.77%.
- The plots treated with poultry manure lead to an increase in the formation of pods.

Impact of Insects on Okra Yields

Fruiting Rate

The fruiting rate was 92.74%, 88.99% and 81.51% in flower left in free pollination in poultry manure, pig manure and control treatments respectively. The corresponding values were 88.24%, 70.38% and 66.04% in flowers isolated from insects from the same treatment above. The difference is significant between the fructification rate of flowers left on free pollination and those flowers isolated from insects in the treatment with pig manure (χ^2 = 44.03; dof = 1; P < 0.001) and control (χ^2 = 20.55; dof = 1; P < 0.001). Generally, the mature fruit rate of flowers left free pollination is higher than those of isolated flowers of insects (Figure 6). The percentage of fruiting rate due to flowering insects is 4.84%, 20.91% and 18.98% in lot with poultry manure, pig manure and control respectively.

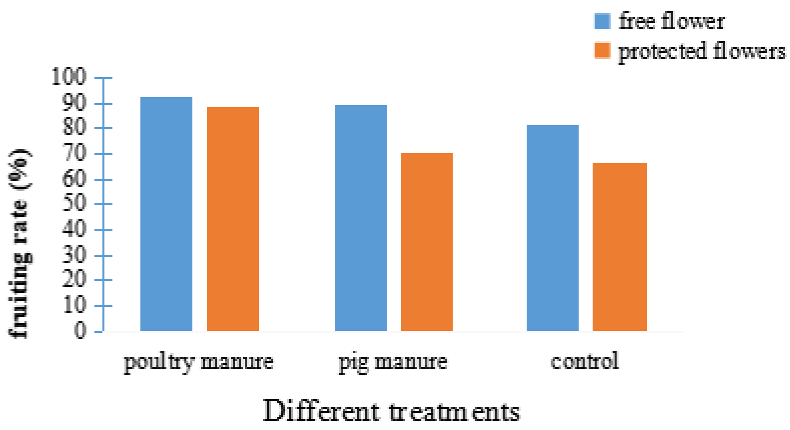

Figure 6: Fruiting rate of okra treatments in 2021 and 2022 at Ntambessi

Number of Seeds Per Pod

The number of seeds per pod was 53.71 (n = 94; s = 21.87), 53.18 (n = 94; s = 22.28) and 46.96 (n = 94; s = 16.64) in plot left in free pollination with poultry manure, pig manure and control respectively. The difference is significant between the treatment (F = 3.29; df = 2; p = 0.039). comparison between treatment pig-control (t = 2.34; df = 186; p = 0.02) and poultry-control (t = 2.38; df = 186; p = 0.018) is significant and not significant between treatment poultry-pig (t = 0.17; df = 186; p = 0.86). The corresponding values were 38, 36 and 30 in plots isolated from insects from the same treatment above. A difference highly significant was observed on the average number of seeds per pod in the treatment with poultry manure (t = 50.78, dof = 203; p < 0.001, HS), pig manure (t = 43.48, dof = 203; p < 0.001, HS) and control (t = 56.98, dof = 203; p < 0.001, HS). The average number of seeds per pod from the flowers left open for pollination is greater than those of flowers isolated from insects. The percentage of fruiting rate due to flowering insects is: 29.63, 25.51 and 3.33 in lot with poultry manure, pig manure and control respectively.

Ratio of Healthy Seeds

The ratio of healthy seeds was 90.60%, 87.91% and 70.57% in plot left in free pollination with poultry manure, pig manure and control respectively. The corresponding values were 79, 75.24% and 67.97% in plots isolated from insects from the same treatment above. The difference is highly significant between the percentage of normal seed of flowers left on free pollination and those flowers isolated from insects in the treatment with poultry manure (χ^2 = 157.84; dof = 1; P < 0.001), pig manure (χ^2 = 167.05; dof = 1; P < 0.001) and control (χ^2 = 253.75; dof = 1; P < 0.001).

The ratio of healthy seeds from the flowers left open pollination is greater than those of flowers isolated from insects. The ratio of healthy seeds due to anthophilous insects is 12.80, 14.41 and 3.63 in lot with poultry manure, pig manure and control respectively.

Table 4: Fruiting rate, mean number of seeds per pod and ratio of healthy seeds according to different treatments of okra in 2021 and 2022 at Ntambessi

Years	Treatment	Lot	NFS	NFF	FR (%)	Seed / fruit		Well-developed seed		
						m	*sd*	TNS	NNS	% NS
2021	Poultry	Uncovered$_1$	258	238	92,25	58	20	2887	2656	91,29
		Covered$_2$	186	165	88,71	44	18	2526	2151	83,21
	Pig	Uncovered$_3$	252	230	91,27	56	14	2816	2525	89,94
		Covered$_4$	167	117	70,06	43	15	2481	2041	81,73
	Control	Uncovered$_5$	176	147	83,52	50	15	2486	2208	86,66
		Covered$_6$	172	119	69,19	38	19	2430	1838	74,57

2022	Poultry	Uncovered$_{1'}$	162	151	93,23	50	16	2183	1980	89,9
		Covered$_{2'}$	139	122	87,77	32	9	977	735	73,82
	Pig	Uncovered$_{3'}$	188	163	86,7	42	18	1848	1626	85,88
		Covered$_{4'}$	157	111	70,7	30	9	940	644	68,74
	Control	Uncovered$_{5'}$	156	134	79,49	43	17	1863	1600	84,48
		Covered$_{6'}$	159	100	62,89	22	12	688	438	61,37
Total (2021&2022)	Poultry	Uncovered$_{7}$	420	389	92,74	54	18	5070	4636	90,60
		Covered$_{8}$	325	287	88	38	13	3503	2826	79
	Pig	Uncovered$_{9}$	440	393	88,99	49	16	4664	4151	87,91
		Covered$_{10}$	324	228	70,38	36	12	3421	2685	75,24
	Control	Uncovered$_{11}$	332	281	81,51	46	16	4349	3808	70,57
		Covered$_{12}$	331	219	66,04	30	15	3118	2276	67,97

NSF = number of flowers studied; NFF = Number of flower formed; FR = Fructification Rate; TNS = Total Number of Seed; NNS= Number of Normal Seed; % NS = percentage of Normal Seed, m = Average, *sd* = Standard Deviation; (2021) - poultry: uncovered$_1$= lot 1, covered$_2$= lot 2; pig: uncovered$_3$ = lot 3, covered$_4$ = lot4; control: uncovered$_5$= lot 5, covered$_6$ = lot 6; (2022) - poultry: uncovered$_1$′= lot 1′, covered$_2$′= lot 2′; pig: uncovered$_3$′ = lot 3′, covered$_4$′ = lot4′; control: uncovered$_5$′= lot 5′, covered$_6$′ = lot 6′; (2021&2022) - poultry: uncovered$_7$= lot 7, covered$_8$= lot 8; pig: uncovered$_9$ = lot 9, covered$_{10}$ = lot10; control: uncovered$_{11}$= lot 11, covered$_{12}$ = lot 12

Discussion

The okra plant (*A. esculentus*) responds positively to the application of organic manure. The different treatments are capable of improving the yield of the crop. There were changes in plant height, pod length, number of leaves, and root collar in both years. This result corresponds to that of Sharma (2004) in India; Nweke, *et al*. (2013) in Nigeria, who showed that plant height, fruit yield and weight yield of okra increases with the application of organic manure. Shahriazzaman, *et al*. (2014) in Dhaka (Bangladesh) also showed that application of organic manure (precisely poultry manure) not only improved the yield of okra but also sustained its production. Organic content of the soil also increases with the application of organic manure (Anim, *et al*., 2006); Leng (2006) stated in his findings that increase in yield when organic manure is applied is due to increase cation exchange capacity of cations such as calcium, magnesium, ammonium and potassium, thereby supplying all necessary nutrients required for growth.

The treatment with poultry manure had the highest number of leaves, largest root collar, highest number of fruits and longest pod length compared to pig manure and control. These results show that poultry manure had more impact on the vegetative growth of the plant compared to pig manure. This correspond to that obtained by Nweke, *et al*. (2013) in Nigeria where in their study of the influence of different types of animal manure on the growth and yield of okra, ranked poultry manure first, followed by goat manure before pig manure. Anim, *et al*. (2006); Nweke, *et al*. (2013); Fagwalawa and Yahaya (2016) also obtained alike results in their individual studies of cultivating okra with poultry manure. Increase number of leaves in treatments containing poultry manure means that the nutrients were readily available for easy absorption by the plants, thereby boosting the structural growth of the plant. This is also due to higher branching which leads to more leaves, and the more the leaves means more photosynthesis resulting in higher yield. This results agrees with that of Aniefiok, *et al*. (2013); Tswanga, *et al*. (2017) in Niger state who showed that in okra production using poultry manure, its nutrients are readily available and it application lead to increase in the number of leaves of the plant. They also showed that the effects brought about by the application of poultry manure may be due to its easy dissolution effect, high water holding capacity and release of plant nutrients into the soil thereby improving nutrient status, thus increasing the overall morphological parameters of the okra plant.

The flowers of *A. esculentus* are brightly coloured and its floral products are attractive to a variety of insects, which visit the plants to collect either nectar or pollen or both during their foraging activities. This corresponds with what was stated by Tchuenguem, *et al*. (2004); Azo'o, *et al*. (2011, 2012); Amada, *et al*. (2018), Otiobo, *et al*. (2021) in Cameroon, that insects visit okra flowers for their floral products. In this study, Hymenoptera, mainly the bees have been reported to be very important foragers for many flowering plants including *A. esculentus* and they are ranked the highest followed by other orders (Klein, *et al*., 2007; Nandhini, *et al*., 2018). Free (1993) in the UK showed that the Apidae had a vital role to play in the pollination of *A. esculentus*. This corresponds to that of Crane (1991) in India who identified the genus Apis as the prime okra pollinator. In the forest region of Ghana, the honey bees were also shown to be the main insect pollinator of *A. esculentus* (Angbanyere and Biadoo, 2014). Njoya, *et al*. (2005) also mentioned *A. mellifera* in the floral entomofauna of okra in Cameroon. Azo'o, *et al*. (2011, 2012) in Maroua-Far North Region of Cameroon recorded *Eucara macrognatha* as the most active visitor of *A. esculentus* flowers. Pauly (1984) in some tropical country in Africa, collected from okra flowers, *E. macrognatha* and *Tetralonia fraterna*. Besides the bees, other insect species have been recorded to visit *A. esculentus* flowers, like butterflies, Drosophila sp. (fly), Belenogaster juncea (wasp) and Podogrixina decolorata (beetle) (Tchuenguem, *et al*., 2004; Azo'o, *et al*., 2011; Otiobo, *et al*., 2020). Comparing the results obtained with that from previous studies, it can be concluded that the floral entomofauna of *A. esculentus* varies with seasons and study side.

The floral products (nectar and pollen) of okra flowers are available in great quantities, enough to sustain the nutritional needs of flowering insects and also have a high concentration of sugars about 21.74% as stated by Azo'o, *et al*. (2012). The pollen is also a rich source of proteins (Pesson & Louveaux, 1984). The bees visit flowers for their nutritional needs and this can be a suitable explanation for attractiveness of these bees to the nectar and pollen of *A. esculentus*. *Apis mellifera* harvested more pollen than nectar, this is because the flowers of *A. esculentus* are deep and their nectaries are not easily accessible due their large body sizes (Azo'o, *et al*., 2011). Toni, *et al*. (2020) in Southern Benin also recorded the presence of *Ceratina viridis* on okra flowers where they visited for the collection of pollen during their foraging activities. *Amegilla* sp have been reported to visit a wide range of flowering plants such pepper and okra (Bell, *et al*., 2005; Hogendoorn, *et al*., 2006). In this study, Ceratina and Amegilla species harvested solely pollen (100%) during their foraging activities.

It has been observed that the okra plant has a variegated reproductive mode: autogamy and allogamy, with the principal one being autogamy in both years. The pollen grains of okra are very large and not air borne (Mc Gregor, 1976), so self-pollination occurs because of the natural contact between the uppermost anthers and the lower parts of the stigma in okra leading to the production of okra fruits though in a lesser amount compared to when pollinators are present (Otiobo, *et al*., 2021). This is also supported by the work of Azo'o, *et al*. (2017) in Cameroon who stated that pollination in okra flowers occurs naturally before the opening of the flowers because the anther is dehiscent and the stigma is always receptive. Despite the fact that okra is self-pollinating; yield is greatly improved when pollination occurs (Angbanyere and Baidoo, 2014).

The fruiting index was higher in free flowers compared to the flowers that were protected to prevent pollinators. This shows that insect activity had great influence on the yield of okra. The number of pod obtained in the free plants was higher than that of the plants covered to prevent pollinator. These differences were highly significant indicating that pollination had a significant effect on yield. Al-Ghzawi, *et al*. (2003) stated in his work that larger number of pods or higher yields was obtained in insect pollinated plants due to greater transformation of flowers into younger fruits. Angbanyere and Baidoo (2014) obtained similar results in Ghana. Fruiting is dependent on pollination intensity most of the times (Mc Gregor, 1976) and significant difference in fruiting rate of the plant which let to increase yield is a consequence of the foraging activity of insects. The number of seeds in free pollinated plants was more than that obtained from plants that were covered to prevent pollinators. This is because in open flowers, there was sufficient pollination and more ovules were fertilized which developed into matured seeds, while most seeds were aborted in covered plants due to inadequate pollination. A study carried out by Stanghellini, *et al*., (1997) on the impact of honey bee and bumblebee pollination and fruit set abortion in cucumber and watermelon revealed that the numbers of aborted seeds were greatly reduced and the number of normal seeds increased as the number of pollinator visit increases.

The fructification rate in manured plots (pig and poultry) was higher compared to that obtained from the control. The fructification rate in treatment with poultry manure was higher compared to that of treatment with pig manure. Anim, *et al*. (2006) in Ghana also showed that the administration of poultry manure doubled the quantity of pods compared to the control. Poultry manure provides greater organic content compared to other manures. The increase in pod number was as a result of the physical and chemical properties of the soil that were improved under the application of manure, so plant responded well under these conditions especially poultry manure with more yields (Anim, *et al*., 2006). The organic content of the soil was increased with application of organic manure, but poultry manure was a better source of organic content compared to pig manure because it has a rich amount of phosphorus, nitrogen and potassium (Martin, 1982).

Conclusion

The application of pig and poultry manure had an impact on the vegetative parameters of the okra plant as the plant height, number of leaves, pod length, and root collar were higher in treatments containing manure compared to the control. Six insect's species belonging to two Orders (Hymenoptera and Lepidoptera) which visited the okra plant during the two studied periods were recorded; Hymenoptera has the highest number of species. *Ceratina* sp ranks first followed by *A. mellifera*. Those insect species are attracted by the floral product offered by the okra plant. The fruiting index was higher in free flowers compared to the flowers that were protected to prevent pollinators. The number of pod and seeds obtained in the free pollinated plants was higher than that of the plants covered to prevent pollinators. The fructification rate in manured plots (pig and poultry) was higher compared to that obtained from the control. The fructification rate in treatment with poultry manure was higher compared to that of treatment with pig manure. Therefore, the use of organic fertilizers, mainly poultry manure is recommended for a better growth and production of our plant. Moreover, building and conservation of insect nests around okra plants should be suggested so as to benefit from the natural assistance of pollinating insects thus increase in the fruit and seed yield of okra.

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Reference

1. Adeboye, M. S. «Production of Field Crops.» Me Graw-Hill publishers company Ltd New Delhi, (1996).
2. Adekiya, A. O., Ejue, W. S. & A. Olayanju. "Different organic manure sources and NPK fertilizer on soil chemical properties, growth, yield and quality of okra." *Scientific Reports*, 10.16083 (2020).

3. Al Ghzawi, A. M., Zaittoun, S.T., Makadmeh, I. & Tawaha, A. R. M. "The impact of wild bee on the pollination of eight Okra genotypes under semi-arid Mediterranean conditions." *International Journal of Agriculture and Biology* 5.4 (2003): 408-410.
4. Amada, B., Dounia, C. D., Ningatoloum, C., Guiffo, G. A. A., Angoula, B. S., Ngo-naïna, J. P. & Tchuenguem, F. F.-N. "Diversity of flowering insects and their impact on yields of *Abelmoschus esculentus* (L.) Moench 1794 (Malvaceae) in Yaoundé (Cameroon)." *Journal of Entomology and Zoology Studies*, 6.6 (2018): 945-949.
5. Angbanyere, M. A., Baidoo, P.K. "The effect of pollinators and pollination on fruit set and yield of okra (*Abelmoschus esculentus* (L.) Moench) in the Forest Region of Ghana." *Journal of Experimental Agriculture Internationa*l, 4.9 (2014): 985-995.
6. Uko, A.E., Udo, I.A. and Shiyam, J.O. "Effects of Poultry Manure and Plant Spacing on the Growth and Yield of Waterleaf (*Talinum fructicosum* (L.) Juss)." J*ournal of Agronomy*, 12.3 (2013): 146-152.
7. Anim, O. J., Blay, E. T. & Frempong, M.E. "Effects of organic manure on okra (*Abelmoschus esculentus* (L.) Moench) production" *Journal of Applied Horticulture*, 8.2 (2006): 155-158.
8. Ayonghe, S. N., Suh, C. E., Ntasin, E. B., P. Samalano, & W. Fantong, "Hydrologically siesmically and tecntonically triggered landslides along the Cameroon Volcanic Line, Cameroon." *African Geosciences Review*, 9 (2002): 325 – 335.
9. Azo'o, E. M., Madi, A., Fernand-Nestor, T.F. and Jean, M. "The importance of a single floral visit of *Eucara macrognatha* and *Tetralonia fraterna* (Hymenoptera: Apidae) in the pollination and the yields of *Abelmoschus esculentus* in Maroua, Cameroon." *African Journal of Agricultural Research*, 7.18 (2012): 2853-2857.
10. Azo'o, E. M., Fernand-Nestor, T.F. and Jean, M. "Influence of the foraging activity of the entomofauna on Okra (*Abelmoschus esculentus*) seed yields." *International Journal of Agriculture and Biology* 13.5 (2011): 761-765.
11. Azo'o, E. M., Tchuenguem, F. F-N., Jean, M. "Biological diversity of the entomofauna associated with Citrullus lanatus (Cucurbitaceae) flowers and assessment of its impact on yields." *Journal of Entomology and Zoology Studies*, 5.5 (2017): 810-815.
12. Bell, R. W., V. Seng., Noel, S., Wendy, V. and S. Hin. "Assessing land suitability for crop diversification in Cambodia." Proceedings of world land Resource Assessment Forum, held at CARDI, Cambodia 23-26 September, 2004 (in press). Distributed initially as CARDI Soil and Water Science Technical Note No. 1, (2005): 40 – 58.
13. Borror, D. J. & White, R. E. "North America insects (North of Mexico)" Broquet (Eds): *The Prairie-Quebec.* (1991): 408.
14. Crane, E. "Apis species of tropical Asia as pollinators and some rearing methods for them." *Acta Horticulture*, 288.2 (1991): 29-48.
15. Elkhalifa, A. E. O., Eyad, A., Mohd, A., Jerold, C. A., Amir, M.A., Nagat, E. E., Khalid, M., Bibhu, P.P. and Syed, A.A. "Okra (*Abelmoschus esculentus*) as a Potential Dietary Medicine with Nutraceutical Importance for Sustainable Health Applications." *Molecules,* 26.3 (2021): 696.
16. Fagwalawa, L. D. & Yahaya, S. M. "Effect of organic manure on the growth and yield of okra." *Imperial Journal of Interdisciplinary Research*, 2.3 (2016): 130–133.
17. Free, J. B. "Insect pollination of crops." *2nd edition, Academic Press, London, UK*. (1993).153 pp
18. Gardner, R. C. "Continuous Arable Cropping with the use of Manure." *Horticultural Science journal,* l (2004): 74-80.
19. Hogendoorn, K., Caroline, L. G., Margaret, S. and Michael, A. K. "Increased tomato yield through pollination by native Australian blue-banded bees (*Amegilla chlorocyanea* Cockerell)." J*ournal of Economic Entomology*, 99.3 (2006): 828-833.
20. Irvine, F.R. Supplementary and emergency food plants of West Africa. *Economic Botany,* 6.1 (1952): 23-40.
21. Jousselin, E. & F. Kjellberg. "The functional implications of active and passive pollination in dioecious figs." *Ecology Letters*

4.2 (2001): 151-158.
22. Leng, B. "Effect of organic manure on soil temperature, early vegetative development in muskmelon and weed growth." *Proceedings, national agricultural plastic congress* 22 (2006): 19-27.
23. Martin, F. W. "Okra, potential multiple-purpose crop for the temperate zones and tropics." *Economic Botany* 36.3 (1982): 340–345.
24. Mathew, I. P. & Karikari, S. K. "Horticulture Principles and Practices." *Macmillan Education Ltd, London and Basingtroke*, (1995): 80-84.
25. Mc Gregor, S.E. "Insect pollination of cultivated plants." *US Department of Agriculture, Agriculture Handbook n° 496. Washington, USA.* (1976): 411.
26. Mutsaers, M. "Bees in their natural environment in south Westhern Nigeria." *The Nigerian Field* 56 (1991): 3 - 18.
27. Nandhini, E., K. Padmini., R. Venugopalan., M. Anjanappa. and Lingaiah, H. "Flower-visiting insect pollinators of okra [*Abelmoschus esculentus* (L.)] Moench] in Bengaluru region." J*ournal of Pharmacognosy and Phytochemistry*, 7.2 (2018): 1406-1408.
28. Neba, A.S. "Morden Geography of republic of Cameroon." *Neba publisher, Bamenda Cameroon*. (1999): 54P.
29. Njoya, M. T., D. Wittmann. & M. Schindler. "Effect of Bee Pollination on Seed Set and Nutrition on Okra (*Abelmoschus esculentus*) in Cameroon." *Proceedings of the International Ollerton J, editors. Plant-pollinator interactions: from specialization to generalization. Chicago (IL): The University of Chicago Press,* (2005): 99–121.
30. Nweke, I. A. & Nsoanya, L. N. "Effect of Poultry Manure and Inorganic Fertiliser on the Performance of Maize (*Zea Mays*) and Selected Physical Properties of Soils of Igbarian Southeastern Nigeria." *Journal of Agriculture and Rural Development*, 16.1 (2013): 1348-1353.
31. Otiobo, A. E. N., Lukong, A. W., Fotso, Tita, M. A. & Theresia, N.A. "Insect Activities and their Impact on the Yield of *Abelmoschus esculentus* L (Malvaceae) in Bambili (Mezam - Cameroon)." *International Journal of Sustainable Agricultural Research*, 7.4 (2020): 304-315.
32. Otiobo, A. E. N., Njoya, M., Tita, M., Dounia, D., Champlain, D.L. & Tchuenguem, F. F.-N. « Le rôle de l'abeille non-Apis dans la fructification de *Abelmoschus esculentus* (L) Moench 1794 (Malvales :Malvacae) à Bambili (Cameroun)» *Entomologie faunistique ;Faunistic Entomology*, 74 (2021): 2295-7235.
33. Ouda, B. A. and Mahadeen, A. Y. "Effect of fertilizers on growth, yield, yield components,quality and certain nutrient contents in broccoli (*Brassica oleracea*)." *International Journal of Agriculture and Biology*, 10.6 (2008): 627-632
34. Pauly, A. "Mission entomologique en Afrique occidentale (1979-1980) : Renseignements éco-biologiques concernant les Hyménoptères." *Notes Fauniques de Gembloux*, 11 (1984) : 1-43
35. Pesson, P. & J. Louveaux. "Pollinisation et Productions Végétales." INRA, Paris. (1984): 663 p.
36. Phillips, T. W. "Semiochemicals of stored-product insects: Research and applications" *Journal of Stored Products Research* 33 (1997): 17-30.
37. Shahriazzaman, M. C., Mazed, H. E. M. K., Pulok, M. A. I., Mehraj, H. & Jamal Uddin, A. F. M. "Responses of Organic Manures on Growth and Yield of Okra (*Abelmoschus esculentus*)." *Journal of Science, Technology & Environment Informatics* 1.2 (2014): 60-67.
38. Shaji, H. & Mathew, L. "Organic fertilizers as a route to controlled release of nutrients." *In: Lewu FB, Volova T, Thomas S, Rakhimol KR, editors, Controlled Release Fertilizers for Sustainable Agriculture. Cambridge, Massachusetts*: (2021): 231-245
39. Sharma, D. H. "Fundamentals of Soil Science" *7th edition U.K. Longman*. (2004) 546p
40. Stanghellini, M. S., Ambrose, J. T. & Schultheis, J. R. "The effects of honey bee and bumble bee pollination on fruit set and abortion of cucumber and watermelon." *American Bee Journal,* 137 (1997): 386-391.
41. Tchuenguem, F. F.-N. "Foraging and pollination activity of *Apis mellifera adansoni*i Latreille (Hymenoptera: Apidae, Apinae) on the flowers of three plants in Ngaoun-

déré (Cameroon): *Callistemon rigidus* (Myrtaceae), *Syzygium guineense* var.*macrocarpum* (Myrtaceae) and *Voacanga africana* (Apocynaceae).” *These doctoral studies, University of Yaoundé I, Yaoundé, Cameroon*. (2005).103p

42. Tchuenguem, F. F.-N., J. Messi. & A. Pauly. “Activity of *Meliponula erythra* on *Dacryodes edulis* flowers and its impact on fruiting.” *Fruits*, 56.3 (2001): 179-188.
43. Tchuenguem, F. F-N., J. Messi., D. Brüchner., B. Bouba., G. Mbofung. and Hemo, J. H. “Foraging and pollination behaviour of the African Honey bee (*Apis mellifera adansonii*) on *Callistemon rigidus* flowers in Ngaoundere (Cameroon).” *Journal of the Cameroon Academy of Sciences*, 4.2 (2004): 133-140.
44. Tchuenguem, F. F.-N., Pando, J. B. & Tamesse, J. L. “Pollination efficiency of *Xylocopa olivacea* (Hymenoptera: Apidae) on *Cajanus cajan* (Fabaceae) flowers at Yaoundé (Cameroon).” *International Journal of Tropical Insect Science*, 34.2 (2014): 138-148.
45. Tiamiyu, R. A., Ahmed, H. G. & Muhammad, A. S. “Effect of sources of organic manure on growth and yields of okra (*Abelmoschus esculentus* L.) in Sokoto, Nigeria. Niger.” *Journal of Basic and Applied Sciences*, 20.3 (2012): 213–216.
46. Toni, H., Djossa, T. B. A., O. Teka. & H. Yédomonhan. “Abeilles pollinisatrices et production de la pastèque (*Citrullus lanatus*) dans la Commune de Kétou au Sud Bénin.” *Afrique Science*, 16.1 (2020): 63-77.
47. Tswanya, M. N., Isah, K. M., Ahmed, M., Yisa, P. Z. & Lile, S. N. “Effect of Poultry Droppings on Growth and Fruit Yield of Okra (*Abelmoschus esculentus*).” *International Journal of Environment, Agriculture and Biotechnology*, 2.3 (2017): 2456-1878.

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