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Full Length Research Paper

Comparative assessment of proximate content and organoleptic quality of African catfish (*Clarias gariepinus*) processed by smoking and solar drying methods

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This experiment was conducted to investigate the effect of two processing methods (smoking and solar drying) on the proximate content, organoleptic characteristics and nutritional qualities of *Clarias gariepinus.* The moisture content of the smoked fish sample was lower (8.10%) than that of the sun dried sample (25.00%). The crude protein, carbohydrate, fat, ash, crude fibre and nitrogen free extract of the smoked fish sample were 67.20, 1.75, 13.20, 5.50, 3.68 and 2.32%, respectively, compared to 52.50, 4.07, 17.40, 11.40, 2.00 and 18.30% observed in the sun-dried fish, respectively. Mean scores of organoleptic evaluation showed that both processed fish products were preferred (≥ 7.00) by the trained panellists. However, there was significant difference ($p<0.05$) between the two processed fish products in terms of organoleptic assessment. Smoked fish had better flavour, taste, texture and general acceptability than the solar-dried fish as revealed by the panellists. With better reduction in moisture content and higher protein content observed in fish subjected to smoking, it is concluded that smoking is better than solar drying in the processing of *C. gariepinus.*

Key words: Assessment, organoleptic-evaluation, *Clarias gariepinus,* processing methods.

INTRODUCTION

Fish is a highly nutritious food and it is particularly valued for its protein which is of high quality compared to meat and egg (Ojutiku et al., 2009). It contains high quality protein, amino acids and absorbable dietary minerals (Bruhiyan et al., 1993). Fish contribute to the world protein and is being used as a good tool for food therapy and source of therapeutic substances for the treatment of coronary diseases, auto-immune diseases, anaemia and protein energy malnutrition (Glomset, 1986; Iheanacho et al., 2017).

However, it is highly perishable because it provides a favourable medium for the growth of macro and microorganisms after death (Ojutiku et al., 2009; Aliya et al., 2012; Babarinde et al., 2012; Oparaku and Mgbenka, 2012). Fish spoilage is a metabolic process that makes fish to be undesirable for human consumption due to changes in its sensory and nutritional characteristics, therefore, it has become increasingly important to ensure that fish once caught is fully and efficiently utilized to avoid deterioration. Thus, the processing and preservation of fresh fish becomes imperative in order to maintain product quality, reduce wastage and prevent economic losses (Olley et al., 2000).

To prolong the shelf life of fish, it is preserved by many processes including sun drying, solar drying, canning and smoking among others (Babarinde et al., 2016). Preservation of fish therefore generally slows down spoilage. Preservation methods are applied with an intention of making the fish safer and extending its shelf-life (Ghazala, 1994). Dried fish is a major component of harvested fisheries in many countries including Nigeria (Food and Agricultural Organization, FAO, 2006). About 25 to 30% of the world fish catch is consumed in the dried, salted, smoked form or combination of these processes (Aliya et al., 2012). Some of these processes, though important for preservation, have various effects on the physical and nutritional quality of fish because it has been observed that different processing and drying methods have different effects on the nutritional compositions of fish (Oparaku and Mgbenka, 2012).

African catfish (*Clarias gariepinus*) is highly relished and considered to be the most farmed tropical catfish species in Nigeria and other African countries (FAO, 2004). *C. gariepinus* is a good aquaculture candidate due to its hardy nature, high tolerance to poor water quality conditions, easy adaptation in captivity and high growth rate (Marimuthu et al., 2012).

The aim of this study was to comparatively assess the proximate composition and organoleptic qualities of *C. gariepinus* subjected to two processing methods as means of preservation.

MATERIALS AND METHODS

Construction of solar tent

Solar tent dryer was designed to dry fish under hot and moderate temperature conditions prevailing in the city of Abakaliki, Ebonyi State, Nigeria. The solar tent dryer was built following the design described by Sengar et al. (2009). The dryer consist of three main parts: collector, drying chamber, and inlet and outlet openings. The design thus consist of a plastic polythene sheet stretched over a metal frame work (76.2 cm wide × 106.68 cm long × 121.92 cm high) with side and top vent (30.48 × 30.48 cm) and the fish racks (45.72 × 45.72 cm) placed with wire mesh. The underneath surface is painted rocks which is used as a heat collector and transmitter area.

Sample collection

A total of seventy (70) adult *C. gariepinus* of about 450 g weight were procured from a private fish farm in Abakaliki and transported to the Department of Fisheries and Aquaculture Laboratory, Federal University, Ndufu Alike Ikwo, Ebonyi State within 30 and 40 min, in 200 L capacity plastic container containing aerated water. Fish were conditioned at the departmental fish pond till they were used for the experiment.

Solar-drying process

Fish sample was gutted and washed thoroughly in potable water and then split-open from the dorsal region. It was salted and allowed to drain before being laid on the drying racks (Figure 1). Conditions for fish drying such as temperature within the solar tent were recorded during drying as 34.5 (8.00 am) to 58.4°C (4.00 pm).

Smoking process

The departmental traditional smoking kiln was used for the smoke-drying process (Figure 2). The firing section of the kiln was filled with hardwood together with saw-dust and wood shavings to produce smoke. Fish sample was introduced into the smoke house (preheated for 30 min). The temperature of the smoking chamber was maintained between 60 and 70°C by adjusting the firewood burning in the earth. Fish fillets were smoked for 3 to 4 h. Smoked fish fillets were cooled overnight.

Proximate analysis

Fish samples (both smoked and solar dried) were taken to the Food Utilization and Nutritional Laboratory Unit of the International Institute of Tropical Agriculture (IITA) Laboratory, Ibadan for proximate analysis. Analysis was done following the procedure of Association of Official Analytical Chemists (AOAC) (2000).

Organoleptic assessment

Thirty (30) semi-trained panelists were selected from the Faculty of Agriculture, Federal University Ndufu Alike Ikwo, for the organoleptic assessment of fillets of smoked and solar-dried fish samples. Samples were packed in a transparent double layer polythene bag and tagged for identification and served to a panel of thirty assessors previously trained in basic organoleptic assessment procedure. Each panelist masticated fillets of coded samples with

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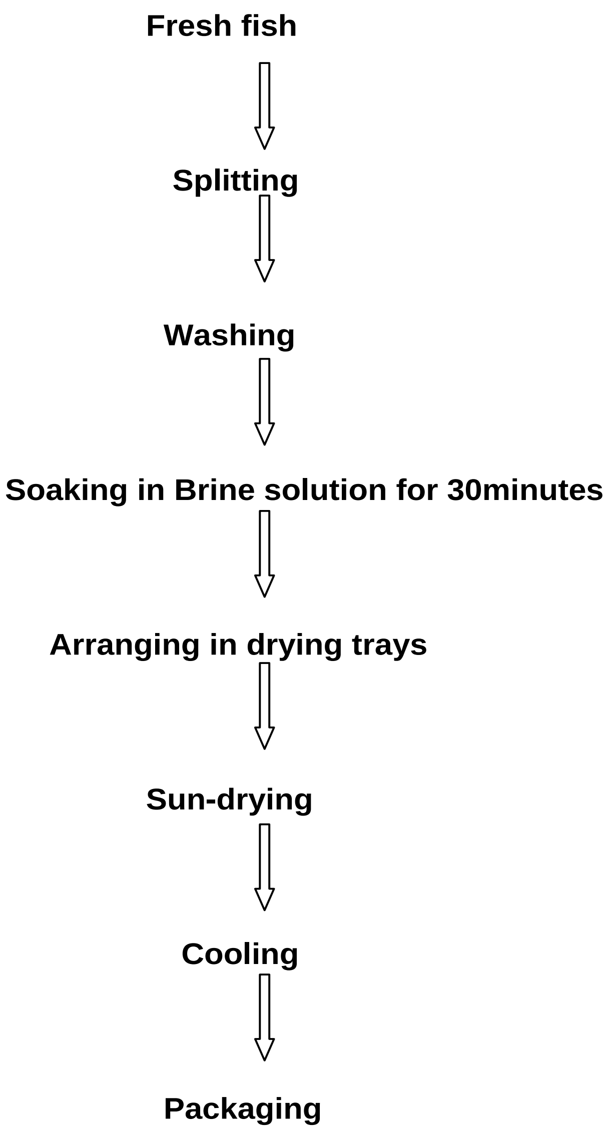

Figure 1. Flow chart for drying of fish using the solar tent.

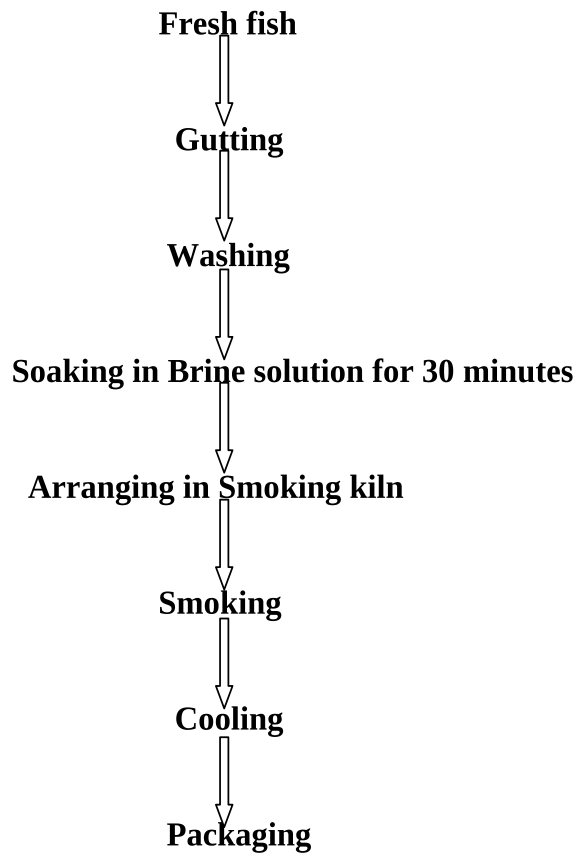

Figure 2. Flow chart for smoking using traditional smoking kiln.

ranked preferences in the following categories: taste, texture, flavour and general acceptability. A 9-point hedonic scale was used, 1 referring to extremely dislike and 9 as extremely like (Wichchukit and Mahony, 2014).

Statistical analysis

Data obtained from the experiment were subjected to paired samples t-test using Statistical Package for Social Sciences (SPSS) version 22, 2016.

RESULTS

Proximate composition

Mean composition of analysed samples from different processing method (smoking and sun drying) are shown in Table 1. Moisture content of the smoked fish samples was 8.10%, while moisture for solar dried fish sample was 25.00%. The crude protein, carbohydrate, fat, ash, crude fibre and nitrogen free extract of the smoked fish sample were 67.20, 1.75, 13.20, 5.50, 3.68 and 2.32%, respectively; while the same proximate indices for solar dried fish were 52.50, 4.07, 17.40, 11.40, 2.00 and 18.30%, respectively.

Sensory evaluation of smoked and solar dried fish (*C. gariepinus*)

The mean sensory scores for smoked and solar-dried *C. gariepinus* are presented in Table 2. The fish samples were assessed on the basis of flavour, taste, texture and general acceptability. The mean score range for all the organoleptic indices examined was between 7.00 and 8.53, indicating that both products were liked by panellists. However, a significant difference ($p<0.05$) was observed between them.

The results on comparative analysis of sensory characteristics of smoked and solar-dried fish are

Table 1. Percentage (%) proximate composition of smoked and sun-dried fish.

Parameter	Smoked fish	Solar-dried fish
Protein	67.20	62.50
Moisture	8.10	25.00
Ash	5.50	11.40
Fibre	3.68	2.00
Fat	13.20	17.40
Carbohydrate	1.75	4.07
NFE	2.32	18.3
Dry matter	97.68	93.30

Nitrogen free extract (NFE) = (100- (moisture + protein + fibre + ash + fat).

Table 2. Mean sensory scores of smoked and solar dried fish.

Parameter		Paired samples test			
		Mean±(SE)	N	Df	Sig.
Pair 1	Flavour (sample A)	8.20±0.15	30	29	<0.0001
	Flavour (sample B)	7.70±0.17	30		
Pair 2	Taste (sample A)	8.10±0.14	30	29	<0.0001
	Taste (sample B)	7.43±0.18	30		
Pair 3	Texture (sample A)	8.20±0.13	30	29	<0.0001
	Texture (sample B)	7.00±0.19	30		
Pair 4	Acceptability (sample A)	8.53±0.15	30	29	<0.0001
	Acceptability (sample B)	7.80±0.18	30		

*Standard error (SE), degree of freedom (df), significant difference (sig). Sample A = smoked fish; sample B = solar-dried fish.

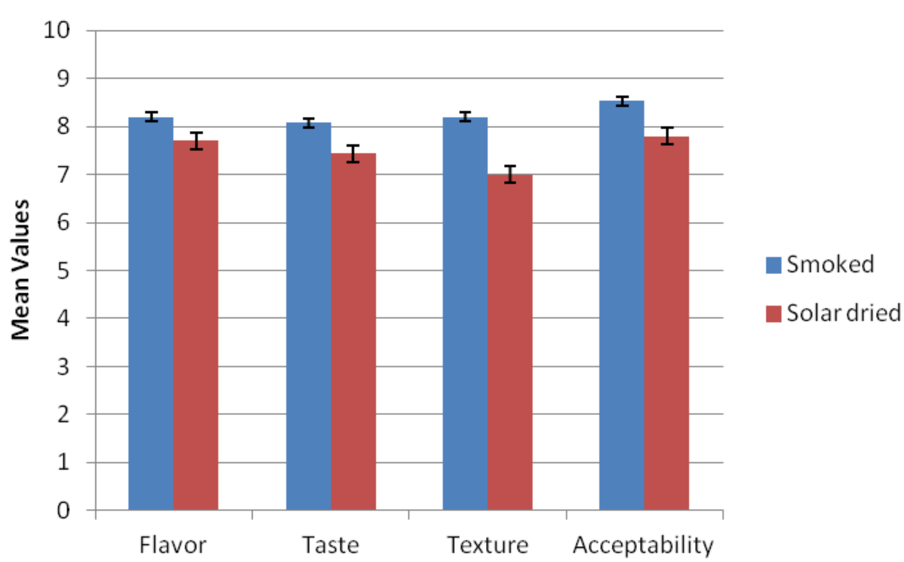

Figure 3. Comparative assessment of organoleptic characteristics of smoked and solar-dried *C. gariepinus.*

presented in Figure 3. From the results, there was significant difference ($p<0.05$) between the two processing methods for all the organoleptic indices examined.

DISCUSSION

When compared with other animal protein sources, fish has been reported to contain high protein, mineral contents and also better amino acid profile (Bruhiyan et al., 1993; Ojutiku et al., 2009). The findings of the present study revealed that *C. gariepinus* subjected to two different fish processing methods contain high percentage of crude protein, ash and dry matter (Table 1). However, higher percentages for protein, fibre and dry matter were seen in smoked fish, while percentage values for ash, nitrogen free extract (NFE), fat, moisture and carbohydrate were observed to be higher in solar-dried fish (Table 1). Agbabiaka et al. (2012) reported 68.17% protein for *C. gariepinus* smoked with *Anthonatha macrophylla* wood. Ogbonna and Ibrahim (2009) reported 53.10% protein content for smoked fish (*C. gariepinus*). A study on the influence of traditional smoke drying on the quality of fish by Ali et al. (2011) revealed that percentage moisture content was least in smoked-dried fish compared to solar-dried, and the former had longer shelf life and keeping quality. Moisture content of catfish decreased sharply after the hot smoking process and this decrease was due to loss of water during smoking. Similar findings were reported by Omojowo et al. (2009) and Kumolu-Johnson et al. (2010), who opined that spoilage of fish resulting from the action of bacteria and enzyme activities could be reduced by salting and reducing moisture content through hot smoking. Moisture content of the smoked *C. gariepinus* samples is still at the safe recommended level for dried fish (6 to 8%) (Yanar, 2007). Akintola and Lawal (2011) reported that high protein content of smoked fish favoured the protection of fish from storage insect attack. Smoke-dried fish is the most acceptable form of fish product in Nigeria (Yanar, 2007; Stolyhwo and Sikorski, 2005). Huda et al. (2010) reported that nutrient content of fish is influenced by several factors including processing method and time of drying.

Reports of panellists revealed that both products were accepted or liked (7.00), since the least mean scores for all the organoleptic indices examined were ≥ 7. However, comparative assessment on organoleptic qualities of smoked and solar-dried fish indicates that smoked fish were preferred to the solar dried fish in terms of taste, texture, flavour and acceptability as was also revealed by the panellists (Figure 3). Preference in taste, flavour, texture and acceptability could be attributed to the processing method (smoke) which might add nutrient to the fish (Eyo, 2001). Agbabiaka et al. (2012) reported that the wood used for fish processing (smoking method) might contain natural chemical compounds (phenols, carbonyl and syringol) which are responsible for the pleasurable taste, colour and flavour in smoked products. Secondly, high protein content (67.20%) and reduced moisture content (8.10%) of smoked fish could be a factor. High moisture as seen in solar-dried fish (25.00%) can induce oxidative rancidity and microbial actions; thus, leading to spoilage which might affect the flavour, taste, texture and acceptability of fish product (Agbabiaka et al., 2012). The finding of the present study is in agreement with the report of Kallon et al. (2017), who obtained similar result when comparing organoleptic qualities, production and economics of smoked fish and solar dried fish in Sierra Leone artisanal fishing industry.

Conclusion

The findings of the current study revealed that both processing fish methods are adequate and effective for fish processing. However, smoking method seems to be more efficient than solar drying method as it was observed that the smoking process added nutrient to the processed fish product and drastically reduced moisture which could prolong the shelf-life of the product.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

REFERENCES

Agbabiaka LA, Amadi AS, Eke LO, Madubuko CU, Ojukannaiye AS (2012).Nutritional and storage qualities of catfish (*Clarias gariepinus*) smoked with *Anthonatha macrophylla.* Sci. Res. Rep. 2(2):142-145.

Akintola AJ, Lawal O (2011). Biochemical factors involved in the resistance ofsome smoked tropical fish samples to insect attack. Turk. J. Biol. 35:89-93.

Ali A, Amodou D, Mohamadou BA, Saidou C, Tenin D (2011). Influence of traditional drying and smoke drying on the quality of three fish species (*Tilapia niloticus, Silurusglanis sp.* and *Arisparkii sp.*) from Lagos Lake, Cameroon. J. Anim. Vet. Adv. 10(3):301-306.

Aliya G, Humaid K, Nasser A, Sami G, Aziz K, Nashwa M, Ponnerassery SS (2012). Effect of the freshness of starting material on the final product quality of dried salted shark. Adv. J. Food Sci. Technol. 4(2):60-63.

AOAC (2000). Association Official Analytical Chemist. Official Methods of Analysis,17th edition Washington D.C.

Babarinde SA, Adebayo TA, Usman LA, Ameen OM, Akinyemi OA, Onajole OT, Adekale O (2016). Preservation of smoked African catfish, *Clarias gariepinus* Burchell against *Dermestes maculatus* De Geer (Coleoptera: Dermestidae) using neem seed oil-iodized salt mixtures. Agric. Conspec. Sci. 81(4):235-240.

Babarinde SA, Pitan OOR, Adebayo TA, Akinyemi AO, Adesina GO, Odumade OI (2012). Susceptibility of 12 smoke-dried fish species to *Dermestes frischii* Kugelann, 1792 (Coleoptera:Dermestidae). Afr. Entomol. 20(1):171-176.

Bruhiyan AKM, Ratnayake WMN, Aukman RG (1993). Nutritional composition of raw fish and smoked Atlantic mackerel: oil and water soluble vitamins. J. Food Comp. Anal. 6:172-184.

Eyo AA (2001). Fish processing technology in the tropics. University of Ilorin press, pp. 112-129.

FAO (2004). The state of world fisheries and Aquaculture. Report (http://www.fao.org) pp. 1-56.

FAO . (2006). Fishery Information, Data and Statistics Unit. Capture

production: quantities 1950-2004. Rome. Retrieved from http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp.
Ghazala S (1994). New packaging technology for seafood preservation,shelf-life extension and pathogen control. In fisheries processing Biotechnological Applications (Ed. Am .Marthin). Chapman and Hall, London, pp. 83-110.
Glomset J (1986). Nutrition research. New England. J. Med. 312:1253-1254.
Huda N, Deiri RS, Ahmed R (2010). Proximate, color and amino acid profile of Indonesians traditional smoked catfish. J. Fish. Aquat. Sci. 5:106-112.
Iheanacho SC, Ogunji JO, Ogueji EO, Nwuba LA, Nnatuanya IO, Ochang SN, Mbah CE, Usman IB, Haruna M (2017). Comparative assessment of ampicillin antibiotic and ginger (*Zingiber officinale*) effects on growth, haematology and biochemical enzymes of Clarias gariepinus Juvenile. J. Pharmacog. Phytochem. 6(3):761-767.
Kallon A, Lebbie A, Sturm B, Garnett T, Wadsworth R (2017). Comparative studies of fish smoking and solar drying in the Sierra Leone artisanal fishing industry. J. Stored Postharv. Res. 8(3):40-48.
Kumolu-Johnson CA, Aladetohun NF, Ndimele PE (2010). The effects of smoking on the nutritional qualities and shelf-life of *Clarias gariepinus* (Burchell 1822). Afr. J. Biotechnol. 9(1):073-076.
Marimuthu K, Thilaga M, Kathiresan S, Xavier R, Mas RH (2012). Effect of cooking methods on proximate and mineral composition of striped snakehead fish (*Channa striatus,* Bloch). J. Food Sci. Technol. 49(3):373-377.
Ogbonna C, Ibrahim MB (2009). Effect of drying methods on proximate composition of catfish (*Clarias gariepinus)*. World J. Agric. Sci. 5(1):114-116.
Ojutiku RO, Kolo RJ, Mhammed ML (2009). Comparative study of sun drying and solar tent drying of *Hyperopisus bebeoccidentalis*. Pak. J. Nutr. 8(7):955-957.
Olley J, Doe PE, Heruwat ES (2000). The influence of drying and smoking on the nutritional properties of fish: An introductory overview. Int. Union Nutr. Sci. Conf. Malaysia pp. 1-6.
Omojowo FSI, Libata G, Adoga IJ (2009). Comparative Assessment of Potassium Sorbate and Sodium Metabisulphite on the Safety and Shelf Life of Smoked Catfish. Nat. Sci. 7:10.
Oparaku NF, Mgbenka BO (2012). Effects of electric oven and solar dryer on a proximate and water activity of *Clarias gariepinus* Fish. Euro. J. Sci. Res. 81(1):139-144.
Sengar SH, Khandetod YP, Mahod AG (2009). Low cost solar dryer for fish. Afr. J. Environ. Sci. Technol. 3(9):265-271.
Stolyhwo S, Sikorski ZE (2005). Polycyclic aromatic hydrocarbons in smoked fish: A critical review. Food Chem. 91:303-311.
Wichchukit S, Mahony M (2014).The 9 point hedonic scale and hedonic ranking in food science: some reappraisals and alternatives. J. Sci. Food Agric. 95(11):2167-2178.
Yanar Y (2007). Quality changes of hot smoked catfish (*Clarias gariepinus*) during refrigerated storage. J. Muscle Foods 18:391-400.

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Full Length Research Paper

Application of multivariate probit on determinants of sesame farmers market outlet choices in Gimbi District, Ethiopia

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Sesame (*Sesamum indicum* L.) is an important crop produced in Ethiopia for oilseed production and it was ranked first in total production from oil crops in 2013. The study is based on a survey of 166 farmers covering six kebeles in Gimbi district, Ethiopia with the objectives of identifying factors affecting choice of market outlet of sesame producers in the study area. Data were collected from both primary and secondary sources in 2015/2016. Multivariate probit model was for analysis. The results indicated that the probability of wholesalers to choose an outlet was positively and significantly affected by household education, distance from the nearest market, quantity produced and market price of sesame but negatively affected by collector market outlets. On the other hand, the probability of choosing cooperative marketing outlet is positively affected by membership of cooperative and distance from the market whereas it is negatively affected by market price of sesame. Therefore, the study confirmed the continued viability of sesame marketing cooperatives as suppliers of sesame-to-sesame buyers in the study area. The results obtained have important implications for farm management and future of farmers, as well as for the assessment of their development impacts.

Key words: Sesame, multivariate probit model, market outlet choices.

INTRODUCTION

Among the important oil crops grown in Ethiopia, sesame seed commands a unique position chiefly because of the fact that it is highly adapted to arid and semi-arid low land environment and yields fairly well. The country's main sesame production areas are located in the semi-arid lowlands of North-West Ethiopia that include mainly Humera, Tsegede and Wolkayit in Tigray and Metema, Quara and Tach Armachiho in Amhara Regional State. These production zones account for more than 70% of the national production (Goitom, 2009).

Ethiopia is among the top-five producers of oilseeds in the world. One of the oilseeds for which Ethiopia is

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known for in the international market is sesame. In the last few years, sesame production and marketing has shown very significant growth. Between 1998 and 2005-2006, the total area of production and the quantity of sesame produced has grown threefold. As a major producer of sesame, Ethiopia stands fourth in the global sesame market following China, India, and Burma, respectively and national sesame production has more than doubled in the past 5 years. Ethiopia exports almost all of its produce and is poised to become one of the top two leading sesame-exporting countries in the world, with a rapidly growing export performance in recent years, destined for markets in China, Japan, Korea, Israel and Turkey. Sesame is the major oil seed in terms of exports in Ethiopia, accounting for over 90% of the values of oil seeds exports (ATA, 2014).

Sesame is currently among the major Ethiopian export crops and is one among the agricultural crops for which Ethiopia is known in international markets (Sorsa, 2009). Evidences indicate that Ethiopia ranks fourth in sesame production in 2011/2012 (FAOSTAT, 2012) in the world, and the third in sesame seed export next to India and Sudan (Alemu and Meijerink, 2010). Evidences reveal that there is still potential arable land in different parts of the country to grow the crop and increase its supply response to the considerable demand for Ethiopian sesame seed in international markets (Sorsa, 2009). This indicates that, growth and improvement of the sesame sector can substantially contribute to the economic development of the country by benefiting agents at national, regional, and local levels. Yet, it is important to unravel how the agents can benefit from the sector through production and selling through different market outlet in the study areas.

Ethiopia's oilseeds production is essentially full of challenges yet replete with opportunities. Despite immense potential for improving the production and productivity of the sector, it is believed that primary producers lack the necessary marketing outlet to improve their production and productivity; trade arrangements are not well organized; the necessary government policies and institutions, and the enforcement of regulations are either non-existent or functioning too ineffectively to ensure a smooth operating chain. Therefore, the objective of the study is to investigate the factors affecting choices of sesame farmer's market outlet in the study areas.

METHODOLOGY

The study was carried out in Gimbi Woreda, located about 441 km West of Addis-Ababa and 2 km West of Gimbi town, the capital of Western Wollega Zone of Oromia region (Figure 1). It has an estimated area of 1,183.44 km^2; bordered in the South by Haru, on the Southwest by Yubdo, in the West by Lalo Asabi, and in the North by the Benishangul-Gumuz Region, on the East by the East Wollega Zone, and on the Southeast by an exclave of the Benishangul-Gumuz Region. The Woreda has a total of 32 Kebles, of which 30 are rural based peasant administration areas. The Woreda total population and households are estimated to be 74,623 and 18,301, respectively. Of the total households, 97% are rural residents making their livelihood from agriculture (CSA, 2007).

Lowland and midland agro-ecological zones characterize the Woreda's climate. Minimum annual temperature in the study area is 14°C and the maximum temperature reaches as high as 26°C while mean annual rain fall ranges from 800 to 2000 mm. The main rainy season in the Woreda is from March to the end of May and from June to the end or middle of September. The economy of the Woreda is dominated by traditional cash and other crops such as maize farming mixed with livestock husbandry. The major crops produced in the Woreda include sesame, maize and sorghum (GWOoARD, 2013).

Gimbi Woreda is known for its high potential for sesame, coffee and maize production. Besides, it is rich in small ruminant animals, incense and gum resources. Except for the very small areas under vegetables and fruits, crops in all farms (commercial and smallholders) are grown under rain fed condition. In the area, sesame, coffee, and maize are the most important marketable commodities, and account for 90% of the Woreda's cultivated area. Both primary and secondary data were used to collect data. Primary data were obtained using structured questionnaires administered to smallholder farmers and wholesalers from three purposively selected kebeles, collectors, commissioners, retailers, processors and exporters. The structured questionnaire was pre-tested with similar households operating within the study area, but not included in the final survey. Data were collected on household characteristics, socioeconomic and demographic characteristics, farm information, input utilization, and access to services such as extension, credit and market information. Experienced enumerators were recruited and well trained for actual field data collection. The data were collected in January 2015/2016.

A two-stage sampling procedure was used to select representative households from the study area. In the first stage, with the consultation of district agricultural experts and development agents, 3 out of 12 sesame producing kebeles were purposively selected based on their sesame production potential. In the second stage, sample size was determined using a simplified formula provided by Yamane (1967). Out of the total 1025 households, 127 households were selected using simple random sampling methods.

Descriptive statistics and econometric models were used to analyze the data collected from households. Descriptive data analysis includes the use of ratios, percentages, means and standard deviations for describing households based on their socioeconomic, demographic and institutional characteristics. To identify factors affecting market outlet choices decision of sesame producers at the individual household level, multivariate probit model was used. The multivariate probit is an extension of the probit model and is used to estimate several correlated binary outcomes jointly. Generally, the multivariate probit model can be written as:

$$y_{im} = \beta_{im} \times_{m + \varepsilon_{im}}$$

Where y_{im} (m= 1... k) represent the dependent variable of sesame market outlet selected by the i^{th} farmer. (i = 1… n). The dependent variables are polychotomous variable indicating whether sales are made through the relevant marketing outlet. The outlet was aggregated into three groups: wholesalers, cooperatives, and collectors. Each farm can use one or more marketing outlet. X_{im} is a 1 × k independent variable that affects the choice of marketing outlet decisions and βm is a k × 1 vector of unknown parameters to be estimated ε_{im}, m = 1, …, m are the error terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V, where V has values of 1 on the leading diagonal and correlations.

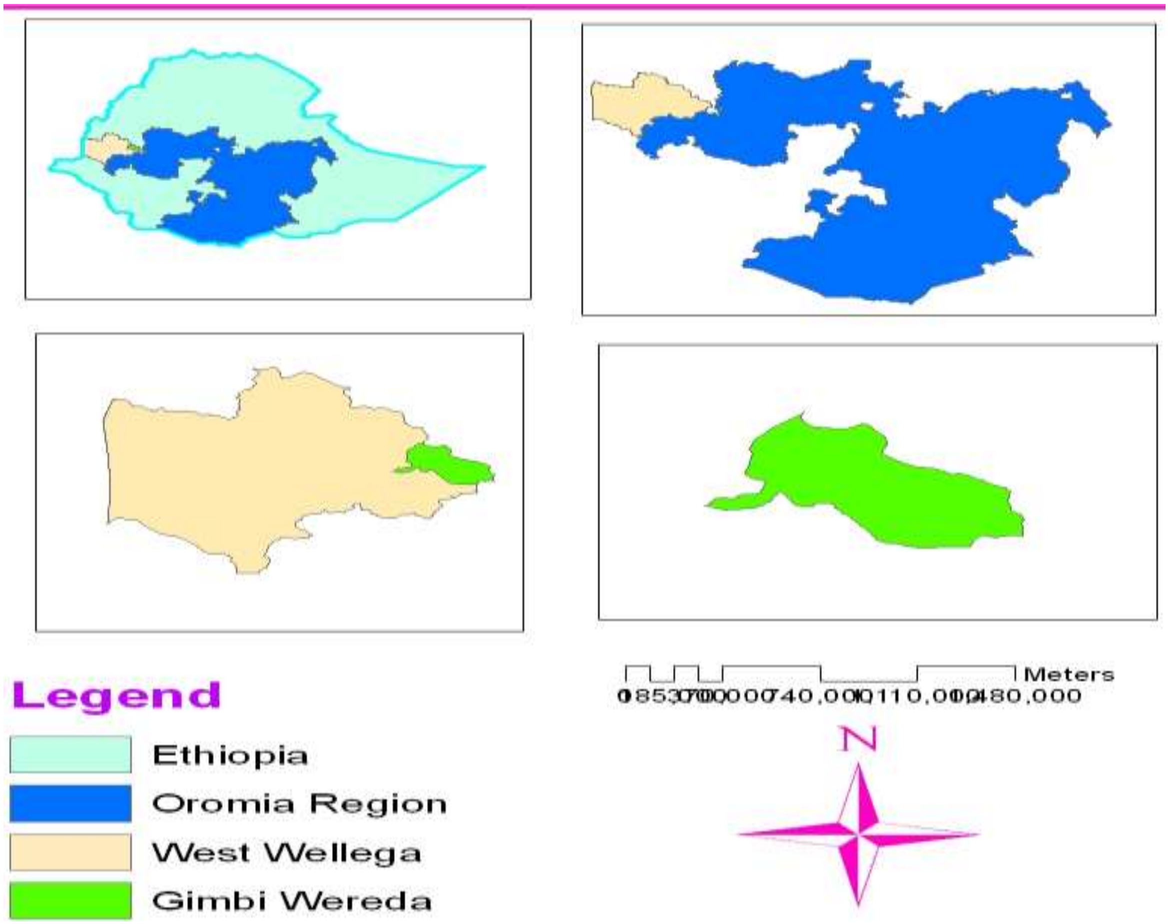

Figure 1. Map of the study area. Sources: Captured by GIS Expert for Research Purposes in 2016.

The aforementioned equation is a system of m equations shown in the following equations:

$$y_{1i}^* = \beta_1' X_{1i} + \varepsilon_{1i}$$
$$y_{2i}^* = \beta_2' X_{2i} + \varepsilon_{2i}$$
$$y_{3i}^* = \beta_3' X_{3i} + \varepsilon_{3i}$$

The latent dependent variables are observed through the decision to adopt or not (yki) such that:

$$y_{im} = \begin{cases} 1 & if \quad y_k^* > 0 \qquad k = 1,2,3. \\ 0 & otherwise \end{cases}$$

There are six joint probabilities corresponding to the six possible combinations of choosing and not choosing each of the three outlets. The probability that all three components of the sesame market outlet have been selected by household 'i' is given as:

$Pr(y_{1i} = 1, y_{2i} = 1, y_{3i} = 1) =$ $pr(\varepsilon_{1i} \le \beta_1' \times_{1i}, \varepsilon_{2i} \le \beta_2' \times_{2i}, \varepsilon_{3i} \le \beta_{3i}' \times_{3i})$

$Pr(y_{1i} = 1, y_{2i} = 1, y_{3i} = 1) =$ $pr(\varepsilon_{3i} \le \beta_3' \times_{3i}, \varepsilon_{2i} \le \beta_2' \times_{2i}, \varepsilon_{1i} \le \beta_{1i}' \times_{1i})$

$Pr(y_{1i} = 1, y_{2i} = 1, y_{3i} = 1) =$ $Xpr(\varepsilon_{2i} \le \beta_2' \times_{2i}, \varepsilon_{1i} \le \beta_1' \times_{1i}, \varepsilon_{1i} \le \beta_{1i}' \times_{1i})$

This system of equations is jointly estimated using maximum likelihood method. The estimation is done using the user-written STATA mvprobit procedure (Cappellari and Jenkins, 2003) that employs the Gewek-Hajivassiliour-Keane smooth recursive conditioning simulator to evaluate the multivariate normal distribution (Train, 2003). The GHK simulator was indicated (Cappellari and Jenkins, 2003) to have desirable properties in the context of multivariate normal limited dependent variables that the simulated probabilities are unbiased, they are bounded within the (0, 1) interval, and the simulator is a continuous and differentiable function of the model's parameters.

The data covered information necessary to make household level indices of social, economic, demographic, and institutional indicators comparable across different categories of sesame market outlets choice at the individual household level. In order to identify factors affecting market outlet choice decision of sesame producers at the household level, continuous and discrete variables were identified based on economic theories and empirical studies as follows.

Marketing outlet (MktO)

Three classes of dependent variables were identified in market

Table 1. Proportion of producers by demographic characteristics across marketing outlets (%).

Variable	Item	Wholesaler	Cooperative	Collector
Sex	Male	94.5	90.1	8.6
Education status	Literate	78.1	74.4	24.4
Membership to cooperatives	Yes	27.8	72.2	47.4
Access to extension service	Yes	82.5	70.5	6.6
Credit	Yes	55.5	81.5	7.8

Source: Authors' computation from survey result, 2015.

Table 2. Proportion of producers by demographic characteristics across marketing outlets (%).

Variable	Wholesaler	Cooperative	Collector
Age	43.01	43.05	44.23
Land	3.61	3.51	3.62
DMkt	22.66	24.17	23.71
Price	24.46	22.26	18.78

Source: Own computation from survey result, 2015.

outlets: whether the farmer chooses to sell sesame to wholesalers, cooperatives and collectors. Each farmer can use one or more marketing outlet. In the analysis, it is measured by the probability of selling sesame to either of the markets. A farming household would choose one or more of the sesame market outlet if and only if the utility expected is higher than otherwise (Fafchamps and Hill, 2005).

RESULTS AND DISCUSSION

In this study, three major sesame market outlets were identified for the farmers to sell majority of their sesame products. More than 90% of male households chose wholesaler and cooperative market outlet, respectively. However, about 91.9 and 83% of female households sell their products to the cooperative and collectors respectively. Although the role of agricultural cooperatives in smallholder farmers marketing is recognized as vital, many of them reported that cooperatives as alternative market outlet in their sesame marketing. Accordingly, from those who are members of cooperatives, more than 70% of them sold their sesame to the cooperatives whereas 27.8 and 47.4% of them sold to the wholesalers and collector respectively (Table 1).

Compared with the collector's outlet, households with more education may have greater access to choose wholesalers and cooperative market outlet. Accordingly, of the literate households, about 78% sold their sesame to the wholesaler's market outlet. Educated farmers may have a greater ability to decide to choose any of better outlets from market channel. On the other hand, more than 80% of illiterate households choose collector market outlet to sell their sesame. Less educated households may be less likely to choose market outlet and practices, since they may be able to earn higher capital if they are used in other outlet. Thus, the probability and level of adoption increase with the education level of the farmers.

Econometric

Table 2 presents the results of the multivariate probit model. The results showed that the correlation coefficients among the equations are highly significant, which means that the multivariate probit model is superior to the individual probit models. In addition, a likelihood ratio test rejects the restrictions implied by separate probit models for the three outlets. According to Fafchamps and Hill (2005), the correlation is positive between the wholesalers and the cooperatives but is negative between the wholesalers and the collectors' outlets as well as cooperatives and collectors. This suggests that farmers who start using an alternative chain to the collector one are more prone to using another one.

According to Nyaupane and Gillespie (2011), the signs of the parameters confirm that the collector outlet is an alternative to both wholesalers and collector outlet, while wholesalers and cooperative are largely influenced in the same way by the variables. Larger farms are more likely to choose the wholesaler outlet, as indicated by the significant and positive relevant parameter. The corresponding parameters are significant and negative for the cooperative and collector outlet (Table 3).

Membership to any cooperatives was another highly significant variable that positively and significantly affect cooperative market outlet choice. This result indicates that if a household is member of any cooperative the probability of choosing wholesalers and collector outlet decreases. This is mostly related to the fact that those

Table 3. The multivariate probit.

Variable	Wholesalers			Cooperatives			Collectors		
	Coef	Std. error	Z	Coef	Std.error	Z	Coef	Std. error	Z
Sex	0.074	0.498	0.15	0.779	0.564	1.38	-723	0.486	-1.49
Age	-0.021	0.013	-1.63	-0.026	0.015	-1.69	0.167	0.012	0.01
HEduc	0.371**	0.013	1.18	-0.148	0.342	-0.04	-0.358*	0.307	-1.17
MCoop	-0.429	0.411	1.05	0.381***	0.011	1.00	-0.599	0.383	-1.56
Credit	0.349	0.401	-0.85	0.231	0.368	0.62	-0.693	0.377	-1.84
DMarket	0.211**	0.012	1.76	0.321**	0.015	2.02	-0.045*	0.012	-0.17
QProdn	0.114*	0.028	0.51	-0.055	0.031	-1.83	-0.889*	0.028	-0.01
Price	0.076*	0.031	0.19	-0.023*	0.034	-0.15	-0.341**	0.027	-1.23
OTran	0.391	0.362	1.08	-0.667	0.503	-1.33	-0.296	0.353	-0.84
MInfmn	-0.326	0.435	0.75	0.301	0.613	0.49	-0.491	0.414	1.19
AExtnto	0.184	0.263	0.70	-0.046	0.281	-0.16	0.144	0.248	0.58
-cons	1.903	1.101	1.73	1.652	1.208	1.37	-1.319	1.062	-1.24
Correlations				**(Coef , t-ratio)**					
R (Wholesalers, Cooperatives)				(0.641***, 4.15)					
R (Wholesalers, Collectors)				(-0.548***, -4.48)					
R (Cooperatives, Collectors)				(-0.431***, -2.79)					

LR test of rho21 = rho31 = rho32 = 0: chi^2 (3) = 29.058; $prob_{>}chi^2$ = 0.0000 Log likelihood = -181.076; Number of observation = 127; ***, **,*: significant at 1, 5 and 10%, respectively. Source: Own computation from survey result, 2015

multipurpose cooperatives provide production and market information they directly or indirectly accessed to their members. Although the role of agricultural cooperatives in smallholder farmers marketing is recognized as vital, many of them reported cooperatives as alternative market outlet in their sesame marketing.

Market price of sesame has positive and significant effect on wholesalers' market outlet choice whereas negative and significant effect on cooperative and collector outlet choice. According to the result, the majority of the household head received more prices from the wholesaler's market outlet compared to cooperative and collector market outlets. These two outlets might have lower capitals than wholesaler might which constrain them from paying higher prices.

Distance from the nearest market has positive and significant on both wholesaler, and cooperatives market outlet choice whereas has negative effect on collector market outlet choice. This indicates that households who are closer to market were assumed to have more probability to choose wholesalers and cooperatives outlet whereas household who are far from the market were expected to be associated with sales to the collector market outlet Fafchamps and Hill (2005). This is may be due to the reason that as the distance to the market center increases transportation and other marketing costs increased.

CONCLUSION AND RECOMMENDATIONS

The objective of the study is to identify the factors affecting outlet choice decisions of farm households. Market outlets were classified into three categories according to farmer market outlet choice decision: wholesalers, cooperatives, and collectors. The model results indicated that the probability to choose the wholesalers outlet was positively and significantly affected by household education, distance from the nearest market, quantity production and market price of sesame but these variables negatively affect the probability of choosing collector market outlets. The probability of choosing cooperative marketing outlet was positively affected by membership to any cooperative and distance from the market whereas negatively affected by market price of sesame. Hence, most of the effects of the variables are in line with the study hypothesis and different literatures as discussed previously. Therefore, governmental and non-governmental organization is needed to improve sesame production in the study area. In the study area farmers are small scale and unorganized; this state of affairs clearly needs strong governmental and non-governmental organizations intervention. In addition, improving credit, training, and market information access is needed to improve the existing sesame production in the study area. Sampled farmers complained about lack of finance, low price of sesame, lack of packaging materials, and lack of shortage and transport facility in the area. In this regard, farmers require immediate intervention and support. Therefore, improving credit and transportation access to the farmers is essential to make sesame market efficient in addition to developing road infrastructures. In addition to this, smallholder farmers have complained about the crop failures at different stages due to sesame diseases, rainfall related problems, soil acidity and cracks, and pest infestation problems. This requires research and development works in the area to sustainably solve these problems.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Agricultural Transformation Agency (ATA) (2014). Sesame sector strategy in Ethiopia; 2014. Available:www.ata.gov.et (Accessed on 20 November 2016).

Alemu D, Gerdien WM (2010). Sesame Traders and the ECX: An Overview with Focus on Transaction Costs and Risks, VC4PPD Report #8, Addis Ababa.

Cappellari L, Jenkins SP (2003). Multivariate probit regression using simulated maximum likelihood. Stata J. 3(3):278-294.

Central Statistical Agency (CSA) (2007). Agricultural Sample Survey 2006-07, Volume I, Addis Ababa.

Fafchamps M, Hill RV (2005). Selling at the farm gate or traveling to market. Am. J. Agric. Econ. 87(3):717-734.

FAOSTAT (2012). Top Five Sesame Seed Producing Countries. www.FAOSTAT.Com. http://www.fao.org/faostat/en/#data/TP/visualize

Goitom A (2009). Commercialization of Smallholder Farming: Determinants and Welfare Outcomes. MSc. Thesis, the University of Agder, Kristiansand, Norway.

GWOoARD (2013). Gimbi Woreda Office of Agriculture and Rural Development Woredas report on agricultural production survey Addis Ababa, Ethiopia.

Nyaupane NP, Gillespie JM (2011). Factors Influencing Producers' Marketing Decisions in the Louisiana Crawfish Industry. J. Food Distr. Res. 42:2.

Sorsa DG (2009). Sesame trade arrangements, costs and risks in Ethiopia: A baseline survey. VC4PD Res. Papers.

Train K (2003). Discrete Choice Methods with Simulation. Published by Cambridge University Press. First edition 334p.

Yamane T (1967). Statistics: An Introductory Analysis, 2nd Ed., New York: Harper and Row.

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Effect of organic mulches and land preparation methods on soil moisture and sesame productivity

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Sesame (*Sesamum indicum* L.) is one of the exportable commodities in Ethiopia, though its productivity is threatened by moisture stress. This research aims to study effect of organic mulches and land preparation methods on sesame productivity and in-situ moisture conservation. The experiment was carried out in Humera, Western Tigray during 2015/16 growing season. The experimental design was factorial randomized complete block design with three replications. There were four type of organic mulches (rice straw, sorghum straw, sesame straw and "Sudan grass") compared with control (no mulching) and two land preparation methods (ridge and flat land preparation). Sesame, variety Setit-1 was used in the experiment. The organic mulching rate of application was 10 ton ha^{-1} and this was applied evenly to the soil immediately after emergence. Soil water content, phonological characteristics, yield and yield components of sesame were collected. Partial budget analysis was computed to evaluate the economic visibility of both factors. The data collected was analyzed with Genstat15 software and treatment showed that significant difference was subjected to mean comparison test. The analyzed results indicated that land preparation methods with organic mulching had significant effect on soil moisture content at different soil depth and grain yield. The highest yield (750 kg ha^{-1}) was recorded under flat land preparation with "Sudan grass" while the lowest yield (140 kgha^{-1}) was recorded under no mulch with flat land preparation methods. The economic analysis showed that flat land preparation with "Sudan grass" produces the highest net benefit (9,499 Birr) and marginal rate of return (223.3%). The overall result showed that investing 1.0 Birr on flat land preparation method mulched with "Sudan grass" earns 2.23 birr. Thus, using flat land preparation with "Sudan grass" as mulch could be an advantage to obtain highest yield and profit for the farmers in dry land areas.

Key words: Organic mulch, land preparation method, soil moisture, Sesame yield.

INTRODUCTION

Sesame (*Sesamum indicum* L.) belongs to *Pedaliaceae* family with a broad leaf and has an indeterminate flowering habit (Tashiro et al., 1991). Though there are shattering and non-shattering types, most sesame seed

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is produced with shattering varieties. Sesame is a crop that is adapted to deep soils which have a loamy texture, are well drained and good natural fertility. Regardless of having an optimal range of between 500 and 650 mm of water during its production phase (Grilo et al., 2013), sesame productivity is threatened by biotic and abiotic factors such as rainfall intensity and distribution on one side and insect pest on the other side; factors responsible for 0.35 - 4 t/ha yield reduction in sesame production (Gebregergis et al., 2016). Therefore, productivity could be attained through creating new cultivars with high yield potentiality as well as application of suitable cultural practices such as fertilization, in-situ water harvesting technique and weed control etc (El-Habbasha et al., 2007). Organic mulching has numerous benefits on soil physical, chemical and biological properties, and as a result increases water holding capacity through increasing infiltration and reducing evaporation. Mulches increased soil organic matter after decomposition and has resulted in mineralization and improvement in soil physical properties. Thus, this condition improves the number of pores and as result increase water holding capacity. Similarly, Ji and Unger (2001) reported that as the mulch decomposes, humus is added to the soil, which increases its water holding capacity. In other ways, soil water retention can be improved via reduction in evaporation. Similarly, Goitom et al. (2017) reported significant moisture retention due to application of organic mulching material. Moreover, De et al. (2005) and Adeniyan et al. (2008) found highest soil moisture content in plots mulched with water hyacinth and sunflower respectively. Soil evaporation reduction by 50% was modeled with 100% soil cover of the soil by organic mulch in Aqua Crop Water Productivity Model (Raes et al., 2009) and by 34 - 50% reduction in soil water evaporation as a result of crop residue mulching reported by Hatfield et al. (2001). Mulch conserve soil moisture and suppress weed growth, and as a result boost yield by 11.2% (Pandya and Rank, 2014). This research aims to evaluate the effects of land preparation methods with organic mulching on sesame productivity.

MATERIALS AND METHODS

Description of the study area

The field experiment was conducted in 2015 main growing season in Humera Agricultural Research Center (Table 1). The study area is found in northern Ethiopia bordered in the west by Sudan, north by Eritrea, south by the Amhara Regional State and in the east by Welkait-Tsegedie District. Humera, main town of Kafta Humera District, is found about 600 km west of Mekelle and situated between 13°14’ to 14°27´N and 36°27´ to 37°32´E.

Experimental design and treatments

In this research, factorial randomized complete block design with 10 treatment and three replications was used. Those treatments included land preparation method (flat bed and ridge) and organic mulch material (sesame straw, sorghum straw, rice straw, “Sudan grass” and control; that is, with no mulch). The gross plot size was 6 m^2 and the net plot size was 3.6 m^2. The distance between the plot and block was 1 m and 1.5 m, respectively. Sesame seed variety setit-1 was sown at row to row and plant to plant distance of 40 cm and 10 cm respectively. The field was tilled and supplied with 100 kg of NPS (19 N-38$P_2 0_5$ +7S) and 50 kg of urea fertilizer. The urea was applied in split form; 25 kg at sowing and 25 at flower initiation. In accordance with the methods adopted by Ramakrishna et al. (2006) and Ajibola et al. (2014), the rate of mulches used was 6 kg per plot which is equivalent to 10 ton/ha. Mulches were evenly applied immediately after emergence of sesame.

Land preparation

The experimental land was first prepared using tractor; thereafter, the different land preparation methods (ridge and flat) were prepared. Land preparation of the crop can either be in the furrows or on the ridges based on the expected soil moisture content required for a particular crop. Ridge and furrow land preparation method is a land preparation technique that has ridge, which is vital for moisture conservation. The ridges were raised and adjusted manually to a height of 20 cm after first plowing. The sesame seeds were then sown at ridges in order to reduce the influence of water logging. The soil surface of the study area is generally flat with slope range of 1 - 5% and is considered as control or check as it is the most common method used in the study area.

Yield and yield components

Number of branches per plant, number of capsules per plant and number of seed per capsule were counted from five randomly selected plants per plot and plant height was measured from five plants per plot. After harvesting, biomass was allowed to dry by setting the bundles upright until all capsules opened. Threshing was done by knocking the inverted bundles a few times until all seeds dropped from the capsules.

To determine the number of seeds per capsule, the seeds of three capsules (lower, medium and uppermost position on the plant) from each of five plants were counted. Seed weight per capsule was taken on fifteen capsules from the randomly tagged plants to determine thousand grain weights. Thousand seed weight were determined by counting 1000 seeds from each plot after sun drying. Seed yield of each plot was weighed in grams and converted to area basis to determine the yield per hectare in kg/ha.

Economic analysis procedure

This partial budget as described by Program (1988) was analyzed on grain yield of sesame crop in order to assess the costs and benefits associated with different treatment (land preparation method and organic mulching). Economic analysis was done using the market price for inputs at land preparation and for grain yield at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopia Birr. Grain yield was adjusted down by 10% to minimize the effect of researcher-managed small plots as compared to the farmers managed plots.The dominance analysis procedure as detailed in Program (1988) was used to select profitability treatments from the range tested. The marginal rate of return (MMR) is calculated using Equation 3 by considering a pair of non-dominated treatments listed in the order of increasing net benefit. MMR denotes a return per unit of investment in the change of field management tested in the field research.

Table 1. Pre-sowing soil characteristics of the experimental site (Humera).

Soil characteristics		Value	Type
Texture	Clay (%)	68	Clay
	Silt (%)	13	
	Sand (%)	19	
Total-N (%)		0.04	Low
P (ppm)		2.78	
K (ppm)		62.8	
OM (%)		0.98	
CEC (meq/100 g soil)		30	
pH water (1:2.5)		8.45	Basic
EC water (mmohs/cm) (1:2:5)		0.16	Non saline

Source: Mekelle Soil Laboratory (2016).

The results of marginal analysis were further checked by the residuals which are residuals are calculated by subtracting the rate of return that farmers require (that is, the minimum of return multiplied by the total variable costs) from corresponding net benefits. Since the combination of field management treatments tested in this study is new to the farmers, 100% is considered as the change of their practice (Program, 1988). Following the analysis, treatments with highest residuals are recommended to farmers.

Gross benefit = Economical yield return × price (birr/kg) (1)

Net profit= Gross benefit – Total cost that vary (2)

$$MRR= \frac{change\ in\ NB}{change\ \ in\ TCV} \quad (3)$$

Where, MRR= is the marginal rate of return, NB= is net benefit ha^{-1} for each treatment, TCV= is the total variable costs ha^{-1} for each treatment.

RESULTS AND DISCUSSION

Soil moisture content during 15 days after sowing

Analysis of variance revealed highly significant difference (p<0.01) on soil moisture content during 15 days after sowing in the upper soil depth (0 - 0.2 m). Flat land preparation method with sorghum and ridge land preparation method with sesame conserved statistically similar soil moisture. There was also statistically similar result among flat land preparation method with sesame, ridge land preparation method with sorghum, flat land preparation method with “Sudan grass” and ridge land preparation with rice. The lowest soil moisture was conserved with ridge land without mulching. However, in the medium soil depth (0.21 - 0.4 m), insignificant (P>0.05) soil moisture was conserved among mulching with land preparation methods treatments. In the lower depth (0.41 - 0.6 m), highly significant difference (p<0.01) WAS shown among treatments. The highest soil moisture (20.7%) was conserved at flat land preparation method with “Sudan grass”, even though statistically similar with ridge land preparation method with rice straw and ridge land preparation method with sorghum, while the lowest (11.2%) was conserved with flat land preparation method with no mulch statistically similar with ridge without mulch (Table 2). This period in sesame growth is known as vegetative (particularly seedling) (Langham, 2007). Thus, treatments that had conserved significant amount of soil moisture created favorable environment for escaping water stress in this sensitive stage (Silva et al., 2016). Moreover, El Harfi et al. (2016) reported sesame as very sensitive to water stress at seedling stage. The no mulch treated plot showed poor soil moisture conservation as compared to treated plots. This could be due to poor infiltration via impact of raindrop on soil physical characteristics or high evaporation rate.

Soil moisture content during 30 days after sowing

The analysis of variance did not show significant difference (p>0.05) on soil moisture content during 30 days after sowing at the upper depth (0 - 0.2 m). However, the highest soil moisture (25.6%) was conserved at ridge land preparation with sesame, whereas the lowest (17.9%) was conserved at flat land preparation method with no mulch (Table 2). Similarly, analysis of variance showed insignificant difference (p>0.05) on soil moisture among treatments in the medium soil depth (0.21 - 0.4 m). However, the highest soil moisture content was (25.3%) conserved at ridge sesame straw while the lowest (17.4%) was conserved at flat land preparation method with no mulch (Table 2). Besides, analysis of variance did not show significant difference (p>0.05) on soil moisture at lower depth (0.41 - 0.6 m); whereas, the highest soil moisture (28.1%) was conserved at ridge with rice while the lowest (18.2%) was conserved at flat land preparation method without mulch (Table 2). This period of growth in sesame is called vegetative (juvenile and pre reproductive) (Langham, 2007) and is in line with De et al. (2005) who reported the highest amount of water conserved in groundnut fields mulched with water hyacinth and the lowest under no mulch in the depth of 0.15 m during 30 days after sowing.

Soil moisture content during 45 days after sowing

Analysis of variance revealed highly significant difference (p<0.01) on soil moisture content at the upper depth (0 - 0.2 m) with the highest soil moisture (28.9%) conserved at flat land preparation method with sesame even though a statistically similar result was observed with flat land preparation method with “Sudan grass” and flat land preparation method with rice; whereas the lowest (17.4%) was conserved at flat land preparation method without mulch though statistically similar with ridge without mulch

Table 2. Effect of mulching and land preparation on soil moisture content at different soil depth and days after sowing.

Treatment	15 DAS (cm)			30 DAS (cm)			45 DAS (cm)			60 DAS (cm)			75 DAS (cm)		
	0 - 20	**21 - 40**	**41 - 60**	**0 - 20**	**21 - 40**	**41 - 60**	**0 - 20**	**21 - 40**	**41 - 60**	**0 - 21**	**21 - 40**	**41 - 60**	**0 - 20**	**21 - 40**	**41 - 60**
F. Sorghum	32.2^{a}	13.4^{de}	12.9^{cd}	20.3$^{c.e}$	21.3^{b}	22.4^{bc}	20.9^{de}	27.9^{cd}	28.9^{ab}	20.3^{bc}	23.3$^{b.d}$	22.9^{ab}	36.4$^{b.d}$	23.6^{de}	20.6^{e}
RF. Sesame	31.6^{a}	19.4^{ab}	16.8^{b}	25.6^{a}	25.3^{a}	25.9^{ab}	20.3^{de}	31.4^{ab}	30.5^{ab}	22.7^{a}	21.2$^{c.e}$	23.6^{ab}	33.9^{dc}	34.8^{a}	34.0^{b}
F. Sesame	28.5^{b}	15.8$^{b.e}$	16.0^{bc}	22.6^{bc}	24.0^{ab}	26.6^{ab}	28.9^{a}	33.0^{a}	32.0^{a}	22.8^{a}	26.8^{a}	26.7^{a}	34.1^{cd}	33.5^{ab}	39.8^{a}
RF. Sorghum	28.2^{b}	16.6$^{a.e}$	17.3^{ab}	22.9$^{a.c}$	23^{ab}	25.9^{ab}	26.3$^{a.c}$	31.1^{ab}	32.6^{a}	21.1^{ab}	23.5$^{b.d}$	23.9^{ab}	32.7^{d}	29.8^{c}	33.8^{b}
F "Sudan grass"	27.0^{bc}	17.9$^{a.c}$	20.7^{a}	21$^{b.d}$	23.8^{ab}	23.8$^{a.c}$	28.3a	31.9^{ab}	29.9^{ab}	18.5^{c}	24.8^{ab}	25.5^{ab}	40.7^{ab}	32.2^{abc}	31.2^{b}
RF Rice	26.2^{bcd}	14.7$^{c.e}$	18.4^{ab}	23.1$^{a.c}$	25.2^{a}	23.9$^{a.c}$	23.6$^{b.d}$	29.7^{bc}	27.1^{bc}	22.9^{a}	20.1^{e}	21.6^{b}	44.1^{a}	31.2^{bc}	33.4^{b}
F. Rice	24.5^{cd}	17.3$^{a.d}$	14.8^{bc}	21.1^{bcd}	22.5^{ab}	23.1^{bc}	26.5^{ab}	29.8^{bc}	29.4^{ab}	19.6^{bc}	24.1$^{a.c}$	23.8^{ab}	39.7$^{a.c}$	31.6^{bc}	26.8^{cd}
RF. "Sudan grass"	23.4^{de}	20.3^{a}	15.2$^{a.c}$	23.4^{ab}	25.1^{a}	28.1^{a}	21.8$^{c.e}$	26.8^{cde}	29.9^{ab}	20.3^{bc}	20.6^{de}	21.7^{b}	35.9$^{b.d}$	31.4^{bc}	31.2^{b}
F. Control	21^{e}	12.8^{e}	11.2^{d}	17.9^{e}	17.4^{c}	18.2^{d}	17.4^{e}	24.1^{e}	23.9^{c}	18.8^{c}	18.3^{e}	24.3^{ab}	17.4^{f}	22.2^{e}	24.5d
RF Control	15.1^{f}	14.7$^{c.e}$	10.8^{d}	19.0^{de}	23.0^{ab}	21.3^{cd}	22.6$^{b.d}$	25.7^{de}	20.1^{d}	20.0^{bc}	19.9^{e}	22.4^{b}	26.9^{e}	25.4^{d}	28.1^{c}
CV (%)	6	12.6	12.3	7.4	7.9	9.3	10.4	5.8	6.9	5.3	7.5	9.1	9.1	5.5	5.2
LSD 0.05	2.7	3.5	3.3	NS	3.1	3.8	4.2	2.9	3.4	1.9	2.9	3.7	5.3	2.8	2.7

(Table 2). Similarly, soil moisture was highly influenced ($p<0.01$) by mulch and land preparation treatment in the medium soil depth (0.21 - 0.4 m). The highest soil moisture (33.0%) was conserved at flat land preparation method with sesame still statistically similar with flat land preparation method with "Sudan grass"; ridge land preparation method with sesame and Ridge land preparation method with sorghum; whereas the lowest (24.1%) was conserved at flat land preparation method with no mulch and presents a statistically similar influence with ridge land preparation method without mulch and ridge land preparation method with Sudan grass (Table 2). Moreover, the analysis of variance revealed significant difference ($p<0.05$) on soil moisture in the lower depth (0.41 - 0.6 m). On top of this, highest soil moisture (32.6%) was conserved at ridge land preparation method with sorghum even if it did not differ statistically as regards flat land preparation method with sesame, ridge land preparation method with sesame, flat land preparation method with "Sudan grass", ridge with "Sudan grass", flat land preparation method with rice and flat land preparation method with sorghum; whereas the lowest soil moisture (20.1%) was found in conserved ridge land preparation method without mulch (Table 2).

This period in sesame growth is known as pre reproductive (50% flowering) by Langham (2007). Those land preparation methods with mulch that conserved significant soil moisture kept delaying the flowering period by neglecting the negative effect of water stress. The "no mulch" land preparation method hastens the period of flower due to water stress.

Soil moisture content during 60 days after sowing

Analysis of variance revealed insignificant difference ($p>0.05$) on soil moisture at the upper soil depth (0 - 0.2 m) among treatments. However, the highest soil moisture (22.9%) was conserved at ridge land preparation method with rice while the lowest (18.5%) was conserved at flat land preparation method with "Sudan grass" (Table 2). However, the analysis of variance revealed highly significant difference ($p<0.01$) among treatments at the medium soil depth (0.21 - 0.4 m). The highest soil moisture (26.8%) was conserved at flat land preparation method with sesame even if statistically similar with flat land preparation method with "Sudan grass", flat land preparation method with rice, ridge land preparation with sorghum and flat land preparation method with sorghum; whereas the lowest (18.3%) was conserved at flat land preparation method with no mulch (Table 2). All treatments did not show significant difference in the lower soil depth (0.41 - 0.6 m). The conserved soil moisture showed insignificant difference in all depths except in the medium soil depth (0.21 - 0.4 m). This growth period in sesame is known as reproductive stage by Langham (2007). The soil moisture conserved in this stage has a great role in converting the produced flower to capsule. In line with our observation, Adeoye (1984) reported high moisture content in a soil depth of 0.6 m, better water infiltration and reduced evaporation in plots mulched with grass.

Soil moisture content during 75 days after sowing

Analysis of variance revealed highly significant difference ($p<0.01$) on soil moisture at the upper soil depth (0 - 0.2 m). The highest soil moisture (44.1%) was conserved at ridge land preparation method with rice which is statistically similar with flat land preparation method with “Sudan grass” and flat land preparation method with rice; while the lowest (17.4%) was conserved at flat land preparation method with no mulch. The analysis of variance also revealed highly significant difference ($p<0.01$) on soil moisture content in the medium depth (0.21 - 0.4 m). The highest soil moisture (34.8%) was conserved at ridge land preparation method with sesame; though statistically similar with flat land preparation method with sesame and flat land preparation method with “Sudan grass”, whereas the lowest (22.2%) was conserved at flat land preparation method with no mulch (Table 2). Moreover, the analysis showed highly significant difference ($p<0.01$) on soil moisture in the lower soil depth (0.41 - 0.6 m). The highest soil moisture (39.8%) was conserved flat land preparation method with sesame while the lowest (20.2%) was conserved flat land preparation method with no mulch (Table 2). Komla (2013) also reported high soil water content (15.3%) in sweet paper mulched with cocoa pod husk whereas the no mulch treatment conserved the lowest (7.7%) in dry season. Similarly, Adeniyan et al. (2008) again indicated higher soil moisture content on sunflower mulched plot as compared to control. This period in sesame growth is known as reproductive stage by Langham (2007). Those treatments that conserved significant soil moisture have a great role in grain filling.

Effect of mulching on agronomic trait of sesame

The analysis of variance did not reveal significant difference ($p<0.05$) on days to 50% flowering among treatment. However, the longest days to 50% flowering was noted in flat land preparation method with “Sudan grass” while the shortest days were noted in flat land preparation method with control. However, the analysis of variance revealed significant difference on days to 90% maturity. Days to 90% maturity taken at ridge with sesame remains statistically similar with flat land preparation method with sesame, ridge land preparation with “Sudan grass” and ridge land preparation with rice straw; whereas the lowest days were taken at flat land preparation method without mulch followed by ridge land preparation without mulch. This is due to role of mulch neglect as well as negative effect of stress.

Plant height

The analysis of variance showed highly significant difference on plant height among treatments. The maximum plant height (95.1 cm) was recorded at flat land preparation method with “Sudan grass” though statistically similar with flat land preparation method with sesame, while the lowest (49 cm) was recorded at flat land preparation method without mulching (Table 3). The maximum plant height measured at those treatments could be due to significant soil moisture conservation and reduced weed infestation. The non-mulch covered plot showed poor overall plant growth, a symptom that consistently occurred in flat land preparation without mulch. This result is in line with Amoghein et al. (2013) who noted tallest plant height in sunflower mulched with rye than no mulch plot. In addition, Ozkan and Kulak (2013) reported maximum (52 cm) and minimum sesame plant height (30 cm) at soil water content of field capacity (FC) and 0.25 of FC, respectively.

Stand per meter square

The analysis of variance revealed that there is highly significant difference on stand per meter square among treatments. The highest plant per meter square (23.4) was found to have survived at ridge with “Sudan grass” though statistically similar with ridge sesame and flat land preparation method with “Sudan grass”; meanwhile, the lowest (12.4) survived at flat land preparation method without mulch (Table 3). Those treatments which showed significant survival rate could be due to their soil moisture conservation efficiency, whereas the bare treatment showed poor survival rate especially as this is vivid with flat land preparation without mulch. The bare treatments also showed high cracking rate and the seedling of sesame which collapsed down to the cracked soil and were also highly suffering from moisture stress as a result of poor stand.

Number of capsule per plant

The analysis of variance revealed highly significant difference on number of capsule per plant among treatments. The number of capsule per plant (42.5) was recorded at flat land preparation method with sesame yet statistically similar with flat land preparation method with “Sudan grass”, ridge “Sudan grass”, ridge without mulch, ridge land preparation with sorghum and ridge land preparation with sesame, while the lowest (20) was recorded at flat land preparation method without mulch.

Table 3. Effect of mulching organic mulching and land preparation method on phenology, yield and yield component of sesame.

Treatment	DF	DM	Plants/m^2	Ph (CM)	NCPP	NSPC	1000 SW	Yield (kg/ha)
Flat with sorghum	40.7	93^{bc}	22.4^{ab}	81.1^{b}	29.6^{b}	42.0^{bc}	3.7^{ab}	400.5^{e}
Ridge and furrow with sesame	40.3	96.0^{a}	23.0^{ab}	80^{b}	33.0^{ab}	46.0^{a}	3.5^{ab}	596.7^{cd}
Flat with sesame	39.0	95.6^{a}	21.9^{b}	92^{a}	42.5^{a}	41.0^{cd}	3.6^{ab}	579.2^{cd}
Ridge and furrow with sorghum	41.3	94.6^{ab}	21.8^{b}	84.0^{b}	34^{ab}	44^{ab}	3.5^{ab}	700^{ab}
Flat with “Sudan grass”	43	92^{cd}	22.7^{ab}	95.1^{a}	41.3^{a}	46.3^{a}	3.8^{a}	750^{a}
Ridge and furrow with rice	40	95^{a}	21.7^{b}	78.1^{b}	30.5^{b}	41.0^{cd}	3.3^{c}	540.7^{d}
Flat with rice	41.0	92.3^{cd}	21.8^{b}	77.6^{b}	29^{b}	38.7^{d}	3.0^{d}	451.3^{e}
Ridge and furrow with “Sudan grass”	39.7	95.3^{a}	23.4^{a}	79.0^{b}	38^{ab}	42.3^{bc}	3.7^{ab}	640^{bc}
Flat with control	40.0	90.6^{d}	12.4^{d}	49.0^{d}	20^{c}	31.0^{e}	2.9^{d}	140.0^{g}
Ridge and furrow with control	39.7	91.6^{cd}	19.9^{c}	63.0^{c}	34.1^{ab}	39.0^{d}	3.7^{ab}	310.0^{f}
CV (%)	7.5	1.2	3.7	4.5	15.2	3.7	4.3	7.2
LSD0.05	NS	1.9	1.3	6.0	8.7	2.6	0.3	63.2

Those treatments that produce significant number of capsule per plant could be due to soil moisture conservation ability, while the bare treatment produce poor capsule which is in association with poor soil moisture conservation. Similar result was reported by Langham (2007) showing moisture stressed sesame plants did not form auxiliary flowers that produce capsule. Rice straw mulched treatment scored 1.7 times of pods/plant as compared with no mulched plot in groundnut (Ramakrishna et al., 2006).

Number of seed per capsule

The analysis of variance revealed highly significant difference ($p<0.01$) on number of seed per capsule among treatments. The highest number of seed per capsule (46.3) was noted at flat land preparation method with “Sudan grass” though statistically similar with ridge land preparation with sesame and ridge and furrow land preparation with sesame, while the lowest (31.0) was noted in flat land preparation method without mulch. Treatments that produced highest seed per capsule could be due to their good soil moisture conservation ability and this conserved soil moisture was essential in translocation of produced assimilate to the sink from the source. This is in line with Ozkan and Kulak (2013) who reported higher number of seeds per pod in sesame (47) under higher moisture content and the lowest (38) scored under water deficit level of irrigation. Moreover, Kim et al. (2007) reported that drought stress extremely reduced seed yield per plant in sesame.

Thousand seed weight

The analysis of variance revealed highly significant difference ($p<0.01$) on thousand seed weight among treatments. The highest thousand seed weight (3.8 g) was recorded at flat land preparation method with “Sudan grass” even if statistically similar with flat land preparation method with sorghum, ridge without mulch, ridge land preparation with “Sudan grass”, flat land preparation method with sesame and ridge land preparation with sorghum, while the lowest (2.9 g) was recorded at flat land preparation method without mulch followed by flat land preparation method with rice. Treatments that produce the highest thousand seed weight could be due to their good soil moisture conservation capacity which is essential for grain filling. The bare treatments produce the lowest thousand seed weight which could be due to poor soil moisture conservation affecting the overall growth and physiology of the crop. This result is in conformity with Kang et al. (2012) who found highest weight (11 g) from 100 soybean seed under bed land preparation with mulch while the lowest (10.5 g) was recorded under no mulch (flat sown). Similarly, Sinaki et al. (2007) noted that water stress reduce soybean seed weight from 3.3 to 3.1 g stating that exerting water stress on soybean decreased seed weight from 3.3 - 3.1 g.

Yield

The analysis of variance revealed highly significant difference ($p<0.01$) on yield among treatments. The highest yield (750kg/ha) was recorded at flat land preparation method with “Sudan grass” statistically similar with ridge and furrow land preparation with sorghum, while the lowest (140kg/ha) was recorded at flat land preparation method with no mulch. The highest yield produced at those treatments could be due to their significant effect on plant height, stand per m^2, number of capsule per plant, number of seed per capsule and thousand seed weight, while the bare treatment showed poor performance on yield component. This result is in line with Ajibola et al. (2014) who observed improved sesame yield (185 kg ha^{-1}) in plots mulched with elephant grass while the lowest yield (57 kg ha^{-1}) was recorded on control. Moreover, significant yield improvement with dry

Table 4. Dominance analysis of the combinations of land preparation method and organic mulching effect on sesame.

Treatments	TCV (Birr)	Gross benefit (Birr)	Net benefit (Birr)	Dominance (D)
F with no mulch	1,002	2,520	1,518	
F with sorghum straw	2,901	7,209	4,308	
F with sesame straw	3,050	10,425	7,375	
F with “Sudan grass”	4,001	13,500	9,499	
RF with no mulch	5,300	5,580	280	D
RF with sesame straw	5,944	8,123	2,179	D
F with rice straw	6,020	8,123	2,103	D
RF with sorghum	6,233	12,600	6,367	D
RF with “Sudan grass”	7,333	11,520	4,187	D
RF with rice	7,778	9,733	1,955	D

F = Flat; RF = Ridge land preparation method

Table 5. Marginal rate of return and residual analysis of the combination of land preparation method and organic mulch.

Treatments	TCV (Birr)	NB (Birr)	MRR (%)	Minimum rate of return (100% × TCV)	Residual	Rank in residual
F with no mulch	1,002	1,518	151.5	1,002	516	4
F with sorghum straw	2,901	4,308	146.9	2,901	1,407	3
F with sesame straw	3,050	7,375	2058.4	3,050	4,325	2
F with “Sudan grass”	4,001	9,499	223.3	4,001	5,498	1

F = Flat; TCV = total cost that vary; NB = Net benefit; MRR = Marginal rate of return.

grass mulch compared with no mulch was reported by Adesina et al. (2014). In contrast, Gruber et al. (2008) reported insignificant difference among mulch treated and non-treated plots on yield.

Among the 10 treatment combination tested, 6 treatments were dominated and excluded from the marginal analysis (Table 4). Irrespective of the mulching material used, all ridge and furrow dominated because of their non-profitability to the farmers. As compared to flat land preparation with no mulch, flat land preparation mulched with sorghum straw offered 146.9% marginal rate of return (Table 5). Also, flat land preparation mulched with sesame straw also gave MRR of 2058.4% when compared to its preceding treatment (that is, flat land preparation mulched with sorghum straw). Similarly, flat land preparation with “Sudan grass” mulch gave MRR of 223.3% Birr when compared with flat land preparation mulched with sesame.

This indicates that farmer can obtain extra 2.23 Birr by investing 1 Birr on flat land preparation with “Sudan grass”. This is also confirmed with residual analysis that indicates the highest profitability which can be gained with flat land preparation mulched with “Sudan grass”.

Conclusion

The current result investigated that land preparation method with organic mulching have influence on soil moisture content at different growth stage and yield of sesame as yield showed increment with mulch land preparation method as compare to bare. Flat land preparation method with Sudan grass had good soil moisture in different growth stage which resulted in better growth and yield. The economic analysis showed growing of sesame with flat land preparation is economically visible. This treatment was best for its net benefit (9,499 Birr), marginal rate of analysis (223.3%) and residual analysis (5,498 Birr), which ranked first compared to other treatments. The marginal rate of return showed that by investing 1 Birr on flat land preparation method mulched with “Sudan grass” we get 2.23 Birr. So application of flat land preparation with Sudan grass is vital for sesame grower in drier area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Adeniyan B, Ojeniyi S, Awodun M (2008). Relative effect of weed mulch types on soil properties and yield of yam in Southwest Nigeria. J. Soil Nat. 2:01-05.

Adeoye K (1984). Influence of grass mulch on soil temperature, soil moisture and yield of maize and gero millet in a savanna zone soil. Samaru Journal of Agricultural Research (Nigeria).

Adesina J, Stewart S, Falase AO, Akinyemi JO, Adegbite GD, Alabi AA, Sliwa K (2014). Effect of Variable Rate of Poultry Manure on the Growth and Yield of Pepper (Capsicum annum) in South Western Nigeria. Academia Arena 6(1):9-13.

Ajibola A, Modupeola T, Adenuga A (2014). Effect of Different Weed Control Practices on Growth and Yield of Sesame in south-west Nigeriả. Biol. Chem. Res. 31(2):1093-1100.

Amoghein MB, Tobeh A, Gholipouri A, Jamaati-e-Somarin S, Ghasemi M (2013). Effect of cover crop in control of weed density and some qualitative and quantitative characteristics of sunflower. Int. J. Agric. Crop Sci. 5(12):1318.

De P, Chakravarti AK, Chakraborty PK, Chakraborty A (2005). Study on the efficacy of some bio resources as mulch for soil moisture conservation and yield of rain fed groundnut *(Arachis hypogaea).* Archives of Agron. Soil Sci. 51(3):247-252.

El Harfi M, Hanine H, Rizki H, Latrache H, Nabloussi A (2016). Effect of Drought and Salt Stresses on Germination and Early Seedling Growth of Different Color-seeds of Sesame (*Sesamum indicum*). Int. J. Agric. Biol. 18(6):1088-1094.

El-Habbasha S, Abd El Salam M, Kabesh M (2007). Response of two sesame varieties (*Sesamum indicum* L.) to partial replacement of chemical fertilizers by bio-organic fertilizers. Res. J. Agric. Biol. Sci. 3(6):563-571.

Gebregergis Z, Assefa D, Fitwy I (2016). Insecticide Application Schedule to Control Sesame Webworm Antigastra catalaunalis (Duponchel) Humera, North Ethiopia.

Goitom T, Alemtsahay T, Berhanu A (2017). Effect of organic mulching on soil moisture, yield and yield contributing components of sesame *(Sesamum indicum* L.) Int. J. Agron. https://doi.org/10.1155/2017/4767509

Grilo JA, Azevedo PV (2013). Crescimento, Desenvolvimento E Produtividade Do Gergelim Brs Seda Irrigado Com Água Do Lençol Freático, Na Agrovila De Canudos, em ceará mirim (rn). Holos 2:19-33.

Gruber S, Acharya D, Claupein W (2008). Wood chips used for weed control in Organic Farming. J. Plant Dis. Prot. 21:395-400.

Hatfield JL, Sauer TJ, Prueger JH (2001). Managing soils to achieve greater water use efficiency. Agron. J. 93(2):271-280.

Ji S, Unger PW (2001). Soil water accumulation under different precipitation, potential evaporation, and straw mulch conditions. Soil Sci. Soc. Am. J. 65(2):442-448.

Kang J, Avtar S, MK (2012). Studies on growth and yield of soybean (*glycine max* l.) under different land preparation methods and fertility levels. Indian J. Legume Res. 35(3):265-267.

Kim KS, Park SH, Jenks MA (2007). Changes in leaf cuticular waxes of sesame (*Sesamum indicum* L.) plants exposed to water deficit. J. Plant Physiol. 164(9):1134-1143.

Komla AN (2013). Effect of Organic Mulch on Growth and Yield of Sweet Pepper *(Capsicum annuum L.)*, 2013, University of Ghana.

Langham DR (2007). Phenology of sesame. Issues in New Crops and New Uses, Janick & Whipkey, eds., ASHS Press, Alexandria, VA pp. 144-182.

Sinaki JM, Heravan EM, Ra AHS, Noormohammadi G, Zarei G (2007). The effects of water deficit during growth stages of canola (*Brassica napus* L.). Am. Eur. J. Agric. Environ. Sci. 4:417-422.

Ozkan A, Kulak M (2013). Effects of water stress on growth, oil yield, fatty acid composition and mineral content of *Sesamum indicum.* J. Anim. Plant Sci. 23(6):1686-1690.

Pandya P, Rank H (2014). Summer sesame response to irrigation methods and mulching. Res. Crops 15(4).

Program CE (1988). From agronomic data to farmer recommendations: an economics training manual. CIMMYT.

Raes D, Steduto P, Hsiao TC, Fereres E (2009). AquaCrop the FAO crop model to simulate yield response to water: II. Main algorithms and software description. Agron. J. 101(3):438-447.

Ramakrishna A, Tam HM, Wani SP, Long TD (2006). Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crops Res. 95(2):115-125.

Silva RTD Oliveira AB, Lopes MD, Guimarães MD, Dutra AS (2016). Physiological quality of sesame seeds produced from plants subjected to water stress. Rev. Ciênc. Agron. 47(4):643-648.

Tashiro T, Fukuda Y, Osawa T (1991). Oil contents of seeds and minor components in the oil of sesame, *Sesamum indicum* L., as affected by capsule position. Japanese J. Crop Sci. 60(1):116-121.

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Full Length Research Paper

BRS Gabriela (*Ricinus communis* L.) castor bean seedlings in function of substrate and container volume

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Castor bean (*Ricinus communis* L.) is an oleaginous of high economic value because its oil has numerous applications in the industry, such as in the manufacture of enamels and paints. Presently, its production is aimed at being used as a biodiesel. The main obstacle to a high production is the survival of the young plants in field in a no-tillage system. An alternative would be the production of seedlings. The objective of this research was to evaluate the initial growth of BRS Gabriela (*R. communis* L.) castor bean seedlings in function of different substrates and container volumes. The work was conducted at the nursery of the State University of Paraíba (UEPB), Catolé do Rocha, PB, Brazil. The experimental design was completely randomized (CRB) in a 4 × 2 factorial design with 6 replications. The factors consisted of 4 container volumes: 1, 0.5, 0.3, and 0.27 dm^{-3} and 2 substrates (S_1 = 50% soil and 50% earthworm humus, and S_2 = 40% soil, 30% earthworm humus and 30% sand). The analyzed variables were stem dry matter (SDM), root dry matter (RDM), plant leaf area (PLA), leaf biomass (LPM), stem biomass (SPM), water content (WC), plant height and stem diameter ratio (PHe/SD), root dry matter and dry shoot dry matter ratio (RDM/SDM), Dickson quality index (DQI) and succulence. The morphological characteristics were influenced by container volume and substrate. The largest container volume, together with the substrate S1 (50% soil and 50% earthworm humus), provided viable seedlings ready to be transplanted to the field.

Key words: *Ricinus communis* L., Initial growth, greenhouse, earthworm humus.

INTRODUCTION

Castor bean (*Ricinus communis* L.), an oilseed of the Euphorbiaceae family, originates from Ethiopia. Due to an easy propagation and adaptation to different climatic conditions, it spread to several regions of the world (Torres et al., 2013).

Because it is an oilseed with a high oil content in the seeds and because it can be used as a substrate for biodiesel, combined with the global crisis due to energy demand and the search for environmental sustainability based on a progressive substitution of petroleum-derived mineral fuels for alternatives sources, a real perspective was created for the expansion of castor bean cultivation

(Lira and Barreto, 2009). Favorable perspectives in the rational implantation of this culture for the production of biodiesel are raised because the oil contained in its seeds has important characteristics such as high density and alcohol solubility. It is also used in fine chemistry in more than 700 products, allowing a diversified industrial use (Marinho et al., 2010).

The production of castor bean seedlings is not a common practice, but it can be an alternative to planting in the semiarid region as a strategy to improve its planting during the short rainy season (Andrade et al., 2012). In order to obtain good results in agriculture, one of the most important factors is the quality of seedlings, which favors a good production. Vigorous seedlings become resistant to pests and diseases.

Among the several factors affecting seedling production, the most important are substrates and their volume, which may lead to a null or irregular germination, poor plant formation and symptoms of deficiency or excess of some nutrients (Mesquita et al., 2012). The definition of the container size for seedling production is an important aspect since it influences several characteristics of seedlings and may impact the percentage of survival in field and the crop productivity (Lima et al., 2006). Container volume is an important factor in the production of seedlings because containers with large volumes favor plant development, allowing plants to stay longer in the nursery without affecting them negatively. When small containers are used, plant growth is limited, resulting in low quality seedlings (Costa et al., 2009).

Substrate exerts great influence on the production of good quality seedlings. Its chemical and physical composition needs must be met with adequate nutrient values, good porosity, adequate leaching and a high cation-exchange capacity (CEC) (Andrade et al., 2015). Several organic and inorganic materials have been used for the formulation of substrates for the production of seedlings. It is necessary to determine the most appropriate ones for each species in order to meet their demand for nutrients and physical properties such as water retention, aeration, easy penetration of roots, and not favor the incidence of diseases (Lima et al., 2006).

The objective of this study is to evaluate the initial growth of BRS Gabriela castor beans (*R. communis* L.) according to different substrates and container volumes.

MATERIALS AND METHODS

This work was conducted from May to June 2014 at the nursery of the State University of Paraíba (UEPB), Campus IV, Catolé do Rocha, PB (6°2'38"S; 37°44'48"W; 275 m). The greenhouse temperature was on average 28°C and humidity around 60%. The experimental design was completely randomized with a 4 × 2 factorial design and 6 replications. The treatments consisted of four container volumes (V_1 = 1 L polyethylene bags, V_2 = 0.5 L polyethylene bags, V_3 = 0.3 L tubes, and V_4 = disposable cups with a capacity of 0.27 L), and two types of substrates (S_1 = 50% soil and 50% earthworm humus, and S_2 = 40% soil, 30% earthworm humus and 30% sand). The water supply was made with the aid of a watering can at 7 o'clock in the morning and 17 o'clock in the afternoon.

Before the installation of the experiment, an analysis of the soil and earthworm humus used in the work was carried out. Soil samples collected at the layer 0 to 20 cm and the earthworm humus came from the UEPB (California earthworm). Both were taken to the Irrigation and Salinity Laboratory (LIS) of the Center for Technology and Natural Resources (CTRN) of the Federal University of Campina Grande (UFCG), PB, for chemical analysis (Table 1).

Substrate moisture was kept at 50% field capacity. The seeds used in the experiment were provided by the State University of Paraíba (UEPB), Campus IV. The sowing was performed at the depth 2.0 cm. The thinning was performed on the 3rd day after emergence, leaving one seedling (the most vigorous one). Weed control was performed manually whenever necessary.

Substrate moisture was kept at 50%. Invasive plants were manually removed as soon as they emerged, and the thinning was performed on the 3rd day after emergence using pruning shears, leaving the more vigorous seedling intact. Soil samples used in the experiment were collected from the layer 0 to 20 cm, and the earthworm humus came from the earthworm collection of the UEPB University, Campus IV. Chemical analyses of the soil and earthworm humus were made at the Irrigation and Salinity Laboratory (LIS) of the Center of Technology and Natural Resources (CTRN) of the Federal University of Campina Grande (UFCG), PB (Soil analysis; Table 1).

The analyzed variables were stem dry matter (SDM), root dry matter (RDM), plant leaf area (PLA), leaf biomass (LPM), stem biomass (SPM), water content (WC), plant height and stem diameter ratio (PHe/SD), root dry matter and dry shoot dry matter ratio (RDM/SDM), Dickson quality index (DQI) and succulence.

The stem and root dry matter were obtained after drying in a forced-air circulation oven at 65°C until constant weight and then weighed using an analytical balance (Mesquita et al., 2012). The leaf area was calculated by the formula:

$$S = 0.2398 \times (L + P) \times 1.9259$$

where L = leaf width and P = main vein length (Severino et al., 2004), then multiplied by the number of leaves to obtain the plant leaf area.

The stem and root biomasses were calculated using the equation:

$$\mathrm{PM} = \mathrm{FM} - \mathrm{DM}\ \mathrm{PM} = \mathrm{FM} - \mathrm{DM} \quad (1)$$

where PM is the biomass; FM is the fresh mass; and DM is the dry matter.

The water content (WC) in the tissues is considered the most accurate (it involves the "turgid weight"). It is an indicative of the water status in the plant (Peixoto and Peixoto, 2004). This water volume was calculated using the formula:

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Table 1. Results of soil chemical analysis and earthworm humus for the production of BRS Gabriela (*Ricinus communis* L.) castor bean seedlings subjected to different container volumes and substrates.

Parameter	pH	EC	P	K	Ca	Mg	Al	Na	T	V	OM
	H_2O	dS/m				$cmolc/dm^3$				%	
Soil	8.20	1.53	3.27	0.26	5.09	1.66	0.00	0.26	7.71	100	1.19
	pH	**EC**	**P**	**K**	**Ca**	**Mg**	**Al**	**Na**	**S**	**NaCl**	**BS**
	H_2O	dS/m					$cmolc/dm^3$				
Humus	7.38	2.11	55.14	1.41	35.4	19.32	0.00	1.82	57.95	1.82	56.13

OM: Organic matter; BS: base sum.

$$WC = \frac{FM - DM}{FM}\{0 ><\}0\{> eq.2 < 0\}$$

where WC is the water content; FM is the fresh mass; and DM is the dry matter.

The DQI was calculated in a balanced way using an equation that includes the ratios of morphological parameters such as TDM, SDM, RDM, He, and D. It was developed in a study carried out with seedlings of *Picea glauca* and *Pinus monficola* (Dickson et al., 1960), according to the formula:

$$DQI = \frac{MST}{\frac{H}{DC}\{0 ><\}0\{> + eq.3 < 0\}\frac{MSR}{MSPA}}$$

Succulence was calculated using the formula proposed by Mantovani (1999). The results were expressed in grams of H_2O m².

$$Succulence = \frac{LFM - LDM}{LA}\{0 ><\}0\{> \ eq.4 < 0\}$$

where LFM is the leaf fresh mass; LDM is the leaf dry matter; and LA is the leaf area.

The data were submitted for analysis of variance using the F test. After verifying the effects of the treatments (P <0.05), a Tukey test (P <0.05) compared means using the software SISVAR (Ferreira, 2014).

RESULTS AND DISCUSSION

It is possible to observe a significant effect for the isolated factors substrate and container volume for almost all variables, except for plant height/stem diameter ratio and water content. There was also a significant effect for the interaction between factors, except for stem and root dry matter.

For the variable stem dry matter, a decrease was observed in function of container volume. The highest value for this variable occurred in the 1 dm^3 container (Figure 1A).

As for the substrates used, it was observed that the substrate containing 50% soil and 50% earthworm humus provided the highest stem dry matter (Figure 1B). This may be associated with aggregation of particles of the substrate S_1. In S_2 (40% soil, 30% earthworm humus and 30% sand), nutrient losses may have occurred due to leaching by irrigation water since sand increases the porosity of the substrate.

Containers with high volumes provide a greater area to be explored and a better spatial distribution of the root system, allowing a greater absorption of water and nutrients (Andrade et al., 2012)

Figure 1C shows that the container with a volume of 1 dm^3 provided the highest root dry matter, corroborating the results obtained by Mesquita et al. (2012), who reported that the results for root dry matter of papaya plants subjected to increasing doses of cattle manure in the largest container volume were high. Similar results were obtained by Antoniazzi et al. (2013), who found a high root dry matter for large-volume containers in a *Cedrela fissilis* Vell. (Meliaceae) crop, however, differing from the observations made by Andrade et al. (2015), who did not verify effects on substrates for BRS Gabriela castor bean seedlings.

As for the action of the substrates on the variable root dry matter, it can be observed in Figure 1D that it followed the same behavior of stem dry matter. The substrate containing the highest percentage of earthworm humus provided the best development of roots.

The growth of the root system, besides being conditioned to the height of the containers, which in the case of plastic bags had a great height, is also related to the volume of each container, involving the root system and making the supply of production factors more efficient for seedling growth and development (Menezes Júnior et al., 2000). The amount of dry matter found in the tissues of a seedling is important as an indication of its quality, as it reflects its growth in function of total nutrients absorbed (Franco et al., 2007).

The variables plant leaf area, leaf and stem biomass and water content were influenced by the interaction between substrates and container volumes (Figure 2).

The interaction 1 dm^3 × S_1 provided the greatest plant leaf area. However, for the interaction container volume ×

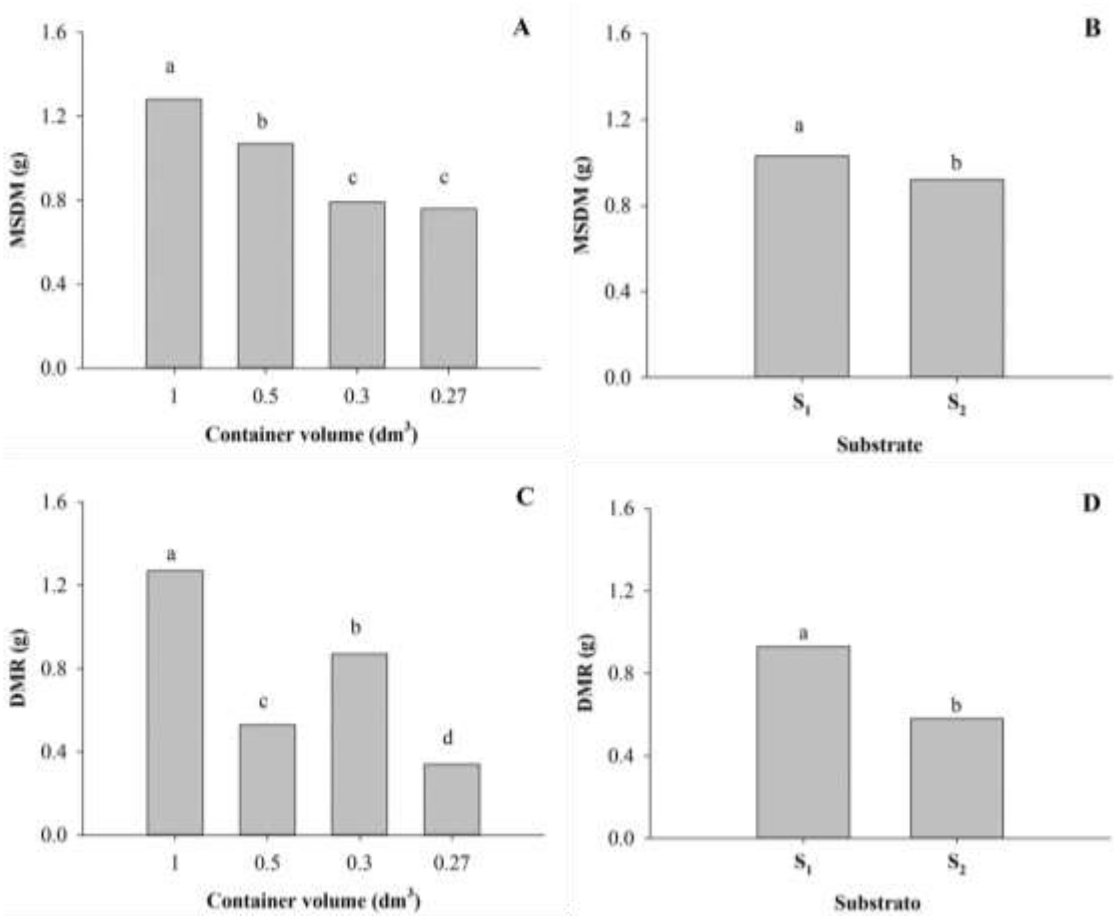

Figure 1. Mass of stem dry matter subjected to different container volumes (A) and substrates (B); mass of root dry matter in different container volumes (C) and substrates (D) for the production of BRS Gabriela castor bean seedlings (*Ricinus communis* L.)

substrate S_2, there was no significant differences regarding this variable (Figure 2A). From the moment the containers limit the development of the root system and, consequently, of shoots, they become an indication that seedlings are at the stage of planting in field, which for the culture of castor bean, occurs close to 30 days after sowing (Andrade et al., 2012).

The highest results for leaf biomass were found in the substrate interaction S_1 with 1, 0.5 and 0.3 dm^3. This was probably because the highest percentage of earthworm humus in this substrate provided nutrients for seedlings (Figure 2B). These results corroborate Lima et al. (2006), who reported that larger containers and alternative substrates promoted a greater development of castor bean seedlings.

In the interaction $S_1 \times 1$ dm^3, the variable stem biomass presented a higher value (Figure 2C). According to Andrade et al. (2012), a container with a high volume provides better quality seedlings at 21 and 36 days after sowing of castor beans. It is important to note that the use of containers with high volumes favors time for the installation of the crop in the field, which under low rainfall conditions, may make a difference (Andrade et al., 2012).

The interaction of the factors $S_2 \times 1$ dm^3 positively influenced the relative water content of castor bean seedlings, differing statistically from the other volumes (Figure 2D). As the substrate S_2 was composed of 30% sand, the root system probably occupied the whole containers, thus providing a fast absorption of water and nutrients since the substrate was kept at a 50% soil moisture.

Figure 3 shows the unfolding of substrate × container volume for the variables plant height and stem diameter ratio (PHe/SD), root dry matter and shoot dry matter ratio (RDM/SDM), Dickson quality index (DQI) and succulence.

For the variable plant height/stem diameter ratio, it can be seen that the interaction S_1 × container volume did not present a significant difference. The highest ratio is observed for S_2 using the volume 0.3 dm^3 (Figure 3A).

Almeida et al. (2014) found better results of PHe/SD in seedlings of *Croton floribundus* in the interaction between

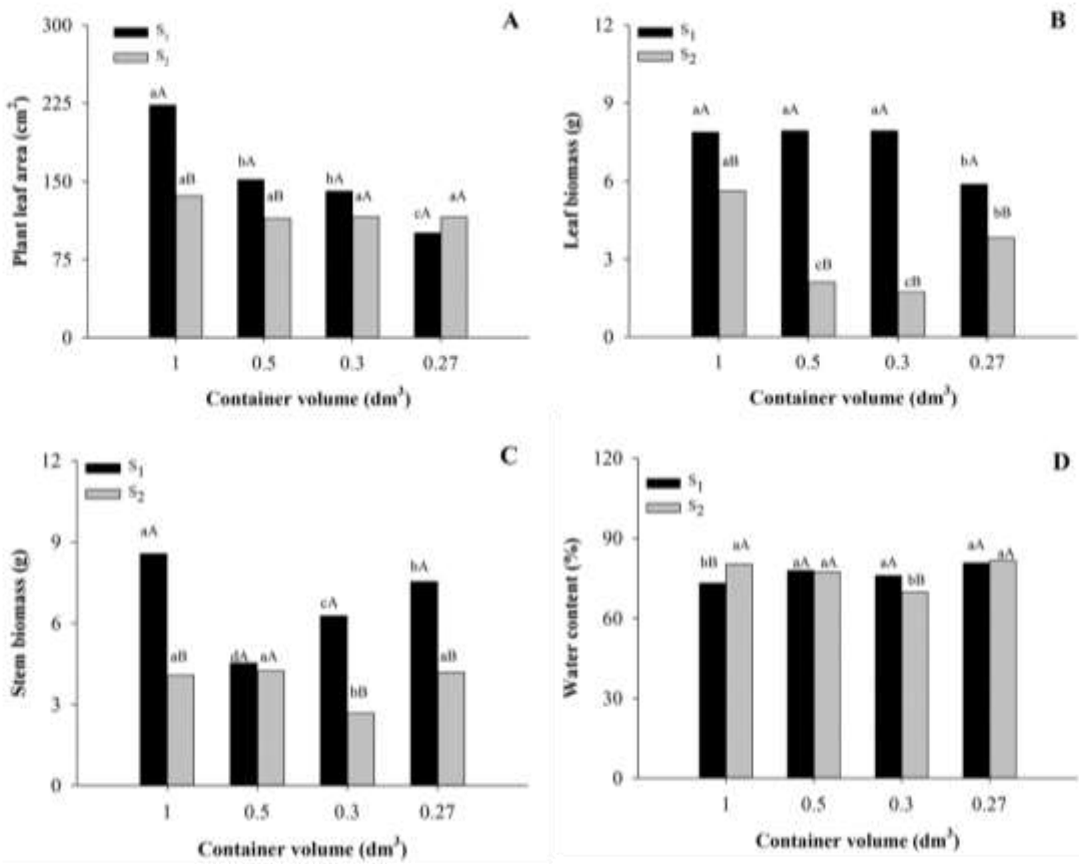

Figure 2. Plant leaf area (A), leaf biomass (B), stem biomass (C) and water content (D) in different container volumes and substrates for the production of BRS Gabriela (*Ricinus communis* L.) castor bean seedlings. Means followed by the same lowercase letter for volume and upper-case letter for substrate do not differ statistically by Tukey test at 5% probability.

volume and the highest capacity of a substrate based on cattle manure. According to the authors, this may be associated with a high plant height growth in greater container volumes, which directly affected the values of the ratio.

The relation PHe/SD is a characteristic that expresses the quality of seedlings to be taken to the field, since a balance in the development is expected (CAMPOS and UCHIDA, 2002).

It can be seen in Figure 3B that for the RDM/SDM variable, the interaction between V_1 and the substrate S_2 presented a higher increase for that variable (0.53 g), differing from the results obtained by Ferraz and Engel (2011), who did not report effects on seedlings of golden trumpet trees (*Tabebuia chrysotricha*) produced in different container volumes. The absence of a significant difference indicates the occurrence of an efficient pattern of dry matter distribution between the two organs of the seedlings (Dutra et al., 2012).

When the Dickson quality index (DQI) was evaluated, it was observed that the volume 1 dm^3 stood out in relation to the others in the two substrates. However, the highest increase was observed for the interaction 1 $dm^{-3} \times S_1$ (1.3) (Figure 3C). These results differ from those observed by Oliveira et al. (2011), who did not observe significant effects for DQI, cultivation time and container volume for a seedling production of *Copernicia hospital.*

Upon evaluating the succulence of plants, higher values were found in the unfolding $S_1 \times 0.3$ dm^3. These results can be justified by a possible increase in the volume of spongy mesophyll cells to the detriment of the volume of palisade parenchyma cells (Oliveira et al., 2011). According to Trindade et al. (2006), succulence has important anatomical and physiological linkages in plants submitted to some type of stress.

Conclusions

The following conclusions were drawn:

(1) The volume of the container V_1 (1 L polyethylene bags) using the substrate S_1 (50% soil, 50% earthworm humus) results in BRS Gabriela castor bean seedlings

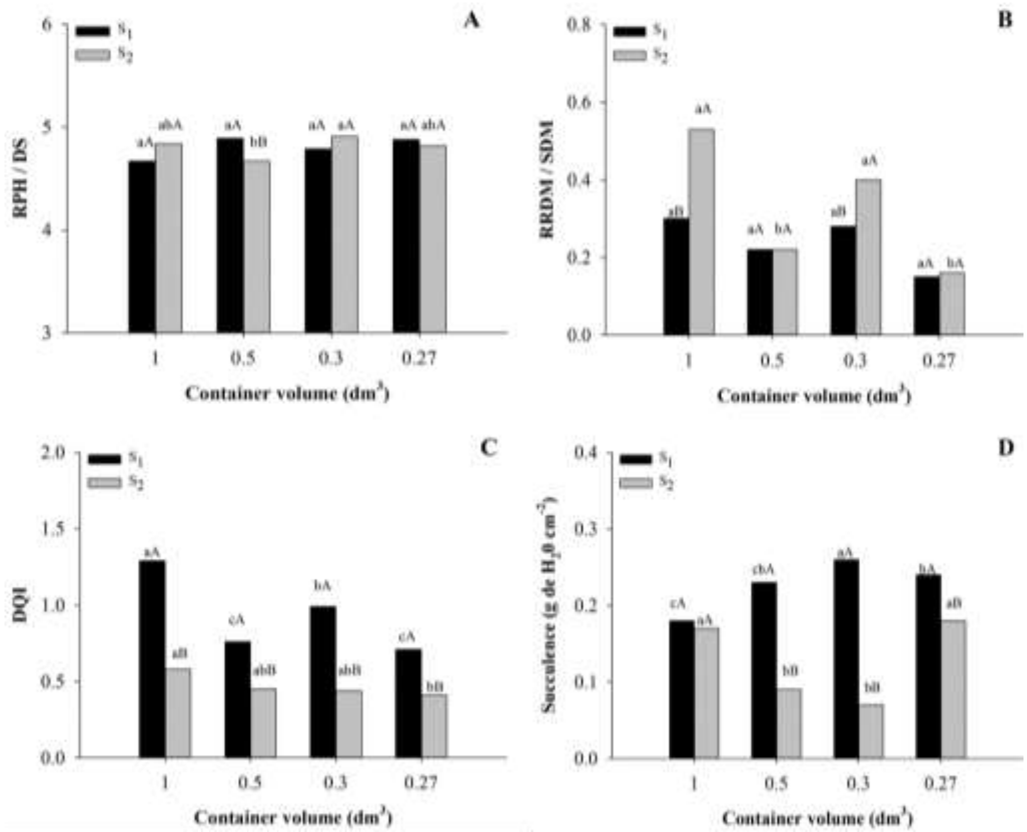

Figure 3. Plant height and stem diameter ratio (A), root dry matter and shoot dry matter ratio (B), Dickson quality index (C) and succulence (D) in different container volumes and substrates for the production of BRS Gabriela castor bean seedlings (*Ricinus communis* L.). Means followed by the same lowercase letter for volume and upper-case letter for substrate do not differ statistically by Tukey test at 5% probability.

(*R. communis L.*) suitable for field transplantation;

(2) The substrate S_1 provided the highest stem and root dry matter;

(3) The interaction between factors (substrate e container of volume) promoted better results for almost all variables (Plant leaf area, leaf biomass, stem biomass, water content, plant height, stem diameter ratio, root dry matter, shoot dry matter ratio, Dickson quality index and succulence);

(4) The main oleaginous prospect with high oil content in the seeds and because it can be used as a substrate for biodiesel. In the face of climate change can be a great opportunity within the renewable bushes. With this, the production of seedlings is essential to ensure the survival of the plants in the field and guarantee their production. The present work indicates which is the best volume of container and substrate for castor bean production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Almeida RS, Mayrinck RC, Zanini Am Dias Bas, Baroni GR (2014). Growth and quality of Croton floribundus spreng seedlings in different containers and substrates. Enciclopédia Biosfera 10(19):672-685.

Andrade FHA, Araújo CSP, Santos FRL, Irineu THS, Andrade R (2015). Formation of BRS gabriela (*Ricinus communis* L.) Seedlings in different volumes of containers and substrates. Terceiro Incluído 5(2):255-265.

Andrade FR, Petter FA, Marimon Junior BH, Zuffo AM, Souza TRS, Gonçalves LGV (2012). Formation of castor seedlings in different containers. Revista Brasileira Ciências Agrárias 7(2):274-279.

Antoniazzi AP, Binotto B, Neumann GM, Sausen TL, Budke JC (2013). Efficiency of containers in the development of Cedrela fissilis seedlings Vell. (*Meliaceae*). Rev. Bras. de Biociências 11(3):313-317.

Campos MAS, Uchida T (2002).. Influence of shading on seedling growth of three Amazonian species. Rev. Pesquisa Agropecuária Bras. 37(3):281-288.

Costa E, Rodrigues ET, Alves VB, Santos LCR, Vieira LCR (2009). Effects of ambiance, containers and substrates on the development of yellow passion fruit seedlings in Aquidauana-MS. Rev. Bras. de Fruticultura 31(1):236-244.

Dickson A, Leaf AL, Hosner JF (1960). Quality appraisal of white spruce and white pine seedling stock in nurseries. For. Chron. 36(1):10-13.

Dutra TR, Grazziotti PH, Santana RC, Massad MD (2012). Initial development of copaiba seedlings under different levels of shading and substrates1. Rev. Ciência Agronômica 43(2):321-329.

Ferraz AV, Engel VL (2011). Effect of tubet size on seedlings quality of jatobá (Hymenaea courbaril L. var. Stilbocarpa (hayne) lee et lang.), Ipê-amarillo (Tabebuia chrysotricha (mart. Ex dc.) Sandl.) And guarucaia (Parapiptadenia rigida Benth.) Brenan) 1. Rev. Árvore 3(3):413-423.

Ferreira DF (2010). SISVAR - System of analysis of variance. Version 5.3. Lavras-MG.

Franco CF, Prado RM, Brachirolli LF, Rozane DE (2007). Growth curve and macronutrient uptake gait in guava seedlings. Rev. Bras. de Ciênc. do Solo 31(6):1429-1437.

Lima RLS, Severino LS, Silva MIL, Vale LS, Beltrão NEM (2006). Volume of containers and composition of substrates for production of castor seedlings. Ciênc. e Agrotecnologia 30(3):480-486.

Lira MA, Barreto FP (2009). Oilseeds with source of raw material for the production of biodiesel. Natal: EMPARN P 64.

Marinho AB, Moreira LG, Viana TVA, Albuquerque AHP, Oliveira CW, Azevedo BM (2010). Influence of nitrogen fertilization on the productivity of the castor bean crop. Rev. Bras. de Agric. Irrigada 4(1):31-42.

Mantovani AA (1999). method to improve leaf succulence quantification. Braz. Arch. Biol. Technol. 42(1):9-14.

Menezes Júnior FOG, Fernandes HS, Mauch CR, Silva JB (2000). Characterization of different substrates and their performance in the production of lettuce seedlings in protected environment. Hortic. Bras. 18(3):164-170.

Mesquita EF, Chaves LHG, Freitas BV, Silva GA, Sousa MVR, Andrade R (2012). Production of papaya seedlings on substrates containing bovine manure and container volumes. Revista Brasileira Ciências Agrárias 7(1):58-65.

Oliveira AB, Medeiros FS, Bezerra AME (2011). Cultivation time and container size in the formation of seedlings *Copernicia hospital*. Acta Scientiarum. Agronomy 33(3):533-538.

Peixoto CP, Peixoto MFSP (2004). Dinâmica do crescimento vegetal (Princípios Básicos).Cruz das Almas. Disponível em < file:///C:/Users/Helio/Downloads/Dinamica%20do%20Crescimento%20Vegetal.pdf>. Acesso em 01. Mai. 2016.

Severino LS, Cardoso GD, Vale LS, Santos JW (2004). Method to determine the leaf area of the castor bean. Rev. Bras. de Oleaginosas e Fibrosas 8(1):753-762.

Trindade AR, Lacerda CF, Gomes FE, Prisco JT, Bezerra MA (2006). Influence of the accumulation and distribution of ions on the acclimatization of sorghum and string bean plants to saline stress. Rev. Bras. de Engenharia Agríc. e Ambiental 10(4):804-810.

Torres FE, Toledo RL, Ribeiro MHPG, Teodoro PE, Ribeiro LP, Corrêa CCG (2013). Influence of weed management and nitrogen fertilization on oil content in castor bean cultivars (Ricinus communis). Rev. de Ciênc. Agrárias 36(3):357-362.

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Full Length Research Paper

Populational dynamics of fruit flies (Diptera: Tephritidae) in guava orchards in the Northwest region of Espírito Santo, Brazil

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The diversity of fruit flies (Diptera: Tephritidae) in commercial guava orchards in the Northwest region of *Espírito Santo*, Brazil was recorded. Also, their population dynamics, correlation with climatic factors and their parasitoids were recorded. This study was carried out in three commercial guava orchards of the cultivar Paluma, located in the municipality of São Roque do Canaã, Central region of the Northwestern *Capixaba* territory, from October 2013 to September 2014. The population monitoring of fruit flies was done by installing McPhail traps provided with an attractive solution (BioAnastrepha®), hung ¾ of the guava canopy height, starting from the ground level. After obtaining the data, the following indexes were calculated: pupal viability (PV), parasitism (P) and fruits infestation (I). A correlation analysis was performed between the number of flies collected, and the meteorological variables of the region. A total of 31.51 kg of guava was collected, in which 18.31 kg were collected in the guava trees and 13.2 kg were found on the ground. 1,699 pupae were obtained, and from these, 442 flies emerged with three genera, *Anastrepha* species and one genus, *Ceratitis* (*Ceratitis capitata* Wiedemann). Only two parasitoids were obtained from the fruits from the ground, which both belong to *Doryctobracon areolatus* (Szépligeti) (*Hymenoptera: Braconidae*). The correlation analysis showed a strong correlation between the flies and fluctuating temperatures. Population peak of fruit flies occurred in February 2014.

Key words*:* *Psidium guajava*, Tephritidae, bioecology, parasitoids.

INTRODUCTION

The guava tree (*Psidium guajava* L.) is a fructiferous species from tropical regions and cultivated in several countries, including Brazil (Boti et al., 2016). One of the great difficulties faced by guava producers is insect attack, which infests branches, leaves and fruits, and in a short period, can cause serious problems to the crops (Gallo et al., 2002).

Insects of the Tephritidae family cause great financial losses in the fruit industries by attacking the reproductive organs of plants, fruits and flowers (Vieira et al., 2014). Fruit flies (Diptera: Tephritidae) are a serious problem every year in guava orchards, leading to increases in production cost due to frequent applications of insecticides and losses in production (Corsato, 2004).

Fruit flies present great taxonomic diversity. They comprise a complex of more than 5,000 species belonging to the Tephritidae family distributed throughout the world (Montes et al., 2011). Damage occurs due to oviposition by females in developing fruits, which causes depreciation of the product for consumption (Nunes et al., 2013). Females perforate the fruits causing cell death close to holes causing malformations in the developing fruits (Lorscheiter et al., 2012). In order to avoid this problem, chemical control is still recommended by most farmers, which is often used wrongly (Duarte et al., 2014).

One of the alternatives to reduction of the use of agrochemicals without affecting productivity is Integrated Pest Management (IPM) programs (Duarte et al., 2012). The use of McPhail traps allows verification of the population fluctuation of these insects and to relate them to the abiotic factors, especially those associated with climate, therefore helping to define which period will have a greater or lesser probability of infestations (Azevedo et al., 2010).

In the Northwest region of the state of Espírito Santo, farmers have been struggling to handle the plague in guava culture. There is lack of studies on the occurrence of this pest in guava orchards in the region. Therefore, it is of great importance to study the bioecological aspects of fruit flies in producing regions, in order to support decision-making of which management methods should be used. The objective of this study was to record the diversity of fruit flies (Diptera: Tephritidae) in commercial guava orchards in the Northwest region of Espírito Santo, Brazil, as well as its population dynamics, in correlation with climatic factors and presence of parasites.

MATERIALS AND METHODS

The field work was carried out in three commercial guava orchards of the cultivar Paluma, one hectare each, with spacing of 6 x 5 m and an average age of eight years, from October 2013 to September 2014. The areas are located in the district of *Santa Júlia*, municipality of *São Roque do Canaã*, Central region of Northwestern *Capixaba* territory (location: 19° 44 '23 "S - 40° 39' 24" W, altitude: 120 m). The average annual temperature is 23.1°C and the average annual rainfall is about 900 mm.

Population monitoring of fruit flies was done using McPhail® traps provided with 300 ml of the attractive solution based on hydrolyzed protein (BioAnastrepha®) diluted 5% and hung ¾ of the guava canopy height, starting from the ground level. The traps were hung and less exposed to the sun, and they were randomly distributed in the orchard, five per hectare (Figure 1). Renewal of the substrates from the traps and the fruit flies collection were carried out biweekly. The collected flies were identified at the genus level and stored in 70% alcohol and afterwards, the species level was indentified.

Fruit samples were collected biweekly in order to study the fruit flies species associated with guava fruits. Fruits that were present in the guava trees were collected randomly and at different canopy heights, as well as freshly fallen fruits, which were in good condition and without larvae holes (Figure 1). The samples size varied and they depended on the fruits available in the orchard.

The fruit samples were identified (date, place and person who collected them) and placed in a Styrofoam boxes and transported to the Agricultural Entomology Laboratory of the Federal University of *Santa Teresa* campus, where they were stored in plastic trays containing moist vermiculite and placed in an air-conditioned chamber at 25°C. After 10 days, the vermiculite was sieved to obtain the pupae. Afterwards, they were transferred to glass vials sealed with void tissue, containing moist vermiculite while the adults emerge. Adults were fed sucrose solution and after two to three days, the flies developed a normal color and their ovipositor matured, which was stored in 70% alcohol. When the parasitoids emerged, they were also stored in 70% alcohol for later identification.

Fruit flies and parasitoids were identified based on the keys described by Zucchi (2000) and Canal and Zucchi (2000). Genus *Anastrepha* females were collected and examined under an optical microscope (×40), according to Zucchi (2000). Data were obtained from the collected fruits on pupal viability indexes (Equation 1), parasitism (P) (Equation 2) and fruit infestation (I) (Equation 3) according to (Carvalho, 2005).

$$VP = \left[\frac{NPa + NM}{NP} \right] \text{ x } 100 \quad (1)$$

Where: PV = pupal viability; NPa = Number of emerged parasitoids; NM = Number of emerged flies; and NP = Total number of pupae obtained.

$$P = \left[\frac{NPa}{NM + NPa} \right] \text{ x } 100 \quad (2)$$

Where: P = Parasitism; NPa = number of parasitoids; and NM = number of flies.

$$I = \left[\frac{NP}{KgF} \right] \quad (3)$$

Where: I = fruits infestation; NP = number of pupae obtained; and KgF = kilogram of fruits harvested.

Data related to the adult fruit flies samples collected with McPhail® trap were plotted in frequency polygons and correlated with the meteorological data from the meteorological station of the Federal Institute of Espirito Santo - Santa Teresa Campus, where

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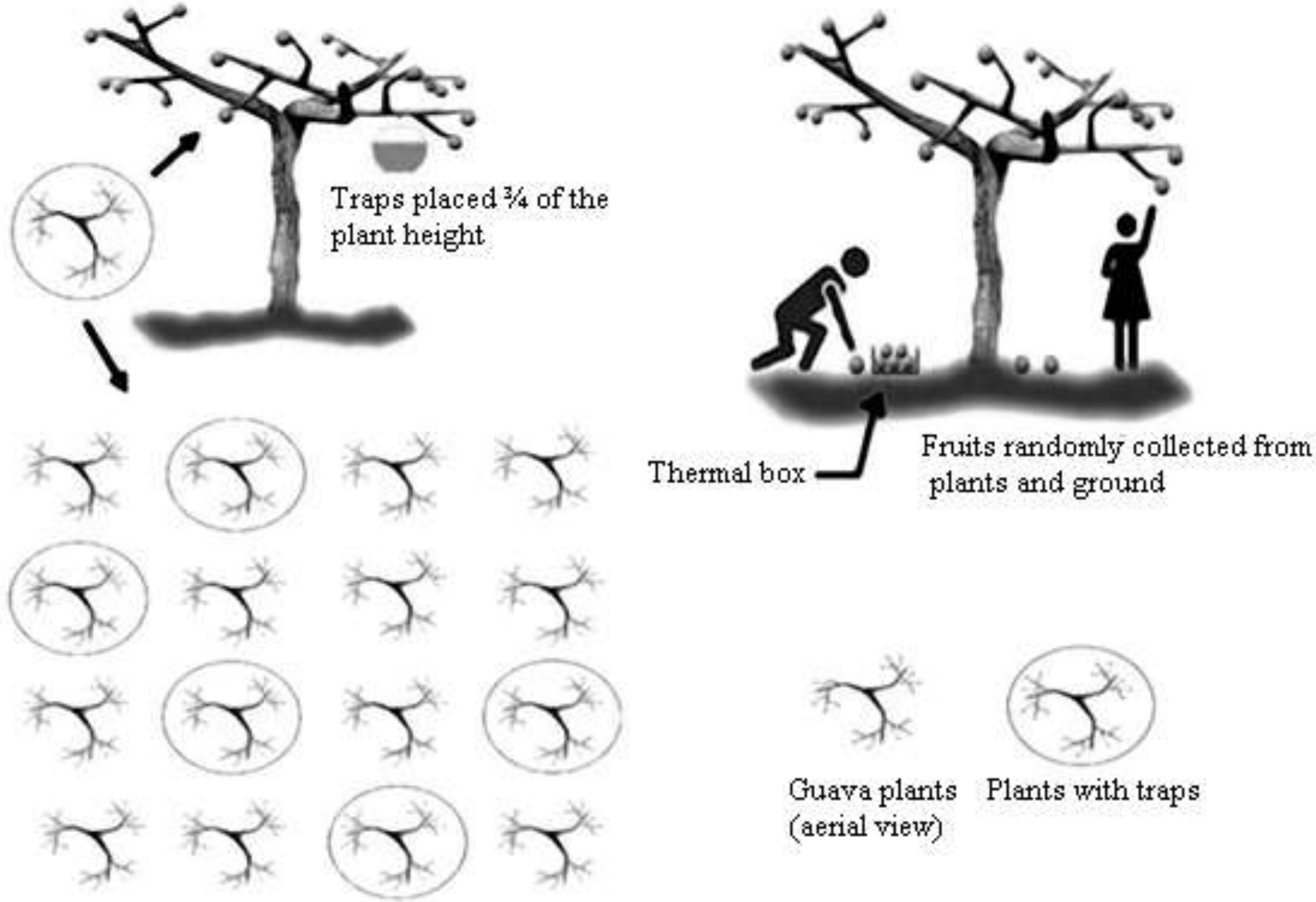

Figure 1. Scheme of traps distributed in the experimental areas (left) and the fruit sample collected (right).

temperature data, minimum temperature, average temperature, average relative humidity and rainfall are shown. Rainfall data were also obtained from rain gauges installed in the three experimental areas.

RESULTS AND DISCUSSION

In total, 31.51 kg of guava were collected of which 18.31 kg were collected from the guava trees and 13.2 kg were fruits from the ground. 1,699 pupae with pupal viability (PV) of about about 40% were obtained from the collections in the region (Table 1).

Results above these values were reported by Corsato (2004) in guava orchards in the north region of *Minas Gerais*, where they observed a pupal viability of 57.9%. Determining pupal viability is important, since the higher the value, the greater the number of individuals that could be added to the fruit fly population in the orchard.

In a study by Boff et al. (2012), in a natural guava orchard in the mountain region of *Lages* - SC, the authors found a pupal viability of 70%, a value well above the 40% observed in this study. This difference may be associated with several ecological factors, such as the orchard location, the presence of alternative hosts for fruit flies or escape areas for natural enemies, as well as the use of insecticides in orchards.

Parasitism was not observed in pupae obtained from fruits collected directly from the plants (Table 1). However, for the pupae obtained from fruits collected in the soil, parasitism was 0.43%, which corroborates with the results of Pereira-Rêgo et al. (2013), which showed that fruits collected from the ground showed greater parasitism. This is due to the infested fruits that fell on the ground having greater exposure to the parasitoids (Vargas et al., 1993). The parasitism found in this study is close to the average parasitism of 0.51% reported by Zanuncio Junior et al. (2013) in guava orchards in the municipalities of Guarapari, Serra and Viana located in the state of Espírito Santo.

From all the pupae obtained, two parasitoids were observed, both belonging to the species *Doryctobracon areolatus* (Szépligeti) (Hymenoptera: Braconidae). Considering that the main form to control tephritidae in the orchards is through the application of insecticides

Table 1. Pupal viability, parasitism and infestation index of fruit flies collected in commercial plantations in the Northwest region of *Espírito Santo*.

Collection location	*VP* (%)	*P* (%)	*I* (Puparium kg^{-1})
Ground	41.22	0.43	86.21
Plant	39.90	0.00	30.60
Total	81.12	0.43	53.92

PV: Pupal viability; P: parasitism; I: infestation index.

Table 2. Number of *Anastrepha* spp. and *Ceratitis capitata* females from the fruit collected in guava orchards in the Northwest region of Espírito Santo.

Collection location	Number of female *Anastrepha* spp. and *Ceratitis capitata*			
	A. fraterculus	***A. obliqua***	***A. zenildae***	***C. capitata***
Ground	256	4	2	10
Plant	146	15	1	8
Total	402	19	3	18
Percentage	90.95%	4.29%	0.67%	4.08%

(Härter et al., 2010), this low natural parasitism may be related to the frequent use of agrochemicals adopted as a management practice by the farmers. Araújo et al. (2015) also found a small number of parasitoids, possibly due to the drought that occurred during the study period and also insecticides that were applied in conventional orchards.

In addition to the use of agrochemicals, other factors may have contributed to the low natural parasitism found in this study, such as the host fruit and climate. Araújo et al. (2015) emphasized that the species composition of parasitoids in a region can vary considerably, depending on a series of factors such as: climate, fruit flies diversity and infested fruits, among other aspects.

The mean infestation index was 58.4 kg^{-1} puparium, being the highest infestation obtained from fruits collected from the ground (Table 1). This result reinforces the importance of crop management by removing fruits from the ground in order to reduce the fruit fly population in guava orchards.

The infestation index found in this study is higher than that found by Silva and Silva (2007), in the municipality of Ferreira Gomes - AP, where an infestation index of 5.4 kg^{-1} puparium of fruits was found. Values close to the infestation index of this study was found by Araújo and Zucchi (2003) in São Paulo, in the municipality of Santo Antônio, and the most abundant species recorded in guava orchard was *Anastrepha sororcula* (Zucchi), presenting an infestation index of 58.7 kg^{-1} puparium.

From the total adult fruit flies that emerged, the species *Anastrepha fraterculus* (Wiedemann), *Anastrepha obliqua* (Macquart), *Anastrepha zenildae* (Zucchi) and *Ceratitis capitata* (Wiedemann) were observed (Table 2). According to a survey on diversity, geographic distribution and fruit fly host conducted in the state of Espírito Santo (Martins, 2011), all species of fruit flies mentioned above already occur in the state of Espírito Santo, and in guava orchards.

The highest amount of individuals was observed for the *A. fraterculus* species (90.95%), which is also cited by Gallo et al. (1988) as the most incident in his study. Alvarenga et al. (2009) collected fruits in rural and urban areas in the municipalities of Jaíba, Janaúba and Nova Porteirinha, in northern region of the state of Minas Gerais, Brazil. They collected *C. capitata* and eight *Anastrepha* species, noting that *C. capitata* occurred mainly in introduced hosts and was prevalent in urban areas, while *Anastrepha* predominated in rural areas.

Other fruit flies species were reported in a study carried out in 2007 in the state of *Amapá* (Silva and Silva, 2007). According to the authors, the weed species were *Anastrepha striata* (Schiner), *A. fraterculus*, *A. obliqua* and *Anastrepha turpiniae* (Stone), with *A. striata* representing 76.4% of the specimens obtained. Therefore, each region of Brazil has a predominant fruit fly species, as well as infestation indexes due to different climatic conditions and available host fruits. A total of 4,475 fruit flies were collected from McPhail® traps, with the *A. fraterculus*, *Anastrepha consobrina* (Loew), *A. obliqua* and *Anastrepha grandis* (Macquart) species (Table 3), as well as the occurrence of *C. capitata*.

A. consobrina (Loew) and *A. grandis* (Macquart) species were found in the orchard with the McPhail ® trap, but they were not found in the guava fruit collected. This is because *A. grandis* (Macquart) hosts several fruits of the family, *Cucurbitaceae* (Bolzan et al., 2016) and *A. consobrina* (Loew) hosts fruits of the Passifloraceae family. Therefore, the detection of these individuals is due

Table 3. Number of female fruit flies captured with McPhail® traps in guava orchards in the Northwest region of Espirito Santo.

Number of individuals collected	Species				
	A. fraterculus	***A. obliqua***	***A. consobrina***	***A. grandis***	***C. capitata***
Total	4203	5	2	21	244
Percentage	93.94%	0.11%	0.02%	0.46%	5.45%

to the host fruits in the surroundings of the orchard.

Several *Anastrepha* species can be found in an orchard, but more than 90% are represented by one or two fly species collected in the traps (Aluja et al., 1996). This observation is confirmed in this study, where the *A. fraterculus* species represented 93.94% of the collected flies, and this is possibly due to *A. fraterculus* being one of the most polyphagous species in Brazil, with a total of 114 registered hosts (Zucchi, 2017) and can be hosted in fruits close to the orchard during the year.

The highest population densities of fruit flies occurred from December 2013 to February 2014, with population peaks in February 2014 (Figure 2), with a total of 804 flies, followed by collections in January and December, with a total of 764 and 559 flies, respectively.

The highest incidence of fruit flies occurred during fruiting season of the guava orchard, which corroborates with the results obtained by Calore et al. (2013), in a study carried out in a semi-organic orchard in the city of *Pindorama* - SP, where they verified that the greatest population peak of the flies occurred in February, and in the period of greater fruiting of the orchard.

In a study on infestation levels of *Anastrepha* spp. species in the guava crop by Araújo and Zucchi (2003), in the city of Mossoró - RN, it was verified that the highest population peaks occurred from May to July, a period that differs from the population peak found in the municipality of São Roque do Canaã - ES. However, the same authors reported that in the semi-arid regions, precipitation together with host availability is the predominant factor in population peaks, and not only the availability of fruits, in line with the results of the current study.

It is possible to observe that in April, there is a small population peak with a total of 341 flies collected, which is probably associated with host plants present in the region. This population peak occurs when Conilon coffee fruits (*Coffea canephora* Pierre ex A. Froehner) and arabic coffee (*Coffea arabica* L.) are available, and monitored orchards are located close to a plantation with two coffee species. Conilon coffee fruits available cannot be related to the population peak, because even though it is a host for tephritidae species, it presents a very low infestation index, which does not act as a natural repository for the fruit flies (Raga et al., 2002). According to Martins (2011), this low infestation is due to the fruits' physical characteristics which are, small and mesocarp has little thickness, limiting the larvae development. According to Martins (2011), this peak is possibly correlated with Arabica coffee, which has 45 times higher infestation rates than Conilon, showing that Arabica is an extremely favorable and important host as a natural repository of tephritidae.

The lowest population densities of flies occurred from May to August 2014 and during this period, few fruits were available in the orchard. This is due to several factors such as, low rainfall index and the decrease of temperature, which makes farmers to avoid pruning during this period, since the guava tends to vegetate less and produce fewer fruits. These results are comparable to those of Teles and Silva (2005), when they reported that the availability of host fruits is the most important factor in determining the occurrence and population fluctuation of fruit flies instead of the abiotic factors.

Samples were collected in all the orchards close to Atlantic forest fragments, which may have contributed to the collected flies coming from the host fruits of this biome. According to Uramoto and Martins (2005), species richness and abundance of fruit flies are higher in preserved areas than in altered ones. The period that had lowest population peaks was precisely in the months when the native vegetation of the region suffered from adverse climatic factors and consequently produced fewer fruits, which would serve as hosts for the flies.

The correlations between the meteorological factors and the population fluctuation of the fruit flies indicate that the population growth of the pest is favored at higher temperatures (Figure 2 and Table 4). On the other hand, neither rainfall nor relative humidity correlated with the number captured.

Conclusion

The species of fruit flies associated with guava fruits are *A. fraterculus, A. obliqua*, *A. zenildae* and *C.capitata*, with *A. fraterculus* being the most abundant species in the Northwest region of *Espírito Santo*.

The only parasitoid species found was *D. areolatus*; however, its parasitism index is not significant to influence the population dynamics of fruit flies.

The population peak of fruit flies in the evaluated region occurred in February. The pupal viability and the fruit flies infestation index in the studied areas were 40% and 58.4 kg^{-1} fruit puparium, respectively.

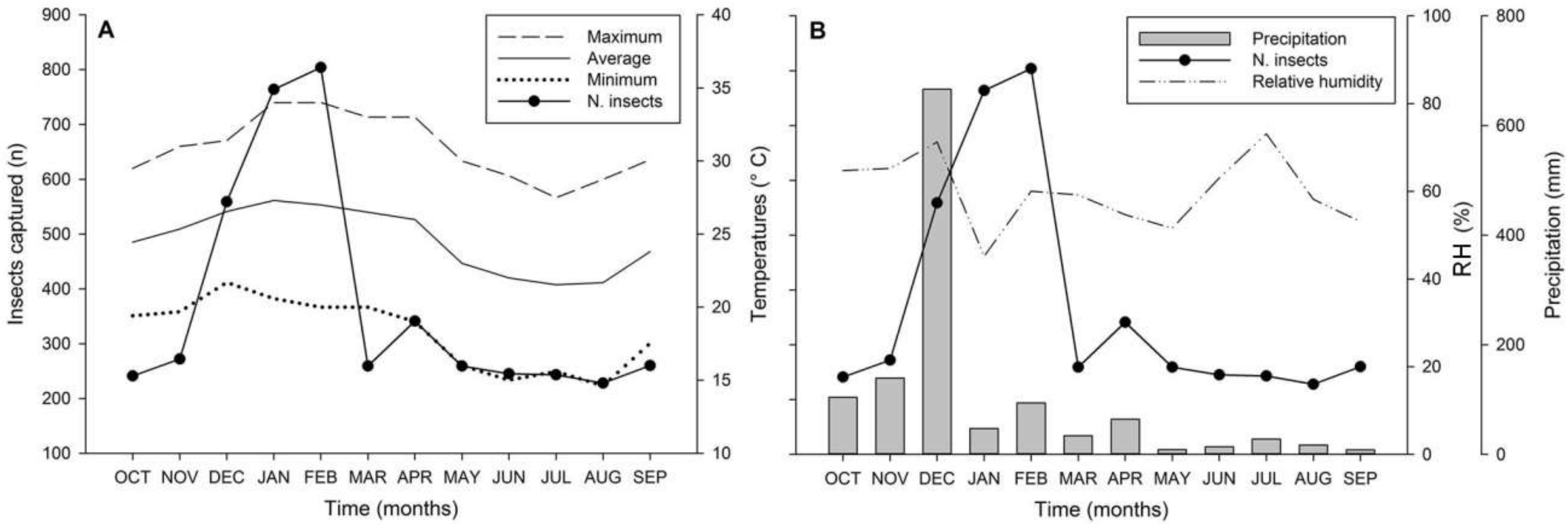

Figure 2. Population dynamics of fruit fly associated with climatic factors in guava orchards in the northwest region of Espírito Santo, from October 2013 to September 2014.

Table 4. Correlation between number of fruit flies collected in commercial guava orchards in the municipality of São Roque do Canaã - ES with McPhail® trap and meteorological factors between October 2013 and September 2014.

Meteorological factor	Number of insects captured[1]
Maximum temperature (°C)	0.733 (<0.01)
Medium temperature (°C)	0.710 (<0.01)
Minimum temperature (°C)	0.608 (<0.05)
Relative humidity (%)	-0.246 (>0.05)
Precipitation (mm)	0.327 (>0.05)

[1]Correlation of Pearson (p-value).

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Aluja M, Celedonio-Hurtado H, Liedo P, Cabrera M, Castillo F, Guillén J, Rios E (1996). Seasonal population fluctuations and ecological implications for management of *Anastrepha* fruit flies (Diptera: Tephritidae) in commercial mango orchards in Southern Mexico. J. Econ. Entomol. 89(3):654-667.

Alvarenga CD, Matrangolo CAR, Lopes GN, Silva MA, Lopes EM, Alves DA, Nascimento AS, Zucchi RA (2009). Moscas-das-frutas (Diptera: Tephritidae) e seus parasitoides em plantas hospedeiras de três municípios do Norte do Estado de Minas Gerais. Arq. Inst. Biol. 76(2):195-204.

Araújo EL, Zucchi RA (2003). Moscas-das-frutas (Diptera: Tephritidae) em goiaba (*Psidium guajava* L.) em Mossoró, RN. Arq. Inst. Biol. 70(1):73-77.

Araújo EL, Fernandes EC, Silva RIR, Ferreira ADCL, Costa VA (2015). Parasitoides (Hymenoptera) de moscas-das-frutas (Diptera: Tephritidae) no Semiárido do Estado do Ceará, Brasil. Rev. Bras. Frutic. 37(3):610-616.

Azevedo FR, Guimarães JA, Simplício AAF, Santos HR (2010). Análise faunística e flutuação populacional de moscas-dasfrutas (diptera: tephritidae) em pomares comerciais de goiaba na região do cariri cearense. Arq. Inst. Biol. 77(1):33-41.

Boff MIC, Pereira BA, Boff P, Franco CR, Santos HAA (2012). Infestação e viabilidade pupal de moscas-das-frutas do gênero *Anastrepha* (Diptera: Tephritidae) em povoamentos naturais e pomar em transição de goiabeira serrana. In: 22º Seminario de Iniciaçao Cientifica, Lages, SC. Resumos... Florianopolis: UDESC. P 1.

Bolzan A, Diaz-Rodriguez GI, Garcia FRM, Nava DE (2016). *Anastrepha grandis*: Bioecologia e Manejo. Embrapa Clima Temperado 404:1-24.

Boti JB, Madalon FZ, Oliveira BR, Haddade IR (2016). Insetos provocadores de danos em folhas, flores e frutos da goiabeira (*Psidium guajava* L., Myrtaceae) nos pomares conduzidos em sistema de cultivo convencional e orgânico, no município de Santa Teresa-ES. Natureza OnLine 14:1-5.

Calore RA, Galli JC, Pazini WC, Duarte RT, Galli JA (2013). Fatores climáticos na dinâmica populacional de Anastrepha spp. (Diptera: Tephritidae) e de Scymnus spp. (Coleoptera: Coccinellidae) em um pomar experimental de goiaba (*Psidium guajava* L.). Rev. Bras. Frutic. 35:67-74.

Canal DNA, Zucchi RA (2000). Parasitoides - Braconidae. In: Malavasi A, Zucchi RA (Ed.). Moscas-das-frutas de importância econômica no Brasil: conhecimento básico e aplicado. Holos. pp. 119-126.

Carvalho RS (2005). Metodologia para monitoramento populacional de moscas-das-frutas em pomares comerciais. Cruz das Almas: Embrapa Mandioca e Fruticultura Tropical. 17 p. (Circular técnica Documentos, 75).

Corsato CDA (2004). Moscas-das-frutas (Diptera: Tephritidae) em pomares de goiaba no Norte de Minas Gerais: biodiversidade, parasitoides e controle biológico. Tese (Doutorado em Ciência). Piracicaba: ESALQ. 95 p.

Duarte RT, Galli JC, Pazini WC (2012). Dinâmica populacional de moscas-das-frutas (Diptera: Tephritidae) em pomar de goiaba no Município de Jaboticabal – SP. Agroecossistemas 4(1):33-41.

Duarte RT, Baptista APM, Pazini WC, Galli JC (2014). Atrativos alimentares no monitoramento populacional de moscas das frutas (Diptera: Tephritidae) em pomar de goiaba. Nucleus 1:45-53.

Gallo D, Nakano O, Silveira Neto S, Carvalho RPL, Batista GC, Berti Filho E, Parra JRD, Zucchi RA, Alves SG, Vendramin JD, Marchini LC, Lopes JRS, Omoto C (2002). Manual de Entomologia Agrícola. São Paulo: Agronômica Ceres 649p.

Gallo D, Nakano O, Silveira Neto S, Carvalho RPL, Batista GC, Berti Filho E, Parra JRD, Zucchi RA, Alves SG, Vendramin JD (1998). Manual de entomologia agrícola. 2.ed. São Paulo: Agronômica Ceres 549p.

Härter WR, Grutzmacher AD, Nava ED, Gonçalves RS, Botton M (2010). Isca tóxica e disrupção sexual no controle da mosca-da-fruta sul-americana e da mariposa-oriental em pessegueiro. Pesqui. Agropecu. 45(3):229-235.

Lorscheiter R, Redaelli LR, Botton M, Pimentel MZ (2012). Caracterização de danos causados por *Anastrepha fraterculus* (Wiedemann) (Diptera, Tephritidae) e desenvolvimento larval em frutos de duas cultivares de quiviseiro (*Actinidia* spp.). Rev. Bras. Frutic. 34:67-76.

Martins DS (2011). Diversidade, distribuição geográfica e hospedeiros de moscas-das-frutas (Diptera: Tephritidae) no estado do Espírito Santo, Brasil. Tese (Doutor em Entomologia). Viçosa: UFV. 91p.

Montes SMNM, Raga A, Boliani AC, Santos PC (2011). Dinâmica populacional e incidência de moscas-das-frutas e parasitoides em cultivares de pessegueiros (Prunus persica Batsch) no município de Presidente Prudente-SP. Rev. Bras. Frutic. 33(2):402-411.

Nunes MZ, Santos RSS, Boff MIC, Rosa JM (2013). Avaliação de atrativos alimentares na captura de *Anastrepha fraterculus* (Wiedemann, 1830) (Diptera: Tephritidae) em pomar de macieira. Rev. Facultad Agron. 112(2):91-96.

Pereira Rêgo DRG, Jahnke SM, Redaelli LR, Schaffer N (2013). Variação na infestação de mosca-das-frutas (Diptera: Tephritidae) e parasitismo em diferentes fases de frutificação em mirtaceas nativas no Rio Grande do Sul. Entomo Brasilis 6(2):141-145.

Raga A, Prestes DAO, Souza Filho MF, Sato ME, Siloto RC, Zucchi RA (2002). Occurrence of fruit flies in coffee varieties in the State of São Paulo, Brazil. Boletín Sanidad Vegetal y Plagas. 28(1):519-524.

Silva RA, Silva WR (2007). Levantamento de moscas-das-frutas e de seus parasitoides no município de Ferreira Gomes, Estado do Amapá. Ciênc. Rural 37(1):265-268.

Teles BR, Silva NM (2005). Flutuação Populacional de Espécies de Anastrepha Schiner (Diptera: Tephritidae) na região de Manaus-AM. Neotrop. Entomol. 34(5):733-741.

Uramoto K, Martins DS (2005). Biodiversity of *Anastrepha* fruit flies (Diptera, Tephritidae) in papaya growing region in Espírito Santo state, Brazil. In: Meeting of the working group on fruit flies of the western hemisphere. Abstracts... Fort Lauderdale: USDA; P 134.

Vargas RI, Stark JD, Uchida GK, Purcell M (1993). Opiine parasitoid (Hymenoptera: Braconidae) of oriental fruits fly (Diptera: Tephritidae) on Kauai Island, Hawaii: Islandwide relative abundance and parasitism rates in wild and orchard guava habitats. Environ. Entomol. 22(1):246-253.

Vieira SMJ, Raga A, Benedetti BC, Oliveira RA, DI Marco PG, Scarponi, APT (2014). Effect of ultraviolet-C radiation on- Kumagai- guavas infested by *Ceratitis capitata* (Diptera-Tephritidae) and on physical parameters of postharvest. Sci. Hortic.165:295-302.

Zanuncio Junior JS, Martins DS, Fornazier MJ, Castro A (2013). Parasitoides associados às moscas-das-frutas em goiaba no estado do Espírito Santo. In: 13º Siconbiol. Anais... Faça bonito. Use o controle biológico.

Zucchi RA (2000). Taxonomia. In: Malavasi A, Zucchi RA (Ed.). Moscas-das-frutas de importância econômica no Brasil: conhecimento básico e aplicado. Ribeirão Preto: Holos. cap. 1:13-24.

Zucchi RA (2017). Moscas de frutas no Brasil - espécies de *Anastrepha* suas plantas hospedeiras e parasitoides. Available at: www.lea.esalq.usp.br/anastrepha/. Accessed on February 15, 2017.

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