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Impact of Two Organic Fertilizers (Mycorrhizae and Poultry Manure) Associated with Pollinators Insects on Growth and Yields of *Sesamum Indicum* L. at Baré (Littorale Region-Cameroon)

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Abstract

Field of sesame was conducted during the rainy season in 2021 and 2022 in Baré (Littorale Region - Cameroon) aiming to contribute to the improvement of the yield of sesame by combining two organic fertilizers and pollinators insects. The main factor was pollination with two levels (plants left on free pollination and plants isolated from insects). The secondary aspect was fertilization with two points mycorhize-poultry manure and control. The growth parameters, the diversity and foraging activity of pollinators insects, the influence of organic fertilizers and pollinator insects were evaluated on the yields. The results showed that the plants located on the plots treated with mycorhize-poultry showed significant growth on the number of the leaves ($p<0.05$), the collar diameter ($p<0.05$) and mean plant height ($p<0.05$). In both years, a total of four orders of pollinator insects have been identified where Hymenoptera (93.14%) ranks first followed by Diptera (8.71%). Those insects harvested intensively nectar (85.22%) and weakly pollen (10.05%). Mean number of seeds per capsule, the average mass per 100 seeds, the normal seeds left and the yield in dry of seeds per hecare on free pollination was greater compared to those isolated from insects ($p<0.001$). The production (the mean number of seeds per capsule, the average mass per 100 seeds, the normal seeds left and the yield in dry of seeds per hecare) were 22.73%, 48.00%, 30.51% and 1.02 ton in the plots having mycorhize-poultry manure associated with pollinators insect, 11.83%, 22.21%, 15.45% and 0.16 ton plots having to control respectively. The use of organic manure especially the mycorhize-poultry manure and the maintenance of pollinators insect nest around the field mays by recommended to improve crop yield.

Keywords: *Sesamum Indicum*, Poultry Manure, Mycorrhizae, Insects, pollination, Yield

1. Introduction

Sesame (*Sesamum indicum* L.) is originated from Asia and Africa (Desai, 1984). Currently, sesame is the widely grown oleaginous in the world; this pedaliaceae grows well on a wide variety of soils; his biological cycle varies from 90 to 120 days depending on the type of climate (Hoopen and Adbou, 2012) [13]. Sesame (*Sesamum indicum* L.) is labeled as the queen of oilseeds because of its high oil content, delicious nutty aroma, and flavor and is traditionally categorized as a health food in Asian countries (Miyake *et al*., 2005) [21]. Sesame seed is used for a wide array of edible products in raw or roasted formand also for industrial uses such as soaps, lubricants, lamp oil, an ingredient in cosmetics; pharmaceutical uses, and animal feed (Bedigian, 2011) [2]. It contains a considerable amount of oil, proteins, carbohydrates, essential minerals, a high amount of methionine and tryptophan, fibers as well as secondary metabolites such as lignans, saponins, flavonoids, and phenolic compounds. Moreover, the seeds are a good source of calcium, phosphorus, and iron and are rich in vitamin B, E, and a small amount of trace elements. Sesame oil has a pleasant, mild taste and is remarkably stable. It has a high content of polyunsaturated fatty acids, oleic, and linoleic acid. Sesame oil has an excellent stability due to natural antioxidants, i.e., sesamin, sesamolin, and sesamol (Sene *et al*., 2018) [30]. Arbuscular mycorrhizal fungi (AMF) are biotrophs forming symbiotic associations with the roots of most terrestrial vascular plants (Fortin *et al*., 2011) [9]. This symbiosis has played a major role in plants colonization of terrestrial environments through improved hydromineral nutrition (Smith & Read, 2008) [31]. In the field, pollinator insects have great ecological and economical importance because they have positive influence on pollination (Pesson and Louveaux, 1984). Those insects can increase fruit yield and best quality of seeds (Morison *et al.*, 2000) [22]. The lack of pollinating insects during flowering time can lead to kidney yields fruits and/or seeds for some cultivars plants (Tchuenguem, 2005) [32]. In Cameroon the floral entomofauna of *Sesamum indicum* is not very well studied. The few studies from the literature are that for Otiobo (2017) [26] and Pharaon (2019) conducted in the Center and Farth-north regions of Cameroon, for Mahfouz *et al*. (2012) [17], Mahmoud (2012) [18] and Kamel *et al*. (2013) [15] of Egypt; which indicate that pollinator insects visit the flowers and collected pollen. According to Gallais *et al*. (2009) [10] floral entomofauna of a plant species can vary from one region to another. The average productivity of sesame has remained low with less significant changes over the last decades. 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 (Gardner, 2004) [11] and less knowledge on the pollinating insects. There is therefore a need to meet the increasing demands of the growing population in developing countries especially in Cameroon 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) [19]. Organic manure is naturally available and contains moderate amounts of essential nutrients needed by plants (Shaji & Mathew, 2021) [25]. Being a short duration vegetable crop, sesame growth, yield and quality are largely influenced by the application of fertilizers. The general objective of this research is to assess the influence of organic fertilizers (poultry manure and mycorrhizae) associated with pollinator insects on sesame development and yields for their optimal management in Baré, specifically (a) to appreciate sesame 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 Pedaliaceae.

2. Materials and methods

2.1 Study Station

The experimental investigations were performed during two seasons from the 1st of March to the 30th of Agust in 2021 and 2022 at Baré, Moungo division, Littorale Region of Cameroon during the rainy period. The field for investigation was a plot, on 5°00'07.2'' N latitude, 9°57'42.9'' E longitude and 200 m of altitude above sea level. Moungo has an equatorial climate, temperatures varies to 24.89 °C to 32.4 °C, rainfall vary from 14.4 mm to 751.2 mm during the rainy season; in this region of Cameroon the important vegetation present are the mangrove (Dongock, 2004).

2.2 Biological Material

The animal material constituted by all pollinator's insects naturally present in the environment of study station; Vegetal material was represented by seeds of *S. indicum* var. IRAT 278 (fig 1) and Organics fertilizers were mycorhize and poultry manure.

Fig 1: Seeds of *Sesamum indicum*

2.3 Method

2.3.1 Preparation, sowing and tending of the experimental plot

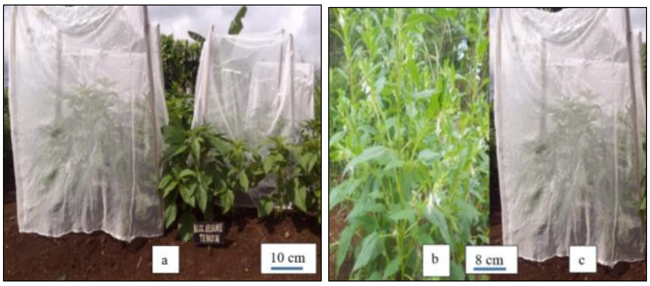
The experimental field (218.5 m^2) was cleared and cleaned using a cutlass on March to August 2021 and 2022. The soil was tilled forming 2 blocks. Each block has 8 m x 4.5 m x 0.25 m. A weeks before planting (2021 and 2022) in the block, different treatment was made: control ($T0_{2021}$ and $T0_{2022}$) and mycorrhizae-poultry manure ($T3_{2021}$ and $T3_{2022}$) the organic fertilize was mixed with the soil in each hole, 0.4 kg ± 2.01 poultry manure was use per hole and the corresponding value was 0.10 kg ± 0.10 of mycorrhizae. Sesame seeds were sown at five grains per hole, 20 holes per line and a spacing between the consecutive hole was 0.50 m and the space between line was 0.20 m. Two weeks after germination, the plants were thinned by manual uprooting. From germination to the opening of the first flower, the experimental farm was weeded and hoed, respectively every two weeks. Pesticides were not used on the farm land.

2.3.2 Determination of the impact of manure on the growth of sesame

One week after the plants had emerged, on the 14th of may 2021 and 2022; On 30 plants of *Sesamum indicum,* the mean plant height was measured using a metter ribbon, the collar diameter was measured using a vernier calliper and the number of leaves counted manually every week until the first flower appears.

2.3.3 Diversity and Activity of pollinators insects

On each block of the experimental farm two treatment was made; Treatment A: 120 plants witch 60 plants per sub-block (T0.1 and T1.1) was bellowed for free pollination (fig 2.a) and treatment B witch a same number of plants (T0.2 and T1.2) destined to prevent pollinators by bagged plants (fig 2.b) in 2021 and in 2022, treatment was repeat witch the same parameter.



a) Traetment to control; b) Plant of *Sesamum indicum* destinated for free pollination insects; c) Plant of *Sesamum indicum* isolated for pollinator

Fig 2: Plants of *Sesamum indicum*

Direct observations on plants destinated for free pollination were made every days during fifteen daily hours: 8am-9am, 10am-11am, 12am-1pm and 2pm-3pm from the 1st of to 15th July in 2021 and 2022. During this period the numbers of pollinator insects on 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) [3] 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 *S. mays* where, $Fi = \{[Vi/VI] * 100\}$ with Vi = number of visits of the insect i on the flowers and VI the number of visits of all the insects on these same flowers (Tchuenguem *et al.,* 2001) [33]. 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) [32].

Floral Products harvested by an insect were noted on each flower; it can be pollen or other product on those flowers. The flowers product being harvested was determined by the position of the insect on the flowers if the bug sticks his mandibula in the inwardness of the corolla, he harvests the nectar; if insects use 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 for Apidae, the collecting hairs of the legs for Halictidae and the ventral brush for Megachilidae (Borror and White, 1991) [3]. Pollen harvesting can be active (if pollen is collected) or passive (if the pollen accumulates on the insect's tegument and then collects it in its organs storage (Jousselin and Kjellberg, 2001) [14].

The duration of visit for each insect during the hose activities were recorded. The floral products collected were systematically noted during the recording of the duration of the visits per flower.

2.3.4 Determination of the impact of organic fertilizers and/or pollinator insects on yield of *Sesamum indicum*

2.3.4.1 Evaluation of the impact of organic fertilizers on yield of *Sesamum indicum*

For each year, the evaluation of yields was based on the impact of organic fertilizers on production by the comparison the number of seeds in the fertilizing block (poultry manure and mycorrhizae) and the control block. At maturity, capsules grown from each block were individually counted. Comparison was done on the capsules set. The average number of seeds per capsule, the average mass per 100 seeds and the percentage of normal seeds were calculated.

For each block. The percentage of normal seeds (Pn) was also determined using the formula: $Pn = \{[(ns1 - ns2) / Tseed] \times 100\}$, $ns1$ normal seeds, $ns2$ abordive seeds and $Tseed$ total of seeds in each block.

2.3.4.2 Evaluation of the impact of pollinators insects on yield of *Sesamum indicum*

The evaluation of impact of pollinators insects on the production was evaluated. The comparison of the number of seeds in sub-block of plants destinated for free pollination and the plants isolated for the pollinator insects on control block was calculated. The percentage of the average number of seeds per capsule, the average mass per 100 seeds, the normal seeds left, the percentage of normal seeds and the yield in dry of seeds per hecare were calculated using the same formula at evaluation of the impact of organic fertilizers on yield of *Sesamum indicum*.

2.3.4.3 Evaluation of the impact of organic fertilizers and pollinators insects on yield of *Sesamum indicum*

The evaluation of yields based on the organic fertilizers (poultry manure and mycorrhizae) and pollinators insects on production was evaluated. The comparison of the number of seeds in sub-block of plants destinated for free pollination using the fertilizes (poultry manure-mycorrhizae) and the plants destinated for free pollination in sub-block of control was evaluated. The percentage of the average number of seeds per capsule, the average mass per 100 seeds, the percentage of normal seeds and the yield in dry of seeds per hecare were calculated using the same formula at evaluation of the impact of organic fertilizers on yield of *Sesamum indicum*.

2.3.5 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).

3. Results and Discussion

3.1 Results

3.1.1 Efficacy of amendment with the organic fertilizers (poultry manure-mycorrhizae) on the growth of sesame (growth parameters)

The collar diameter, the number of leaves and the mean plant height increase with time in each of the treatments according to observation days. The plants present in the blocks treated with mycorhize-poultry manure have a rapid growth with regard to the various parameters studied in relation to those of the control blocks.

-Collar diameter

Table 1 presented the results on variation on collar diameter under to control and poultry manure-mycorrhizae treatment.

a) In 2021, the collars diameters were 0.31 ± 0.2, 0.53 ± 0.13, 0.85 ± 0.06, 1.04 ± 0.19 and 1.22 ± 0.50 in treatment $T0_{2021}$ ($T0_{2021}$, control); 0.40 ± 0.07, 0.86 ± 0.58, 1.29 ± 0.04, 1.38 ± 0.29 and 1.52 ± 0.07 in treatment $T1_{2021}$ ($T1_{2021}$, mycorrhizae-poultry manure). The correlations are positive and significant between treatments $T0_{2021}$ and $T1_{2021}$ (r = 0,83; ddl = 4; $P < 0,05$).

b) In 2022, the same value were 0.31 ± 0.08, 0.48 ± 0.07, 0.87 ± 0.19, 1.15 ± 0.27 and 1.37 ± 0.44 in treatment T0$_{2022}$ (*T0*$_{2022}$, control); 0.40 ± 0.03, 0.88 ± 0.07, 1.34 ± 0.41, 1.42 ± 0.51 and 1.88 ± 0.11 in treatment T1$_{2022}$ (*T1*$_{2022}$ mycorrhizae-poultry manure).The correlations are positive and significant between treatments *T0*$_{2022}$ and *T1*$_{2022}$ (r = 0,81; *ddl* = 4; P < 0,05).

c) For the two years (2021, 2022), the same value were 0.31 ± 0.05, 0.50 ± 0.10, 0.86 ± 0.12, 1.09 ± 0.23 and 1.29 ± 0.47 in treatment T0$_{2021/2022}$ (*T0*$_{2021/2022}$, control); 0.40 ± 0.05, 0.87 ± 0.32, 1.31 ± 0.22, 1.40 ± 0.41 and 1.70 ± 0.09 in treatment T1$_{2021/2022}$ (*T1*$_{2021/2022}$ mycorrhizae-poultry manure). The correlations are positive and significant between treatments *T0*$_{2021/2022}$ and *T1*$_{2021/2022}$ (r = 0,71; *ddl* = 4; P < 0,05).

Table 1: Variation of collar diameter of *Sesamum indicum* per treatments

	Diameter of collet									
	S4L		S4L+1W		S4L+2W		S4L+3W		S4L+4W	
	m	***s***	***m***	***s***	***m***	***s***	***m***	***s***	***m***	***s***
Treatment (T0)$_{2021}$	0.31	0.02	0.53	0.13	0.85	0.06	1.04	0.19	1.22	0.50
Treatment (T0)$_{2022}$	0.31	0.08	0.48	0.07	0.87	0.19	1.15	0.27	1.37	0.44
m (T0)$_{2021/2022}$	**0.31**	**0.05**	**0.50**	**0.10**	**0.86**	**0.12**	**1.09**	**0.23**	**1.29**	**0.47**
Treatment (T1)$_{2021}$	0.40	0.07	0.86	0.58	1.29	0.04	1.38	0.29	1.52	0.07
Treatment (T1)$_{2022}$	0.40	0.03	0.88	0.07	1,34	0.41	1.42	0.51	1.88	0.11
m (T1)$_{2021/2022}$	**0.40**	**0.05**	**0.87**	**0.32**	**1.31**	**0.22**	**1.40**	**0.41**	**1.70**	**0.09**

-Number of leaves

Table 2 presented the results on variation on number of leaves per different treatments.

a) In 2021, the number of leaves were 4.13 ± 0.08, 9.73 ± 0.88, 16.55 ± 2.01, 35.28 ± 3.05 and 46.30 ± 9.43 in treatment T0$_{2021}$ (*T0*$_{2021}$, control); 6.48 ± 1.76, 16.20 ± 2.05, 22.19 ± 3.88, 45.89 ± 3.69 and 61.27 ± 3.12 in treatment T1$_{2021}$ (*T1*$_{2021}$, mycorrhizae-poultry manure). The correlations are positive and significant between treatments *T0*$_{2021}$ and *T1*$_{2021}$ (r = 0,53; *ddl* = 4; P < 0,05).

b) In 2022, the same value were 4.12 ± 0.13, 10.48 ± 0.14, 17.22 ± 1.11, 38.66 ± 7.85 and 48.78 ± 8.14 in treatment T0$_{2022}$ (*T0*$_{2022}$, control); 6.51 ± 1.23, 17.51 ± 2.41, 24.09 ± 2.34, 46.81 ± 4.98 and 64.15 ± 4.39 in treatment T1$_{2022}$ (*T1*$_{2022}$, mycorrhizae-poultry manure). The correlations are positive and significant between treatments *T0*$_{2021}$ and *T1*$_{2021}$ (r = 0,71; *ddl* = 4; P < 0,05).

c) For the two years (2021, 2022), the same value were 4.12 ± 0.10, 10.10 ± 0.51, 16.88 ± 1.56, 36.97 ± 5.45 and 47.54 ± 8.78 in treatment T0$_{2021/2022}$ (*T0*$_{2021/2022}$, control); 6.49 ± 1.49, 16.85 ± 2.23, 23.14 ± 1.18, 46.35 ± 3.11 and 62.71 ± 3.75 in treatment T1$_{2021/2022}$ (*T1*$_{2021/2022}$, mycorrhizae-poultry manure). The correlations are positive and significant between treatments *T0*$_{2021/2022}$ and *T1*$_{2021/2022}$ (r = 0,77; *ddl* = 4; P < 0,05).

Table 2: Variation of number of leaves of *Sesamum indicum* per treatments

	Number of leaves									
	S4L		S4L+1W		S4L+2W		S4L+3W		S4L+4W	
	m	***s***	***m***	***s***	***m***	***s***	***m***	***s***	***m***	***s***
Treatment (T0)$_{2021}$	4.13	0.08	9.93	0.88	16.55	2.01	35.28	3.05	46.30	9.43
Treatment (T0)$_{2022}$	4.12	0.13	10.48	0.14	17.22	1.11	38.66	7.85	48.78	8.14
m (T0)$_{2021/2022}$	**4.12**	**0.10**	**10.10**	**0.51**	**16.88**	**1.56**	**36.97**	**5.45**	**47.54**	**8.78**
Treatment (T1)$_{2021}$	6.48	1.76	16.20	2.05	22.19	3.88	45.89	3.69	61.27	3.12
Treatment (T1)$_{2022}$	6.51	1.23	17.51	2.41	24,09	2.34	46.81	4.98	64.15	4.39
m (T1)$_{2021/2022}$	**6.49**	**1.49**	**16.85**	**2.23**	**23.14**	**1.18**	**46.35**	**3.11**	**62.71**	**3.75**

-Mean plant height

Table 3 presented the results on variation on mean plant height per different treatments.

a) In 2021, the mean plant height were 18.27 ± 0.0, 21.88 ± 0.70, 27.48 ± 3.13, 35.74 ± 4.04 and 40.49 ± 6.77 in treatment T0$_{2021}$ (*T0*$_{2021}$, control); 24.11 ± 0.18, 36.88 ± 6.07, 43.94 ± 3.06, 55.01 ± 2.66 and 69.49 ± 4.10 in treatment T1$_{2021}$ (*T1*$_{2021}$, mycorrhizae-poultry manure). The correlations are positive and significant between treatments *T0*$_{2021}$ and *T1*$_{2021}$ (r = 0,41; *ddl* = 4; P < 0,05).

b) In 2022, the mean plant height were 18.09 ± 2.25, 21.97 ± 0.54, 28.33 ± 4.70, 37.35 ± 5.01 and 44.66 ± 5.38 in treatment T0$_{2021}$ (*T0*$_{2021}$, control); 24.47 ± 0.00, 36.90 ± 5.20, 44.17 ± 4.37, 58.77 ± 3.33 and 73.04 ± 2.15 in treatment T1$_{2021}$ (*T1*$_{2021}$, mycorrhizae-poultry manure). The correlations are positive and significant between treatments *T0*$_{2021}$ and *T1*$_{2021}$ (r = 0,93; *ddl* = 4; P < 0,05).

c) For the two years (2021, 2022), the same value were 18.18 ± 1.14, 21.92 ± 0.62, 26.88 ± 3.91, 36.54 ± 4.52 and 42.57 ± 6.07 in treatment T0$_{2021/2022}$ (*T0*$_{2021/2022}$, control); 24.29 ± 0.09, 36.89 ± 5.63, 44.05 ± 3.71, 56.89 ± 2.99 and 71.26 ± 3.12 in treatment T1$_{2021/2022}$ (*T1*$_{2021/2022}$, mycorrhizae-poultry manure). The correlations are positive and significant between treatments *T0*$_{2021/2022}$ and *T1*$_{2021/2022}$ (r = 0,77; *ddl* = 4; P < 0,05).

Table 3: Variation of mean plant height of *Sesamum indicum* per treatments

	Mean plant height									
	S4L		S4L+1W		S4L+2W		S4L+3W		S4L+4W	
	m	*s*	*m*	*s*	*m*	*s*	*m*	*s*	*m*	*s*
Treatment (T0)$_{2021}$	18.27	-	21.88	0.70	27.48	3.13	35.74	4.04	40.49	6.77
Treatment (T0)$_{2022}$	18.09	2.25	21.97	0.54	28.33	4.70	37.35	5.01	44.66	5.38
m (T0)$_{2021/2022}$	**18.18**	**1.14**	**21.92**	**0.62**	**26.88**	**3.91**	**36.54**	**4.52**	**42.57**	**6.07**
Treatment (T1)$_{2021}$	24.11	0.18	36.88	6.07	43.94	3.06	55.01	2.66	69.49	4.10
Treatment (T1)$_{2022}$	24.47	-	36.90	5.20	44,17	4.37	58.77	3.33	73.04	2.15
m (T1)$_{2021/2022}$	**24.29**	**0.09**	**36.89**	**5.63**	**44.05**	**3.71**	**56.89**	**2.99**	**71.29**	**3.12**

3.1.2 Diversity and abundance of pollinator insects on flowers of *Sesamum indicum*

Table 4 shows the diversity and abundance of visits on flowers of *Sesamum indicum* of the control (T0). It appears from this table that three groups of pollinators visited flowers belonging to order Diptera, Hymenoptera and Lepidoptera during the flowering period. The number of Hymenoptera was higher (86.87 %), followed by Diptera (12.05 %) and Lepidoptera (1.06%). The results indicate that Hymenoptera are the major pollinators visiting flowers of sesame in 2021 and 2022.

Table 5 shows the diversity and abundance of visits on flowers of *Sesamum indicum* of the poultry manure and mycorrhizae treatment (T1). It appears from this table that four groups of pollinators visited flowers belonging to order Diptera, Hymenoptera, Lepidoptera and Orthoptera during the flowering period. The number of Hymenoptera was higher (92.63 %), followed by Diptera (3.45 %), Lepidoptera (3.02%) and Orthoptera (0.86). The results indicate that Hymenoptera are the major pollinators visiting flowers of sesame in 2021 and 2022.

Table 4: Diversity and abundance of visits on flowers of *Sesamum indicum* of the control (T0)

Insects			2021		2022		2021/2022	
Orders	**Family**	**Genre, Species**	***n***	***p %***	***n***	***p %***	***n***	***p %***
Diptera	Calliphoridae	(1 sp.)	16	11.51	7	4.89	23	8.15
	Muscidae	*Musca domestica*	11	7.91	0	0	11	3.90
	Total	**2 species**	**27**	**19.42**	**7**	**4.89**	**34**	**12.05**
Hymenoptera	Apidae	*Apis mellifera*$^{po, nt}$	53	38.12	71	49.65	124	43.97
		Xylocopa olivacea $^{po, nt}$	31	22.30	43	30.06	74	26.24
		Amegilla sp. $^{po, nt}$	5	3.59	3	2.09	8	2.83
	Eumenidae	*Delta* sp. ^{nt}	0	0	1	0.69	1	0.35
	Halictidae	*Halictus* sp.$^{po, nt}$	11	7.91	7	4.89	18	6.38
	Megachilidae	*Chalicodoma* sp.^{nt}	4	2.87	3	2.09	7	2.48
		Megachile sp. $^{po, nt}$	7	5.03	6	4.19	13	4.60
	Total	**7 species**	**111**	**79.85**	**134**	**93.07**	**245**	**86.87**
Lepidoptera	Pieridae	*Catopsilia flerella*^{nt}	1	0,71	2	1,39	3	1,06
	Total	**1 specie**	**1**	**0.71**	**2**	**1.39**	**3**	**1.06**
Total	**8 species**		**139**		**143**		**282**	

nt: nectar; po: pollen; n: number of visits; p: percentage of visits; p = (n/ total of visits) × 100.

Table 5: Diversity and abundance of visits on flowers of *Sesamum indicum* of the treatment poultry manure and mycorrhizae (T1)

Insects			2021		2022		2021/2022	
Order	**Family**	**Genre, Species**	***N***	***p %***	***n***	***p %***	***n***	***p %***
Diptera	Calliphoridae	(1 sp.)^{nt}	8	3.34	7	3.12	15	3.23
	Muscidae	*Musca domestica*^{nt}	1	0.41	0	0	1	0.21
	Total	**2 species**	**9**	**3.76**	**7**	**3.12**	**16**	**3.45**
Hymenoptera	Apidae	*Apis mellifera*$^{po, nt}$	81	33.89	118	52.67	199	42.98
		Xylocopa olivacea $^{po, nt}$	86	35.98	56	25.00	142	30.66
		Amegilla sp. $^{po, nt}$	5	2.09	8	3.57	13	2.80
	Eumenidae	*Delta* sp. ^{nt}	0	0	3	1,33	3	0,64
	Halictidae	*Halictus* sp.$^{po, nt}$	15	6.27	6	2.67	21	4.53
	Megachilidae	*Chalicodoma* sp.^{nt}	3	1.25	4	1.78	7	1.51
		Megachile sp. $^{po, nt}$	28	11.71	16	7.14	44	9.50
	Total	**7 species**	**218**	**91.21**	**211**	**94.19**	**429**	**92.63**
Lepidoptera	Acraeidae	*Acraea acerata*^{nt}	4	1.67	0	0	4	0.86
	Pieridae	*Catopsilia flerella*^{nt}	4	1.67	4	1.78	8	1.72
		Eurena sp. (1 sp.) ^{nt}	0	0	2	0.89	2	0.43
	Total	**3 espèces**	**8**	**3.34**	**6**	**2.67**	**14**	**3.02**
Orthoptera		(1 sp.)	4	1.67	0	0	4	0.86
	Total	**1 espèce**	**4**	**1.67**	**0**	**0**	**4**	**0.86**
Total	**13 espèces**		**239**		**224**		**463**	

nt: nectar; po: pollen; n: number of visits; p: percentage of visits; p = (n/ total of visits) × 100.

3.1.3 Activity of pollinators insects

3.1.3.1 Floral products harvested

The foraging behavior of these insect species is to nectar and pollen harvest.

3.1.3.2 Duration of insect visits to flower

Table 6 &7 show the cumulate period 2021 and 2022, the mean duration of a visit on *S. indicum* flowers were 7.26 sec (n = 117; s = 3.02) for the nectar and 5.09 sec (n = 80; 1.57) for the pollen to the control; 2.40 sec (n = 80; s = 0.80) for the nectar and 2.63 sec (n = 60; 1.08) for the pollen to the poultry manure and mycorrhizae. The difference between the mean duration of the visit in 2021 and 2022 was highly significant (t = -8.41; ddl = 138; p <0.001).

Table 6: Visits duration of pollinators insects of flowers of *Sesamum indicum* in 2021 and 2022 to control (T0)

Years	Orders	Foods reaped	*n*	Visits duration of flowers (sec.)			
				m	*S*	*Mini*	*Maxi*
2021	Diptera (2 species)	Nectar	27	16,23	7,61	5	35
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			27	16,23	7,61	5	35
	Hynemoptera (6 species)	Nectar	40	5,86	2,54	2	9
		Pollen	40	4,51	0,88	2	12
		Nectar + pollen	30	8,76	1,92	2	15
			110	6,37	1,78	2	15
	Lepidoptera (1 specie)	Nectar	1	2	0,00	1	1
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			1	2		1	1
2022	Diptera (1 specie)	Nectar	7	12,30	5,01	8	22
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			7	12,30	5,01	8	22
	Hynemoptera (7 species)	Nectar	40	4,21	3,00	2	7
		Pollen	40	5,68	2,27	2	9
		Nectar + pollen	40	8,13	2,76	2	16
			120	6,00	2,67	2	16
	Lepidoptera (1 specie)	Nectar	2	3,00	0,00	2	4
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			2	3,00	0,00	2	4
	Diptera (2 species)	Nectar	34	14,26	6,31	5	35
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			34	14,26	6,31	5	35
Total	Hynemoptera (7 species)	Nectar	80	5,03	2,77	2	9
		Pollen	80	5,09	1,57	2	12
		Nectar+ pollen	70	8,44	2,34	2	16
			230	6,18	2,22	2	16
	Lepidoptera (1 specie)	Nectar	3	2,50	0,00	1	4
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			3	2,50	0,00	1	4
		Nectar	117	7,26	3,02	1	35
		Pollen	80	5,09	1,57	2	12
		Nectar + pollen	80	8,44	2,24	2	16
			277	**6,93**	**2,27**	**1**	**35**

Table 7: Visits duration of pollinators insects of flowers of *Sesamum indicum* in 2021 and 2022 to poultry manure and mycorrhizae (T1)

Years	Orders	Foods	*n*	Visits duration of flowers (sec.)			
		Reaped		*m*	*s*	*Mini*	*Maxi*
2021	Diptera (2 species)	Nectar	9	4,01	1,05	3	8
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			9	4,01	1,05	3	8
	Hynemoptera (6 species)	Nectar	30	1,80	0,14	1	6
		Pollen	30	2,38	1,46	1	5
		Nectar + pollen	30	3,90	1,08	2	6
			90	2,69	0,89	1	6
	Lepidoptera (2 species)	Nectar	2	2,00	0,00	2	2
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			2	2,00	0,00	2	2
2022	Diptera (1 specie)	Nectar	7	3,05	1,74	2	8
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			7	3,05	1,74	2	8
	Hynemoptera (7 species)	Nectar	30	2,07	1,92	1	5
		Pollen	30	2,89	0,71	2	7
		Nectar + pollen	30	2,96	1,33	2	8
			90	2,64	1,32	2	8
	Lepidoptera (1 specie)	Nectar	2	1,50	000	1	2
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			2	1,50	0,00	1	2
	Diptera (2 species)	Nectar	16	3,53	1,39	2	8
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			16	3,48	1,39	2	8
Total	Hynemoptera (7 species)	Nectar	60	1,93	1,03	1	6
		Pollen	60	2,63	1,08	1	7
		Nectar+ pollen	60	3,43	1,20	2	8
			180	2,66	1,10	1	8
	Lepidoptera (1 specie)	Nectar	4	1,75	0,00	2	3
		Pollen	-	-	-	-	-
		Nectar + pollen	-	-	-	-	-
			4	1,74	0,27	2	3
		Nectar	80	2,40	0,80	2	8
		Pollen	60	2,63	1,08	1	7
		Nectar + pollen	60	3,43	1,20	2	8
			200	**2,82**	**1,02**	**1**	**8**

3.1.4 Impact of manure on yields

The manure increases the yields of *Z. mays* by improves seed quality. Table 8 presents the results the percentage of the average number of seeds per capsule, the average mass per 100 seeds, the percentage of normal seeds and the yield in dry of seeds per hecare in different treatments.

3.1.4.1 Impact of pollinators insects on yields

During pollen harvest, pollinators insects of *S. indicum* are regular shaken the flowers, then pollen was released and transported by the wind until female flower. These insects therefore increase the possibilities of pollination. Table 8 presents the results on average number of seeds per capsule, the average mass per 100 seeds, the percentage of normal seeds in the control and the poultry manure and mycorrhizae traetment. It is clear from this table that:

- In the control

In 2021 (a) The average number of seeds per capsule was 82.50 ± 2.90 in treatment $T0.1_{2021}$ and 72.50 ± 1.12 respectively in treatment $T0.2_{2021}$; The comparison of these means shows that the difference is very highly significant between treatments T0.1 $_{2021}$ and T0.2 $_{2021}$ (t = 67.08; ddl = 58; $P < 0.001$);

(b) The average mass per 100 seeds was 0.34 ± 0.06 g and 0.26 ± 0.07 g respectively in treatment $T0.2_{2021}$; The comparison of these means shows that the difference is very highly significant between treatments T0.1 $_{2021}$ and T0.2 $_{2021}$ (t = 18.09; ddl = 58; $P < 0.001$);

(c) The percentage of normal seed was 80.61% in treatment $T0.1_{2021}$ and 65.52% in treatment $T0.2_{2021}$; The comparison of these percentages shows that the difference is very highly significant between treatments T0.1 $_{2021}$ and T0.2 $_{2021}$ (X^2 = 100.18; ddl = 1; $P < 0.001$).

In 2021 the average number of seeds per capsule, the average mass per 100 seeds, the percentage of normal seeds by the pollinators insects were 12.12%, 23.52% and 18.72% respectively.

In 2022: (a) The average number of seeds per capsule was 82.25 ± 3.20 in treatment $T0.1_{2022}$ and 72.75 ± 3.30 in treatment $T0.2_{2022}$; The comparison of these means shows that the difference is very highly significant between treatments T0.1 $_{2022}$ and T0.2 $_{2022}$ (t = 43.10; ddl = 58; P < 0.001);

(b) The average mass per 100 seeds was 0.32 ± 0.07 g in treatment $T1.1_{2022}$ and 0.25 ± 0.05 g in treatment $T0.2_{2022}$; The comparison of these means shows that the difference is very highly significant between treatments T0.1 $_{2022}$ and

T0.2 $_{2022}$ (t = 16.97; ddl = 58; $P < 0.001$);
(c) The percentage of normal seed was 79.36% in treatment T0.1$_{2022}$ and 70.44% in treatment T0.2$_{2022}$; The comparison of these percentages shows that the difference is very highly significant between treatments T0.1 $_{2022}$ and T0.2 $_{2022}$ (X^2 = 49.20; ddl = 1; $P < 0.001$).

In 2022 the average number of seeds per capsule, the average mass per 100 seeds, the percentage of normal seeds by the pollinators insects were 11.55%, 21.97% and 49.20% respectively.

For the two years, the mean number of seeds per capsule was 82.38 ± 3.04 in treatment T0.1$_{2021/2022}$ and 72.63 ± 6.71 in treatment T0.2$_{2021/2022}$; The comparison of these means shows that the difference is very highly significant between treatments T0.1 $_{2021/2022}$ and T0.2 $_{2021/2022}$ (t = 27.60; ddl = 118; $P < 0.001$). The average mass per 100 seeds was 0.33 ± 0.06 g in treatment T0.1$_{2021/2022}$ and 0.26 ± 0.06 g in treatment T0.2$_{2021/2022}$; The comparison of these means shows that the difference is very highly significant between treatments T0.1 $_{2021/2022}$ and T0.2 $_{2021/2022}$ (t = 17.20; ddl = 58; $P < 0.001$); The percentage of normal seed was 80.00 % in treatment T0.1 $_{2021/2022}$ and 67.64 % in treatment T0.2$_{2021/2022}$; The comparison of these percentages shows that the difference is very highly significant between treatments T0.1 $_{2021/2022}$ and T0.2 $_{2021/2022}$ (X^2 = 92.47; ddl = 1; $P < 0.001$).

In 2021/2022 the average number of seeds per capsule, the average mass per 100 seeds and the percentage of normal seeds by pollinators insects were 11.83%, 22.21% and 15.45% respectively.

In 2021 the yield in dry of seeds per hecare was 0.3 ton in treatment T0.1$_{2021}$ and 0.14 ton in treatment T0.2$_{2021}$. The yield in dry of seeds per hecare by pollinators insects was 0.16 ton. In 2022 the yield in dry of seeds per hecare was 0.29 ton in treatment T0.1$_{2022}$ and 0.14 ton in treatment T0.2$_{2022}$. The yield in dry of seeds per hecare by pollinators insects was 0.15 ton. In 2021/2022 the yield in dry of seeds per hecare was 0.3 ton in treatment T0.1 $_{2021/2022}$ and 0.14 ton in treatment T0.2$_{2021/2022}$. The yield in dry of seeds per hecare by pollinators insects was 0.16 ton.

Table 8: Average number of seeds per capsule, average mass per 100 seeds, percentage of normal seeds in the control and the poultry manure and mycorrhizae traetment

Traetments	average number of seeds per capsule			average mass per 100 seeds (g)				
	n	m	s	m	S	Number of normals seeds	Total of seeds	percentage of normal seed
T0.1 $_{2021}$	30	82,50	2,90	0,34	0,06	1995	2475	80,61
T0.2 $_{2021}$	30	72,50	1,12	0,26	0,07	1425	2175	65,52
T0.1 $_{2022}$	30	82,25	3,20	0,32	0,07	1958	2467	79,36
T0.2. $_{2022}$	30	72,75	3,30	0,25	0,05	1523	2162	70,44
mT0.1 $_{2021/2022}$	30	82,38	3,04	0,33	0,06	1977	2471	80,00
mT0.2 $_{2021/2022}$	30	72,63	6,71	0,26	0,06	1474	2179	67,64
T1.1 $_{2021}$	30	93,25	4,43	0,48	0,04	2708	2798	96,78
T1.2 $_{2021}$	30	78,25	6,24	0,34	0,06	2018	2348	85,94
T1.1 $_{2022}$	30	94,75	3,10	0,52	0,06	2783	2843	97,89
T1.2. $_{2022}$	30	80,00	6,06	0,35	0,09	2100	2400	87,50
mT1.1 $_{2021/2022}$	30	94,00	3,76	0,50	0,05	2745	2820	97,34
mT1.2 $_{2021/2022}$	30	79,13	6,15	0,35	0,08	2059	2374	86,72

- In poultry manure and mycorrhizae combined with the pollinators insects treatment:

In 2021 (a) The average number of seeds per capsule was 93.25 ± 4.43 in treatment T1.1$_{2021}$ and 72.50 ± 1.12 in treatment T0.2$_{2021}$; The comparison of these means shows that the difference is very highly significant between treatments T1.1 $_{2021}$ and T0.2 $_{2021}$ (t = 94.71; ddl = 58; $P < 0.001$);
(b) The average mass per 100 seeds was 0.48 ± 0.04 g in treatment T1.1$_{2021}$ and 0.26 ± 0.07 g in treatment T0.2$_{2021}$; The comparison of these means shows that the difference is very highly significant between treatments T1.1 $_{2021}$ and T0.2 $_{2021}$ (t = 56.91; ddl = 58; $P < 0.001$);
(c) The percentage of normal seed was 96.78% in treatment T1.1$_{2021}$ and 65.52% in treatment T0.2$_{2021}$; The comparison of these percentages shows that the difference is very highly significant between treatments T1.1 $_{2021}$ and T1.2 $_{2021}$ (X^2 = 902.14; ddl = 1; $P < 0.001$).

In 2021 the average number of seeds per capsule, the average mass per 100 seeds, the percentage of normal seeds by poultry manure and mycorrhizae combined with the pollinators insects were 22.26%, 45.83% and 32.30% respectively.

In 2022: (a) The average number of seeds per capsule was 94.75 ± 3.10 in treatment T1.1$_{2022}$ and 72.75 ± 3.30 in treatment T0.2$_{2022}$; The comparison of these means shows that the difference is very highly significant between treatments T1.1 $_{2022}$ and T1.2 $_{2022}$ (t = 101.43; ddl = 58; $P < 0.001$);
(b) The average mass per 100 seeds was 0.52 ± 0.06 g in treatment T1.2$_{2022}$ and 0.25 ± 0.05 g in treatment T0.2$_{2022}$; The comparison of these means shows that the difference is very highly significant between treatments T0.1 $_{2021}$ and T0.2 $_{2021}$ (t = 72.10; ddl = 58; $P < 0.001$);
(c) The percentage of normal seed was 97.89% in treatment T1.1$_{2022}$ and 70.44% in treatment T0.2$_{2022}$; The comparison of these percentages shows that the difference is very highly significant between treatments T1.1 $_{2022}$ and T1.2 $_{2022}$ (X^2 = 769.89; ddl = 1; $P < 0.001$).

In 2022 the average number of seeds per capsule, the average mass per 100 seeds, the percentage of normal seeds by poultry manure and mycorrhizae combined with the pollinators insects were 23.21%, 51.92% and 28.04% respectively.

For the two years, the mean number of seeds per capsule was 94.00 ± 3.76 in treatment T1.1$_{2021/2022}$ and 72.63 ± 6.71 in treatment T0.2$_{2021/2022}$; The comparison of these means shows that the difference is very highly significant between treatments T1.1 $_{2021/2022}$ and T0.2 $_{2021/2022}$ (t = 57.94; ddl = 118; $P < 0.001$). The average mass per 100 seeds was 0.50 ±

0.05 g in treatment $T1.1_{2021/2022}$ and 0.26 ± 0.06 g in treatment $T0.2_{2021/2022}$; The comparison of these means shows that the difference is very highly significant between treatments $T1.1_{2021/2022}$ and $T0.2_{2021/2022}$ ($t = 64.09$; $ddl = 58$; $P < 0.001$); The percentage of normal seed was 97.34 % in treatment $T1.1_{2021/2022}$ and 67.64 % in treatment $T0.2_{2021/2022}$; The comparison of these percentages shows that the difference is very highly significant between treatments $T1.1_{2021/2022}$ and $T0.2_{2021/2022}$ ($X^2 = 823.08$; $ddl = 1$; $P < 0.001$).

In 2021/2022 the average number of seeds per capsule, the average mass per 100 seeds and the percentage of normal seeds by poultry manure and mycorrhizae associated with the pollinators insects were 22.73%, 48.00% and 30.51% respectively.

In 2021 the yield in dry of seeds per hecare was 1.11 ton in treatment $T1.1_{2021}$ and 0.14 ton in treatment $T0.2_{2021}$. The yield in dry of seeds per hecare by poultry manure and mycorrhizae associated with the pollinators insects was 0.97 ton. In 2022 the yield in dry of seeds per hecare was 1.21 ton in treatment $T1.1_{2022}$ and 0.14 ton in treatment $T0.2_{2022}$. The yield in dry of seeds per hecare poultry manure and mycorrhizae associated with the pollinators insects was 1.07 ton. In 2021/2022 the yield in dry of seeds per hecare was 1.16 ton in treatment $T1.1_{2021/2022}$ and 0.14 ton in treatment $T0.2_{2021/2022}$. The yield in dry of seeds per hecare poultry manure and mycorrhizae associated with the pollinators insects 1.02 ton.

3.2 Discussion

The sesame (*S. indicum*) responds positively to the application of organic manure. The different treatments are capable of improving the yield of the crop. There were changes in collar diameter, number of leaves and mean plant height in both years. This result corresponds to that of Sharma (2004) [29] in India; Nweke *et al.* (2013) in Nigeria, who showed that plant height, yield and weight yield of maize increases with the application of organic manure. Organic content of the soil also increases with the application of organic manure Gardner (2004) [11]; Leng (2006) [16] stated in his findings that increase in yield when organic manure is applied is due to increase cation exchange capacity of cations such as phosphor, calcium, magnesium, ammonium and potassium, there by supplying all necessary nutrients required for growth.

The treatment with mycorrhizae-poultry manure had the highest mean plant height, number of leaves, collar diameter, average number of seeds per capsule, average mass per 100 seeds, percentage of normal seeds and the highest the yield in dry of seeds per hecare compared to control. These results show that mycorhize-poultry manure had more impact on the vegetative growth of the plant compared to control. 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 maize, ranked poultry manure first, followed by goat manure before pig manure. Gardner (2004) [11], Nweke *et al.* (2013) and Fagwalawa and Yahaya (2016) [7] also obtained a same result in their individual studies of 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, there by boosting the structural growth of the plant. This is also due to higher branching which leads to more leaves, and the more the leaves mean more photosynthesis resulting in higher yield.

The flowers of *S. indicum* are brightly colored and its products are attractive to a variety of insects, which visit the plants to collect nectar and pollen during their foraging activities. This corresponds with what was stated by atabita *et al.* (2016) and Pharaon *et al.* (2019) [28], in Cameroon, these insects visit sesame flowers for their floral product. In this study, Hymenoptera, mainly the bees have been reported on *S. indicum*. Free (1993) [8] in the UK showed that the Apidae had a vital role to play in the pollination of *S. indicum*. This corresponds to that of Crane (1991) [4] in India who identified the genus Apis as the prime sesame pollinator. The floral products (nectar and pollen) of sesame flowers are available in great quantities and is also a rich source of proteins, carbons hydrates, sugar and vitamins; This shows that insect activity had great influence on the yield of sesame. The number of seeds 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. Fruiting is dependent on pollination intensity most of the times (Mc Gregor, 1976) [20] 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.

The fructification rate in manured plots (mycorrhizae-poultry manure) was higher compared to that obtained from the control. In a report earned by Haro & Sanon (2020) [12], sesame was grown in greenhouse and inoculated with two inocula of native arbuscular mycorrhizal fungi from Burkina Faso; the results obtained show an improvement in height growth of 431.25%, the relative growth rate in height of 145.87%, the collar diameter of 163.92%, the aboveground biomass of 102.9%, root biomass of 126.67% and total biomass of 110.1% of plants inoculated with arbuscular mycorrhizal fungi compared to the inoculated control. Nweke & Nsoanya (2013) [24] also showed that the administration of poultry manure doubled the quantity of pods compared to the control. Mycorrhizae-Poultry manure provides greater organic content compared to other manures. The increase in seeds 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 (Nweke & Nsoanya, 2013) [24]. The organic content of the soil was increased with application of organic manure, but mycorrhizae associated to poultry manure was a better source of organic content compared to poultry manure only because it has a rich amount of phosphorus, nitrogen and potassium.

4. Conclusion

The application of mycorrhizae-poultry manure had an impact on the vegetative parameters of the sesame as the collar diameter, mean plant height and number of leaves were higher in treatment containing manure compared to the control. Thirteen insect's species belonging to four Orders which visited the sesame during the two studied periods; Order of Hymenoptera has the highest number of species.

Those insects are attracted by the nectar and pollen of *S. indicum*. The number of seeds obtained in the free pollinated plants was higher than that of the plants covered to prevent pollinators. The fructification rate in manured plots (mycorrhizae-poultry) was higher compared to that obtained from the control. Therefore, the use of organic fertilizers, mainly mycorhize-poultry manure is recommended for a better growth and production of our plant. More over, building and conservation of insect nests around sesame should be suggested so as to benefit from the natural assistance of pollinating insects thus increase the yield of *S. indicum*.

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