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Full Length Research Paper

Effects of different soil amendments on the performance of okra (*Abelmoschus esculentus* L.) in a bimodal rainforest zone

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Okra contributes an important part of the diet to many people in the tropics, more especially in Cameroon. But its production is seriously affected by poor soil fertility. In other to mitigate this problem, a field experiment was conducted from April to august 2016 at Institute of Agricultural Research for Development (IRAD) Nkolbisson-Yaoundé with the main objective to evaluate the effects of different soil amendments on the performance of okra (*Abelmoschus esculentus* L.) crop. The experiment was laid out using a randomized complete block design (RCBD) with three replications and eleven treatments: (Tithonia leaves (6700 kg/ha), piggery manure (6700 kg/ha), foliar fertilizer (0.6 kg/ha), urea (200 kg/ha), NPK20-10-10 (200 kg/ha), Tithonia leaves (3350 kg/unit) + NPK20-10-10 (100 kg/unit), Tithonia leaves (3350 kg/unit) + Urea (100 kg/ha), urea (100 kg/ha) + NPK 20-10-10(100 kg/ha), Tithonia leaves (100kg/ha) + foliar fertilizer (0.3 L/ha), Tithonia leaves (3350 kg/ha) + piggery manure (3350 kg/ha) and control (0 kg/ha). The Results showed that the growth and yield of okra were significantly (P<0.05) affected by different soil amendments. The number of days to achieve 50% shoot set was significantly (P<0.05) greater (50.66±1.24) with the use of NPK 20-10-10 as compared to the rest of the treatments. The number of days to achieve 50% flowering was significantly (P<0.05) greater (59.33±1.46) with the use of Tithonia leaves as compared to the rest of the treatments. The tallest plants and highest number of fruits per plant were recorded from the urea treatment, while the use of foliar fertilizer resulted in many branches and leaves per plant. A combination of NPK and Tithonia leaves resulted in heavy fruits per plant. NPK treatments produced the highest number of fruits and the heaviest fruits as compared to the foliar and control treatments. From the results obtained, it can be concluded that the application of foliar fertilizer, urea and NPK 20-10-10 + Tithonia and NPK which recorded the highest growth and yield parameters among all the treatments are the best treatments and should be adopted by farmers in the study area to maximize their yields. However, further studies on other combinations of organic fertilizers need to be carried out in different areas in order to come out with desired new alternatives that will reduce the use of high quantity of inorganic fertilizers.

Key words: Performance, soil amendments, okra, bimodal, fertilizer.

INTRODUCTION

The importance of vegetables in providing balanced diet and nutritional security has been realised world over

(Adeniji and Peter, 2005). Vegetables are now recognized as healthy food globally and play important role in overcoming micronutrient deficiencies and providing opportunities of higher farm Income. Okra *(Abelmoschus esculentus* L.) Moench) originated from tropical Africa and India (Alkaff and Hassan, 2003), it is one of the most well-known and utilized species of the family Malvaceae in Cameroon. It is also an important vegetable crop grown for its immature pods that can be consumed as a fried or boiled vegetable or may be added to salads, soups and stews (Adeniji and Peter, 2005). Mature okra seeds are good sources of protein that could be as high as poultry eggs and soybean (Akintoye et al., 2011). In Cameroon, okra occupies the third place after tomato and pepper (AGRISTAT, 2014) in terms of vegetable production. Although okra is very popular in Cameroon, the yield is still low (3.11 tons /ha) due to biotic and abiotic factors (FAOSTAT, 2013). The low yield has been attributed to poor soil fertility and deficiency in important mineral nutrients (Sanchez and Jama, 2002). This is because fertilizers have become a scarce commodity and even when available; it is beyond the reach of the poor resource farmers due to high costs (Farinde and Owalarefe, 2007). Both fertilizers and organic manures have a potential role in crop growth and development (Eghball et al., 2004). Organic manures improve soil fertility by activating soil microbial biomass (Ahmad et al., 1998). Animal and plant manure provide a source of all necessary macro- and micro nutrients in available forms, thereby improving the physical and biological properties of the soil (Abou El Magd et al., 2006). According to Olatunji et al. (2007), the application of organic manure had been found to have higher comparative economic advantage over the use of inorganic fertilizer. Common organic materials such as animal manure are not usually available in sufficient quantities and their application is labour intensive (Palm et al., 1997). Therefore, there is need to use alternative sources of organic fertilizers such as green manure to enrich the soil for crop production. According to Chukwuka and Omotayo (2008) and Crespo et al. (2011), *Tithonia diversifolia* can improve the physical and chemical properties of soil and increase nutrients in the soil. Igua and Huasi (2009) also reported that residues of *T. diversifolia* increases soil nitrogen and consequently increases maize yield. Piggery manure contains nitrogenous compounds (including ammonia, ammonium compounds and nitrates) (Bertora et al., 2008). It also contains phosphoric compounds, which mainly occur in inorganic form (74 to 87% of the total P content) (Lens et al., 2004). This composition therefore makes piggery manure useful in agriculture (Fangueiro et al., 2012). The purpose of this study was to evaluate the effect of *T. diversifolia* green manure and piggery manure in improving the physical and chemical properties of soils as well as yield of okra.

With limited information on response of okra to application of piggerygery manure and Tithonia in fatalistic soils of Yaoundé, the study was carried out with the main objective of evaluating the effects of these organic matters on the production of okra with inorganic fertilizer.

MATERIALS AND METHODS

The study was conducted at Institute of Agricultural Research for Development (IRAD) Nkolbisson –Yaoundé- Cameroon in the month of April to August 2016. The study site (Figure 1) is located at an altitude of 759 m above sea level and lies at latitude 3° 51'N and longitude 11° 40'E. The annual rainfall distribution is bimodal with peak rainfall in May and October. The area has a mean annual rainfall of 1500 mm and mean annual temperatures of 24.7°C .The relative humidity range between 50 and 80% in the dry season and 70 and 90% in the rainy season. The most dominant types of soil at Nkolbisson is ferralitic, and acidic (pH 5- 6) with a low cation exchange capacity (CEC). A cultivar (Clemson Spineless) of okra was used as the planting material. This variety was obtained from AVRDC (world vegetable centre).

The treatments consisted of Tithonia (6700 kg/ha), piggery manure (6700 kg/ha), foliar fertilizer (70% N, 25% P, 5% K, trace elements, vitamins and amino acids) (0.6L/HA), urea (200 kg/ha), NPK20-10-10 (100 kg/ha), Tithonia (3350 kg/ha) + NPK20-10-10 (100 kg/ha), Tithonia (3350 kg/ha) + urea (100 kg/ha), urea (100 kg/ha) + NPK20-10-10 (100 kg/ha), Tithonia (100 kg/ha) + foliar fertilizer (0.3 L/HA), Tithonia (3350 kg/ha) + piggery manure (3350 kg/ha) and control (0 kg/ha). The experiment was laid out in a randomized complete block design (RCBD) with 11 treatments replicated three times. Blocks were separated from each other by a 1 m path. Each plot measured 4 x 1.5 m, giving a surface area of 6 m^2 and okra was sown 40 cm between rows and 30 cm within rows with 52 plants per plot.

The soil was treated with Chloropyrifos which is an organophosphate insecticide in order to reduce the insect population. Piggery manure and Tithonia were mixed with the soil on their respective seedbed two weeks before planting so as to enable the decomposition and the release of nutrients before planting. Leaves of *T. diversifolia* were harvested, slashed into smaller sizes before incorporating into the soil, while npk and urea fertilizers were applied two weeks after sowing. Foliar fertilizer at 0.6 L/ha was applied weekly 14 days after sowing (DAS). 4 grains of Clemson Spineless okra variety were sown per hole at a depth of about 1 cm deep at a spacing of 40 cm between line and 30 cm between stand. This was later thinned to 2 plants per stand. The thinning operation was done two weeks after emergence when 2-3 true leaves were produced giving a total of 52 plants per plot. The trial was kept relatively weed free almost every week till harvest. Cypermethrin (250 ml/Ha) and chloropyrifos (340 ml/ha) were used to control diverse insects, while the fungicides Mancozeb & Imidachlopride at the rates of 5L/Ha were used to prevent fungal attack.

Data on growth parameters were taken. Plant height was

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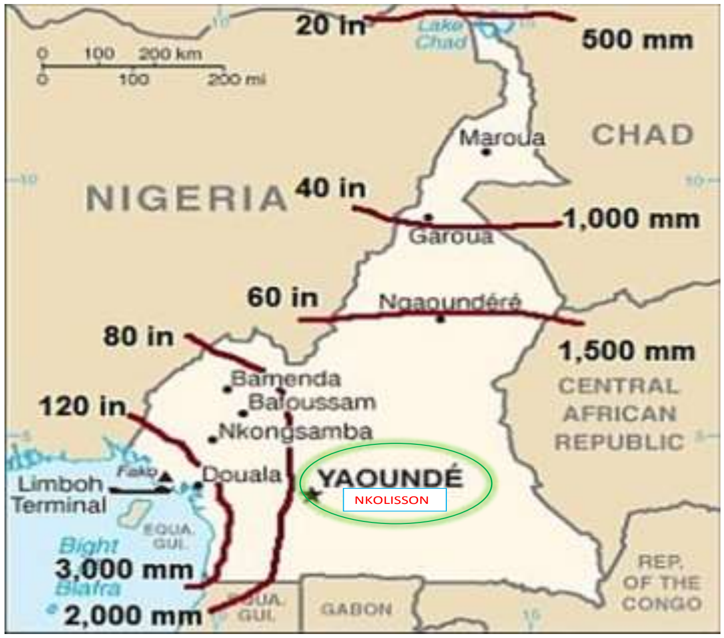

Figure 1. Map of the study area.

Table 1. Effects of different soil amendments on the growth and development of okra.

Treats	Plant height/plant 30 DAS	plant height/plant 60 DAS	Leaf number/plant 30 DAS	Leaf number/plant 60 DAS	Number of branches/plant 30 DAS	Number of branches/plant 60 DAS
CON	12.36±2.54[bc]	43.78±7.58[fg]	3.83±0.32[abc]	11.11± 3.22[d]	2.56±1.65 [ab]	3.06 ±1.29[ab]
FLR	11.42±2.33[c]	43.00±8.06[g]	3.50± 0.47[d]	15.77±5.01 [a]	2.89±1.71[a]	3.28±1.47[a]
FLR +THN	14.86±2.75[a]	49.44±6.85[efg]	3.88±0.28 [ab]	11.78±1.58 [cd]	0.67±1.53[e]	1.72±1.05[d]
NPK	14.75±1.69[a]	63.28±9.57[bc]	4.00±0.09[a]	13.00±2.39[bcd]	1.11 ±1.07[cde]	2.39 ±1.06[bcd]
NPK+THN	14.14±2.17[a]	55.00±6.28[de]	3.88±0.49 [ab]	11.11±2.62[d]	1.89 ±1.84[abcd]	2.39 ±1.17[bcd]
NPK+URA	13.75±2.20[ab]	50.89±8.54[e]	3.61±0.41 [cd]	11.61±1.99[cd]	1.11±1.65[cde]	2.33±1.05[bcd]
PGM	11.88±2.70[c]	49.72±9.79[ef]	3.72 ±0.50[bcd]	13.17±3.43[bcd]	2.56±1.68[ab]	2.94±1.41[ab]
PGM+THN	13.86±3.01[ab]	60.22±8.09[cd]	3.94±0.40 [ab]	14.94±3.88[ab]	0.72±1.32[e]	1.67±1.07[d]
THN	11.91±2.39[c]	53.89±14.07[de]	3.72±0.40 [bcd]	12.39±1.82[cd]	2.11 ±1.20[abc]	2.61±1.17[abc]
URA	14.25±2.59[a]	73.33±13.86[a]	3.94 ±0.27[ab]	13.28±3.78[bc]	1.61 ±1.57[bcde]	2.11±1.48[cd]
URA+THN	14.08±2.94[a]	67.22±13.97[ab]	3.94 ±0.27[ab]	13.06 ±3.64[bcd]	0.89 ±1.74[de]	2.06±1.45[cd]

Means followed by the same letter(s) on same column are not significantly different at 5% level of significance. NPK (Nitrogen, phosphorous and potassium), CON (Control), FLR (foliar fertilizer), PGM (piggery manure), THN (Tithonia leaves), URA (urea).

measured from soil level to the tip of the highest leaf with a meter rule. Number of leaves was counted at 30 and 60 days after sowing (DAS), and the number of days to achieve 50% flowering and 50% pod set were recorded. The number of fresh pods per plant (yields) and the average fresh pod weight were recorded. The data were subjected to analysis of variance (ANOVA using JMP software).

RESULTS AND DISCUSION

The results indicated that the different soil amendments had highly significant ($P < 0.05$) effect on plant height (Table 1). At 30 DAS, the tallest plants (14.86 cm) were recorded from the combined treatment of foliar fertilizer and Tithonia which was significantly ($p < 0.05$) taller than those of control, piggery manure and Tithonia applied alone. At 60 DAS, the tallest plant (73.33 cm) was recorded from the urea treatment while the shortest plant (11.42 cm) came from the foliar fertilizer treatment. Urea gave the best performance with regards to okra height with the reason being a better nitrogen release than the

Table 2. Effects of different soil amendments on the number of days to achieve 50% shoot set and 50% flowering by okra.

Treatments	Days to 50% shoot set	Days to 50% flowering
CON	39.00±2.27^{d}	46.33±2.38^{d}
FLR	48.67±0.32^{ab}	46.33±2.38^{d}
FLR+THN	48.00±1.40^{ab}	56.33 ±0.65^{ab}
NPK	50.67±1.24^{a}	58.00±0.65^{a}
NPK+ THN	47.33±0.94^{ab}	54.67±0.90^{ab}
PGM	41.33±2.10^{cd}	49.00±2.55^{cd}
PGM+ THN	45.00 ±6.43^{bc}	52.33 ±7.50^{bc}
THN	50.00±3.48^{a}	59.33±1.46^{a}
URA	49.00±1.80^{ab}	57.33± 1.46^{ab}
URA+NPK	50.00±1.23^{a}	58.67±0.90^{a}
URA+ THN	50.33±1.12^{a}	59.00±1.50^{a}

Means followed by the same letter(s) on same column are not significantly different at 5% level of significance. NPK (Nitrogen, phosphorous and potassium), CON (Control), FLR (foliar fertilizer), PGM (piggery manure), THN (Tithonia leaves), URA (urea).

other treatments. Results are also in line with the findings of Bin-ishaq (2009) who reported that urea is associated with significant progressive increases in height of okra plant. The increase in plant height at 60 days after sowing probably is due to the supply of more nutrients from inorganic fertilizer at the critical growth stage (flowering and fruit set) which corroborates the findings of Naik et al. (2002) who reported that urea subsequently increases plant height of okra over NPK, poultry, urea and Tithonia.

The number of leaves per plant at 30 DAS was significantly (P<0.05) increased by the application of NPK 20-10-10, urea + Tithonia leaves, piggery manure + Tithonia leaves, urea, foliar fertilizer + tithonia leaves and NPK 20-10-10+Tithonia leaves. With the highest number of leaves (4) recorded on NPK and the lowest number (3.5) of leaves on foliar fertilizer. At 60 DAS, the number of leaves from foliar fertilizer treatment was significantly (p<0.05) different from other treatments. Foliar fertilizer treatment recorded the highest number of leaves (15.77), while the treatment NPK 20-10-10 plus Tithonia and the control had the lowest number of leaves (11.11).

Generally, number of branches per plant is an important indicator of the yield component. The result of the study revealed that the different soil amendment had significant (P < 0.05) effects on the number of branches of the okra plant (Table 1).

During the first 30 days after sowing, the treatment with foliar fertilizer had the highest number of branches (2.99) as compared to others. The number of branches from control, Tithonia, piggery manure and foliar fertilizer treatments were not significantly (P >0.05) different. The number of branches was significantly different in the control treatment than other treatments, except foliar fertilizer (2.56). The lowest number of branches was recorded from foliar fertilizer plus Tithonia treatment (0.67). At 60 days after sowing, number of branches (3.29) on foliar fertilizer was significantly (p<0.05) higher as compared to others. The lowest number of branches was also recorded on foliar fertilizer plus Tithonia leaves application (1.72). Foliar fertilization does not only improve plant growth traits, crop yields and nutrient uptake but also enhances nutrient use efficiency. The results below showed that the highest number of branches was found on plots treated with foliar fertilizer. These benefits of the foliar fertilizer under study might be related to its multi-nutrient content, which upon absorption by the leaf tissues improved the growth traits of okra plants and resultantly increased okra branches. This notion is further supported by the findings of Chaurasia et al. (2005) who also reported that enhanced growth traits, increased yield and better nutrient uptake by vegetable crop was influenced by foliar fertilization. This is contrary to the findings of Abbas et al. (2010*)* who reported that the soil or leaf application of recommended chemical fertilizer alone remained more effective in producing more branches of okra than the single application of three foliar fertilizer products.

Effects of different soil amendments on the yield components

Results from Table 2 indicated a significant difference (p < 0.05) in number of days to achieve 50% flowering and shoot set by the okra variety from the various treatments. According to the results, NPK 20-10-10, Urea+Tithonia, Tithonia and Urea+NPK 20-10-10, showed highly significant (p < 0.05) difference in the number of days to achieve 50% shoot set and flowering as compared to the other treatments. However, NPK 20-10-10 took the highest number of days (50.67) to achieve 50% shoot set, while Tithonia took 59.33 days to achieve 50% flowering. The application of NPK 20-10-10,

Table 3. Effect of different soil amendments on the yield components of okra.

Treatments	Number of fruits / plant	Weight of fruits(g)/plant	Number of fruits(g)/treatment	Weight of fruits(g)/treatment	Weight of grains(g)/treatment
CON	5.89 ±2.04^{c}	26.66±14.93^{bc}	191.00^{ab}	2900.00^{b}	285.67^{ab}
FLR	8.28±3.04^{ab}	33.56±14.45^{ab}	147.00^{b}	2900.00b	293.53^{ab}
FLR + THN	6.22±1.42^{c}	29.22 ±6.37^{ab}	202.00^{ab}	1466.67ab	330.08^{ab}
NPK 20-10-10	9.28±2.99^{a}	35.78±14.08^{a}	305.33^{a}	5200.00a	521.52^{a}
NPK 20-10-10+ THN	8.17±2.19^{ab}	36.57±13.96^{a}	199.67^{ab}	3833.33ab	378.50^{ab}
NPK 20-10-10+URA	6.94±2.19^{bc}	28.25±9.89^{ab}	157.00^{b}	3033.67b	203.50^{b}
PGM	8.39±2.78^{ab}	21.18 ±13.02^{c}	158.66^{b}	2533.33^{b}	286.75^{ab}
PGM+ THN	9.28±3.12^{a}	33.66±7.04^{ab}	245.00^{ab}	3866.67^{ab}	484.18^{ab}
THN	7.22±2.64^{bc}	30.73±7.86^{ab}	234.00^{ab}	3366.67^{ab}	445.61^{ab}
URA	9.83±2.78^{a}	34.09±11.68^{ab}	237.00^{ab}	3900.00^{ab}	392.91^{ab}
URA+THN	5.83±2.63^{c}	33.59±6.63^{ab}	234.00^{ab}	4200.00^{ab}	396.95^{ab}

Means followed by the same letter(s) on same column are not significantly different at 5% level of significance. NPK (Nitrogen, phosphorous and potassium), CON (Control), FLR (foliar fertilizer), PGM (piggery manure), THN (Tithonia leaves), URA (urea).

Urea+Tithonia leaves, Tithonia leaves and Urea+NPK 20-10-10, extended the period to achieve 50% shoot set as compared to the control (39.00) and piggery manure (41.33) which recorded shorter periods. The results also showed no significant differences between urea, foliar fertilizer, foliar fertilizer+tithonia and NPK 20-10-10+Tithonia. This result is in contrast to the findings of Ekwu and Nwokwu (2012) who reported that high amounts of nitrogen on okra reduced the flowering period. Kawthar et al. (2010) reported that reduction in number of days to 50% flowering observable with fertilizer treated plants could be attributed to acceleration of the vegetative phase through the stimulating effect of the absorbed nutrients during photosynthetic process which reflected on both vegetative growth and flower initiation.

Urea had the highest number of fruits (9.83) significantly different from Urea+Tithonia (5.89) and control treatments (5.83) that had the lowest number of fruits/plant. It is also worthnoting that all the treatments had a higher number of fruits/plant as compared to the control. The results indicated that urea has a significant influence on the fruit height of okra. This capacity of producing more fruit is probably due to high nitrogen content of urea which could favour the photosynthetic activity of the plant. This result corroborates that of Akande et al. (2003) who reported that urea increases productivity and improves yield. Contrary, Awodun (2007) observed that more fruits are produced in response to applying foliar fertilizer than urea.

Regarding fruit weight, NPK 20-10-10+Tithonia produced the heaviest fruits per plant (36.57 g) as compared to other treatments, while the lightest fresh okra fruit weight was recorded from piggery manure (21.66 g). The result also showed that there was no significant difference ($p<0.05$) between NPK 20-10-10 + Tithonia (36.57g) and Tithonia alone (36.57) treatments in terms of fruit weight. The fruit weight/plant was not significantly different between control, NPK 20-10-10+Urea and piggery manure, but was significantly different ($p<0.05$) as compared to the treatments: Tithonia alone, urea, foliar fertilizer, urea+Tithonia, foliar fertilizer+Tithonia, and piggery manure +Tithonia.

The main effect of NPK 20-10-10+Tithonia application showed significant increase on fresh fruit weight per plant as shown in Table 3. The heaviest fresh fruit weight per plant from NPK 20-10-10+Tithonia treatment can be related to nutrient availability to crops and release patterns by NPK 20-10-10+Tithonia. This result indicates that combination of NPK 20-10-10 and Tithonia as soil treatment is a better nutrient package for okra. This may be due to the fact that the inorganic fertilizer component of the mixture provided early nutrients to the growing crop, while the organic component provided additional nutrients at the later stage of the crop's development. This finding corroborates with the view of Chung et al. (2000), who reported that the application of organic manures fortified with adequate amount of inorganic fertilizer positively influenced crop yield. This finding also confirmed the results of Ayoola and Makinde (2007) who reported that organic fertilizer can be enriched with inorganic fertilizer to obtain optimum crop yield. This ability of NPK to produce heaviest fruits shows that NPK was readily available and in the best form for easy absorption by the plant root. The obtained results corroborated the finding of Tiamiyu et al. (2012) where they reported that, inorganic fertilizer could increase fruit weight of crops when compared with other sources of manures.

Weight of grains (g)/treatment

The weight of grains per treatment showed that NPK treatment had highly significant effect on the weight of grains per treatment. This analysis showed that NPK had the heaviest grains weight (521.52 g) per treatment as compared to others. The lightest grains were recorded on NPK+urea treatment (203.50). These results also showed that there were no significant (p>0.05) different between all the treatments, except NPK+urea.

This ability of inorganic fertilizer to produce heavier grains might be due to the fact that NPK has the capacity to produce more nutrients as well as high photosynthetic activity. The increase in the yield might be due to greater availability of nutrients in which their presence plays a significant role in food storage and seed maturity. This is in conformity with Guievence and Budence (2000) who reported increased uptake of nutrients, resulting in more photosynthesis and enhanced food accumulation in edible part of the fruits as well as seeds maturity.

Conclusion

Although, okra can be cultivated without the application of fertilizers as seen in the control treatment, this study shows that the growth and yield of okra is greatly enhanced by the application of organic and inorganic fertilizers.

It was also observed from the study that urea produced the tallest plants, while the foliar fertilizer gave the highest number of leaves and branches at 60 days after sowing. For yield components, urea and NPK 20-10-10+Tithonia treatments gave the highest number of fruits/plant and the highest mean fruit weight, respectively. The highest number of fruits and the fruit weight per treatment were recorded on NPK fertilizer. The results also revealed that organomineral (organic + inorganic) fertilizers maintained the highest number of plant stands as compared to sole applications. And application of urea, foliar fertilizer and NPK 20-10-10+ Tithonia proved to be efficient as a good source of fertilizers that supported good vegetative growth and fruit yield in okra. A combination of tithonia or piggery manure and inorganic fertilizer greatly boost the production of okra in terms of fruit weight and number and this is economical for peasant farmers lacking means to obtain inorganic fertilizers.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

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Full Length Research Paper

Linkages of research agencies in technology transfer for sustainable agricultural development in south east Nigeria

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The study assessed the linkages that exit among research agencies in transfer of technology for continuous agricultural production in South East Nigeria. Four research questions and hypotheses guided the study. The study adopted ex-post-facto research design. The population for the study was 2,276 comprised of 112 agricultural extension agents, 393 officers of research institutes and 1,771 registered contact farmers. The sample for the study was 486 made up of 112 extension agents, 197 officers and 177 farmers. A sixty seven (67) structured questionnaire items developed from related literature reviewed and face validated by three experts was used for data collection. The reliability of the questionnaire items was determined using Cronbach Alpha method and a co-efficient of 0.80 was obtained. Three research assistants helped to distribute and retrieve the copies of the questionnaire which were analyzed using mean, t-test and Analysis of Variance (ANOVA) statistical tools. The findings of the study revealed 12 mechanisms adopted by each agency for agricultural technology transfer. 09 delivery channels; 36 constraints and 13 strategies for effective technology transfer. It was therefore recommended that the agencies should formulate and pursue the same objective; government to formulate policies for uniform implementation of technology transfer, establish and equip research institutes with infrastructural facilities, provide adequate training and retrain extension agents and farmers to enhance technology transfer linkages using the identified strategies.

Key words: Agriculture, technology transfer, linkages, research, agencies, extension.

INTRODUCTION

Agriculture occupies a strategic position in the economic development of any country. Agricultural development is driven by the dynamics of demand and supply of farm knowledge among research institutes, extension agents

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and farmers (Dimelu and Emodi, 2012). To achieve a high standard of agricultural development a nation is expected to have strong research and extension system for advancement in agricultural technology with continuous upward shifts in the production and distribution of agricultural produce. Okey and Joel (2014) noted that advancement in agricultural technology has resulted in continuous upward shifts in the production, distribution and consumption of agricultural produce worldwide. Such increase in technology transfer bridges the gap between countries because of differences in environments. The challenge is how to improve agricultural production and rural income without irreparably damaging the natural resources on which production rests through technology transfer. One of the most urgent challenges in the next several decades is feeding the growing world population without irreparably damaging the air, land or water systems (Paul, 2017). The major instrument to success of feeding the hungry mouth is effective and efficient technology transfer.

Technology transfer refers to deliberate, goal-oriented relationship between two or more persons, groups or organizations who exchange technological knowledge (Autio and Laamanen, 1995). Technology transfer refers to movement of ideas, inventions and prototypes within companies, from research producers to a wide group of users including government departments and non-profit agencies, such as industries and universities (Harman and Harman, 2004). Technology transfer requires research stations to disseminate information through extension agents and others to ensure that target audience receive the innovation through media and other means. Stock and Tatikonda (2000) described technology transfer as the act of conveying and utilizing technological innovation by the recipient to achieve set objectives, within cost and time targets. Technology transfer is, therefore, the movement of relevant specialized knowledge or innovations from research institutes to farmers for adoption with the help of extension agents and providing feedback to researchers in order to achieve the intended objectives

The objective of any technology process as indicated by Wang (2003) is the successful adoption of innovation or research findings by a significant majority of clients. Technology transfer is a critical process in transforming agricultural research innovations into applications for end users. Technology transfer helps to improve economic growth, transform lives and boost outputs. The rate at which technology transfer is accepted for adoption depends on the effectiveness of the linkages.

Linkage implies the communication and working relationship established between two or more organizations pursuing common objectives in order to improve productivity. Linkage as a term indicates connection between systems so as to form a greater system (Havelock, 2006). The author further stated that if the barriers between two systems are permeable enough for messages and responses to flow out of each to the other, then, a link is created. It therefore, means that research institutes and extension services are two systems connected by information flow and feedback (Agbamu, 2000). The poor coordination and linkage mechanisms in innovation and adoption have become a recurrent problem (Madukwe, 2008). So, effective interaction of agricultural research scientist, extension agents and farmers as key components of agricultural technology transfer must have a strong linkage to increase production and the standard of living.

Innovations are derived through careful experiments conducted by researchers domiciled in research institutes departments and, faculties of agriculture across the country. Government established these agencies and institutions to generate and circulate innovations needed for increased production (Joans, 2013) Presently, there are twenty two (22) research institutes in Nigeria, each with specific mandate in crop, animal or other commodities and fields (Nigeria webmaster, 2017). There are also 23 faculties of agriculture across Nigerian universities and one international institute for tropical agriculture (IITA), at Ibadan. Their research efforts give rise to a body of knowledge, technologies, practices and system which form the basis for agricultural innovations. Agricultural, research institutes in Nigeria are managed by the Federal Government. The Federal Agricultural Coordinating Units are expected to work with collaborating institutions in technology transfer linkage activities. This is because research is carried out annually by staff of research institutes, universities, colleges of agriculture and state Agricultural Development Programmes. Therefore, to train a researcher, an extension staff or farmer demands that universities must understand the activities of each group and link strongly but each is on its own. Universities in Nigeria are under the National University Commission (NUC); colleges of agriculture under National Commission for Colleges of Education (NCCE); agricultural research institutes autonomous and extension under the ministry of Agriculture (ADP). In practice, there is need for linkage between the ministry of agriculture and the commissions.

In South East Nigeria, the researchers observed that over 70% of the population are farmers but the teaming population are hungry. This is because beaurocratically the innovations are not timely delivered to the target audience. Furthermore, the expected linkages among the commissions, research institutes and extension agents are either weak or not in existence. Agricultural research system is characterized by a top-down, centralized, linear, and isolated structure with weak linkages and often non-existent (Dimelu and Emodi, 2012). Majority of agricultural innovations in the study area arise from publicly sponsored research centers or universities, which typically are unprepared to engage in formal mechanisms of technology transfer. Generally, studies have shown poor technology transfer linkages and collaborative attitudes among agencies involved in agricultural and rural development (Uzuegbulam, 2001). Despite the availability of highly productive and remunerative technology, a wide gap exist between what researchers have achieved in their experimental farms, research institutes and education and the average yield obtained in farmer's field. Many factors responsible are ineffective system of linkages and transfer of improved farm practices, farmers' inadequate knowledge and meager support from government for innovations in the agricultural sector (Uzuegbulam, 2001).

It therefore means that weak linkages in technology transfer to the farmers result in distortions and gaps in derivable advantages; leading to unsustainable agricultural development. This study assessed linkages in technology transfer for sustainable agricultural development in South East Nigeria. Specifically, the study sought to:

1. Identified mechanisms in transfer of technology for sustainable agricultural development.
2. Examined the delivery channels within the service agencies in technology transfer linkages for sustainable agricultural development.
3. Identified constraints to effective linkages in technology transfer for sustainable agricultural development.
4. Determined strategies for enhancing technology transfer linkages by relevant agencies for sustainable agricultural development.

METHODOLOGY

The study adopted ex-post-facto research design. Ex-post factor research design is a non-experimental research technique that compares pre-existing groups on some dependent variables (Lammers and Badia, 2005). The design was considered appropriate for this study as the different research agencies were compared on their roles in technology transfer linkages for sustainable agricultural development in South East Nigeria. South East Nigeria has five states which are Abia, Anambra, Ebonyi, Enugu and Imo States.

The population for this study was 2,276 made up of 112 agricultural extension agents, 393 officers of research institutes and 1,771 registered farmers. The sample for the study was 486 made up of 112 extension agents, 197 officers and 177 farmers. The entire population of extension agents was studied because of the manageable size while proportionate random sampling technique was used to pick 50% of the officers and 10% of farmers based on their experience. The justification for the use of the entire population, 50 and 10% was based on the suggestion by Gall et al. (2007) that for a population of 2000 to 5000 a minimum of 10% may be used while 50% may be used in respect of hundreds.

The instrument for data collection was a 67 item structured questionnaire developed from the literature reviewed for the study. The instrument was made up of four sections (A-D). Each of the sections addressed a specific research questions with each questionnaire item assigned a four point response options of strongly agree, agree, disagree and strongly disagree with values of 4, 3, 2 and 1 respectively. The questionnaire items were face validated by three experts; two from National Root Research Institute Umudike-Abia State and one from University of Nigeria Nsukka, To determine the internal consistency of the items, 12 copies of the questionnaire were sent to four each of officers, extension agent and farmers in Kogi state (a near-by state with same characteristics as the study area). The copies were retrieved and analyzed using Cronbach alpha method and an overall coefficient of 0.80 was obtained. The researchers with the help of three assistants selected based on their familiarity with the study area collected the data from the three groups of respondents. Out of 486 copies of the questionnaire distributed 484 were retrieved and analyzed (112 from extension, 197 from officers and 175 from farmers). Mean was used to answer the research questions, standard deviation for checking the spread of the respondent from the mean while t-test *and* Analysis of Variance (ANOVA) statistics were used to test the null hypotheses at the probability of 0.05. In taking decision on the agreed item, any item with a mean value of 2.50 or above was regarded as agreed while any item with a mean value below 2.50 was regarded as disagreed. With reference to the hypotheses tested; any item with a value greater than 0.05 was accepted but not upheld if otherwise.

RESULTS

The results of the study were presented in Tables 1 to 8. Table 1 indicated that all the 12 items were mechanisms in technology transfer while the corresponding hypothesis in Table 2, revealed a significant difference in the mean ratings of the two groups of respondents (officers and extension agents). Table 3 indicated that all the nine items were the channels of linkages for technology transfer and the tested hypothesis in Table 4 showed a significant difference. With reference to constraints to technology transfer, the three groups of the respondents agreed that 35 of the items in Table 5 were constraints that hinder linkages in technology transfer for sustainable agricultural development. The corresponding hypothesis in Table 6 indicated that no significant difference exists among the three groups of respondents on the constraints to the linkages. The three groups of respondents agreed that the 13 items in Table 7 were strategies for enhancing technology transfer linkages for sustainable agricultural development. The corresponding hypothesis in Table 8 indicated that there was a significant difference in the mean ratings of the three groups of respondents on the strategies for enhancing linkages in technology transfer for sustainable agricultural development in South East Nigeria.

DISCUSSION

The findings of the study revealed that 12 mechanisms for technology transfer linkages were to combine research and extension functions into one unit, fieldwork by subject-matter specialists in extension, create inter agencies committee, farmers' participation in research and extension activities, establish job descriptions to strengthen agencies' relationships and redefine roles and responsibilities between research and extension units. The study also revealed that constraints such as limited ICT resources for effective linkages, insufficient flow of

Table 1. Mean ratings of respondents' on the mechanisms in technology transfer linkages for sustainable agricultural development [N = 309 (112 extension agents and 197 officers)].

S/N	Item statements	$\bar{X}$	SD	Decision
1	Combining research and extension functions into one unit	2.90	0.90	Agree
2	De-centralizing research and extension activities into regions	3.20	0.80	,,
3	Fieldwork by subject –matter specialists in extension	3.10	0.61	,,
4	Starting extension liaison positions in research institutions	3.20	0.80	,,
5	Domicile communication/information departments in institutions	3.20	0.80	,,
6	Redefining roles and responsibilities between research and extension units	3.10	0.67	,,
7	Creating inter agencies committee	2.51	1.05	,,
8	Locating research unit adjacent to extension units	2.80	0.67	,,
9	Farmers' participation in research and extension activities	3.10	0.67	,,
10	Establishing job descriptions to strengthen agencies' relationships	3.10	0.67	,,
11	Establishing joint reviews of research and extension activities	3.70	1.28	,,
12	Promotion of formal and informal linkages	3.10	0.67	,,

Table 2. t-Test analysis of the responses of extension agents and officers on the mechanism in technology transfer linkages for sustainable agricultural development.

Occupation	Group statistics at 0.05 level of significant							
	N	Mean	SD	df	Std. Error	t-cal	Sig*	Remark
Officers	197	3.04	8.37	307	0.81	-0.20	0.00	S
Ext. agents	112	3.20	5.91					

Table 3. Mean ratings of respondents on delivery channels in technology transfer linkages for sustainable agricultural development [N = 309 (112 extension agents and 197 officers)].

S/N	Item statements	$\bar{X}$	SD	Decision
1	Publication in journals/bulletins	2.9	1.02	**Agreed**
2	Conferences/workshops	2.70	0.50	,,
3	Technical reports	3.10	0.67	,,
4	Television	2.60	0.67	,,
5	Radio/posters	2.80	0.50	,,
6	Monthly review meetings	3.60	1.20	,,
7	Field projects	3.40	1.02	,,
8	Exhibitions/farmer's fairs	3.20	0.80	,,
9	Farm magazines/newsletters/hand books/leaflets	2.60	0.50	,,

Table 4. t-Test analysis of the responses of extension agents and officers on delivery channels in technology transfer linkages for sustainable agricultural development .

Occupation	Group statistics at 0.05 level of significant							
	N	Mean	SD	df	Std. Error	t-cal	Sig*	Remark
External agents	112	3.27	0.18	307	0.03	26.53	0.00	S
Officers	197	2.50	0.33					

feedback to research institutes from extension/farmers, poor communication/interaction among staff of the

Table 5. Mean ratings of respondents on the constraints to effective linkages among the agencies in technology transfer for sustainable agricultural development (N = 484).

S/N	Item statements	$\bar{X}$	SD	Decision
Organizational constraints				
1	None assigned to specific functions such as adaptive research or provide feedback to researchers	2.10	0.50	Disagree
2	Linkage activities assigned inappropriately to institutes or departments	2.60	0.50	Agree
3	Assign inappropriate linkage activities to institute or department	2.90	0.50	,,
4	research activities by individual agencies reduce effectiveness	3.40	1.02	,,
5	Insufficient coordination among research institutions	3.00	0.50	,,
6	Institutional incompatibilities in conducting needed research	3.20	0.80	,,
7	Different time schedules for planning and budgeting	3.60	1.28	,,
8	Overlapping mandate/objectives	3.60	1.20	,,
9	Limited qualified human resources in the agencies for linkage	3.50	1.11	,,
10	Poor logistics support and incentive for linkages	3.50	1.11	,,
11	Administrative bottleneck associated with public agencies	3.20	0.92	,,
12	Excessive organizational fragmentation of research agencies	3.50	1.11	,,
Communication				
13	Poor access to knowledge and information on new technology	3.60	1.20	,,
14	Limited ICT resources for effective linkages	3.10	0.06	,,
15	Traditional public characteristics of most extension information	3.20	0.80	,,
16	Different educational backgrounds and communication patterns of researchers extension agents and farmers.	3.30	0.92	,,
17	Value system may differ between researchers	3.20	0.80	,,
18	Weak or non-existent of communication in critical areas of research linkages	3.40	1.02	,,
19	Insufficient flow of feedback to research institutes from extension/farmers	3.20	0.80	,,
20	Inefficient utilization of existing ICT resources	3.50	1.11	,,
21	Poor communication/interaction among staff of the agencies	3.10	0.67	,,
22	Loss of messages/information in the transfer process	3.10	0.67	,,
23	Inability to understand nature of linkage patterns by each agency	3.10	0.67	,,
Logistics				
24	Weak legal framework	2.70	0.80	,,
25	Poor macro system linkages	3.20	0.80	,,
26	Inappropriate government policy in agriculture	3.40	1.02	,,
27	Influence of international/donors mandates	2.90	0.80	
28	Lack of farmers interest in extension	2.50	0.60	,,
29	Gap in qualification and salary of staff of the agencies	3.10	0.80	,,
30	Poor training opportunities for professionals	3.50	1.11	,,
31	Poor government commitment to extension	3.10	0.67	,,
32	Little incentive from management to perform linkage functions	2.90	0.80	,,
33	Financial resources may be scarce for linkage functions such as testing of research results and training of extension staff	3.10	0.67	,,
34	Overloading few employers in the agencies for linkages	2.30	1.20	,,
35	General poor attitude and low morale of extension workers	3.40	1.02	,,
36	Lack of adequate source of finance for research and linkages	3.80	1.36	,,

agencies, inappropriate government agriculture policies, influence of international/donors' mandates and lack of farmers participation and interest in research and extension. The hypothesis tested revealed significant difference in the opinions of the three groups of respondents in each case.

The findings of the study were in line with the findings of Uzuegbulam (2001) that there is poor technology transfer, linkages and collaboration altitudes among agencies involved in agricultural development. The findings of the study were further in conformity with the findings of Dimelu and Emodi (2012) that the system is characterized by a top-down, centralized, linear, and isolated structure with weak linkages as result

Table 6. Analysis of Variance (ANOVA) of the three groups of respondents on the constraints for effective technology transfer linkages among the agencies for sustainable agricultural development.

Constraints	ANOVA					
	Sum of squares	Df	Mean square	F	Sig.	Remark
Between groups	6.01905	2	3.0095238	4.069217	0.040.	S
Within groups	601.8285	482	2.9002801			

Table 7. Mean ratings of three groups of respondents on the strategies for enhancing technology transfer linkages for sustainable agricultural development [N = 484 (112 extension agents, 197 officers and 176 farmers)].

S/N	Item statements	$\bar{X}$	SD	Decision
1	Evaluating research and development results in terms of the whole farming system	3.30	0.92	Agree
2	Recognizing the linkages of sub-systems within the farming system	3.20	0.80	,,
3	Forming coordinating units among the agencies	3.40	1.02	,,
4	Adopting practice of shearing research information among the agencies,	3.30	0.92	,,
5	Regular training of extension agents and contact farmers	3.50	1.11	,,
6	Linkage with research to impart farmer orientation to research	3.40	1.02	,,
7	Allocating operating funds for linkage with other agencies	3.00	0.92	,,
8	Forming field/group teams and committees for linkages	3.10	0.67	,,
9	Increasing access to individual and agencies; use of information and communication technology	3.10	0.67	,,
10	Planned orientation programme for extension professionals on linkages	3.50	1.11	,,
11	Adopting comparative advantages approach to extension outreaches and programme	2.90	0.67	,,
12	Building linkage responsibilities into job description	3.10	0.67	,,
13	Allocating time to linkage activities among staff.	3.30	0.92	,,

Table 8. Analysis of variance (ANOVA) on the strategies for enhancing technology transfer linkages for sustainable agricultural development.

Strategies	Sum of squares	df	Mean square	F	Sig.	Remark
Between groups	165.385	2	82.692	3.51179	.037	S
Within groups	847.692	482	23.547			

available and highly productive and remunerative technology, wide gap in findings of research stations on their experimental farms and the average yield obtained on farmer's field. The authors observed that there are inadequate knowledge and managerial ability of farmers, little support from government for the agricultural sector resulting in failure to transfer new technologies and innovations to farmers. The respondents indicated that they carry our mechanisms identified by the study independently thus the significant difference in their opinions. The finding of the study was against the University of Montana's report (2011) that many individuals and organizations participate in the technology transfer strategic planning process, both in private conversation and structured discussion sessions. The findings of this study was also in disagreement with the findings of Laamanem (1995) that the innovations' focus on shifting towards networking which is component dependent.

RECOMMENDATIONS

Based on the findings of the study, it was recommended that the agencies should have uniform objectives and form committees and monitoring teams for proper linkages for the achievement of set objectives. Government should improve elements of technology areas in which the agencies are found weak, by utilizing the strategies identified by this study. Furthermore, there should be policies that could bring effective technology transfer linkages among the agencies for sustainable agricultural development.

Conclusion

It is the wish of each agency to perform needed activities or functions to enhance agricultural development in the study area but the problem is that these agencies are working independently. Despite the need for successful transfer of technology which can only be achieved by generating innovations and subsequent transfer to the end users; the agencies work in isolation. Technology transfer is an end in itself but a means to increase the rate of technological innovation and stimulate innovation transfer. Thus, today's recipients can be tomorrow's donors through a successful transfer of technology. To be a donor of technology, the recipients need to possess the capacity to assimilate, adapt, and modify the imported technology through education and training. It is necessary that research institutes, educational institutions and extension departments collaborate effectively for effective technology transfer to the end users for agricultural development in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Agro-morphological diversity in yam genotypes from Recôncavo of Bahia, Brazil

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The aim of this study was to evaluate the diversity of yam genotypes concerning their agro-morphological traits based on the Ward-modified location model (Ward-MLM) procedure. 209 genotypes from the commercial production area of the Recôncavo region in the state of Bahia, Brazil were used. Three agronomic traits (length, width and weight of the rhizophore) and two morphological traits (rhizophore shape and skin color) were evaluated. A considerable agro-morphological diversity was detected in the data for the 209 yam genotypes. The Ward-MLM procedure showed that the optimal number of groups according to the criteria of pseudo F and pseudo t^2 is four. The separation by genotype groups was associated with their origin from two regions with different soil and climatic conditions. The Ward-MLM procedure has shown its usefulness to detect diversity and cluster genotypes by simultaneous use of morphological and agronomic traits.

Key words: Cluster analysis, discriminant analysis, *Dioscorea* species, Ward-modified location model (MLM).

INTRODUCTION

Yam belongs to the Dioscoreaceae family and to the genus *Dioscorea* with more than 600 species, ten of which have rhizophores that are used as food (Lebot, 2009; Nascimento et al., 2015). The species *Dioscorea rotundata* and *Dioscorea cayennensis* (also known as *Dioscorea cayennensis-rotundata* complex) are the most cultivated in the world and account for 95% of yam world production (Obidiegwu et al., 2009; Silva et al., 2014).

This crop is currently the fourth most important tuber-root crop in the world, after potato (*Solanum tuberosum* L.), cassava (*Manihot esculenta* Crantz), and sweet potato (*Ipomoea batatas* L.) (Siqueira, 2011; Silva et al.,

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2016). FAO estimates show that yam was collected from approximately 7.6 million hectares in 2014 generating 68 million tons of tubers (FAOSTAT, 2014). Globally, Nigeria ranks first with a production of 45 million tons in 2014 (FAOSTAT, 2014).

In Brazil, approximately 247,000 tons were produced on 25,700 hectares in 2014 (FAOSTAT, 2014). Approximately 90% of domestic production of *Dioscorea* species stems from the Northeast region, especially the states of Bahia, Paraíba, Pernambuco, Alagoas and Maranhão, where the yam crop represents an important agribusiness (Santos et al., 1998; Santos and Macedo, 2002; Santos et al., 2007a; Silva et al., 2014).

The importance of this species is related with the production of rhizophores with high nutritional and energetic value, constituting a staple food for human consumption which is already being used in all classes of Brazilian society (Mesquita, 2001; Santos et al., 1998; Santos, 1996). A large part of the production is destined for the domestic market and another part for export, mainly to Europe (Santos and Macedo, 2002; Santos et al., 2007b).

Regarding species of *Dioscorea* spp., it is estimated that 150 to 200 occur in Brazil, the only edible genre of the Dioscoreaceae family present in all regions of the country. In the producing regions, species such as *D. cayennensis* and *D. rotundata* are mostly used, followed by the species *D. alata*. However, most species are still poorly studied (Pedralli, 2002). In Bahia, the species *D. rotundata* and *D. cayennensis* (Boca funda) occupy more than 90% of the cultivated area, followed by *D. alata* (São Tomé and Jibóia) and *Dioscorea trifida* (yam or cará mimoso) as well as *Dioscorea bulbifera* (liver yam), sporadically (Carvalho et al., 2009). The largest acreage of yam in this state lies in the Recôncavo region, notably in the municipalities of Maragogipe, São Felipe, Cruz das Almas and São Félix, showing a significant socio-economic importance as a promising alternative for small and medium producers in the region (Mesquita, 2001).

Notwithstanding the socio-economic importance of the yam crop, its expansion is still extremely limited, mainly due to the scarcity of technical and scientific information that will provide sustainability and increase the productivity (Da Silva Dantas et al., 2013; Siqueira et al., 2011). Despite being a species with great plasticity which can adapt from tropical humid to tempered climates without frost and drought (Pereira et al., 2003), the diversity of yam genotypes needs to be studied in order to provide information for enabling the development of technologies and basic knowledge to support and further explore this culture, assist in breeding programs and conserve the species in the Recôncavo region of Bahia, Brazil (Carvalho et al., 2009).

The diversity of this species can be estimated using genetics (Arnau et al., 2017; Loko et al., 2016) and phenotypical information (Dansi et al., 2013; Sheikh and Kumar, 2017). Using phenotypical traits, the diversity can be accessed by morphological characterization and subsequent cluster analysis (Asare et al., 2016). Cluster analysis of these variables can be carried out individually, as the distances are calculated depending on the type of variable used. Cruz (2013) provided procedures to estimate dissimilarity measures based on quantitative traits that could be analysed using Euclidean or Mahalanobis (1936) distances, binary data adopting for example the Jaccard (1908), Nei and Li (1979) coefficients and multicategoric variables to which the Cole-Rodgers et al. (1997) coefficient is applied.

The joint analysis of different types of variables can provide a better indication of the potential on the existing variability in germplasm banks and genotype groups. However, few studies have used this methodology to quantify the diversity of the yam crop due to the lack of knowledge of statistical techniques for this approach and the lack of freely available computer programs for such an analysis. Under these circumstances, the Modified Location Model (MLM) procedure (Franco et al., 1998) is fundamental to quantify the variability using quantitative and qualitative data simultaneously. This procedure is characterized by the Ward grouping method (Ward Junior, 1963) defining groups based on the Gower similarity matrix (Gower, 1971) and by the vector average of the quantitative variables estimated by MLM, regardless of the value of the qualitative variables. It has been used in different cultures for various purposes (Barbé et al., 2010; Cabral et al., 2010; Gonçalves et al., 2009; Pestana et al., 2011; Sudré et al., 2010).

This study aims to quantify the genetic diversity (using the morpho-agronomic traits) of yam genotypes from the Recôncavo region of Bahia, using both quantitative and qualitative data based on the Ward-MLM procedure.

MATERIALS AND METHODS

Yam (209, *D. cayennensis*) genotypes from the commercial production areas in the municipalities of São Felipe (12°50'50" S, 39°05'22" W, altitude 195 m) and Cruz das Almas (12°40' S, 39°06'23" W, altitude 220 m) in the Recôncavo region of Bahia, Brazil were used (Table 1).

In each property of the respective commercial production areas, the yam plantation system used the individual staking mechanism with rods. In these areas, plants were chosen randomly and were marked with red ribbons for better visibility in the field where fortnightly analysis was performed. The evaluated morphological traits relate to the plant’s subterranean part (production) and the part above ground: rhizophore length in cm (RL); rhizophore width in cm (RWD); rhizophore weight in kg (RW) (Figure 1); rhizophore shape (RS – 1 - long and 2 - irregular) and skin color (SC – 1 - brown and 2 - yellow). The sample measurements of the morphological quantitative descriptors were carried out in accordance with the International Plant Genetic Resources Institute and International Institute of Tropical Agriculture (IPGRI, 1997).

For the quantitative descriptors, descriptive statistics were calculated, comprising of the minimum and maximum values, mean, standard deviation and variation coefficient, using SAS (SAS

Table 1. Summary of 209 yam genotypes from the commercial production areas in the municipalities of São Felipe and Cruz das Almas used in the study.

Provenance (Municipality)	Number of genotypes
Bom Gosto (São Felipe)	124
Sapucaia (Cruz das Almas)	40
Sanca (Cruz das Almas)	30
Cadete (Cruz das Almas)	15
Total	209

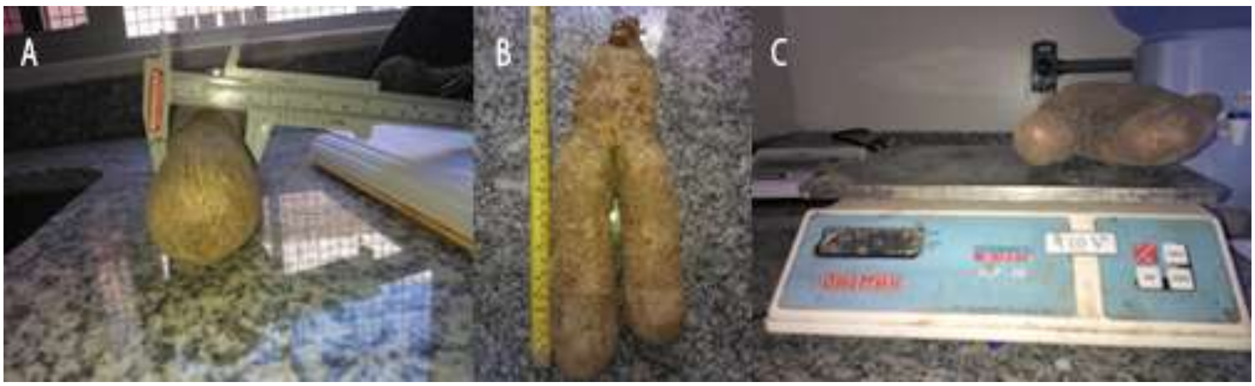

Figure 1. Agronomic traits evaluated in 209 yam genotypes from the commercial production areas in the municipalities of São Felipe and Cruz das Almas in the Recôncavo region of Bahia, Brazil. A: rhizophore width in cm (RWD); B: rhizophore length in cm (RL); C: rhizophore weight in kg (RW).

Institute, 2011). The frequency percentages of the classes for each morphological descriptor and the entropy level of the traits using the Renyi entropy coefficient (Renyi, 1961) were calculated according to the formula:

$$H' = -\sum_{i=1}^{n} pi \ln(pi)$$

where entropy is a measure of the frequency of the distribution of (n) genotypes P = (p1, p2... ps). pi= fi/n; p1 + p2 + ... + ps = 1; N = f1 + f2 + ... + fs, where f1, f2, ... fn are the counts of each of the classes in the descriptor considered. The values of the entropy level (H') were classified as low (H '<0.50), moderate (H' = 0.50-0.75) and high (H '≥ 0.75) (Jamago, 2003).

Quantitative and qualitative variables were analyzed simultaneously using the Ward-MLM procedure for the composition of groups of accessions through the CLUSTER and IML procedures of SAS (SAS Institute, 2011). For Ward's clustering method, the distance matrix was obtained by the Gower algorithm (Gower, 1971). The definition of the optimal number of groups was carried out according to the pseudo-F and pseudo-t^2 criteria combined with the likelihood profile associated with the likelihood ratio test (SAS Institute, 2011).

The graph of the difference between groups and the correlation of the variables with the canonical variable was established using the CANDISC procedure of SAS (SAS Institute, 2011). The distance proposed by Matusita (1955), adapted by Krzanowski (1983) and later by Franco et al. (1998), for the distribution of variables was used to determine the dissimilarity among the groups.

RESULTS AND DISCUSSION

The rhizophore weight (RW) was the descriptor with the highest variation, with a coefficient of 86.9% (Table 2 and Figure 1). The range of variation was from 0.11 to 9.88 kg, with an average value of 1.46 kg. The average weight of marketable rhizophores is of great importance for decision-making by the farmer, given that, depending on the market and changes in rhizophore trade prices, the highest average weight rhizophores reach prices which are 20 to 30% higher than average rhizomes and 80% higher than small rhizomes, which can be a strategy to achieve greater profitability (Pereira et al., 2003).

The rhizophore length (RL) ranged from 5.0 to 67.0 cm, with an average of 33.0 and a 37.1% variation coefficient. Regarding the rhizophore width (RWD), the range was 31.1 to 155.0 cm, with an average of 80.7 cm and a variation coefficient of 35.3% (Table 2). The wide range and average in these descriptors between evaluated yam genotypes may suggest the existence of a broad genetic variability that can be used in breeding programs of the species. In general, considering all analyzed descriptors, the breeders must know the genetic inheritance of such traits and the peculiar edaphoclimatic factors in each micro-region, that influence the phenotypic plasticity of yam genotypes, and in crop management. It is important

Table 2. Descriptive statistics for the quantitative descriptors rhizophore length in cm (RL); rhizophore width in cm (RWD); rhizophore weight in kg (RW) and frequency percentages for the classes of the qualitative descriptors rhizophore shape (RS) and skin color (SC).

Descriptor	Minimum value	Maximum value	Average	Mean SD	CV (%)
Quantitative					
RL	5.0	67.0	33.0	12.2	37.1
RWD	31.1	155.0	80.7	28.5	35.3
RW	0.11	9.88	1.46	1.27	86.9

Qualitative	Classes	Frequency	Entropy level
RS	Elongated	82.30	0.47
	Irregular	17.70	
SC	Brown	94.26	0.22
	Yellow	5.74	

Table 3. Number of groups formed by the Ward-MLM method based on the logarithmic function of the probability (log-likelihood) and its increase.

Group number	Log-likelihood	Increment
1	-2349.38	0.00
2	-2333.30	16.08
3	-2329.33	3.97
4	-2261.04	68.29*
5	-2242.20	18.84
6	-2201.21	40.98
7	-2189.65	11.56
8	-2223.56	6.09
9	-2179.89	3.67

*The highest increment value

to not only define superior agronomic traits, but to stabilize them in order to provide local materials of high productivity and effective agronomic materials for the producers.

The entropy level can be used to quantify the variability present in qualitative descriptors by observing the relative frequencies of the classes for each evaluated descriptors. Low entropy values are associated with a lesser amount of phenotypic classes and high values associated with descriptors with a large number of classes, which reveals genetic variability among the studied accessions (Vieira et al., 2007). In this study, the values were found to be 0.47 and 0.22, indicating a high concentration of genotypes in only one class within each evaluated qualitative descriptor. A possible explanation may be the fact that the only source of yam genotypes (Moreira et al., 2007) is from the Batatan region, close to Cruz das Almas, as well as the limited number of qualitative descriptors used in this study.

An important aspect in the cluster analysis interpretation consists of determining the number of groups that best describe the real structure of the analyzed data. Based on the likelihood function, the largest increase occurred in the formation of four groups, with a value of 68.29 (Table 3 and Figure 2). According to Gonçalves et al. (2009) and Barbé et al. (2010), analysis of the likelihood function can define more precise criteria in the formation of groups, resulting in the determination of less subjective groups. Padilla et al. (2005), evaluating the diversity of 120 populations of *Brassica rapa* subsp. *Rapa* L., found that the largest increase in the probability function was achieved when five groups were considered. In turn, Barbé et al. (2010), evaluating the genetic diversity of bean lines, verified the formation of three groups with increments of 14.66 in the logarithmic probability function. Thus, the number of groups can vary

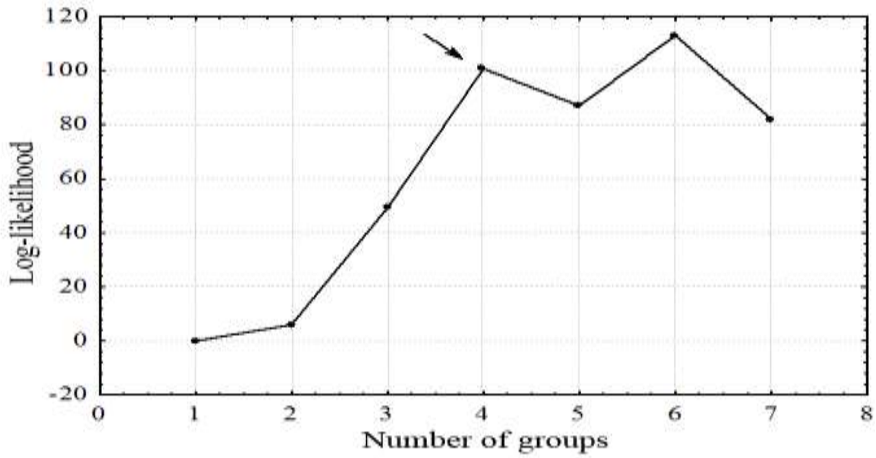

Figure 2. Graphic expressing the logarithmic likelihood function of probability (log-likelihood) with respect to the number of groups.

Table 4. Average of quantitative descriptors for each of the four groups formed by the WARD-MLM algorithm and canonical correlation coefficients for the first two canonical variables.

Quantitative descriptor	Groups				CAN1	CAN2
	G1	G2	G3	G4		
Length (cm)	34.9	29.6	17.4	35.1	-0.16	-0.20
Width (cm)	72.5	114.1	64.7	79.2	0.50	0.80
Weight (kg)	1.19	2.10	1.26	9.66	0.92	-0.31

depending on the studied species, the number of genotypes and the number and type of descriptors (Gonçalves et al., 2009).

Of the four groups (G1, G2, G3 and G4) formed by the Ward-MLM procedure, group 4 stood out in relation to the average of quantitative descriptors. The trait rhizophore length varied between 17.4 cm (group 3) and 35.1 cm (group 4). For the trait rhizophore width, variation was 64.7 cm (group 3) to 114.1 cm (group 2). The trait rhizophore weight ranged from 1.19 kg (group 1) to 9.66 kg (group 4) (Table 4 and Figure 3). The productivity of tradable rhizophores is the main purpose of commercial exploitation of yam. The rhizophore weight is an important factor on the consumer market. According to Santos (1996), rhizophores weighing between 0.70 and 1.50 kg are intended for the US market, those between 1.60 and 2.00 kg exported to France and those between 2.10 and 3.00 kg are destined for other European markets, while those weighing more than 3 kg are not of the export type and achieve lower prices. Thus, one must identify the factors responsible for obtaining these larger rhizophores to prioritize those for export, which will lead to a better remuneration for the producer. Most likely, some of these determining factors in the production of heavier rhizophores are the type and amount of fertilizer used in the culture management as well as the use of irrigation.

The existing variation in the other traits (Table 4 and Figure 3) may be related to genotype × environment interaction. In Taro, a wide variation due to differences in locations, growing seasons and different management practices is observed (Pereira et al., 2003). Regarding yam genotypes, a likely explanation for the detected variation lies in the accessions from different regions, the management employed by traditional farmers through the introduction or exchange of materials within and between communities (Moreira et al., 2007), thereby generating a varying representation of variability.

For the canonical variate analysis, we found that the first two variables explained 94.26% of the total variability among the genotypes (Figure 4). This value indicates that the graphical representation of the first two canonical variables was appropriate for displaying the genetic relationship between groups as well as between genotypes within the same group.

The trait of the rhizophore weight had the highest correlation with the first canonical variable, followed by rhizophore width and rhizophore length, with values of

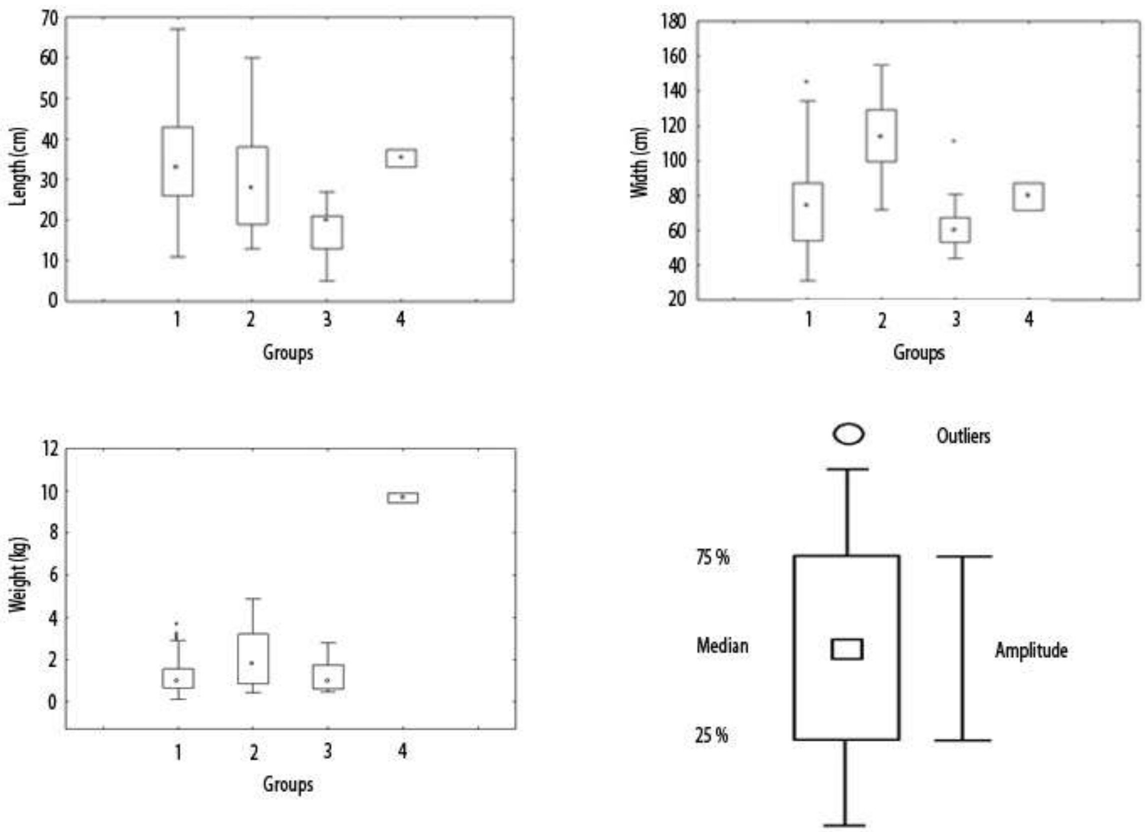

Figure 3. Box plots of the minimum and maximum values, median, 25 and 75% percentiles and outliers for descriptors length, width and weight of 209 yam genotypes in four groups formed by the Ward-MLM algorithm.

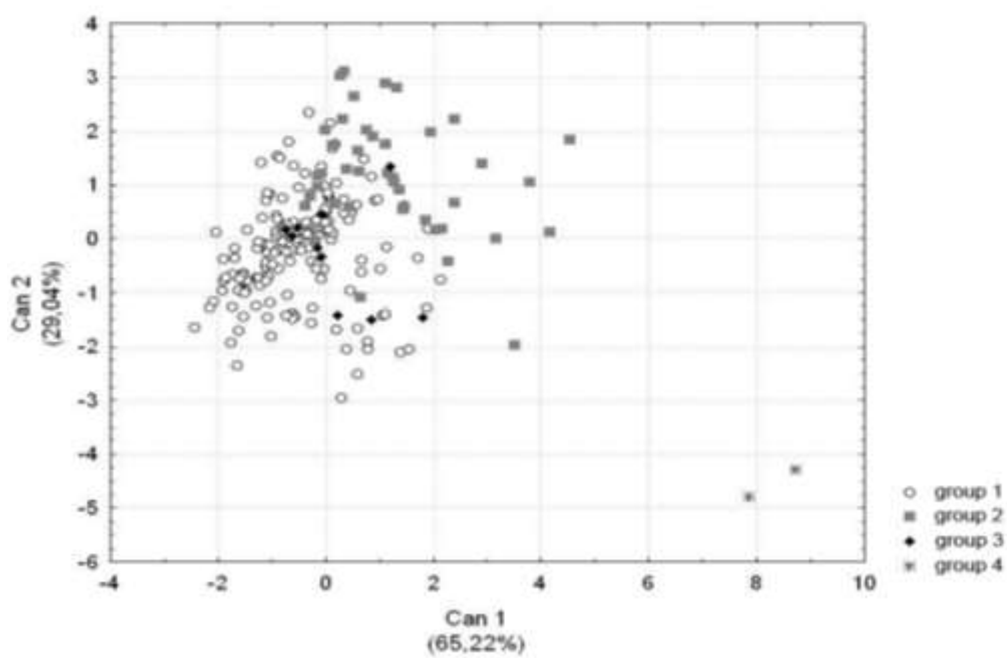

Figure 4. Boxplot referring to the first two canonical variables with four groups (G1 - G4) formed by the Ward-MLM algorithm considering 209 yam genotypes.

Table 5. Distance between groups using the distance proposed by Franco et al. (1998) formed by Ward-MLM analysis.

Groups	G1	G2	G3
G2	4.70	-	-
G3	2.60	5.09	-
G4	95.47	82.31	87.03

0.92, 0.50 and -0.16, respectively. On the other hand, for the second canonical variable, the highest correlation estimates occurred for width (0.80), followed by rhizophore weight (-0.31) and rhizophore length (-0.20) (Table 4). The discriminatory power of the Ward-MLM method in the formation of groups is noticeable. From the results, the criteria used for the separation of the groups considering the canonical variables were apparently associated with the origin of genotypes, as they are from two regions with different soil and climatic conditions.

The distance between the formed groups corroborates the graphical representation of the canonical variables; groups 1 and 3 are the closest with a distance of 2.60, while group 4 was the furthest with 95.47 (Table 5). This fact can be explained by differences in genetic material (rhizophores seeds) planted by each producer. Furthermore, plants of vegetative propagation are, in general, highly heterozygous preserving the allelic diversity at individual level (IPGRI, 1997). The great similarity detected in the other groups may be due their common origin. Moreira et al. (2007) observed that in those regions of Recôncavo in Bahia, where yam is cultivated, most rhizophore seed come from a single region called Batatan which covers the municipality of Maragogipe.

Conclusions

In this work, the diversity of 209 yam genotypes was accessed from the commercial production area of the Recôncavo region in the state of Bahia, Brazil. Considering the traits studied, the rhizophore weight (RW) was the descriptor with the highest variation (0.11 to 9.88 kg). The entropy values reported in this study indicated a high concentration of genotypes in only one class within each evaluated qualitative descriptor. The Ward-MLM algorithm was efficient for forming four homogeneous groups using morphological data. The group 4 stood out in relation to the average of quantitative descriptors and the canonical variate analysis, showed that the first two variables explained 94.3% of the total variability among the genotypes. Thus, the results obtained in this work will be very useful for selecting genotypes of different groups for breeding purposes.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Abbreviations

RL, rhizophore length; **RWD,** rhizophore width; **RW,** rhizophore weight; **RS,** rhizophore shape; **SC,** skin color.

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Structuring potential of some cover crops and crambe in Haplortox under no-tillage system

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An experiment was conducted at the Agronomic Institute of Paraná – IAPAR, at the Experimental Station of the municipality of Santa Tereza do Oeste – PR, in Hapludox of clayey soil. Studies with the use of plants cover crops with vigorous root system in different systems of soil management systems are needed, in order to have a diversity of species capable of producing different amounts of crop residues which by decomposing, can alter the physical attributes and consequently, the productivity of the successor culture. The objective of this study was to evaluate the effect of *crambe* crop and plant cover crops in succession on the physical characteristics of a Haplortox under no-tillage system. The experimental area has been cultivated under no-tillage system for 18 years. The experimental area consisted of 15 plots, each plot with 20x25 m. In 12 plots, plant cover crops were planted, six species of summer and six of winter and the last three consisted of plots with no-tillage system with gypsum application, no-tillage system with scarification and traditional no-tillage (control) in a completely randomized design. The physical attributes of this soil were soil density (DS), total porosity (PT), microporosity (Micro), macroporosity (Macro) and saturated hydraulic conductivity (Ksat) of the soil in the periods of 2014 (initial characterization of the soil) and 2015 (after *crambe* culture). The microporosity (0.0-0.1 m layer) and Ksat (all soil layers) presented significant differences between treatments in the period of 2015. Microporosity was lower in the pigeon pea coverage (PP) (36.08%), while the largest occurred in the coverage of *crambe* C5 (45.38%). The Ksat was higher in the dwarf pigeon pea (DPP) (298.20 mm h^{-1}) and sunn hemp (SH) (163.39 mm h^{-1}) coverage in the 0.0-0.1 m layer. The highest Ksat was observed for *crambe* C9 (96.81 mm h^{-1}), C8 (74.13 mm h^{-1}), velvet bean (70.95 mm h^{-1}) and C5 (53.94 mm h^{-1}) respectively, in the soil layer of 0.1-0.2 m.

Key words: Soil management, soil structure, residues.

INTRODUCTION

In no-tillage, the maintenance of vegetation cover and residues on the soil surface provide a continuous supply of organic residues and can occur for improvement of some soil physical properties, such as aggregation, infiltration, permeability, among others (Bertol et al., 2004).

Knowledge of decomposition of plant residues and release of nutrients is essential for no-tillage system (Canova et al., 2015). Among the soil physical properties, the soil structure can be regarded as the most important under the agricultural point of view, because fundamental conditioning attributes are assigned to the soil-plant relationships (Torres et al., 2013).

Thus, when the areas in no-tillage system are handled improperly (no crop rotation, but a succession of soybeans/corn with the movement of the soil surface or even insufficient soil cover), they provide negative changes in soil physical properties due to compression. One of the measures taken to break these layers is the practice of scarification (Gabriel Filho et al., 2000; Spoor, 2006; Jin et al., 2007), although this process breaks the compacted layers, it makes the soil susceptible to the new compressions (Tormena et al., 2002; Botta et al., 2006), since the benefits of this practice has shown short duration in the physical characteristics of the soil, with a tendency to return to its original condition in a short time (Busscher et al., 2002).

The introduction of plant cover crops with root traits that can grow in soils with high strength has been an alternative that can promote the decompressing of the soil and potential to improve the structural quality, even helping in the cycling of nutrients leached in depth. In addition, the use of cover crops aims to protect the soil against erosion, maintain greater amount of organic matter in the soil and relieve the effects of compression by leaving stable biopores where the roots of succeeding crops can use these to grow deeper (Botta et al., 2004; Hamza; Anderson, 2005; Oliveira et al., 2011; Crusciol et al., 2012; Ferrari Neto et al., 2012; Nascente and Crusciol, 2012).

The seeding of cover crops is now been searched for by several authors, in order to minimize the negative effects of soil compaction, through improvements in its structure. Thus, Reinert et al. (2008) studied the species: sunn hemp (*Crotalaria juncea*), dwarf pigeon pea (*Cajanus cajan*), gray velvet bean (*Stilozobium cinereum*) and jack bean (*Canavalia ensiformis*) in the physical quality of an Acrisol. Andrade et al. (2009) evaluated the effect of the species: signalgrass (*Brachiaria brizantha*); corn (*Zea mays*) intercropped with signalgrass; pigeon pea; pearl millet (*Pennisetum glaucum*); green panic grass (*Panicum maximum*); sorghum (*Sorghum bicolor*); stylo (*Stylosanthes guianensis*) and crotalaria. Bordin et al. (2008) and Ferrari Neto et al. (2011) studied the coverages of pearl millet and dwarf pigeon pea. While, Teodoro et al. (2011) studied the coverage of gray velvet bean, Florida bean (*Mucuna aterrima*), lablab bean (*Dolichos lablab*), jack bean, rattlebox and dwarf pigeon pea in Cerrado soils.

Another cover that has attracted attention is the *crambe* culture (*Crambe abyssinica* Hochst), which also has a root system that can reach depths greater than 15 cm (Carlsson et al., 2007) and can be used as a winter crop and it is an alternative to the crop rotation. Oplinger et al. (1991) reported that under stress conditions, plants develop long roots, which later become conical. Crambe is an oleaginous belonging to the family of cruciferous vegetables, the same of rapeseed and canola. Originating in the hot, dry region of Ethiopia, the crambe was domesticated in the cold, dry zone of the Mediterranean. Due to its origins, it tolerates drought and cold, and is suitable for autumn/winter plantations in Brazil.

In Brazil, researches on the *crambe* were first carried out by the MS Foundation, to evaluate the culture of behavior as ground cover in no-tillage system. Culture has short annual cycle, from 85 to 90 days, drought tolerance, good grain production from 1000 to 1500 kg ha^{-1} and up to 38% oil content (PITOL, 2008). According to Feroldi et al. (2012), culture can be an alternative to be cultivated after soybean harvest, in the period of March and April.

Studies with the use of plants cover crops with vigorous root system in different systems of soil management systems are needed, in order to have a diversity of species capable of producing different amounts of crop residues that by decomposing alter the physical attributes and consequently increasing the crop yield. Thus, the aim of this study was to assess the impact of ground cover species, management system and *crambe* cultivation on soil structure.

MATERIALS AND METHODS

The experiment was conducted at the Agronomic Institute of Paraná – IAPAR, at the Experimental Station of the municipality of Santa Tereza do Oeste - PR. presenting as geographical coordinates longitude W 53 35' 05.47'' and latitude S 25° 05' 00.29'' and altitude 756 m (Google Earth, 2015) (Figure 1). The climate according to Köppen classification (Cfa) is humid subtropical, with average annual rainfall of 1800-2000 mm (IAPAR, 2000). The soil is classified as Hapludox of clayed soil (29% sand, 11% silt and 60% clay) (EMBRAPA, 2013).

Before the experiment, soil samples were collected for the initial physical characterization, in the layers of 0.0-0.1, 0.1-0.2 and 0.2-0.3 m (Tables 2, 3 and 4) in year 2014. The chemical samples were collected in triplicates in layers of 0.00 to 0.20 m (Table 1). The experimental area is being cultivated in no-tillage system for 18

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Figure 1. Aerial image of the layout of the 15 plots.

Table 1. Result of chemical analysis for each experimental stand in the beginning of the assessment for the present study on layers from 0.00 to 0.20 m.

Experimental stand (treatment)	pH	C	P	K	Ca	Mg	Al	H+Al	*S	*T	*V	*Al
		g dm^{-3}	mg dm^{-3}	------------------ cmol$_c$ dm^{-3} ----------------							%	
1	4.83	21.29	17.66	0.47	4.95	2.40	0.11	7.69	7.82	15.51	49.71	2.17
2	4.83	25.71	26.70	0.43	5.45	2.60	0.49	8.50	8.48	16.98	49.88	10.32
3	5.03	22.68	19.12	0.48	5.47	2.67	0.37	7.34	8.62	15.96	53.05	7.96
4	4.88	23.20	16.33	0.47	4.83	2.56	0.18	7.52	7.86	15.37	50.46	3.42
5	4.86	23.37	17.16	0.43	5.04	2.23	0.07	7.60	7.70	15.30	49.98	1.40
6	4.79	24.49	25.62	0.41	4.67	2.21	0.18	8.25	7.29	15.53	46.12	3.67
7	5.01	21.47	4.69	0.29	4.82	2.16	0.08	6.27	7.28	13.53	52.86	2.10
8	4.87	21.64	24.61	0.42	3.92	2.37	0.43	7.67	6.71	14.38	45.50	11.59
9	4.57	22.68	29.26	0.45	3.46	1.91	0.48	8.80	5.82	14.61	38.25	14.85
10	4.52	24.07	11.64	0.33	3.04	1.66	0.58	9.42	5.03	14.45	35.01	16.03
11	4.71	20.26	11.53	0.30	3.74	1.88	0.26	7.60	5.92	13.52	42.73	7.45
12	4.54	26.75	19.10	0.34	4.27	2.39	0.44	9.99	7.00	16.99	40.80	8.05
13	4.62	26.23	10.48	0.36	4.07	2.29	0.39	9.31	6.72	16.03	40.50	10.47
14	4.68	24.59	13.61	0.33	4.32	1.96	0.30	8.80	6.61	15.42	42.03	7.42
15	4.35	23.98	15.00	0.26	2.87	1.21	0.73	10.41	4.34	14.74	28.80	18.87

C– Organic carbon - P – Available phosphorus - K – Exchangeable potassium - Ca – Calcium exchangeable - Mg – Magnesium exchangeable - Al – Exchangeable aluminum H+Al - Potential acidity - S* - Base sum - T* - Cations exchange capacity - V* - Base saturation - Al* - Aluminum saturation.

years. Prior to the experiment, the area had the following sequence of crops: corn/oats for hay (2011/2012 harvest), beans and soy/wheat and black oats (2012/2013 harvest), soybean (2013/2014 harvest).

The conduction of the experiment began in March 2014 with the implementation of six species of summer vegetation and six of winter, followed by soybean (2014/2015 harvest). The last application of liming in the area was held in 2011 with 3 ton ha^{-1} of limestone (PRNT 85%) (Souza et al., 2005).

The experimental area consisted of 15 plots, in a completely

Table 2. Average values of soil density (DS), total porosity (PT), microporosity (Micro), macroporosity (Macro) and hydraulic conductivity of saturated soil (Ksat) with the incorporation of summer plant cover crops and *crambe* culture and in three management systems, in the soil layer of 0-0.1m (average of four replications) in the initial characterization (2014) of soil and after handling of *crambe* (2015).

Soil management systems		DS (Mg m^{-3})		PT (%)		Micro (%)		Macro (%)		Ksat (mm h^{-1})	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
		Soil layer of 0.0 - 0.1 m									
Summer cover	PM	1.05^{Aa}	1.09^{Aa}	58.72^{Aa}	57.14^{Aa}	42.85^{Aa}	40.94^{Aab}	15.87^{Aa}	16.20^{Aa}	30.93^{Aa}	52.57^{A}b
	DPP	1.04^{Aa}	0.98^{Aa}	59.34^{Aa}	61.67^{Aa}	43.78^{Aa}	43.60^{Aab}	15.56^{Aa}	18.08^{Aa}	59.12^{Ba}	298.20^{Aa}
	SH	1.08^{Aa}	1.03^{Aa}	57.60^{Aa}	59.45^{Aa}	45.26^{Aa}	41.78^{Aab}	12.33^{Ba}	17.66^{Aa}	37.56^{Ba}	163.39^{Aab}
	PP	1.09^{Aa}	1.08^{Aa}	57.48^{Aa}	57.54^{Aa}	39.91^{Aa}	36.08^{Ab}	17.57^{Ba}	21.46^{Aa}	9.46^{Ba}	99.89^{Ab}
	R	1.07^{Aa}	1.02^{Aa}	58.15^{Aa}	59.76^{Aa}	41.10^{Aa}	42.84^{Aab}	17.05^{Aa}	16.92^{Aa}	27.14^{Aa}	20.25^{Ab}
	VB	1.07^{Aa}	1.10^{Aa}	58.07^{Aa}	56.91^{Aa}	42.89^{Aa}	42.87^{Aab}	15.19^{Aa}	14.04^{Aa}	14.98^{Aa}	37.09^{Ab}
Crambe culture	C1	1.00^{Aa}	1.09^{Aa}	60.98^{Aa}	57.35^{Aa}	44.00^{Aa}	39.15^{Aab}	16.98^{Aa}	18.20^{Aa}	73.86^{Aa}	68.76^{Ab}
	C2	1.09^{Aa}	1.08^{Aa}	57.57^{Aa}	57.64^{Aa}	43.43^{Aa}	38.64^{Aab}	14.14^{Ba}	18.99^{Aa}	38.91^{Aa}	23.14^{Ab}
	C3	0.92^{Ba}	1.07^{Aa}	64.17^{Aa}	57.84^{Ba}	46.16^{Aa}	40.78^{Bab}	18.01^{Aa}	17.06^{Aa}	89.43^{Aa}	40.80^{Ab}
	C4	1.11^{Aa}	1.06^{Aa}	56.45^{Aa}	58.37^{Aa}	42.36^{Aa}	41.51^{Aab}	14.09^{Aa}	16.86^{Aa}	4.52^{Aa}	37.15^{Ab}
	C5	1.02^{Aa}	0.98^{Aa}	60.06^{Aa}	61.50^{Aa}	42.52^{Aa}	45.38^{Aa}	17.54^{Aa}	16.12^{Aa}	37.92^{Aa}	90.21^{Ab}
	C6	1.05^{Aa}	1.10^{Aa}	59.03^{Aa}	56.66^{Aa}	45.66^{Aa}	41.66^{Aab}	13.37^{Aa}	14.99^{Aa}	24.06^{Aa}	40.44^{Ab}
	C7	1.06^{Aa}	1.07^{Aa}	58.73^{Aa}	58.13^{Aa}	41.46^{Aa}	41.85^{Aab}	17.27^{Aa}	16.29^{Aa}	62.91^{Aa}	82.27^{Ab}
	C8	0.98^{Aa}	1.01^{Aa}	61.50^{Aa}	60.31^{Aa}	45.27^{Aa}	42.72^{Aab}	16.23^{Aa}	17.59^{Aa}	61.78^{Aa}	22.36^{Ab}
	C9	0.99^{Ba}	1.14^{Aa}	61.20^{Aa}	55.25^{Ba}	42.39^{Aa}	40.96^{Aab}	18.82^{Aa}	14.29^{Ba}	56.28^{Aa}	13.70^{Ab}
General Av.		1.05		58.82		42.33		16.49		57.30	
DMS line		0.11		4.42		4.69		4.37		85.92	
DMS column		0.20		7.74		8.22		7.66		150.55	
CV (%)		7.65		5.36		7.91		18.91		106.94	

Averages followed by the same capital letters on the line and lower case in the column do not differ by Tukey test at 5% significance. PM = pearl millet; DPP = dwarf pigeon pea; SH = sunn hemp; PP = pigeon pea; R = rattlebox; VB = velvet bean; C1 = black oat; C2 = common Oat; C3 = Cereal Rye; C4 = black oat + cultivated radish; C5 = black oat + white lupine; C6 = black oat + garden pea; C7 = SNTS: Scarified no-tillage system; C8 = GNTS: Gypsum no-tillage system; C9 = NTTS: No-tillage traditional system (control).

randomized experimental design. In 12 plots were implanted plants cover crops (six of winter and six of summer) and in three plots with different management systems (gypsum no-tillage, scarified no-tillage and traditional no-tillage, the latter used as control). The plots cultivated with summer cover crops were pearl millet (PM), dwarf pigeon pea IAPAR 43-Aratã (DPP), sunn hemp (SH), pigeon pea (PP), rattlebox (R) and velvet bean (VB), and the other six species of winter vegetation cover were: white oat UPFA Gaudéria, black oat *Cabocla* IPR. cereal rye IPR 89, black oat + cultivated radish IPR 116 association, black oat + white lupine association and black oat + garden pea IAPAR 83 association (the choice was based on soil cover species with good root development, use by some producers and more adapted to the region). The gypsum no-tillage system consisted of an application of 3 t ha^{-1} of gypsum in the surface (the gypsum was applied to evaluate its effect on the root system of plants); the scarified no-tillage suffered a scarification up to 0.3 m deep. Each plot had an area of 500 m^2 (20 x 25 m), as shown in Figure 2. Before the implementation of species of vegetation cover, the area was dried out with application of glyphosate herbicide in the dosage of 3.5 L ha^{-1}.

The summer cover crops and *crambe* crop were deployed in March 31, 2015. The *crambe* was grown in 9 plots (consisting of 6 winter covers portions of the previous year and 3 with management systems). Summer covers were sown with pearl millet (15 kg ha^{-1}), sunn hemp (25 kg ha^{-1}), rattlebox (15 kg ha^{-1}), both with spacing of 0.17 m, dwarf pigeon pea (30 kg ha^{-1}), pigeon pea (50 kg ha^{-1}), with spacing of 0.34 m and velvet bean (70 kg ha^{-1}), with spacing of 0.45 m, using a New Holland tractor model TT3840 equipped with seeder with nine lines of Metasa Kuhn PDM PG 900 brand without fertilization. The plots with *crambe* were seeded with 12 kg ha^{-1} (FMS hybrid bright) using seeder-fertilizer with six lines of Metasa Kuhn brand with spacing of 0.34 m and seeding density of 40 seeds per meter without fertilization. The species desiccation of the summer cover crop occurred in flowering time with original roundup application (4 L ha^{-1}). Subsequently, Triton was used for plant residues to be evenly distributed in the area.

The mechanical handling system was conducted in the plot to 0.30 m deep at October 20, 2014 through scarification, using a New Holland tractor TL85 EXITUS model equipped with Kohler scarifier of five adjustable rods with 0.50 m spacing, cutting blade, depth limiter and harrowing roller.

Cultural practices for the control of weeds, pests and diseases were carried out in the experimental area according to technical recommendations for *crambe* culture using a tractor/hydraulic sprayer set with a capacity of 600 L and 14 m-spray bar in order not to have interference of the weed community on the *crambe* development and productivity. Historical data of rainfall and average temperature for the region of Santa Tereza do Oeste – PR, in addition to the monthly average rainfall, minimum, maximum and average temperature for the study period are presented in Figure 3.

Undisturbed soil samples were collected after the *crambe* management on October 08, 2015, to determine the physical attributes of the soil at depths of 0.0-0.1 0.1-0.2 and 0.2-0.3 m with the aid of steel rings with known volume and four replications in

Table 3. Average values of soil density (DS), total porosity (PT), microporosity (Micro), macroporosity (Macro) and hydraulic conductivity of saturated soil (Ksat) with the incorporation of summer plant cover crops and *crambe* culture and in three management systems, in the soil layer of 0.1-0.2m (average of four replications) in the initial characterization (2014) of soil and after handling of *crambe* (2015).

Soil management systems		DS (Mg m^{-3})		PT (%)		Micro (%)		Macro (%)		Ksat (mm h^{-1})	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
		Soil layer of 0.1 - 0.2 m									
Summer cover	PM	0.99^{Bb}	1.12^{Aa}	61.72^{Aa}	56.83^{Ba}	47.79^{Aa}	38.97^{Ba}	13.93^{Bb}	17.85^{Aa}	34.87^{Aab}	44.45^{Abcd}
	DPP	1.07^{Aab}	1.07^{Aa}	58.88^{Aab}	58.70^{Aa}	41.76^{Aab}	43.11^{Aa}	17.12^{Aab}	15.59^{Aa}	45.59^{Aab}	64.34^{Aabc}
	SH	1.06^{Aab}	1.09^{Aa}	59.10^{Aab}	57.89^{Aa}	41.70^{Aab}	41.78^{Aa}	17.40^{Aab}	16.10^{Aa}	62.43^{Aa}	40.90^{Abcd}
	PP	1.12^{Aab}	1.11^{Aa}	56.82^{Aab}	57.10^{Aa}	40.65^{Ab}	40.45^{Aa}	16.17^{Aab}	16.65^{Aa}	24.96^{Aab}	35.21^{Abcd}
	R	1.07^{Aab}	1.07^{Aa}	58.98^{Aab}	58.49^{Aa}	41.63^{Aab}	42.74^{Aa}	17.35^{Aab}	15.75^{Aa}	33.66^{Aab}	41.33^{Abcd}
	VB	1.04^{Aab}	1.06^{Aa}	59.77^{Aab}	59.17^{Aa}	45.15^{Aab}	44.10^{Aa}	14.62^{Ab}	15.06^{Aa}	21.49^{Bab}	70.95^{Aab}
***Crambe* culture**	C1	1.09^{Aab}	1.12^{Aa}	58.01^{Aab}	56.61^{Aa}	39.65^{Ab}	39.05^{Aa}	18.35^{Aab}	17.57^{Aa}	40.63^{Aab}	40.21^{Abcd}
	C2	1.07^{Aab}	1.11^{Aa}	58.90^{Aab}	57.02^{Aa}	41.37^{Aab}	39.49^{Aa}	17.52^{Aab}	17.53^{Aa}	37.29^{Aab}	20.02^{Ad}
	C3	1.09^{Aab}	1.16^{Aa}	57.97^{Aab}	55.06^{Aa}	40.53^{Ab}	38.70^{Aa}	17.44^{Aab}	16.36^{Aa}	60.39^{Aa}	19.12^{Bd}
	C4	1.09^{Aab}	1.11^{Aa}	58.03^{Aab}	56.92^{Aa}	40.41^{Ab}	41.21^{Aa}	17.62^{Aab}	15.71^{Aa}	16.13^{Ab}	22.83^{Acd}
	C5	1.09^{Aab}	1.05^{Aa}	58.17^{Aab}	59.19^{Aa}	39.78^{Ab}	42.01^{Aa}	18.38^{Aab}	17.18^{Aa}	22.99^{Bab}	53.94^{Aabcd}
	C6	1.10^{Aab}	1.05^{Aa}	57.73^{Aab}	59.41^{Aa}	40.94^{Aab}	41.01^{Aa}	16.78^{Aab}	18.40^{Aa}	13.03^{Ab}	35.75^{Abcd}
	C7	1.16^{Aa}	1.15^{Aa}	55.48^{Ab}	55.66^{Aa}	40.38^{Ab}	39.40^{Aa}	15.11^{Aab}	16.27^{Aa}	33.22^{Aab}	42.81^{Abcd}
	C8	1.01^{Ab}	1.03^{Aa}	61.01^{Aa}	60.19^{Aa}	45.25^{Aab}	45.18^{Aa}	15.75^{Aab}	15.01^{Aa}	35.51^{Bab}	74.13^{Aab}
	C9	1.08^{Aab}	1.06^{Aa}	58.45^{Aab}	58.94^{Aa}	38.50^{Ab}	40.90^{Aa}	19.95^{Aa}	18.05^{Aa}	49.95^{Bab}	96.81^{Aa}
General Av.		1.08		58.21		41.45		16.75		41.16	
DMS line		0.08		3.04		4.06		2.93		24.51	
DMS column		0.03		5.33		7.11		5.14		42.95	
CV (%)		5.16		3.73		6.98		12.49		42.48	

Averages followed by the same capital letters on the line and lower case in the column do not differ by Tukey test at 5% significance. PM = pearl millet; DPP = dwarf pigeon pea; SH = sunn hemp; PP = pigeon pea; R = rattlebox; VB = velvet bean; C1 = black oat; C2 = common Oat; C3 = Cereal Rye; C4 = black oat + cultivated radish; C5 = black oat + white lupine; C6 = black oat + garden pea; C7 = SNTS: Scarified no-tillage system; C8 = GNTS: Gypsum no-tillage system; C9 = NTTS: No-tillage traditional system (control).

each layer. It was determined, the density of the soil (DS) by the volumetric ring method; total porosity (PT) by the percentage of soil water saturation; microporosity (Micro) (EMBRAPA, 1997), macroporosity (Macro) by sand column (Reinert and Reichert, 2006) and hydraulic conductivity of saturated soil (Ksat) (EMBRAPA, 1997).

Statistical analysis was performed for data collection using System for Analysis of Variance – SISVAR ® (Ferreira, 2010) software. Average variables were compared by Tukey test at 5% probability.

RESULTS AND DISCUSSION

Tables 2, 3 and 4 shows the values of soil density (Mg m^{-3}), total porosity (%), microporosity (%), macroporosity (%) and hydraulic conductivity of saturated soil (mm h^{-1}) in the treatments of summer plant cover crop and the *crambe* culture and in the management systems: SNTS: No-tillage system with soil scarification; GNTS: No-tillage system with application of 3 t ha^{-1} gypsum; NTTS: No-tillage traditional system (control) in the initial characterization (2014) of soil and after handling of *crambe* (2015) in soil layer of 0.0-0.1;

Table 4. Average values of soil density (DS), total porosity (PT), microporosity (Micro), macroporosity (Macro) and hydraulic conductivity of saturated soil (Ksat) with the incorporation of summer plant cover crops and *crambe* culture and in three management systems, in the soil layer of 0.2-0.3 m (average of four replications) in the initial characterization (2014) of soil and after handling of *crambe* (2015).

Soil management systems		DS (Mg m^{-3})		PT (%)		Micro (%)		Macro (%)		Ksat (mm h^{-1})	
		2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
		Soil layer of 0.2 -0.3 m									
Summer cover	PM	0.99^{Aa}	1.05^{Aa}	62.21^{Aa}	60.23^{Aa}	46.80^{Aab}	45.25^{Aa}	15.41^{Aab}	14.98^{Aa}	41.27^{Aab}	26.86^{Ac}
	DPP	1.11^{Aa}	1.08^{Aa}	57.55^{Aa}	58.96^{Aa}	42.13^{Aab}	40.87^{Aa}	15.42^{Aab}	18.09^{Aa}	31.00^{Bab}	58.84^{Aabc}
	SH	1.12^{Aa}	1.08^{Aa}	57.18^{Aa}	58.85^{Aa}	43.42^{Aab}	43.62^{Aa}	13.76^{Aab}	15.22^{Aa}	51.27^{Bab}	79.32^{Aa}
	PP	1.01^{Aa}	1.09^{Aa}	61.28^{Aa}	58.70^{Aa}	46.15^{Aab}	45.14^{Aa}	15.13^{Aab}	13.57^{Aa}	35.88^{Aab}	18.37^{Ac}
	R	1.08^{Aa}	1.11^{Aa}	58.80^{Aa}	57.81^{Aa}	39.48^{Ab}	41.43^{Aa}	19.32^{Aa}	16.38^{Aa}	31.31^{Aab}	29.12^{Abc}
	VB	0.97^{Aa}	0.99^{Aa}	62.77^{Aa}	62.38^{Aa}	47.07^{Aab}	46.26^{Aa}	15.70^{Aab}	16.12^{Aa}	39.56^{Bab}	74.93^{Aab}
Crambe culture	C1	1.10^{Aa}	1.06^{Aa}	57.89^{Aa}	59.86^{Aa}	40.64^{Aab}	42.85^{Aa}	17.25^{Aab}	17.01^{Aa}	11.63^{Bb}	58.08^{Aabc}
	C2	1.08^{Aa}	1.07^{Aa}	58.83^{Aa}	59.38^{Aa}	45.48^{Aab}	44.06^{Aa}	13.35^{Ab}	15.31^{Aa}	18.86^{Aab}	27.68^{Abc}
	C3	1.09^{Aa}	1.13^{Aa}	58.42^{Aa}	57.17^{Aa}	39.60^{Ab}	40.43^{Aa}	18.82^{Aab}	16.74^{Aa}	55.26^{Aab}	23.26^{Bc}
	C4	1.11^{Aa}	1.11^{Aa}	57.39^{Aa}	57.72^{Aa}	39.74^{Ab}	41.49^{Aa}	17.64^{Aab}	16.23^{Aa}	29.72^{Aab}	24.78^{Ac}
	C5	1.02^{Aa}	1.01^{Aa}	61.24^{Aa}	61.70^{Aa}	45.57^{Aab}	45.19^{Aa}	15.68^{Aab}	16.50^{Aa}	36.44^{Aab}	57.94^{Aabc}
	C6	1.09^{Aa}	1.10^{Aa}	58.48^{Aa}	58.33^{Aa}	41.90^{Aab}	43.63^{Aa}	16.59^{Aab}	14.70^{Aa}	17.93^{Aab}	23.57^{Ac}
	C7	1.00^{Aa}	1.10^{Aa}	61.64^{Aa}	58.26^{Aa}	46.66^{Aab}	42.43^{Aa}	14.97^{Aab}	15.83^{Aa}	59.78^{Aa}	54.86^{Aabc}
	C8	0.94^{Aa}	0.98^{Aa}	63.85^{Aa}	62.70^{Aa}	49.68^{Aa}	48.27^{Aa}	14.16^{Aab}	14.43^{Aa}	45.10^{Bab}	86.08^{Aa}
	C9	1.05^{Aa}	1.06^{Aa}	59.83^{Aa}	59.90^{Aa}	43.24^{Aab}	43.45^{Aa}	16.59^{Aab}	16.45^{Aa}	39.48^{Aab}	62.59^{Aabc}
General Av.		1.06		59.64		43.73		15.91		41.09	
DMS line		0.11		4.11		5.45		3.38		27.04	
DMS column		0.19		7.21		9.55		5.93		47.37	
CV (%)		7.33		4.92		8.89		15.17		46.93	

Averages followed by the same capital letters on the line and lower case in the column do not differ by Tukey test at 5% significance. PM = pearl millet; DPP = dwarf pigeon pea; SH = sunn hemp; PP = pigeon pea; R = rattlebox; VB = velvet bean; C1 = black oat; C2 = common Oat; C3 = Cereal Rye; C4 = black oat + cultivated radish; C5 = black oat + white lupine; C6 = black oat + garden pea; C7 = SNTS: Scarified no-tillage system; C8 = GNTS: Gypsum no-tillage system; C9 = NTTS: No-tillage traditional system (control).

0.01-0.02 and 0.02-0.03 m, respectively.

There was a significant interaction between the periods (results obtained in the initial soil characterization and after management of *crambe*) and management systems at the surface layer of 0.0-0.1 m (Table 2), for all physical parameters evaluated, and in the culture *crambe* the differences were more significant. Between periods, the lowest soil density (DS) and bigger porosity (PT) occurred to *crambe* C3 (0.92 Mg m^{-3}; 64.17%) and C9-NTTS (0.99 Mg m^{-3}; 61.2%), respectively in the period of 2014. For this same soil layer, there was significant difference between the coverage in the 2014 period, for the DS and PT.

In 2015, the average values of DS (1.07 and 1.14 Mg m^{-3} for *crambe* C3 and C9-NTTS) were higher than the previous year. In the same period, there was no difference for the DS, PT and Macro between the vegetation cover. The other parameters (Micro and Ksat) were significant. Any significant differences were merely random. Regardless of soil density, the presence of biopores, soil structure faults, and capillary discontinuity provided by the sample are sufficient

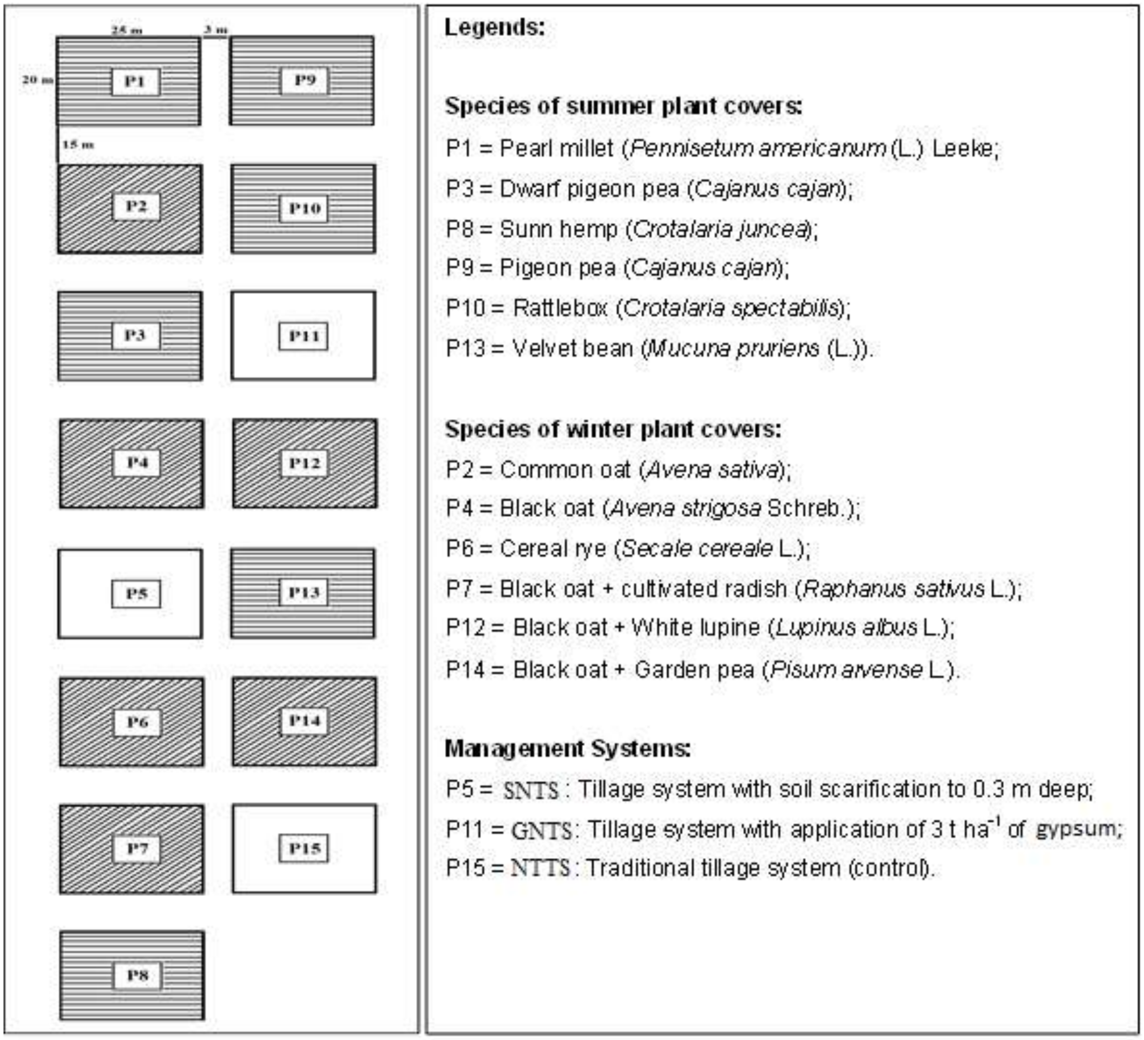

Figure 2. Sketch of the plots, with soil cover crops (summer and winter) and three management systems.

parameters to alter the values.

In the period of 2015, significant differences between treatments occurred for microporosity (0.0-0.1 m soil layer) and Ksat (all soil layers). Regarding micro volumes, difference occurred among the periods observed for *crambe* C3 (40.78%), with lower values in 2015. Among the coverings, higher percentages were observed for crambe C5 (45.38%) and smaller for pigeon pea coverage (PP - 36.08%) did not differ from the others, in 2015.

Significant differences occurred between the periods for Macro and Ksat. For Ksat, differences occurred between vegetable toppings. Between periods, larger macro percentages were checked for the covers of sunn hemp (SH - 17.66%), pigeon pea (PP - 21.46%) and crambe C2 (18.99%), and as minors to the crambe C9-NTTS (14.29%) in 2015. Although on the present study the macro values (18.08%) for the dwarf pigeon pea (DPP) did not presented significant difference among the periods, Argenton et al. (2005) on corn + gray velvet bean covers in reduced no-tillage in the layer of 0.05-0.1 m, the values were 49 mm h^{-1}.

As in the subsurface layer of 0.1-0.2 m, Table 3 showed significant differences among the periods for all soil physical parameters, especially the PM coverage, velvet bean (VB), *crambe* C3, C5, C8-GNTS and C9-NTTS. In the 2014 period, there was a lower DS (0.99 Mg m^{-3}) and an increased PT (61.72%) and Micro (47.79%), while the Macro (17.85%) was higher in 2015. For Ksat, the difference among the periods occurs for the VB (70.95 mm h^{-1}), *crambe* C5 (53.94 mm h^{-1}), *crambe* C8-GNTS (74.13 mm h^{-1}) and *crambe* C9-NTTS (96.81 mm h^{-1}), with the largest value in 2015. The exception occurred for *crambe* C3 (19.12 mm h^{-1}) which presented the lowest value. Among the covers in the 2014 period, Micro was higher in the PM coverage (47.79%) and lowest was the *crambe* C9-NTTS (38.50%), C1 (39.65%), C5 (39.78%), C7-SNTS (40.38%), C4 (40.41%), C3 (40.53%) and PP (40.65%). In this same period, the values of macro were higher in *crambe* C9-NTTS

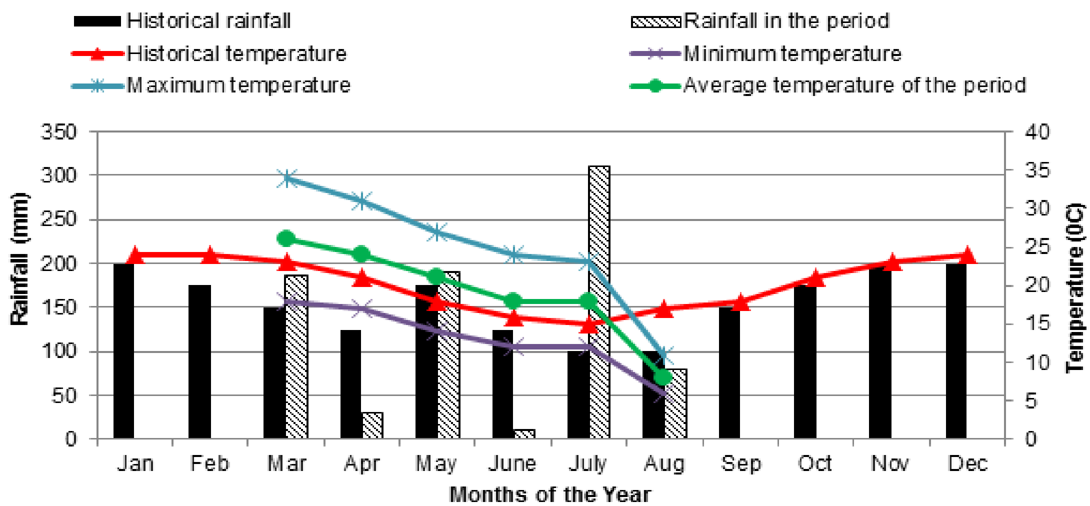

Figure 3. Monthly average rainfall and average temperature for the period of 26 years (historical average), obtained from the Meteorological Station of the Agronomic Institute of Paraná – IAPAR, Experimental Station of Santa Tereza do Oeste - PR. Minimum, maximum and average temperature from March/2015 to August/2015.

(19.95%) and lower in PM coverage (13.93%) and VB (14.62%).

In the soil layer of 0.2-0.3 m (Table 4), there was a significant difference between the coverages for micro, macro and Ksat in 2014. The highest values were for *crambe* C8-GNTS (49.68%) and lower for coverage CS (39.48%), *crambe* C3 (39.60%) and C4 (39.74%). The micro presented the highest values for the CS coverage (19.325%) and the lowest values for the *crambe* C2 (13.35%). The highest Ksat was observed for *crambe* C7-SNTS (59.78 mm h^{-1}) and the lowest for C1 (11.63 mm h^{-1}).

Significant differences occurred between the periods for Macro and Ksat. For Ksat, differences occurred between vegetable toppings. Between periods, larger macro percentages were checked for the covers of sunn hemp (SH - 17.66%), pigeon pea (PP - 21.46%) and *crambe* C2 (18.99%), and as minors to the *crambe* C9-NTTS (14.29%) in 2015. Although, in the present study, the macro values (18.08%) for the dwarf pigeon macro and Ksat in 2014. The highest values were for *crambe* C8-GNTS (49.68%) and lower for coverage CS (39.48%), *crambe* C3 (39.60%) and C4 (39.74%). The micro presented the highest values for the CS coverage (19.325%) and the lowest values for the *crambe* C2 (13.35%). The highest Ksat was observed for *crambe* C7-SNTS (59.78 mm h^{-1}) and the lowest for C1 (11.63 mm h^{-1}).

The results in Table 1 indicate that from 0.1 m depth, there was no difference among the DS values, PT, Micro, and Macro and between management systems, that is, the effects of the treatments were restricted to the first 0 1 m deep, with the exception of *crambe* C9-NTTS (96.81 mm h^{-1}) in the layer of 0.1-0.2 m and C8-GNTS (86.08 mm h^{-1}) and SH (79.32 mm h^{-1}) in the soil layer of 0.2-0.3 m, in 2015.

A possible explanation for these results may be due to atypical climatic factors that occurred during the *crambe* cycle, showing that it could express all its genetic potential as structural soil culture. The accumulated rainfall rates were 546 mm (Figure 2), which are distributed to the full flowering with 223 mm, followed by a low rainfall (12 mm) until the beginning of maturation and excessive rainfall (311 mm) at the end of maturation, exceeding the historical average. According to Pitol (2008), the water requirement of the *crambe* crop is 150 to 200 mm until full bloom. The authors did not report that higher rates could damage the crop, but after flowering there was little rain and rainfall above 20 mm near the harvest. According to Roscoe et al. (2010), the ideal is the absence of rains near the harvest, being tolerable rains smaller than 20 mm. According to SIMEPAR (2016), in the first half of July 2015, there was a high precipitation accumulation, exceeding the average of the region. The rains were incessant and intense, accompanied by a high incidence of lightning, wind gusts of moderate to strong and hail. While in the second half, the lowest temperatures of the year were recorded with low intensity of frost formation. While the mean temperature for the post-emergence period of *crambe* ranged from 8 to 26°C. According to Roscoe et al. (2010), *crambe* presents a good productive performance at 25°C. However, Falasca et al. (2010) and Knights (2002) reported that for the vegetative phase, the best temperature is between 15 and 25°C.

Conclusion

In the period of 2015, the significant differences between treatments occurred for microporosity (0.0-0.1 m layer) and Ksat (all soil layers). Microporosity was lower in the pigeon pea coverage (PP) (36.08%), while the largest occurred in the coverage of *crambe* C5 (45.38%). The Ksat was higher in the dwarf pigeon pea (DPP) (298.20 mm h^{-1}) and sunn hemp (SH) (163.39 mm h^{-1}) coverage in the 0.0-0.1 m layer.

The highest Ksat was observed for *crambe* C9-NTTS (96.81 mm h^{-1}), C8-GNTS (74.13 mm h^{-1}), velvet bean (VB) (70.95 mm h^{-1}) and C5 (53.94 mm h^{-1}), respectively, in the soil layer of 0.1-0.2 m.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Diversity and infestation indices of fruit flies (Diptera: Tephritidae) in guava (*Psidium guajava* L.)

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The fruit flies are considered major pests in the world fruit production due to the direct damage they cause to fruits and the ability to adapt to areas where they are introduced. The objective of this research was to study the fruit fly diversity, the infestation indices in fruits and to characterize the tephritids community in a guava (*Psidium guaja*va L.) cultivar "Paluma", in a commercial orchard located in São Luís, state of Maranhão, northeastern Brazil. In the survey, fly hunting bottles containing hydrolyzed protein in a ratio of 500 ml/10 L of water were used. To assess the infestation indices, fruits were collected, individualized in plastic containers with sterile sand, and kept in a climate-controlled chamber. 2,901 specimens of fruit flies were collected. From these, 2,328 were collected in traps and 573 in fruit samples. The species found belong to the genus *Anastrepha,* including *Anastrepha striata, Anastrepha obliqua, Anastrepha fraterculus, Anastrepha sororcula, Anastrepha distincta*, *Anastrepha zenildae* and *Anastrepha pickeli*. Considering the total tephritids collected in fruits and traps, a low diversity (H' = 0.2689 and 0.4147, respectively) was found. *A. striata* predominated among the collected species. The largest number of insect pests captured occurred in May 2008, a period of increased guava fruit availability in the orchard. The infestation indices were 231.02 pupae/kg and 26.42 pupae/fruit.

Key words: Tephritids, Myrtaceae, population dynamics, ecology.

INTRODUCTION

Fruit production in Brazil has grown significantly and the country holds a prominent position in the international market by increasing the position of fruit growing in the national economy. Brazil is the third largest fruit producer

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in the world and is a leading producer of tropical fruits (FAOSTAT, 2013).

The marketing of fresh fruit in the world is severely limited by the occurrence of fruit fly (Diptera: Tephritidae), which is considered as one of the main pests of the world fruit production, due to the direct damage they cause and the ability to adapt in other areas, where introduced (Godoy et al., 2011). Yield losses due to fruit damages caused by fruit flies is associated with high control costs, and affect international trade relations due to phytosanitary restrictions that are imposed (Godoy et al., 2011). The tephritids economic importance is due to the yield losses they cause in world fruit production, since they feed on fruits from several species. Moreover, they are quarantine pests (Araujo et al., 2013).

Guava (*Psidium guajava* L., Myrtaceae) is one of the most attacked fruits in Brazil by the fruit fly species *Anastrepha* spp. and *Ceratitis capitata* (Wied).

The population of fruit flies fluctuates due to a succession of primary or alternate hosts, the environment complexity and abiotic factors (Montes et al., 2011). The average temperature (°C) inversely influences the fruit fly occurrence, for example, lower temperatures favor an increase in the Tephritidae population (Araujo et al., 2008). With a population monitoring study, it is possible to follow the pest fluctuation in a specific area, to detect exotic or quarantine species, allowing for a more comprehensive characterization of the insect pest population in qualitative and quantitative terms.

Knowledge of fruit fly species of economic importance in a particular area, can only be obtained based on intensive surveys, made directly from host fruit, which enables detection of larvae present in the fruit, the degree of infestation in an orchard and the direct damage caused by the flies. Therefore, there is a need to determine the guava fruit infestation indices and to identify the fruit fly species that occur in the state of Maranhão, northeastern Brazil, in order develop low environmental impact strategies to control this insect. Thus, the aim of this work was to study diversity, the fruit infestation rates and to characterize the tephritid community in a commercial orchard of guava by faunal analysis.

MATERIALS AND METHODS

The research was conducted in a guava cultivar "Paluma", commercial orchard located in Vila Maracanã district, in the São Luís island (02°31'47'' S and 44°18'10'' W), state of Maranhão, northeastern Brazil.

The orchard was eight years old and was composed of 1,200 plants. The guava plant spacing was 6 × 5 m. The soil is from Itapecuru formation, classified as Latossol. The orchard was sprinkler irrigated with 6 mm water per plant every three days during the dry season.

Fourteen MacPhail model traps with attractive food (5% corn hydrolyzed protein, stabilized with borax), were installed under the tree canopies with 1.5 m height from the ground. Samples were collected every two weeks from February 2008 to January 2009. The captured insects were water sieved, separated by sex, counted and stored in bottles containing 70% alcohol solution for taxonomic identification, which was done based on the terminalia of female specimens, observing the aculeus. They were identified using a key from Zucchi (2000).

Mature fruits were collected at random on the top and from the ground under the trees to check the infestation rates. The fruits were weighed on a precision electronic scale in laboratory conditions and individually packaged in plastic containers with a thin layer of sterile sand (1.5 to 2.0 cm in height) on the bottom, to allow larvae to become pupae. These containers were covered and kept in a climate chamber of BOD type with temperature 25 ± 2°C and relative humidity 70 ± 10%, with photoperiod of 12 h and inspected every 48 h.

After 10 to 15 days, the substrate was sieved (1.5 mm mesh size) and the obtained pupae were counted and wrapped in transparent plastic containers with 6.5 cm in height and 4.5 cm in diameter, provided with a plastic cover pressure, for adult emergence observation. Thereafter, the adults were preserved in 70% alcohol solution for further identification.

Two parameters were used to obtain the infestation indices. The first was the number of pupae per fruit (pupae/fruit) and the second, the number of pupae per kg of fresh fruit (pupae/kg) (Araujo and Zucchi, 2003). Each infestation index refers to the average value obtained for the samples of infested host species. The maximum and minimum values indicate the indices variation according to the place of collection and the number of samples examined.

The fruit fly species faunal analyses was done by means of the software ANAFAU (Moraes et al., 2003). The tephritid community was characterized by the indices of frequency, constancy, richness, dominance and predominant species. The indices of evenness and the Shannon-Weaner diversity were also computed. The definition of extreme classes (super) was based on the class hierarchical classification (Silveira Neto et al., 1976).

RESULTS AND DISCUSSION

Considering all collections, a total of 2,901 specimens of fruit flies were obtained. All species belonged to the genus *Anastrepha,* including *Anastrepha striata* (Schiner, 1978), *Anastrepha obliqua* (Macquart, 1835), *Anastrepha fraterculus* (Wiedmann, 1980), *Anastrepha sororcula* (Zucchi, 1979), *Anastrepha distincta* (Greene, 1934), *Anastrepha zenildae* (Zucchi, 1979) and *Anastrepha pickeli* (Lima, 1934). From this total, 2,328 specimens were collected in the traps and 573 were obtained from the fruits. The mean pupal viability was 42.85% for the entire study period (Tables 1 and 2).

A total of 273 female flies were identified in the guava fruits. *A. striata* was the major species reaching 94.5% of the total (Table 3). The presence of *A. striata* in this orchard suggests that there was a spread of this insect pest, since this species is more common in the north region of the country (Zucchi et al., 2011). *A. striata* was also the major species found in the traps, reaching 90.8%

Table 1. *Anastrepha* spp. (Diptera: Tephritidae) collected in a commercial orchard of guava cv. Paluma in São Luis, state of Maranhão, northeastern Brazil.

Species	Number of adult tephritids		
	Collected in traps	Collected in fruits	Total
Anastrepha striata	1,671	550	2,221
Anastrepha obliqua	526	11	537
Anastrepha fraterculus	78	04	82
Anastrepha sororcula	22	06	28
Anastrepha distincta	17	00	17
Anastrepha zenildae	12	02	14
Anastrepha pickeli	02	00	02
Total	2,328	573	2,901

Table 2. Number of pupae and adults of *Anastrepha* spp. (Diptera: Tephritidae) obtained in fruits of guava cv. Paluma in São Luis, state of Maranhão, northeastern Brazil.

Period	Number of pupae	Number of adults	Pupae viability (%)
February/08	9	5	55.55
March/08	30	16	53.33
April/08	132	49	37.12
May/08	250	97	38.80
June/08	73	29	39.72
July/08	107	37	34.57
August/08	370	169	45.67
September/08	151	60	39.73
October/08	126	61	48.41
November/08	14	08	57.14
December/08	47	26	55.31
January/09	28	16	57.14
Total	1,337	573	42.85

Table 3. Number of females of *Anastrepha* spp. (Diptera: Tephritidae) collected in a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

***Anastrepha* spp.**	Collected in fruits		Collected in traps	
	No.	%	No.	%
A. striata	258	94.5	1,145	90.8
A. obliqua	09	3.3	59	4.7
A. sororcula	04	1.5	18	1.4
A. fraterculus	01	0.4	34	2.7
A. distincta	-	-	03	0.2
A. zenildae	01	0.4	01	0.1
A. pickeli	-	-	01	0.1
Total	273	100	1,261	100

of the total (Table 3). Some fruit fly species associated with their hosts have been recorded in the state of Maranhao including *A. obliqua* in starfruit (*Averrhoa carambola* L.), *A. striata* in both guava and hog plum

Table 4. Faunal analysis of the *Anastrepha* spp. (Diptera: Tephritidae) collected in fruits in a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Species	Number of Individuals	Number of Collections	Domin[1]	Abund[2]	Freq[3]	Const[4]
A. striata	258	12	D	va	VF	W
A. obliqua	09	03	ND	va	F	Y
A. sororcula	04	02	ND	va	F	Z
A. fraterculus	01	01	ND	va	F	Z
A. zenildae	01	01	ND	va	F	Z

Shannon-Weaner diversity index = H' = 0.2689; Variance H = V(H)= 0.0030; confidence interval (P=0.005) H = [0.262293; 0.275450]; [1]Dominance: SD = super dominant; D = dominant; ND = non dominant; [2]Abundance: va = very abundant; a = abundant; c = common; d = disperse; [3]Frequency: VF = very frequent; F = frequent; [4]Constancy: W = constant; Y = accessory; Z = accidental.

Table 5. Faunal analysis of A*nastrepha* spp. (Diptera: Tephritidae) collected in traps in a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Species	Number of Individuals	Number of collections	Domin[1]	Abund[2]	Freq[3]	Const[4]
A. striata	1.145	12	SD	AS	VF	W
A. obliqua	59	04	D	VA	F	Y
A. sororcula	18	03	ND	C	F	Y
A. fraterculus	34	04	ND	C	F	Y
A. distincta	03	01	ND	C	F	Z
A. zenildae	01	01	ND	C	F	Z
A. pickeli	01	01	ND	C	F	Z

Shannon-Weaner Diversity Index = H = 0.4147; Variance H = V(H) = 0.0008; Confidence interval (P=0.005) H = [0.413043; 0.416298]; [1]Dominance: SD = super dominant; D = dominant; ND = non-dominant; [2]Abundance: SA = super abundant; VA = very abundant; A = abundant; C = common D = disperse; [3]Frequency: VF = Very frequent; F = frequent; [4]Constancy: W = constant; Y = accessory; Z = accidental.

(*Spondias purpurea* L.) in the municipality of Caxias and *A. zenildae* in guava (Oliveira et al., 2000) in the municipality of Santa Inês. Lemos et al. (2002), also found the predominance of *A. striata* in guava in the municipality of Itapecuru Mirim.

Azevedo et al. (2010) and Santos et al. (2011), studying the main hosts of *Anastrepha* spp. found that *A. fraterculus, A. sororcula*, *A. striata* and *A. zenildae* focus on Myrtaceae, which has wide geographic distribution across the continent. This finding was possible due to to the fruit fly surveys carried out in the Cariri region, state of Ceará and the extreme south of the state of Bahia, respectively, both in the northeastern Brazil.

Azevedo et al. (2010), found four *Anastrepha* spp. including *A. zenildae*, *A. sororcula*, *A. fraterculus*, *A. obliqua* and *Ceratitis capitata* associated with guava in the Cariri region, state of Ceará. Duarte et al. (2013) noted greater diversity of *Anastrepha* spp. in guava fruits in the state of São Paulo, southeast Brazil. Lima et al. (2012) observed that *A. striata* and *A. obliqua* predominated among the four species observed in mango orchards (*Mangifera indica* L.), in Boa Vista, state of Roraima, northern Brazil.

Among the species collected in traps, there was the species *A. pickeli*, not yet recorded in the state of Maranhao. Araujo et al. (2009) recorded *A. pickeli* for the first time in the municipality of Mossoró, state of Rio Grande do Norte. Azevedo et al. (2010) also found *A. pickeli* in a study carried out in Cariri, state of Ceará, both states are located in northeastern Brazil.

Considering the total number of tephritids collected in fruits and traps, a low diversity (H' = 0.2689 and 0.4147, respectively) was found. The faunal analysis indicated that *A. striata* predominated among the species collected in fruits (Table 4) and traps (Table 5). Marsaro Junior et al. (2013) noted that *A. striata, A. sororcula A. obliqua* and *A. fraterculus* were the most frequent and predominant species found in a guava orchard in Boa Vista, state of Roraima, northern Brazil. These fruit fly species are reported as major insect pests of guava.

A. obliqua stood out as the dominant, very abundant and very common species whereas the others were only considered as frequent. Similarly, Oliveira et al. (2009) found that *A. obliqua* reached a very frequent rate in mango orchard in the coast of the state of Ceará. However, Zilli and Garcia (2010) and Alberti et al. (2012)

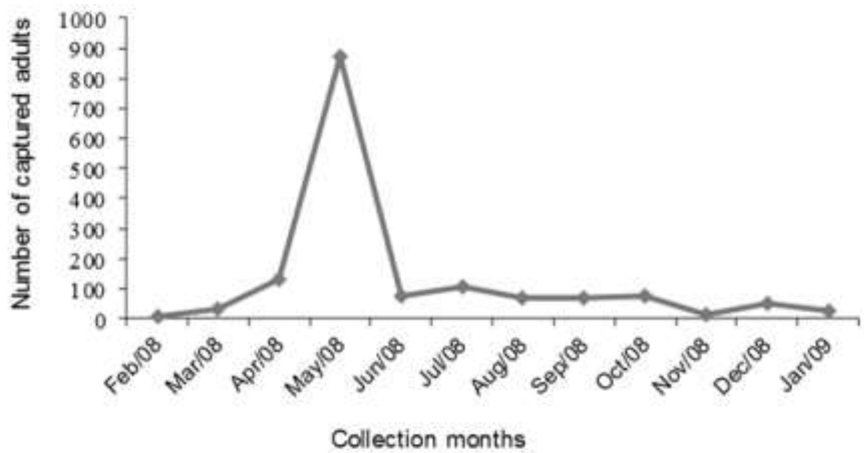

Figure 1. *Anastrepha* spp. (Diptera: Tephritidae) population fluctuation captured in traps in a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Table 6. *Anastrepha* spp. (Diptera: Tephritidae) indices from a guava cv. Paluma commercial orchard in São Luis, state of Maranhão, northeastern Brazil.

Period	Number of fruit samples	Average fruit mass (kg)	Average fruit weight (g)	Number of pupae	Pupae/kg	Pupae/fruit
February/08	12	2.0	0.164	09	4.5	0.75
March/08	24	3.9	0.160	30	7.7	1.25
April/08	20	2.9	0.144	132	45.5	6.60
May/08	42	6.1	0.144	250	40.9	5.95
June/08	28	3.7	0.133	73	19.7	2.60
July/08	28	4.3	0.153	107	24.8	3.82
August/08	14	1.6	0.113	370	231.2	26.42
September/08	16	1.2	0.072	151	125.8	9.43
October/08	30	2.8	0.093	126	45.0	42.0
November/08	30	4.2	0.140	14	3.3	0.46
December/08	40	4.9	0.123	47	9.5	1.17
January/09	20	3.1	0.155	28	9.0	1.40

noted *A. obliqua* as uncommon in orange orchard (*Citrus sinensis* Pers.) in Chapecó and Iraceminha municipalities both located in the state of Santa Catarina, southern Brazil.

With regards to the *Anastrepha* spp. population fluctuation, there was a higher incidence of flies captured in May 2008, when fruits were found in abundance in the orchard (Figure 1). These results are similar to those reported by Araujo et al. (2008), Alberti et al. (2012), Santos et al. (2013) and Duarte at al. (2013) who explained that a high incidence of fruit flies can be related to the greater presence of fruit in the orchard.

A total of 304 guava fruit samples were obtained from February 2008 to January 2009. The average fruit weight varied from 0.072 to 0.165 kg. The average number of pupae obtained from these fruits varied from 9 to 370 individuals (Table 6). Infestation rates for guava commercial orchard in São Luis, state of Maranhão, northeastern Brazil, was higher in August and September 2008, reaching 231.2 pupae/kg and 26.42 pupae/fruit; and 125.8 pupae/kg and 9.43 pupae/fruit, respectively.

Several factors may influence the fruit fly infestation indices in orchards. Azevedo et al. (2010) studying commercial orchards in the Cariri region noted that these tephritids population fluctuation is directly related to the availability of host fruits and the amount of rainfall in the region. In commercial orchards dominated by a single host, the largest population peak occurs at the time of greater availability of ripe fruits (Azevedo et al., 2012).

Conclusions

The *Anastrepha* spp. recorded in association with guava in the commercial orchard were *A. striata*, *A. obliqua*, *A. fraterculus*, *A. sororcula*, *A. distincta*, *A. pickeli* and *A. zenildae*. *A. pickeli* was recorded for the first time in the state of Maranhao. *A. striata* was the most frequent, dominant and constant species in the guava commercial orchard. The largest number of captured insects occurred in May 2008, a period of increased availability of fruits in the orchard. The highest *Anastrepha* spp. infestation index in guava fruits was recorded in August 2008.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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Full Length Research Paper

An analysis of determinants of access to and use of credit by smallholder farmers in Suakoko District, Liberia

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Agricultural credit has been argued to be very important for sustainable agricultural development and poverty reduction in rural areas. This study seeks to identify and to analyze the determinants of smallholder farmers' access to and use of credit in Suakoko district, Bong County, Liberia. This research is quantitative using a survey questionnaire distributed to 105 smallholder farmers. Data was analyzed using descriptive statistics and causal analysis was performed using a binary Logit regression model. Results from regression indicate that 39% of the farmers were credit users. The marginal effects of bank account and other sources of income show significant and positive effects on access to credit. However, education, occupation and group membership are significant but have negative effects on access to credit by smallholder farmers. The results also show that 38% of credit users applied credit received for agricultural activities, while the rest utilized it for non-agricultural activities. It is recommended that a policy should be established to ensure older farmers gets adult literacy while younger farmers get formal education. Moreover, the government should issue a policy aimed at increasing opportunities for off-farm activities through creation of jobs and motivating self-employment. Finally, the government should promote the creation of development groups geared towards providing collateral support for members and also serve as guarantors for farmers to receive banks credit/loans in order to increase agricultural productivity in the study area.

Key words: Credit access, rural, farmers, smallholder, Suakoko district, Liberia.

INTRODUCTION

Agriculture is critical for global economic growth and it accounted for one third of the world's gross domestic product (GDP) in 2014. In 2016, analyses found that 65% of poor working adults relied on agriculture to live. Agricultural development is projected to feed 9.7 billion people by 2050. It is considered the most powerful poverty reduction tool (World Bank, 2017). In most developing countries, agriculture is the most important economic activity providing food, employment, foreign exchange and raw materials for industries (Tadesse, 2008).

In Africa, steady progress is being made towards

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agricultural transformation. Expenditures on agriculture have taken an upward trend and there is evidence of faster growth in agricultural productivity and improved nutrition. There is also increase investment by private sectors in agriculture evident by famers who have options in seeds planted, fertilizers used and produce markets (AGRA, 2016). However, factors such as war, lack of agricultural financing, climate change, floods, and global warming still pose major threats to Africa's agricultural productivity (World Bank, 2017).

Agriculture in Liberia has contributed 42% of the national Gross Domestic Product (GDP) in 2016 (CBL, 2016). The food crops sub-sector dominates agriculture's contribution to the national GDP. Rice is the main staple food grown by over 74% of the population on uplands (CFSNS, 2008). Cassava is the second most important food crop grown by about 62% of the population (CAAS-Lib, 2007). Paddy rice and cassava production and area harvested increased by more than 3% per annum during the period 2001 to 2016. Rice and cassava have contributed 22 and 23% of the agricultural GDP, respectively. Tree crops, especially rubber, cocoa and coffee make an important contribution to the economy, accounting for 34% of the agricultural GDP in 2016.

Diao (2010) asserts that "agricultural development requires a comprehensive long term strategy and such a strategy needs to be supported by long term commitment both from the government and international development partners. While opportunities for agricultural growth are there, challenges to realize them are huge". For example, agricultural credit has been argued to be very important for sustainable agricultural development and poverty reduction in rural areas. This study therefore sought to identify and to analyze the determinants of smallholder farmers' access to and use of credit in Suakoko district, Bong County, Liberia.

LITERATURE REVIEW

Khan et al. (2011) contend that agricultural credit is defined as financial support that a farmer can get in order to bridge the gap between his/her income and expenditure in the field and noted that it is an essential ingredient in the growth strategy of agricultural sector. According to Mohan (2006), agricultural credit is a loan advanced to farmers for purchase of improved seeds, fertilizer, modern implements and may also include liquid capital for financing the harvesting, haulage of produce and other similar farm activities. Dethier and Effenberger (2012) perceive agricultural credit as any other credit facility in the market but confined to agricultural development. Salami and Arawomo (2013) described agricultural credit as a facility that is extended from a lender to a borrower, which is repaid at maturity ranging from few days to several years.

Farmers' access to and efficient utilization of financial resources including credit is very vital in increasing farm productivity, rural household incomes and reducing poverty levels in agrarian societies. Rural credit has proven to be a powerful instrument against poverty reduction and development in rural areas. In the developing countries, the role of agricultural credit is closely related to providing needed resources which farmers cannot source from their own capital. Credit is viewed as more than just another resource such as labour, land, equipment and raw materials but rather, credit can be considered from its ability to energize or motivate other factors of production. Most often, credit determines access to most of the resources on which smallholder farmers depend for agricultural production because of lack of adequate capital to access these resources (Auma and Mensah, 2014).

Smallholder farmers have become an important contributor to the Liberian economy (Republic of Liberia, 2010). The sector contributes to the national objective of creating employment opportunities, generating income and providing a source of livelihood for the majority of low-income households in the country (CARI, 2015). Liberian small holder farmers who have the potential to feed the nation are actually the poorest and most food insecure in the population. They are principally subsistence farmers with limited outlets to market surplus production or to participate in the cash economy. As a group, they are geographically dispersed and therefore are often marginalized. The smallholder farmers in Liberia do not have access to value chain processes such as processing machines, driers, storage and other post-harvest facilities (Hilson and Van Bockstael, 2012). In the last decade, Liberia's agricultural productivity has been decreasing, consequently threatening food security as well as increasing poverty rates. The government of Liberia and other stakeholders has attributed the decline in agricultural productivity to the cost of local financing services and poor credit access (USAID, 2015). Farmers still face constraints in accessing financial help. As a result most of them are discouraged to continue ensuring the productivity of their farms as acknowledged by Liberian government through smallholder agricultural productivity enhancement commercialization (SAPEC) (CARI, 2015).

Microfinance institutions such as Liberian Entrepreneurial and Asset Development (LEAD), United States Agency for International Development- Food and Enterprise Development program (USAID-FED), Bangladesh Rural Advancement Committee (BRAC), and Progressive Farmers Organization (PFO), have been providing credit, extension services, business training, and input (hand tools and seeds) in order to improve the situation of access to credit by smallholder farmers and low income earners in Liberia (McNamara et al., 2011). Despite these efforts, most smallholder farmers still do not access the credit; the reasons for this lack of access are not precisely known.

RESEARCH METHODOLOGY

Study site

This study was conducted in Bong County which is in the north-central region of Liberia. Bong County was envisioned to be very important for this study because there is intensive smallholder farming, which tends to be the dominant economic activity, serving as a source of sustainable livelihood for the population. The central Agricultural Research Institute (CARI) is also situated in Suakoko, Gbarnga in Bong County, creating an opportunity for farmers in this region to serve as the direct recipients of CARI research products. This therefore encourages farmers to undertake production and marketing of agricultural products in order to increase agricultural productivity and access to income for better living standards.

Sampling

There are 4000 smallholder farmers in Bong County. Five hundred of the farmers are in Suakoko District, Bong County, Liberia. According to Gray (1983) and Kothari (2004), 10 to 30% is a good representative sample of the population for studies that are descriptive in nature which can help in reducing sampling errors. This study therefore sampled 105 smallholder farmers in Suakoko District, Bong County, Liberia. Respondents were sampled using a simple random sampling method by randomly selecting smallholder farmers from the list given to the researcher by agricultural extension officers in Suakoko District.

Research Instrument

This research is quantitative and primary data were collected using a structured survey questionnaire. The questionnaires were administered using a face-to-face interview approach because immediate follow up clarification is possible unlike the mail or telephone survey.

Data analysis

Data collected from the survey questionnaires were input to SPSS. Analysis was performed using descriptive statistics as well as causal analysis using Logit regression model. T-test and Chi-square test statistics were employed to compare credit users and no credit user with respect to the hypothesized explanatory variables.

The model

Access and use of credit' in this study, means receiving and spending credit received from a given loaning source. The reaction variable for this situation is dichotomous variable. The most utilized way to deal with these assumed spurious variable relapse models are the logit, the straight likelihood models (LPM) and the probit (Gujarati, 2003). The LPM is basic however conflicting because of blemishes. It is established on the supposition the odds of an occasion happening is identified with an arrangement of clarified factors directly. This model is approximated utilizing customary slightest square technique. A financial problem with the LPM is that it creates chances that lie between 0 and 1. This makes truncation of the chances at 0 or 1 necessary, hence creating very many observations for which the approximated chances are 0 or 1.

The probit and the logit are non-linear models both maximum likelihood method (ML), for estimations. This is because both models overcome the limiting aspects of using LPM by transforming the regression model in a way that the outcome is minimized to 0, 1 interval. More so, Wooldridge (2002) observed that the latter models guarantee the logical limit to lie between 0 and 1. Because of these advantages, they are the models that are most frequently used. The logit and probit models are very similar in various applicable ways, while the major difference between these models is the way they are distributed, as recorded in the Cumulative Distribution Function (CDF). Probit exhibits a standard distribution. Logit, on the other hand, shows a logistic distribution. The selection between the two types of regression is highly dependent on the assumptions taken in regard to the distribution. The logit model is generally preferred by researchers because of its comparative simplicity.

The logit regression model is characterized by flexibility, convenience, and power, and is often preferred where the dependent variables are of a categorical nature or/and where it has a normal distribution. A binary logit model that is best for the analysis of determinants of small scale farmers' access to credit was used. The dependent variable takes the value of 0 or 1 depending on small scale farmers' use of credit or not. However the dependent variables were continuous and distinct. The Logit model was used for this study. The cumulative LPM was specified as shown below:

$$P_i = F(Z_i) = F(\alpha + \sum \beta_i X_i) = \frac{1}{1+e^{-Z_i}} \quad (1)$$

Where, P_i is the probability of formal credit use by an individual or not; *e* denotes the roots of original logarithms, which is an estimated equal to 2.718; X_i stands for the i^{th} explanatory variables; α and β_i are parameters to be approximated.

The logistic model can be noted down with reference to the log of odds as well as the odd which makes one gets an understanding of the coefficients. The ratio of the odds show that the probability ratio (P_i) which a person could choose as an option to the probability ($1-P_i$) of which they would not choose.

$$(1 - P_i) = Exp^{(-Z_i)} / [1 + Exp^{(-Z_i)}] \quad (2)$$

Therefore,

$$P_i / (1 - P_i) = Exp^{Z_i} \quad (3)$$

Taking the natural logarithm of Equation (3):

$$Z_i = Ln\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1 X_1 + \beta_2 X_1 + \ldots + \beta_m X_m \quad (4)$$

Where Zi is the indicator of smallholder farming household access to credit or not, P is the probability of the event's occurrence, Xi is a vector of household socio-economic and institutional characteristics. α or β_0 is a constant, βi are corresponding vectors of regression and ε is disturbance term.

In specific terms, the Logit model suggested is stated as:

Z_i *(1/0)* = β_0 + β_1*(AGE_HEAD), + β_2* (EDUC_HEAD) + β_3*(MARI_STAT)+β_4*(OCC_HEAD)+β_5*(GEN_HEAD)+β_6*(HH_SIZ)+β_7*(BANK_ACCT)+β_8*(AC_EXT_SER)+β_9*(FARM_EXP)+β_{10}*(GROUP_MEM)+β_{11}*(OTH_INC_SOUR)+**ε** (5)

RESULTS AND DISCUSSION

Descriptive statistics

Results of the survey show that 39% of farmers have access to credit and 61% did not. Results also show that

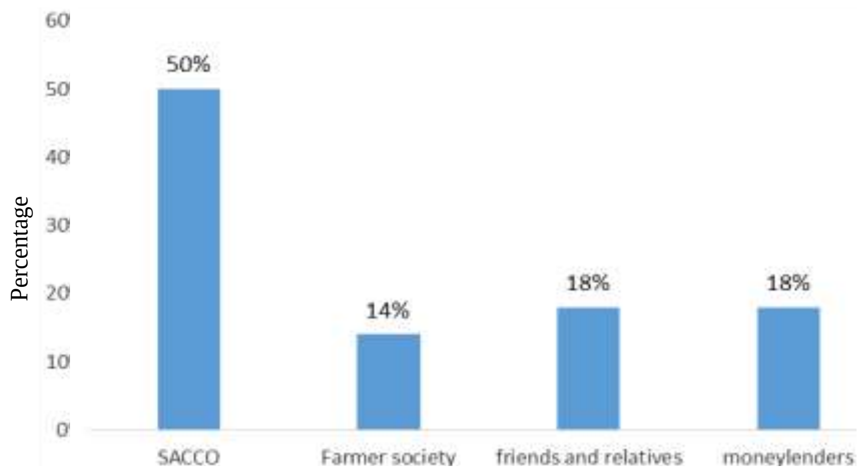

Figure 1. Percentage of credit sources in Suakoko.

all credit sources in Suakoko district were informal. 50% of the respondents borrowed from savings and credit cooperative (SACCO), while 14% received credit from farmers' society, 18% borrowed from friends and relatives, and 18% from moneylenders as shown in Figure 1. According to information gathered, the government does not give credit to smallholder farmers in Liberia. The only microfinance bank giving out credit to farmers in Suakoko has been closed since the war and banks in Suakoko have not started giving out agricultural credit.

The results in Table 1 show that out of small scale farmers who failed to access credit, 61% were male and 39% were female. Respondents who got access to credit comprised of 66% male and 34% female. The results further showed that there is a statistical indifference at 5% in both categories of farming households with p-value of 0.612. This implies that there are more male headed households whether user or non-user of credit.

Out of the smallholder households who failed to get credit, the majority or 75% had no formal education while 16% had primary education and 9% had secondary education. Out of those who had access to credit, 44% had no formal education while 36% had primary education and 20% had secondary education. The results further show that there is a statistical difference at 5% in both categories of farming households with p-value of 0.005. This shows that farmers with higher level of education are more likely to access credit because they are likely to get salaried employment and also can use their skills to increase farm productivity. These results are in agreement with Tang et al. (2010) who found out that education is a factor that contributes to the increase in chances to seek credit from formal credit companies. The results also concur with Chen and Chivakul (2008) who found out that at primary and secondary levels, education has positive effect on access to credit. The findings however contradicts with those by Tien et al. (2010) who found out that many of the poor family providers worked in sector of the unskilled where educational qualifications does not influence demand for credit.

The results further show that there is a significant statistical difference in the marital status of farmers who had access to credit as shown by p-value of 0.004. Married farmers dominated non-users of credit by 62% while those who were not married were 38%. As of farmers who were able to access credit, 33% were married and 67% were not married.

In terms of occupation, results show that most farmers who qualified for credit are those who have other employment hence receive salaries and constituted 35% while those in self-employment comprised of 25%. Farmers who were unemployed and qualified for credit were 40%. As for farmers who did not get credit, they constitute 8% of the salaried employed, 6% of those who are self-employed, and 86% of the farmers were unemployed. There is a statistically significant difference between the two categories at 5% level of confidence with p-value of 0.000. The findings are similar to those by Kiplimo (2011) who found out that smallholder farmers with steady occupation can easily repay loans even when their agricultural income is low since they get salaries.

Other sources of income for the respondents with the household that accessed credit and those that did not were statistically different as illustrated by p-value of 0.000. Among credit users 32% did not have other sources of income while 68% had other sources of income. On the other hand, among the non-users of credit, 75% did not have other sources of income while 25% had other sources of income. The results suggest that respondents who had other sources of income are more likely to access credit due to the fact that they are not depending on farm productivity alone to repay loan.

Out of the households who did not access credit, 5% managed to access extension services while 95% did not. Out of those households who accessed credit, 40%

Table 1. Proportion of credit users and non-users defined across categorical variables.

Variable		Credit user		Non-users		Chi square	P-value	Total	
		N	%	N	%			N	%
Gender	Male	27	66	39	61	0.257	0.612	66	63
	Female	14	34	25	39			39	37
Education	No-education	18	44	48	75	10.37	0.005	66	63
	Primary	15	36	10	16			25	24
	Secondary	8	20	6	9			14	13
Marital status	Married	12	33	43	62	7.96	0.004	55	55
	Not married	24	67	26	38			50	48
Occupation	Unemployed	16	40	56	86	24.52	0.000	72	69
	Salaried-employed	14	35	5	8			19	18
	Self-employed	10	25	4	6			14	13
Other sources of income	No	13	32	48	75	19.2	0.000	61	58
	Yes	28	68	16	25			44	42
Agricultural Extension	No	25	60	58	95	20.01	0.000	83	81
	Yes	17	40	3	5			20	19
Group membership	No	6	15	31	48	12.51	0.000	37	35
	Yes	35	85	33	52			68	65
Bank account	No	18	43	62	98	42.8	0.000	80	76
	Yes	24	57	1	2			25	24

Table 2. Summary statistics of continuous variables.

Variable	Credit user				Non-user				p-value
	Min	Max	Mean	Std	Min	Max	Mean	Std	
Average HH size	5	19	10.25	3.67	5	17	9.70	3.054	0.0130
Average age	28	76	44.56	8.62	24	64	38.82	8.485	0.009**
Land size	0.5	6	2.04	1.46	0.25	4	1.56	1.122	0.019
Annual farm income	12.200	47.000	26.000	11623	10.800	35.500	21.000	7595.76	005**
Years of extension	1	3	1.55	0.688	1	1	1.00	0.000	0.017
Years of farm experience	5	30	15.82	6.406	1	26	13.33	6.532	0.030

accessed agricultural extension services while 60% did not. This demonstrates that users and non-users of credit are statistically different in terms of extension services as shown by a P-value of 0.000 at 5% significant level. This means that farmers who accessed extension services are more likely to access credit.

The results further show, out of the smallholder farmers who failed to access credit, 52% were members of various groups while 48% were not members of any group. On the other hand, 85% of farmers who had access to credit have group membership while those who were non-group members constituted a total of 15%. Results on group membership for farmers show that there is a statistical difference between those who had access to credit and those who did not as shown by p-value of 0.000 at 5% significant level.

Furthermore, farmers who failed to access credit were distributed as: 98% did not have a bank account and 2% had a bank account. While, farmers who were able to access credit, 43% did not have a bank account and 57% had a bank account. Moreover, results indicate that those who had bank accounts were more likely to access credit because having a bank account serves as guarantee to lenders.

According to the findings in Table 2 the households that had access to credit had a number that ranged from 5 to 19 people while those who did not access credit ranged from 5 to 17 people. There was an insignificant mean difference for both categories. The findings of the study are not aligned to those of Marge (2000) who concluded that larger households are prone are more likely credit.

In terms of age, there was a slight difference between the two categories of those who had access to credit and those who did not since their age difference was 44.56 and 38.82 years respectively. The mean on the other hand, was different at 5%. In those households that accessed credit, the oldest farmer was 76 years old while the youngest was 28 years old. For those who did not access credit, the age range was 24 to 64 years. These findings are in agreement with those by Tang et al. (2010), who concluded that the likelihood of old farmers to seek credit was higher as opposed to younger farmers due to their expanded social networks and social capital. Nwaru (2010) however argued that the difference in age was insignificant for access of credit.

The findings show that the land size difference ranged from 0.5 to 6 acres for farmers who accessed credit and 0.25 to 4 acres for those who did not. The mean difference for the land size was insignificant, as the average size of land for farmers who accessed credit was 2.04 and 1.56 acres for those who did not. All farm land in the study area were customarily owned. This study contradicts Diagne's (2006) study on determinants of household access to and participation in formal and informal credit markets. Diagne (2006) found a significant difference in land size and also found that those who used credit were able to cultivate large land as opposed to those who did not. This implies as size of cultivated land increase the operational expense for labour, input and technology use increase, which require cash capital, it leads to high demand for credit.

All the farmers who participated in this study had access to a certain amount of income which was different in both categories of farmers. The mean yearly farm income level was Ld (Liberian Dollar) 26,000 with the minimum of Ld 12, 000 and a maximum of Ld 47,000. On the other hand, families who could not access credit had an average yearly income of Ld 21, 000 with a minimum of Ld 10,800 and a maximum of Ld 35, 500.

As for the years of receiving agricultural extension services, the results show that smallholder farming households in the study area who accessed credit had a mean of 1.55 years with a minimum of 1 year and a maximum of 3 years. Smallholder households who did not get credit had a minimum and a maximum of 1 year each. This implies that an agricultural extension service in the area of study is significantly low. Most of the farmers lack access to agricultural extension services. Of the few who accessed these services, it has not been for many years.

In terms of year of farming experience, farming households who accessed credit had a mean average of 15.82 years with a minimum farming experience of 5 years and a maximum of 30 years. Those who failed to access credit had a mean average of 13.33 years with a minimum farming experience of 3 years and a maximum of 26 years. This implies that smallholder farmers who accessed credit had more years of farming experience.

Binary logit regression

A Logit regression was performed to ascertain the effects of marital status, occupation, gender, age, education, household size, bank account, agricultural extension services, farming experience, group membership, and other sources of income on the likelihood that participants have access to credit. The results show that the Logit model was statistically significant, $\chi 2$ (13) = 35.978, $p < .001$.

The results in Table 3 indicate that, the marginal affects for bank accounts and other sources of income highlight an important positive impact on access to credit in Suakoko district. However, education, occupation and group membership re-significant but have negative impact on access to credit. The results further indicate that gender, agricultural extension and farm experience were statistically insignificant on access to credit in the study area. This implies that increase in ownership of bank accounts and having other sources of income increase the chances of accessing credit from several credit sources in the study area. This finding concurs with Marge (2003) who indicated that a transitory change on income is necessary for a positive effect on access to credit because of its effect on consumption. Kumar (2005) cited income to be among the important determinants of access to credit but also concluded that there was a negative relationship between access to credit and household income due to the fact that the more income farmers generate, the more they tend to be self-sufficient and shy away from credit. Moreover, Leavy and Poulton (2007) concluded that most of the small scale farmers generate income from other sources which are unrelated to their farms. The outcome reveals that what increased the chances of access to credit was the farmers' availability of other sources of income rather than farming. This is because those households that would get more income from other sources are able to possess assets that would act as collateral when seeking loans. These results were aligned to those by Ojo (2003) who had drawn the conclusion that farmers ought to increase the sources of their income so as to increase their chances of qualifying for credit uptake. The result shows that level of education was significant with a negative influence on access to credit by smallholder farmers in the study area. This implies that an increase in level of education will reduce the probability of credit access. The study conforms with Chen and Chivakul (2008) who found that education has a positive effect on credit access at lower levels of education but negative effect at higher level of education. Tang et al. (2010) and Kiplimo (2013) found education to be significant but these studies also found that education has a positive impact on access to credit unlike the current study. The findings

Table 3. Binary logit regression.

Variable	Marginal effect	Std. Error	P. Value
Age	-0.159	0.307	0.606
Education	-5.093	5.067	0.010**
Marital status	-1.733	3.977	0.190
Occupation	-19.005	8.140	0.000**
Gender	4.962	7.305	0.461
Household size	-679	0.976	0.404
Bank account	2.846	1.253	0.023**
Agricultural extension	4.763	6.396	0.554
Farming experience	0.123	.251	0.239
Group membership	-0.499	4.379	0.012**
Other income sources	2.471	1.217	0.042**
Constant	-6.087	2.804	0.030

of this study contradict those of Tien et al. (2010) who found that most of the poor household heads in Vietnam work in unskilled sectors, where education does not influence demand for credit.

While occupation was quite significant at 5% in explaining access to credit in the study area, it had a negative effect. An increase in a unit of occupation of the smallholder farmer reduces the chance of accessing credit by 0.19%. This implies that the more farmers are salaried or employed or self-employed, the less they will demand credit in the study area. This is because they will use their salaries or other sources of income to purchase farm equipment and hire labor for increased farm productivity. This study conforms to the findings of Laffont and N'Guessian (2000) who opined that most credit sources require generally shorter advance reimbursement periods. Hence, smallholder farmers with salaries from employment or a business tend to profit more from lenders.

Conclusions

Developing new demand-driven services that will address the needs of the poor communities is a required initiative that should be considered by policy makers. In addition, facilitating product markets for the small-scale farmers and offering training opportunities on agricultural products would enhance agricultural productivity. It is also necessary for policy makers to improve education systems so that the poor are equipped with the skill and knowledge to effectively access credit at less cost and use them wisely in order to generate more income. The more educated the household head, the more they will tend to use modern technologies and also credit which will bring about increase productivity which is really needed in Liberia. SAPEC and other policy makers need to ensure older farmers get adult literacy while younger farmers get formal education. Being educated will also help farmers to not only restrict themselves to farming but find other jobs to get other income which will enable them easily access credit. Other source of income and occupation were found to have influence on access to credit by smallholder farmers in Suakoko. Farmers who engage in off-farm activities earn more income and are able to get credit. Hence, other than focusing on increasing agricultural production only, the government should also emphasize on policies aimed at increasing opportunities for off-farm activities. This can be enhanced through creation of jobs and motivating self-employment. Farmers who are members of development groups were found to be more likely to access credit. This might be because of the fact that those farmers have group security in terms of collateral and high social capital that would increase access to credit use. In other words, encouraging farmers to form part of development groups would improve the availability of credit to the farmers. Hence, the government should promote development groups geared towards providing collateral for members in Suakoko district. In Suakoko, banking institutions do not give out credit to farmers.

The government of Liberia especially SAPEC need to bridge that gap. Having bank account has a significant influence on access to credit in the study area. To build the quantity of farmers that access credit, there should be policies put into place to help farmers get credit from these banking institutions. Government should serve as guarantor for farmers. When farmers in the study area are able to access formal credit, it will help greatly in increasing productivity. Credits received from informal sources are not sufficient to buy farming tools and fertilizers.

The research is limited in that it did not take into account risk attributes of smallholder farmers in the study area. A farmer who is risk adverse may decide not to get credit because of fear. The researcher will like other research to focus on risk attributes of farmers and also credit institutions that lend to smallholder farmers.

CONFLICTS OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

The efficacy of selected biological control agents against citrus black spot (CBS) pathogen *Phyllosticta citricarpa*

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Citrus black spot (CBS) caused by *Phyllosticta citricarpa* (McAlpine) Van der Aa (asexual state) synonym *Guignardia citricarpa* Kiely (sexual state) is one of the most devastating diseases of citrus which occurs in various citrus producing areas around the globe. Management is mainly based on monthly applications of copper fungicides and strobilurins under field conditions. In this study, bio-control agents were evaluated as alternative post-harvest treatments against citrus black spot disease. Two bio-control agents namely, *Bacillus subtilis* Cohn *and Trichoderma harzianum* Rifai were evaluated for their efficacy against *P. citricarpa*. Their efficacy was further compared with commercial fungicides Dithane 750 (Mancozeb, 750 g/kg). Results obtained showed that *T. harzianum* treatments were highly suppressive towards pathogen growth *in vitro* (85%) as compared to *B. subtillis* (4%) and Dithane 750 (12%). Treatment of artificially inoculated fruits with combined formulations of both biocontrol agents resulted in reduced CBS severity as compared to their single applications. These findings suggest that *T. harzianum* had highest suppression of pathogen growth as compared to *B. subtilis*. The results also suggest that their combined application can provide an effective disease management when compared to sole application of Dithane 750. Further studies are however, needed to determine their effectiveness under field conditions and also their efficacy can be sustained when applied with commercial fungicides.

Key words: *Bacillus subtilis*, biocontrol, dithane 750, *Trichoderma harzianum*.

INTRODUCTION

Citrus black spot caused by *Phyllosticta citricarpa* (McAlpine) van der Aa is a major disease affecting citrus production worldwide, where weather conditions are favourable (Paul et al., 2005). The disease affects all citrus species of economic importance however the disease causes more damage to sweet oranges and

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lemons due to their high susceptibility (Kotźe, 1981). The disease is of high economic importance in citrus growing countries including South Africa (Smith et al., 1997). The causal pathogen causes external blemishes on the fruit rind, making the fruit unsuitable for fresh market which in some cases, result in severe fruit drop and crop losses (Araújo et al., 2013). Worldwide, the potential economic loss is mainly due to the rejection from fresh market as a result of unsightly lesions (Paul et al., 2005; Everett and Rees-George, 2006). Potential quarantine of fruit sales to other citrus production regions can also result in economic losses of millions of dollars (Meyer et al., 2012).

Citrus black spot management relies mainly on the application of preventative fungicides during fruit susceptibility (Schutte et al., 1997). Various groups of fungicides have been used against citrus black spot with varying degree of efficacy (Rodrigues et al., 2007). However, loss of sensitivity and pathogen resistance is a common factor resulting in poor disease control by most fungicides groups (Akinnifesi et al., 2006; Rodrigues et al., 2007). Growing international concern on chemical residues on treated fruits has also resulted in need to identify and develop alternative safe measures. Biological control agents such as *Trichoderma* spp. and *Bacillus* spp. have been shown to be effective against a number of plant pathogens (Kupper et al., 2011; Abdalla et al., 2014).

Also, combined application of biological control agents has been shown to be effective against some plant diseases (Begum et al., 2010). There is limited information regarding the use of both *Trichoderma. harzianum* strain and *Bacillus subtilis* in the suppression of pathogen growth *in vitro* and disease severity *in vivo*. The main aim of this study was to evaluate the combined efficacy of biological control agents (*T. harzianum* and *B. subtilis*) in comparison with commercial fungicides (Dithane 750) against CBS pathogen *P. citricarpa*.

The specific objectives were, to determine the effect of *B. subtilis* and *T. harzianum,* as compared to Dithane 750 on *P. citricarpa* growth *in vitro* and to investigate the effectiveness of both biological control agents on citrus black spot development, when applied separately or in combination.

MATERIALS AND METHODS

Microbial culture preparations and maintenance

A pure culture of *P. citricarpa* isolate (PPRI 8774) was obtained from the National Fungal Collection, Biosystematics Division, Agricultural Research Council-Plant Protection Research Institute (ARC-PPRI), Pretoria, South Africa. The pathogen was originally isolated from an infected 'Valencia' citrus fruits from Letsetele farm in Limpopo, South Africa.

The isolate was preserved on 2% Potato dextrose agar (PDA) and stored at 4°C until further use. The pathogen was identified as *P. citricarpa* using both morphological and molecular characterization. Molecular characterization was based on Polymerase Chain Reaction (PCR) technique described by Perez et al. (2007). Two biological agents namely *T. harzianum* (PPRI 8230) and *B. subtilis* (B246) were obtained from ARC-Plant Protection Research Institute and Quality Management Services (QMS) Company at Tzaneen area in Limpopo Province, South Africa, respectively. Both *B. subtilis* and *T. harzianum* were maintained in Nutrient Agar and 2% PDA, respectively and kept at 4°C until further use.

Effect of biocontrol agents on P. citricarpa growth in vitro

The growth inhibition of *P. citricarpa* by *T. harzianum* and *B. subtilis* was carried out on Potato Dextrose Agar (PDA) and Nutrient Agar (NA), respectively, using the dual culture technique. This was determined by placing 5 mm mycelial plug obtained from a 7 days old *P. citricarpa* culture, at 1 cm from the periphery of 90 mm Petri plates with PDA and incubated for 3 days at ± 28°C (Evans et al., 2003). After 3 days, a 5 mm mycelial plug obtained from 7 days old *T. harzianum* culture was placed 1 cm away from the edge, of the same Petri dish on the side of *P. citricarpa*. Control treatments were not inoculated with a biological control agent.

All plates were incubated for 7 days at ± 26°C. In *B. subtilis* treatments, dual culture method described by Etebarian et al. (2005) was followed. Half of the petri plates containing nutrient agar were streaked with 100 ml suspension of *B. subtilis* and incubated for 48 h. Thereafter, 5 mm mycelial plug of 7 days old *P. citricarpa* culture was inoculated as described above.

Fungicide solution was prepared by mixing 7.5 g of Dithane 750 with 100 ml sterile distilled water and kept at 4°C until further use (concentration). Used fungicide dilutions were according to manufacturer's instructions. For pathogen suppression, 10 ml of prepared suspension of Dithane 750 was added to 1 litre PDA after autoclaving at 40°C and dispensed into 90 mm petri plates. Each treatment was replicated four times and experiment was repeated twice.

For *in vivo* evaluation, a total of 200 healthy Valencia fruits were harvested from Letsetele citrus farm, surface sterilised with 0.1% Sodium hypochloride for 3 min, rinsed with sterile distilled water twice and air dried at room temperature for 24 h. Inoculum preparation and fruit inoculation was done according to the method described by Baldassari et al. (2009). Mature Valecia orange leaves were used for pathogen inoculum production. A 10 mm leave disk was cut with cork borer and placed on ripe orange fruit. Inoculated fruits were incubated at ± 25°C for 21 days after which lesion size was measured using a Venier caliper.

Bio-control treatments were prepared by mixing 50:50 suspensions of *B. subtilis* (1×10^7cells/mL) and *T. harzianum* culture filtrate (5×10^5 spores/Ml) and applied separately or in combination 24 h after fruits were inoculated with pathogen. For control, inoculated fruits were sprayed with sterile distilled water. All treatments were laid out in a completely randomized design (CRD) with five replicates. Disease severity was evaluated on a scale of 0 to 4 where 0= no lesion, 1 = 10% fruit area affected, 2 = 10 to 25% fruit area affected, 3 = 25 to 30% fruit area affected, 4 ≥ 50% area affected. Collected data was analysed using Statistic 10.0 software. Duncan's Multiple Range test was used to compare treatment means at P≤ 0.05 probability level.

RESULTS AND DISCUSSION

Results for *in vitro* experiment are presented in Figure 1.

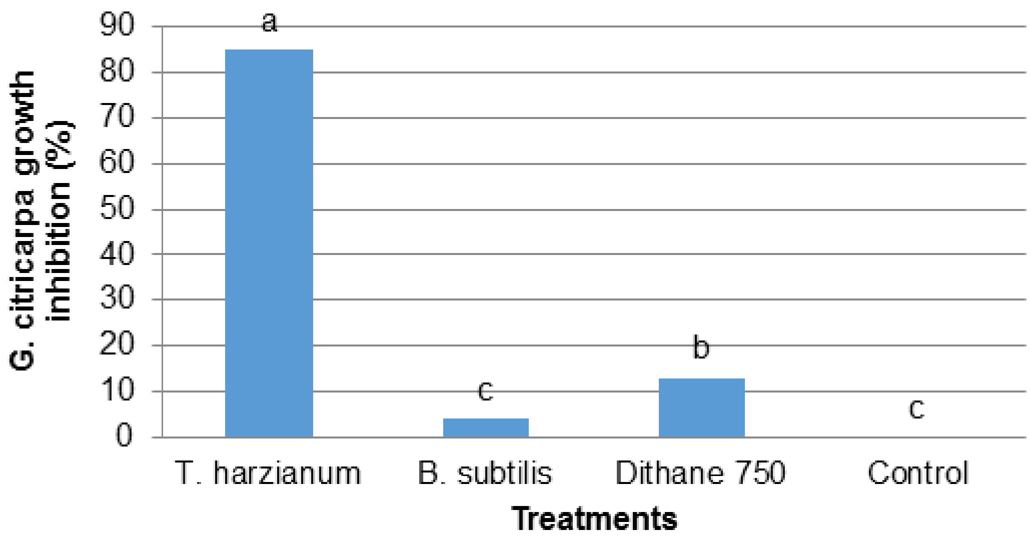

Figure 1. Inhibitory effect of bio-control agents and fungicide on *P. citricarpa* after 30 days of inoculation.

Table 1. Effect of *T. harzianum*, *B. subtilis* and Dithane 750 on CBS development on artificially inoculated citrus fruit.

	Pathogen lesion size (mm)[a]			
Treatments	**1**	**7**	**14**	**21**
T. harzianum	0.0[ab]	0.0[a]	0.0[a]	0.2[a]
B. subtilis	0.0[a]	0.3[a]	0.8[ab]	1.3[b]
Dithane 750	0.0[a]	0.2[a]	1.1[b]	1.2[b]
Inoculated control	0.0[a]	1.2[b]	2.8[c]	2.6[c]
Un-inoculated control	0.0[a]	0.0[a]	0.0[a]	0.0[a]

[a]Lesion size on inoculated fruit was measured from days 1 to 21. [b]Numbers followed by the same letters are not significantly different according to Duncan's Multiple Range Test.

The table is not correct. The treatments comparison is wrong because there are a lot of variations (culture medium, organisms, fungicide, seeding of the organism, etc.). The treatments can be compared with its control, but not with each other Dual culture test results which showed highest pathogen growth inhibition occurring in *T. harzianum* treatments at 85%. P. *citricarpa* growth inhibition was lowest in *B. subtilis* treatment at 4%. The same results regarding the suppressive effect of *B. subtilis* was also observed in inoculated fruits (Table 1), where lesion size was significantly higher than *T. harzianum* treatments at 1.3 and 0.2 mm, respectively. However, the level of inhibition was not significantly different in comparison with Dithane 750. Dithane 750 is currently one of the fungicides used in the management of Citrus black spot (CBS), however loss of pathogen sensitivity is a concern (Kupper et al., 2011).

Various reports have shown positive efficiency of *T. harzianum* in the management of other plant diseases (Thilagavathi et al., 2007; Begum et al., 2010). The same results was also observed in our study where *T. harzianum* was able to significantly suppress the growth *P. citricarpa in vitro* and also reduce disease severity in artificially infected citrus fruits (Table 2). Treatment of infected fruits with *B.subtilis* also resulted in a significantly high number of fruits, showing disease symptoms and severity (1.8).

However, when *B. subtilis* was applied in combination with *T. harzianum*, a significant reduction in disease severity was observed. In previous reports, application of strain mixture of *B. subtilis*, *Pseudomonas* and *Trichoderma* spp. resulted in an increased suppression of *B. cinerea* than when each biocontrol agent was applied alone (Thilagavathi et al., 2007). It has been suggested by various authors that when applying biocontrol agents as combination in disease management, they should be compatible to achieve consistent control (Raaijmakers et al., 1996).

Table 2. Effects of *T. harzianum* and *B. subtilis* applied separately or in combination on CBS occurrence and severity.

Treatments	CBS infected fruits (%)	CBS severity[a]
T. harzianum	10.5±0.2	1.0[bb]
B. subtilis	16.3±1.3	1.8[c]
combined	9.6±1.2	0.2[a]
control	50.5±1.3	5.3[d]

[a]Disease severity was rated on a scale of 0 to 4. [b]Numbers within a same column followed by the same letter are not significantly different according duncan's multiple range tests.

In our study, results show that treatment of CBS infected fruits with a combination of both *T. harzianum* and *B. subtilis* formulations significantly reduced number of citrus, showing CBS symptoms which also reduced disease severity (Table 2). Citrus fruit treatment with both *T. harzianum* and *B. subtilis* significantly reduced the number of diseased plants and suppressed disease symptom appearance. This combined effect corresponds with previous findings where combined application of *B. subtilis* and yeast isolates reduced gray mould in treated apple fruits (Zangoei et al., 2014). Considering the good performance of both biocontrol when used in combination, it is anticipated that their use against citrus black spot could be beneficial when applied as a post-harvest treatment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Livelihood issues in herdsmen-farmers' conflict among farming communities in Kogi State, Nigeria

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Conflicts between crop farmers and herders are common in nearly every part of Nigeria. It is a formidable challenge to economic development, threat to food security and sustainable livelihood of the agrarian communities. The study assessed the causes and effects of herdsmen-farmers' conflicts on livelihood of agrarian communities in Kogi State. A total of 135 randomly selected crop farmers was used. Data were collected by use of structured interview and focus group discussion, and analysed using descriptive statistics and factor analysis. The results showed that crop farmers were predominantly male (85.2%), married (85.9%) and with mean age of 51 years. They were small scale farmers with average farm size of 2.9 ha and were engaged in the production of yam (97.8%), cassava (92.6%), maize (92.6%) and other arable crops, mainly for income and household food supply. The farmers indicated that violation of laws/tradition, livelihood interference and cultural factors were the major causes of conflict between crop farmers and herdsmen. Consequently, the socio-economic life, production outcome and settlement of crop farmers are affected, cumulating to breakdown in livelihood assets of farmers. The study recommends that there should be strategic and regular orientation of resource users on the need for co-existence and adherence to regulations regarding use of resources. Multi-stakeholders' efforts exploring grass root participation should be promoted by government and non-governmental organizations (NGOs) in policies and strategies for management of conflict. Farmers should be assisted with productive resources and training by extension services to reduce vulnerability and protracted conflict in the farming communities.

Key words: Conflict, crop farmers, herders, livelihood, production, natural resource.

INTRODUCTION

Over time, many herding and farming communities in the same area have developed interdependent relationships through reciprocity, others by exchange and support (Moritz, 2010). Mwamfupe (2015), opines that farmer-herders' relationships are characterized by both conflict and complementarity and are actually two faces of the same coin. According to Hussein (1998), the relationship has always moved between cooperation, competition and

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conflicts. Herders graze on farmlands that belong to crop farmers and farmers depend on animal dugs for improving soil fertility. Also pastoralists require the calories produced by crop farmers, much as the crop farmers often require the protein and dairy products produced by pastoralists (Abba and Usman, 2008). However, with decreasing interdependent livelihood activities, the relationship is increasingly characterized by incessant conflicts.

Tonah (2006) reports that farmer-herder clashes have only since the 20th century become widespread in the coastal countries of West Africa. It is becoming common in nearly every part of Nigeria. According to Pasquale et al. (2007), pastoralist-crop farmers' conflict is the most predominant type of resource use conflict. In a newspaper study of conflict in Nigeria, Fasona and Omajola (2005) reported that farmer-herdsmen conflict accounted for about 35% of conflicts cases reported in Nigerian newspapers. It is widespread in the country and has been on the increase in recent times.

Nweze (2005) reported that between 1996 and 2005, 19 people died and 42 were injured in farmers-herders' conflicts in Imo State. Another study of 27 communities in central Nigeria shows that over 40% of household surveyed had experienced agricultural land-related conflicts, with respondents recalling conflicts that were as far back as 1965 and 2005 (Nyong and Fiki, 2005). In the guinea savannah area of Kwara State, scholars reported that out of about 150 households interviewed, 22 experienced losses of livestock, while eight household reported loss of human lives (Olabode and Ajibade, 2010; Fiki and Lee, 2004). Further study by Ofuoku and Isife (2009) also reveal that in the south-south region of Nigeria, especially in Delta and Edo states, more than 40 million worth of crops are usually lost annually due to invasion of cattle. More recently, documentation from Sunday Trust Newspaper by Okoli and Atelhe (2014), reported about 13 cases of farmer-herdsmen conflicts across states of the federation which claimed 300 lives of the citizens.

In Kogi State, there have been instances of conflict between cattle herders and crop farmers in Igala Mela/Odolo Local Government Area (LGA), Ibaji, and Ofu LGAs over crop destruction by cattle, killing of a herder and stabbing of a farmer, respectively, following reprisal attacks on different occasions (personal communication). Thus, Gbaka (2014), rightly states that significant loss of lives and property has occurred in many parts of Nigeria including Katsina, Plateau, Taraba, Kogi, Kwara, Nasarawa, Adamawa, Gombe, Yobe, Kebbi, Zamfara and Sokoto states in the north; Oyo State in the south west; Abia State in the south east; and Delta and Edo in the south south. In the past eight years, conflict accounted for 615 deaths out of a total of 61,314 fatalities in the Nigeria Watch database (Olayoku, 2014).

Advances in literature have attributed farmer-herdsmen conflict to competition over resource use, particularly land, population growth of herds and human, production system, south ward movement of pastoralists into the humid and sub humid zones, incomparable goals of the disputants and behaviors that undermine the goals of each other (Olabode and Ajibade, 2010; Nyong, 2010; Abbass, 2009; Adebayo and Olaniyi, 2008; Abba and Usman, 2008; Tonah, 2006). On the contrary, Umar (2002), in a study of pastoral agricultural conflict in Zamfara State found that the Hausa farmers and the Fulani herders have some perception for each other and this affects their relationship. While the Fulani see the Hausas as Kado (meaning infidels or unbelievers) whose property they can use without offence to God, the Hausas on their own part see the Fulan i as intruders, uncivilized and uninformed. This perception has been on since the Jihad of Sokoto caliphate and so they have been at loggerhead and hence can be engaged in conflict with slightest provocation. More broadly, other scholars report that climate change, the migration further south, growth of agro-pastoralism, expansion of farming on pastures, invasion of farmlands by cattle, assault on non-Fulani women by herders, blockage of stock routes and water points, freshwater scarcity, burning of rangelands, cattle theft, inadequate animal health care and disease control, overgrazing on fallow lands, defecation on streams and roads by cattle, extensive sedentarisation, ineffective coping strategies, ethnic stereotyping, and the breakdown of conflict intervention mechanisms are the root causes of such violence in rural areas (Ofuoku and Isife, 2009; Adekunle and Adisa, 2010; Blench, 2010; Odoh and Chigozie, 2012; Solagberu, 2012; Audu, 2013; Bello, 2013; McGregor, 2014).

Conflict threatens the livelihood resources of people particularly farming communities due to high dependent on natural resources for survival. Herder-farmer conflicts not only have a direct impact on the lives and livelihoods of those involved, they also disrupt and threaten the sustainability of agricultural and pastoral production in West Africa (Moritz, 2010) and invariably the sustainability of livelihoods of rural communities. Livelihood in this context includes all forms of economic generation and employment that support health and well-being such as agriculture, small businesses and manufacturing (United State Agency for International Development (USAID), 2005). According to the report, it comprises means by which households obtain and maintain access to the resources necessary to ensure immediate and long survival. These essential resources can be categorized into physical, natural, human, financial, social and political. Households used these assets to withstand shocks and manage risk that threatens their well-being. According to the report, conflict restricts or blocks access to one or more of these assets and at its instance, people try to find other ways of obtaining those resources, or compensate for the loss of one resource by intensifying their efforts to secure another (USAID, 2005). Furthermore, conflict has the capacity to severely undermine and constrain development efforts by destroying infrastructure, interrupting production system and diverting resources from productive uses (Adetula, 2007). More often, crop farmers are highly vulnerable, perhaps due to the subsistence, small scale, rudimentary system of production and over dependence on natural resources for livelihood. Besides, they have limited resources and are dependent on rainfall, traditional farming implements (hoes and cutlasses), family and hired labour with poor access to institutional and infrastructural facilities (input, advisory services and market information, roads, etc.) (Attah, 2012), which have implications for yield per hectare. An investigation on the livelihood impacts on rural farming communities is crucial for appropriate response and intervention by stakeholders. Besides, it is relevance for informed strategy on effective and sustainable management and resolution of conflict. Thus, the study aimed to:

(1) Describe the socioeconomic characteristics of rural crop farmers in Kogi State;
(2) Ascertain the perceived causes of conflict between crop farmers and herdsmen and
(3) Ascertain the effects of conflict on livelihood of rural crop farmers in Kogi State.

THEORETICAL FRAMEWORK

Inter-group conflict according to Beltran (2010) is an incompatibility of goal, beliefs, attitudes or behaviour. The author enumerated common incompatibility of goals that can cause inter-group conflict to include power, economic and value differences. Economic conflict is competition for resources, while power conflict is a situation where a group fights for dominance over one another. Value conflict on the other hand, involves disagreement between group's beliefs or lifestyles. In other words, conflict has various components including differences in tasks, values, attitudes and goals as groups try to gain control over scarce resources. Butera and Marcel (2008) assert that conflicts emerge from a complex sequence of events in which cultural and political factors are always present; while structural theory emphasizes the immediate and underlying factors that could cause conflict, and presents a number of factors that are responsible for the emergence and escalation of conflict.

According to Moritz (2010), explanations of herdmen-farmers' conflicts have generally been structural in nature, invoking factors shared by all members of both communities. The author affirms that the two main theoretical approaches to the study of farmers-herders' conflict in Africa are both structural: environmental security and political ecology. Environmental security scholars, like Thomas Homer-Dixon, emphasize on the role of resource scarcity and increasing competition for these scarce resources as the primary, though not the only reason for more frequent violent conflicts over natural resources (Homer-Dixon, 1999). Political ecologists have challenged Homer-Dixon's thesis that there is a causal link between resource scarcity and violent conflicts (Hartmann, 2001). In another hand, Manu et al. (2014), opines that many factors that contribute to conflicts in Africa have little or no link to environment, natural resources and rural development. These factors include political, religious, ethnic, economics, land tenure system and historical feuds. Moritz (2010) further enumerates several structural factors identified by researchers that contribute to the increasing incidence of conflicts between herders and farmers, namely, resource scarcity, decreasing interdependence of pastoral and agricultural economies, institutional failure to resolve conflicts, the larger political context and historical context or cultural differences between herders and farmers.

The USAID (2005) reiterates that even where there are other primary causes of an escalation of tensions, livelihood failure can contribute to the emergence of conflict by weakening the social fabric, making people resort to desperate means to obtain resources, and deepening vulnerability to exploitation by those with an interest in promoting conflict for political or economic gain. Also, as the effects of conflict are increasingly felt at the community and individual levels, the original ideological causes of a conflict will frequently be supplanted by others linked to protection or restoration of livelihoods (USAID, 2005). In another hand, shocks associated with conflicts invariably impact on the livelihood of the disputants and communities at large.

METHODOLOGY

The study was carried out in Kogi State. The state lies between latitudes $6° 33^1$ and $7°49^1$N and longitudes $6°45^1$ and $7° 49^1$E. It has a population of 3,278,487 inhabitants (National Population Commission, 2006) with large expanse of fadama lowlands in the river basins and stretches of tropical rainforest in the south and western belt of the state. Agriculture is the principal means of livelihood of about 85% of the population, and the dominant crops are yam, maize, cassava and cocoyam and tree crops. Other occupations of the inhabitants of the state include fishing done by communities living along the river banks and trading (Onucheyo, 1999). The livestock kept include cattle, sheep, goats and chicken on free range basis.

The population of the study constituted all crop farmers in the state. A survey design in a multistage sampling technique was used. Out of the 21 Local Government Areas (LGAs) in the state, 16 are mostly associated with farmer-herder conflict. Nine were purposively selected, representing the three agricultural zones in the state. In each of the selected LGAs, three farming village communities were purposively selected because of the high incidence of crop farmers-herders' conflict making a total of 27 villages. Five crop farmers were randomly selected from list of crop farmers in each of the 27 villages, thus giving a total of 135 crop farmers used for the study.

The respondents were requested to indicate their sex, age in years, marital status, educational qualification, farm size in hectare, the crops grown, production motives, source of labour, membership of organizations and income (naira/year). To identify factors responsible for conflict, respondents indicated on a four point Likert type scale of very great extent (4); great extent (3); some extent (2); no extent (1), the extent to which the listed factors contributed to outbreak of conflict in their communities. Some of the items listed included: damage to the crops by cattle, blockage of the cattle routes with crop farms, pollution of source of water by the herders, etc.

Information on the effects of conflict on agricultural production and livelihood was elicited. The crop farmers indicated from the list of possible effects, the perceived seriousness of the items using four point Likert type-scale of very serious = 4, serious = 3, not very serious = 2, not serious = 1. Data were analysed using descriptive statistics and exploratory factor analysis using principal component method with varimax rotation of Kaiser normalization. Factor analysis is used mainly when one is interested in knowing whether some underlying pattern or relationship exist among variables; discovering a new set of factors; or confirming existing factors as being the true factors (Kleinbaum and Kupper, 1978). The factor loading high under each factor variable (Beta weight) represents a correlation of variables to the identified factors and has the same interpretation as any correlation coefficient. However, only variables with loading of 0.40 and above (10% overlapping variance), (Chukwuone et al., 2006) were used in naming factors. Also factors that loaded in more than one places were discarded.

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

Table 1 indicates that 85.2% of crop farmers were males, married (85.9%) with average household size of 12 persons. Crop farmers have a large household size which may have resulted from the need for family labour with the consequence of more dependant family members. The average age of the respondents was about 51 years. Majority (52.2%) of the farmers were below the mean age indicating that the farmers are still in their active and productive years. Consequently, they may respond violently to conflict or aggression from herdsmen due to youthful exuberance. Also, the results show the dominance of males in farming probably because men are more energetic and capable of involving in tedious production activities associated with farming than women (Adesiji et al., 2012). However, it is surprising because women are presently taking up several agricultural activities including the ones traditionally accepted as male roles, perhaps due to continuous exodus of able-bodied rural male folk to peri-urban and urban areas in search of greener pasture.

About 70% of the crop farmers had formal education. Though, the respondents are literate but the educational level attained is relatively low. Only 29.6 and 22% had first school leaving certificate and senior school certificate, respectively. This could negatively affect the farmers' perception of conflict situation and subsequently their behavior and altitude to conflict. This might be one of the reasons why farmer-herders' conflict has remained unabated and a regular phenomenon in the state. The respondents are subsistence farmers with average farm size of 2.9 ha. The major crops grown were maize (92.6%), yam (97.8%), cassava (92.6%) and legume (48.2%). These are among the most common staple food crops in most rural communities in Nigeria. According to Olabode and Ajibade (2010) some of these crops (yam, maize, and guinea corn) are of nutritional value and attractive to cattle. Consequently, the farms could be a source of conflict as herds get attracted to the crops during grazing. Farming was done purposely for income and consumption (88.2%). This confirms Adisa and Adekunle (2010) who reported that the motive for farming was majorly for income generation in North Central Nigeria.

The average annual income of farmers was ₦190,545. This is far below one dollar per day, showing the level of poverty in the farming communities. Thus, attacks on the farms could attract serious dispute with opponents, being the major means of livelihood. Hence, farmer-herders' conflict are often a consequence of struggle for survival. A significant proportion (59.7%) of the respondents belonged to organizations. This is not only a veritable tool for enhancing production through economy of scale, but more importantly, an instrument for conflict resolution and sustainable peace when effectively harnessed. According to Ekong (2010) membership of social organization in the rural areas is of immense value if such organizations could help members accomplish tasks an individual cannot achieve alone.

Perceived causes of conflict between herdsmen and farmers

Table 2 shows the results of rotated matrix indicating the extracted factors based on the responses of rural crop farmers. Three major causal issues were identified namely violation of agreements, livelihood interference and cultural factors.

Violation of agreements/traditions

The causative variables were sedentarization of herders on farm land without permission (0.84), herders assuming grazing right without the consent of farmers in the area (0.62), little respect for traditional grazing custom (0.61), population growth (0.59), and herders' claim of land as common property (0.59) (Table 2). Others included non-compliance with laid down rules (0.46), sexual harassment (0.43), and uncontrolled grazing (0.42). The migratory and sedentary patterns of pastoralists influence their belief and altitude to land ownership and use. In most communities in Nigeria, herders are given temporary settlement right which they often over- stay and subsequently demand equal right of tenure and exploitation. Moreover, the Fulani herders believe that land is a common property that should be used without permission from anybody. This explains the regular violation and non-compliance to traditional laws guiding

Table 1. Percentage distribution of crop farmers by socio-economic characteristics.

Socio economic variables	% (n= 135)	Mean
Sex		
Male	85.2	-
Female	14.8	-
Age		
Below 21	0.7	-
21 - 30	7.1	-
31 - 40	17.7	50.84
41 - 50	26.7	-
51 - 60	25.5	-
61 - 70	15.6	-
Above 70	6.7	-
Marital status		
Married	85.9	-
Widowed	5.9	-
Single	8.2	-
Educational levels		
No formal education	30.4	-
First school leaving certificate	29.6	-
Senior school certificate	22.0	-
ND/NCE	10.4	-
BSC/HND/MSC	7.6	-
Household size		
Below 5	7.4	-
5 - 9	37.6	-
10 - 14	23.0	12.2
15 - 19	14.2	-
20 - 24	10.4	-
Above 24	7.4	-
Farm size (ha)		
1 - 5	94.1	-
6 - 10	5.2	2.9
Above 10	0.7	-
Types of crop grown		
Maize	92.6	-
Yam	97.8	-
Cassava	92.6	-
Rice	23.0	-
Tree crops: cashew, cocoa, etc.	25.2	-
Vegetable crop	20.7	-
Plantain/pineapple	31.1	-
Legume crop	48.2	-
Production motive		
Income purposes	10.3	-
Commercial and consumption	88.2	-

Table 1. Contd.

Membership of social organization		
Agricultural organization	43.8	-
Religious organization	18.8	-
Social clubs	37.2	-
Income		
Below 300,000	77.7	-
300,001-400,000	14.8	190,545.45
400,001-500,000	2.2	-
500,001-600,000	2.2	-
Above 600,000	3.0	-

Table 2. Factor analysis of causes of conflict as perceived by crop farmers.

Factors	Herders violation Factors	Livelihood interference	Cultural factor
Damage to crops by cattle	0.38	-0.06	-0.10
Sexual harassment	0.43	0.02	0.23
Pollution of the available source of water in the community	0.13	0.69	0.18
Herders' over stay in a location	0.33	0.48	-0.21
Cattle herders not obeying the elders	0.2	0.56	-0.16
Uncontrolled grazing	0.42	0.09	-0.08
Cultural differences	-0.21	0.02	0.77
Proximity of the disputants	0.02	-0.18	0.78
Language barrier	-0.26	0.06	0.83
Little respect for traditional gazing custom	0.61	0.22	0.04
Destruction of farm land	-0.03	0.55	-0.16
Unaccepted sedetarization of herders on farm land without permission	0.84	0.08	-0.16
Non-compliance with laid down rules	0.46	0. 36	-0.06
Declining influence of traditional rulers	0.53	0.43	-0.14
Population growth	0.59	0.19	-0.29
Pilferage from the farmers farms	0.27	0.57	-0.03
Herders giving grazing right without the consent of the farmers in the area	0.62	0.16	0.06
Destruction of irrigation equipment by herders themselves	0.17	-0.37	0.42
Burning of rangeland	0.13	0.71	0.08
Herders claiming the land as common property	0.59	0.38	-0.15

land ownership and grazing of livestock. Moreover, the more sedentarized the herdsmen are on farmers' farmland, the less available land for farming and this could increase potentials for conflict between crop farmers and herdsmen. Besides, the disputants are from different ethnic groups with varying values, belief which affect conflict behavior; and invariably acceptance and compliance to existing laws.

Furthermore, growth in human population increases pressure on land, as both actors strive to meet the food needs of the population. This could compel farmers to increase their farm size including marginal land areas and cattle routes/fadama land. Invariably, this reduces rangeland for gazing and sometimes interferes with livestock route. According to Ayih (2003) in Okoli and Altehe (2014), people tend to move from Northern and Southern Nigeria into the Middle Belt region where population is relatively low and where there is availability of vast arable land, increasing competition over farmland. With this development, grazing areas that were hitherto abundant are being taken over by scattered small farms, making grazing difficult.

Grazing rights assumed by herders without farmers' consent means disregard to grazing custom with erroneous perception of land as a common property. Furthermore, farmers' non-compliance with grazing routes could be responsible for the uncontrolled grazing of cattle by herders. Farmers are often attracted to farmland across livestock routes, perhaps due to high quantity of organic manure on the route or for dry season vegetable production, for example use of fadama shallow aquifer for crop production possess negative consequences for pastoralists who depend on such facilities for dry season grazing. Pastoralists consider where they traditionally graze herd to be their land, while farmers on the other hand, view any undeveloped land as available for cultivation, probably with permission from the traditional authority in the area. Consequently, as a way of showing disapproval of farmers' action, herders often allow animals to graze uncontrollably on the crops, exacerbating potential for conflicts.

Livelihood interference

This includes factors that negate livelihood activities of farming communities. They include burning of range land (0.71), pollution of community water source (0.69), pilfering from farms (0.57), cattle herders not obeying the elders (0.56), destruction of farmland (0.55), and herder's over stay in a location (0.48) (Table 2). This is in congruence with Ofem and Inyang (2014), who reported that burning of range land, pollution of water source, disrespect for traditional leaders, and destruction of farmland were the major causes of conflict between herders and farmers. Similarly, Adebayo and Olaniyi (2008), further reported grazing on harvested crops, theft of farmers' produce by herders and pulverization of soil, among others as causes of conflict between crop farmers and herders. The traditional practice of burning range land is common among herders and is carried out to stimulate early sprouting of fresh pastures as the dry vegetation get burnt. Often in the process of burning, fire spreads into adjourning farms destroying farms, stored food stuff in the bans and farm implements. Also, it adversely affects soil biomass, conservation and sustainability of the environment. Over- stay in a location by herdsmen could result to destruction of farm land, pilfering from farms and burning of rangeland. As herders stay long in an area, the hoof of animal irreversibly hardens the soil upon which they pass and makes cultivation extremely difficult. In most communities in Nigeria, herders are given temporal settlement right which they often over-stay and subsequently demand equal right of tenure and exploitation. This largely accounts for greater conflict situations in almost all states of the federation.

In the case of water pollution particularly along fadama areas, traditionally used for dry season grazing, herdsmen often lead their cattle into water sources to drink and in the process they defecate and urinate inside. This could trigger open fight between youths in such communities and the herdsmen. The communities are denied access to safe drinking water and environment. Above all, Fulani herdsmen wonder into fields during growing season while their herds eat or trample on crops due to lack of attention or the cattle's stray movement resulting to tension in communities (Haro and Dayo, 2005).

Cultural factors

Cultural differences among resource users promote conflict situation in communities. These are issues associated with language barrier (0.83), proximity of disputants (0.78), cultural differences (0.77), and destruction of irrigation equipment by herders (0.42) (Table 2). In an environment with cultural variations, sometimes evidence from differences in language, values, belief, livelihood strategies and practices, there are possibilities of misunderstanding between individuals in such communities, which could translate to conflict with little provocation. Conflict arises from inconsistencies of needs of members, inefficient communication between groups with different languages and culture. Crop farmers come near herders as they expand farms and rotate production due to declining soil fertility and search for marginal lands; and farmers with farms close to cattle routes or camps are likely to be in regular conflict with herdsmen. Proximity to disputant increases potential for conflict because according to realistic theory of conflict, when competition over resource is present, proximity and contact increase inter-group hostility. Also, Hewstone and Greenland (2000), stated that the incompatibility of goals and competition for scarce resources make the source of conflict to be realistic. The incompatibility of goals, belief, values associated with differences in culture explain the attitude, behaviour and responses to conflict.

Overall, the results of factor analysis present combination of factors as causes of conflict among resource users. The respondents recognized the existence of underlying structural factors livelihood issues linked to either competition over resource, livelihood failure and protection. This supports Maiese (2003) that there can be rarely any clear cut single source of event that can precipitate conflict, but rather combination of interdependent factors. Farmers and herders live in common geographic areas with scarce natural resources particularly land and water, which are dependent on environmental changes as basic livelihood assets, hence the incompatibility of goals and the resultant conflict between the group. The results show the preponderance of the actions that are linked to livelihood failure and competition; and responses of group in conflict to attempts by the other group to undermine their livelihood

Table 3. Factor analysis of perceived effects of conflict on crop farmers.

Variable	Socioeconomic	Production losses	Displacement
Break down of law and order in the communities	-0.02	0.11	0.10
Decrease in output	**0.67**	0.17	-0.17
Absence of agricultural labour force	0.17	**0.78**	0.16
Destruction of crops on the field	0.58	0.13	-0.04
Poor harvest	**0.62**	0.11	0.00
Late planting	0.23	**0.70**	-0.16
Harvesting premature crops	0.60	0.46	-0.14
Abandonment of crops in the field	0.23	**0.79**	-0.14
Rottening of crops in the ban/ storage places	0.22	**0.83**	-0.05
Lack of proper care of crops in the field	0.23	**0.82**	-0.12
Displacement of farming population	0.25	0.28	0.27
Insufficient food supply to the farming communities	**0.72**	0.03	-0.16
Longer times spent in the farm	**0.69**	0.21	-0.18
Outbreak of hunger and diseases	**0.75**	0.27	-0.13
Loss of lives and injuries sustained	**0.54**	0.17	0.07
Loss of income	**0.58**	0.07	-0.06
Migration of herders into marginal areas	0.31	0.01	**0.55**
Unsaved environment for farming	0.38	0.13	**0.52**
Forced relocation of farms	-0.12	-0.05	**0.77**
Increased no of widows, widowers and orphan	-0.26	-0.10	**0.90**
Destruction of mutual trust and intensification of suspicious along ethnic and religious divides	**0.66**	0.20	0.22
Teenage pregnancy	-0.40	-0.02	0.52
Misbehaviour and uncontrollable conduct of youth	0.02	0.39	0.31
Proliferation of small arms	-0.47	0.08	0.49

goals. The underlying structural factors of the environment, political, institutional malady, poverty, religious, ethnicity among others are also evidence, though with relatively low perception by the crop farmers. Thus, while livelihood pursuits can trigger conflicts, conflicts can negatively impacts on livelihood assets of farmers both natural, physical, human, social, political and financial.

Effects of conflict on the livelihood of crop farmers

Principal component analysis indicated that conflict affects socio-economic, production output and security of life of crop farmers (Table 3).

Socio-economic factors

Table 3 shows that conflict between crop farmers and herders resulted to outbreak of hunger and diseases (0.75), insufficient food supply to the farming community (0.72), longer time spent in the farm (0.69), decrease in farm output (0.67), suspicion along ethnic and religious divide (0.66), poor harvest (0.62), lost of income (0.58) and sustains injuries (0.54). Some variables like outbreak of hunger and diseases, injuries, loss of income, suspicion along religion and ethnic divide and poor harvest have positive relationship, which means that conflict increases the aforementioned conditions of life and is as well exacerbated by these conditions. Similar studies also reported loss of a whole farm of standing crops, loss of human lives, quality of relationship and material resources (Fiki and Lee, 2004; Adisa and Adekunle, 2010).

Conflict significantly affects both physical and financial livelihood assets of farmers. Destruction of crop in farms could cause poor harvest, insufficient food supply, loss of productive resource culminating to poor income, outbreak of hunger, nutrition related diseases and poverty. This could influence farmers to resort to unsustainable livelihood options, spend more time on the farm so as to make up for supply deficit; and others might increase dependent on neighbours and relations for survival leading to vicious cycle of poverty among households. On another hand, when crops are destroyed and the farming environments become unsafe that farmers abandon crops in the farms; it could lead to loss of biodiversity and poor access to human and financial assets. Abba and Usman (2008) also reported that farmers abandon the cultivation of some crops to avert conflict with herdsmen.

Above all, conflict leads to breakdown of social system evidence as ethnic and religious divide, insecurity of life, hunger and poverty. It destroys or/and weakens the social assets of rural communities. Farmers witnessed destruction of mutual trust and intensification of suspicious along ethnic and religious groups, and general breakdown of laws and order in communities. Invariably, this affects the social and political assets of farmers because members of communities can hardly come together with common voice on issues that require public intervention.

Production losses

Conflict in agrarian communities results to rottening of crops in ban and other storage places (0.83), lack of proper care of crops in the field (0.82), abandonment of crop in the farm (0.79), absence of agricultural labour force (0.78), and late planting (0.70) (Table 3). This entails losses along production process, ranging from production, harvesting, preservation and marketing. This is because herder-farmers' conflict creates an atmosphere of uncertainty, insecurity, breakdown of economic activities and migration of people to safer places. Farmers compromise many production activities resulting to low yield, poor economic return and loss of planting materials. Similarly, agricultural labour usually supplied by rural youths/households is seriously affected due to loss of life and displacement. Most youths migrate to more peaceful locations, thereby creating labour scarcity in the conflict-stricken zones. This negatively impacts on human capital formation as well as agricultural productivity, and subsequently farm decision and livelihood activities.

Farmers' displacement

Herdsmen-farmers' conflict leads to forced relocation of farmers (0.77), increased number of widows and orphan (0.90), migration to marginal areas (0.55) and unsafe environment for farming (0.53) (Table 3). The result confirms Olabode and Ajibade (2010) who reported a wide spread displacement of farmers from their farms following destruction of farms by the invading pastoralist and subsequently a fall in farm yield as farmers abandoned their more fertile farm land in avoidance of conflict. Natural resources including land are the major source of livelihood for rural communities; and availability and accessibility to such resources enable farmers to maintain their wellbeing and livelihoods. Forced relocation and migration of farmers could cause scarcity and intensify competition over resources due to over concentration of displaced persons in a particular area. Increased number of widows suggests losses of life associated with conflict and subsequent drain on the human capital accumulation of households and communities. Seddon and Hussein (2002) reiterated that the loss of a household member through death may be a critical economic loss particularly, if that person was a major contributor to the household's livelihood. Availability and cost of labour is affected because many rural households depend on cheap family labour. Furthermore, availability and access to social amenities like education, workshops, trainings, cooperatives, and financial institutions which are pivotal to sustainable livelihood are hampered due to insecurity of the environment.

Conclusion

Conflict in agrarian communities largely revolves on livelihood issues. The results show that in addition to some structural factors, conflicts are associated with livelihood pressure and competition between crop farmers and herdsmen. Specifically, the dominant composite causes revealed in the study are violation of agreement/laws, interference on livelihood sources, and cultural differences. Consequently, this impacts on the social, economic and political lives of crop farmers and subsequently, the entire livelihood assets of crop farmers ranging from physical, natural, human, financial, and social to political assets.

The livelihood structure, food security and wellbeing of farmers are threatened and compromised which contribute to poverty, food and nutrition insecurity and poor health of farming communities, and further escalation of conflicts. Therefore, sustainably addressing conflict in farming communities is critical to achieving economic, agricultural development and sustainable livelihood. Strategies by government, NGOs and communities that target conflict management or resolution should promote support for sustainable livelihood. In other words, provision of grazing land, pasture route, use of formal and informal security outfits and institutions should be accompanied with efforts that support and strengthens diversified livelihood capacity ranging from entrepreneurship training, provision of social, infrastructural facilities and interventions in agricultural sectors with competitive advantage for communities. Farmers should be assisted with productive resources like improved seeds, technologies and other agro inputs by the government to reduce vulnerability and protracted conflict in communities.

There should be strategic and regular orientation of resource users and citizens on the need for co-existence and adherence to regulations regarding use of resources by development agencies including extension organizations. Above all, multi-stakeholders' efforts exploring grass root alliance and commitment should be promoted by government, policy makers and NGOs in policies and strategies for management of conflict and establishment of compliance to laws and regulation of instituted rural authorities.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Topdressed nitrogen fertilization on second-crop corn in soil with improved fertility

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The aim of this study was to evaluate the performance of sources and application rates of topdressed nitrogen (N) on second-crop corn following soybean in an improved fertility *Latossolo* in the region of Campos das Vertentes, MG. Brazil. A randomized block experimental design was used in a 4 x 5 +1 factorial arrangement, with four replications. The treatments consisted of the combination of four N sources via forms of urea: conventional urea (common urea), urea coated with 16% elemental sulfur (Urea+S), urea treated with base compound urease inhibitor with a 0.4% boron and 0.15% copper (Ureia+B+Cu), urea treated with 1.060 mg kg^{-1} of the urease inhibitor N-(n-butyl) thiophosphoric triamide (Urea+NBPT), and five application rates of N through urea: 30, 45, 60, 90, and 120 kg ha^{-1}, plus an additional treatment without N supplied in topdressing. The N concentrations in the leaves and grain, the exported N, the mineral N in the soil (nitrate and ammonium), grain yield, and profitability were evaluated. The N sources increased the N concentrations in the leaves, in the grain, and the exported N. However, the grain yield and the N concentration in the soil did not vary in accordance with the sources of urea. Increasing application rates of N increase N concentration in the leaves and in the grain, exported N, grain yield, and the mineral N concentration in the soil up to a depth of 10 cm. Application of N in topdressing is not economically beneficial considering the final yield of the second-crop corn following soybean in a soil with improved fertility.

Key words: *Zea mays* L, Urea, Nitrogen, No-tillage system, N rates.

INTRODUCTION

In recent years, there has been a considerable increase in yield in the main grain crops in Minas Gerais, Brazil. Specifically for corn, mean yield increased from 3.9 to 5.4 t ha^{-1} from the 2005/06 crop year to the 2014/15 crop year. In these 10 years, production increased from 5.3 to 6.9 million tons (CONAB, 2016).

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In the 2014/15 crop year, the contribution of second-crop ("safrinha") corn was very significant. Cultivated area increased by 288% from the 2005/06 to the 2014/15 crop year. In the latter crop season, the second-crop corn was responsible for production of 54.6 million t of corn grain in Brazil, with mean grain yield of 5.7 t ha^{-1} (CONAB, 2016).

Along with expansion of the soybean crop to the south of the state of Minas Gerais (MG), and specifically the region of Campos das Vertentes, MG, there has been expressive development of second cropping. These regions have become important grain production centers in the state.

Nevertheless, various agronomic technologies are being adopted that have not yet been duly consolidated for the soil and climate conditions of the region. Prominent among them is topdressing fertilization on second-crop corn.

Currently, in these regions, low N application rates are often recommended, as in other regions with second-crop corn. In general, this has been justified by the lower potential yield associated with greater climate risk factors, such as low water availability, cool weather, and less solar radiation in the central region of Brazil (Shioga et al., 2004). However, the efficiency of nitrogen (N) use is highly dependent on local soil and climate conditions and that makes regionalized studies necessary (Gott et al., 2014) as proposed here.

N is the most important nutrient in the corn crop mainly due to its role in plant growth. It is a structural component of chlorophyll and, as such, participates directly in plant photosynthetic activity and in increasing total percentage of proteins, which results in ear weight gain (Fancelli and Neto, 2004). The high export rate of N through the grain, the decreased uptake rate under water deficit conditions, and high volatilization and leaching losses make N the nutrient of highest demand in the corn crop (Soratto et al., 2010).

Volatilization of ammonia (NH_3) is one of the most important processes connected with reduction in N use efficiency, and volatilization increases when N is supplied by ureas. Under conditions of wet soil that is covered by crop residues and receives high solar radiation, loss of NH_3 through volatilization may reach values greater than 50% of the N applied via urea (Vitti et al., 2007). Under these soil and climate conditions, peak volatilization of NH_3 occurs on the second or third day after application of urea (Cantarella, 2007).

Additives applied to urea have reduced volatilization losses in inhibiting activity of the urease enzyme. The inhibitor occupies the site of activity of the enzyme and inactivates it. It thus delays the start and the speed of volatilization. Delayed hydrolysis of urea reduces the concentration of NH_3 in the surface soil, limiting its loss. Upon preventing rapid hydrolysis, the inhibitor increases the possibility of rainwater and irrigation incorporating the components of urea in the soil profile (Cantarella, 2007). Another attempt at increasing the efficacy of urea utilization consists of coating the granules with polymers or other materials, including elemental sulfur (Oliveira et al., 2014).

Some studies have shown the efficiency of urease inhibitors in reducing the speed of transformation of urea to NH_3, with reduced losses through volatilization of N compared to common urea. However, new studies must be performed under different soil and climate conditions (Chien et al., 2009).

Although some studies have shown reduction in N losses through volatilization with the use of urea with urease inhibitors, often crop yields have not been affected. This shows the need for new studies because these fertilizers increase production costs by 15 to 20 %.

Within this context, the aim of this study was to evaluate the performance of sources and application rates of N supplied by ureas in topdressing in second-crop corn following soybean in a soil with improved fertility in the region of Campos das Vertentes, MG, Brazil.

MATERIALS AND METHODS

The experiment was conducted from March to June 2012 on the Santa Helena Farm at 21º15'40'' S and 44°30'30" W, in Nazareno, MG, Brazil. Altitude of the location is 1020 m. The soil was classified as a *Latossolo Vermelho Distrófico*, with clayey texture (Embrapa, 2013).

The area has a management history of high technological investment for grain production and was in *Brachiaria* pasture until 2005. From the 2005 to 2010 crop years, the area was tilled and planted to corn in the main crop season, with winter fallow. In the 2011/2012 crop year, soybean was planted in the main crop season, followed by second-crop corn. A no-tillage management system was used beginning with the planting of annual crops. The chemical characteristics of the soil with improved fertility (Kappes and Zancanaro, 2014) of the experimental area were performed prior to the experiment beginning, according to analytical procedures the 0,0-010 m layer described in Silva (2009) had the following chemical properties: clay and organic matter, 560 and 32.8 g kg^{-1},respectively; pH in water, 5.0; available P and K, 6.1 and 141 mg kg^{-1}, respectively (extracted by Mehlich-1); exchangeable Al, Ca, and Mg, 0.0, 2.4, and 0.7 cmolc dm^{-3}, respectively (extracted by 1 mol L^{-1} KCl); cation exchange capacity (CEC) at pH 7.0, 8.0 cmolc dm^{-3}, base saturation of CECpH7.0, 44.0 %; N-NH_4+ and N-NO_3-, 14.2 and 41.2 mg dm^{-3}, respectively, and H+Al, 4.5 cmolc dm^{-3}.

The corn cultivar DOW 2B587 Hx was sown with a mechanized planter (with nine planting rows spaced at 0.6 m) in dryland conditions following soybean. The crop was sown in February 2012, with a final population estimated at 60 thousand plants ha^{-1}.

The treatments were in a 4 x 5 +1 factorial arrangement in a randomized block design, with four replications. The plots consisted of six rows spaced at 0.6 m and 10 m length. In these plots, we compared application rates of 30, 45, 60, 90, and 120 kg ha^{-1} of N supplied by the following urea sources: conventional urea (Common urea), urea coated with 16% elemental sulfur (Urea+S), urea treated with base compound urease inhibitor with 0.40% boron and 0.15% copper (Urea+B+Cu), and urea treated with 1060 mg kg^{-1} of the urease inhibitor N-(n-butyl) thiophosphoric triamide (Urea+NBPT). An additional treatment without topdressed N

(Control) was evaluated.

The treatments (sources and rates of N via ureas) were applied manually in strips, around 20 cm beside the plant row, in the four expanded sheets stage (V_4). Fertilization at planting was that adopted by the producer in the rest of the field, for an expected yield of 7.2 t ha^{-1}. It consisted of application of 15 kg ha^{-1} of N and 75 kg ha^{-1} of P_2O_5 supplied by monoammonium phosphate (MAP) in the planting furrow, and 60 kg ha^{-1} of K_2O supplied via broadcast KCl prior to sowing.

The plant health treatments (herbicide, insecticide, and fungicide application) were performed when necessary according to the protocol of the farm (time, amount, and type of product to be applied). To monitor the climatic variations in the experimental period, a meteorological station was set up with automatic recording of data at around 1000 m from the location of the experiment.

In the tasseling stage (V_T), soil samples were collected for evaluation of mineral N (ammonia N + nitrate N) available in the soil in the 0-10, 10-20, 20-40 cm depth layers. Sampling consisted of five single samples per plot in the treatments: Common urea; Urea+S, and Control (without topdressed N).

The explanation for selection of the three treatments is due to the representation of mineral N in the treatments that contrast management practices without application of N, traditional application of N via conventional urea, and N applied with stabilized urea sources. The samples were air dried immediately after collection (aiming to reduce changes in the forms of N in the soil), passed through a sieve with a 2 mm diameter mesh, and refrigerated at a temperature below 1°C (Mattos et al., 1995). Ammonia N + nitrate N was determined by the semi-micro Kjeldahl steam distillation method (Tedesco et al., 1995).

Leaf samples were taken in the female flowering stage by collecting 15 leaves per plot on plants at a point opposite to and below the ear. Leaf N was analyzed using the Kjeldahl method (Tedesco et al., 1995). Grain yields were evaluated by harvesting three 4-m rows per plot after physiological maturity of the crop. Grain yields was determined after mechanical shelling, adjusting the moisture content to 130 g kg^{-1}. Based on calculation of N concentration in the grain, in which the same method of leaf analysis was used (Tedesco et al., 1995), N export was estimated by multiplying the concentration in the grain by the total grain weight.

The data were subjected to analysis of variance. The mean values of the treatments were compared by the F test and regression models were fitted to the dependent variables in accordance with the application rates of topdressed N. The variables of N urea sources were compared by the Scott-Knott test at the level of 0.05 probability. The Sisvar statistical program (Ferreira, 2011) was used.

An economic analysis was made based on the costs of topdressed nitrogen fertilizers in August 2013. The data were compared to the income generated from grain sales. The prices paid per kg of nitrogen fertilizer were: Urea+B+Cu = R$ 1.46, Urea+S = R$ 1.57, Urea+NBPT= R$ 1.34, and Common urea = R$ 1.20. The estimated cost of mechanized application of topdressed nitrogen was R$ 10.00 ha^{-1} in 2012 (considering the mean total operational cost of the farm), and the other expenses for the crop were considered constant. The commercial value of the 60 kg bag of corn was R$ 32.62. The U.S. dollar exchange rate on August 18, 2013 was R$ 2.42 (CEPEA/ESALQ, 2013).

RESULTS AND DISCUSSION

There was water deficit during the tasseling and flowering period of the second-crop corn (Figure 1). In this period – from Abril 10 to May 10, 2013 – there was accumulation of only 20 mm of rainfall, which hurt crop performance in the period of greatest water demand (Bergamaschi et al., 2004).

The interaction between N sources and application rates was not significant for the N concentration in the leaves. Nevertheless, the leaf N concentration varied according to the sources (Figure 2A). The sources and application rates increased the leaf N concentration in relation to the treatment without application of N (control) (Figures 2A and B).

The concentrations observed in the treatments that received N are above the reference value for leaf N concentration (30 g kg^{-1}), according to Cantarutti et al. (2007). This shows that modern corn genotypes extract more N to express their yield potential because the soil, which was built up (Kappes and Zancanaro, 2014), has a good nutrient reserve, including initial mineral N content.

The results of leaf N concentration in this study indicate that the favorable climate conditions at the time of N application (Figure 1) allowed efficient uptake of nitrogen fertilization by the corn crop and also a decrease in possible losses through volatilization from application of ureas. There was a rain of 28 mm, 24 hours after fertilizer application. Another relevant aspect is the contribution of organic N from the soil. The high organic matter content in the soil made considerable mineral N content available to the plants through mineralization of organic N. The leaf N concentration of 28 g kg^{-1} in the control treatment confirms this hypothesis.

Although the interaction between application rates and sources of N was significant for the grain N concentration variable, the N sources affected the grain N concentrations only at the application rate of 30 kg ha^{-1} (Table 1). The stabilized urea sources proved to be superior to conventional urea. Regardless of the sources, the corn plants grown with 120 kg ha^{-1} of N in topdressing had higher grain N concentrations.

The grain N concentrations did not vary much among the treatments (12.9 to 15.1 g kg^{-1}) (Table 1). These concentrations are near those found by Duarte et al. (2005), which ranged from 13.7 to 17.5 g kg^{-1} in a study conducted with different N sources applied in the main crop season in a *Latossolo* of the *Cerrado* (Brazilian tropical savanna). The narrow range of N rates (90 kg ha^{-1}) applied in the treatments of this study probably limited greater variations among the grain N concentrations. Cantarella and Duarte (2014) consider 15 g kg^{-1} as an adequate level of grain N concentration, a value that may vary according to the genotype used.

The amount of N exported through the grain was not changed by the sources of urea (Figure 3A). Nevertheless, it increased along with an increase in the N rates applied (Figure 3B). The N exported was 94 kg ha^{-1}, on average, among the sources tested. Converting the N values exported by the grain produced, the mean value is 14.6 kg t^{-1} of grain, which is similar to Cantarella and

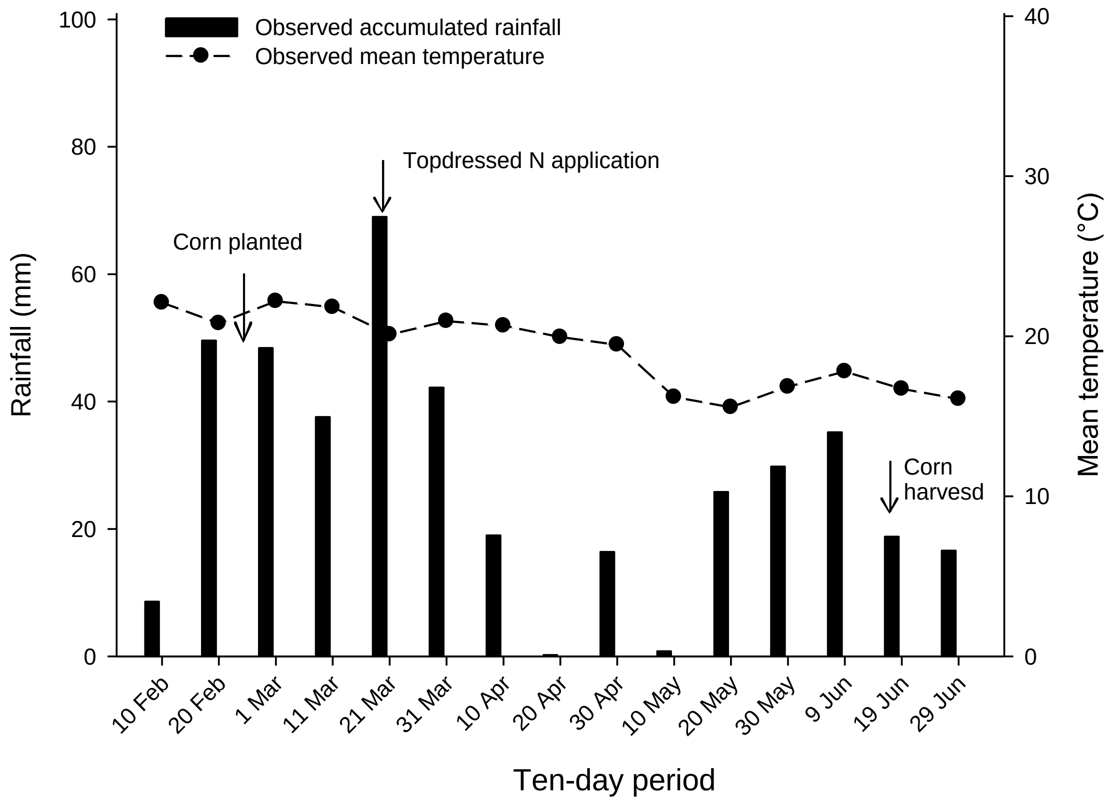

Figure 1. Rainfall and mean temperature observed during the experimental period, Nazareno, MG, Brazil, 2011/2012 crop season.

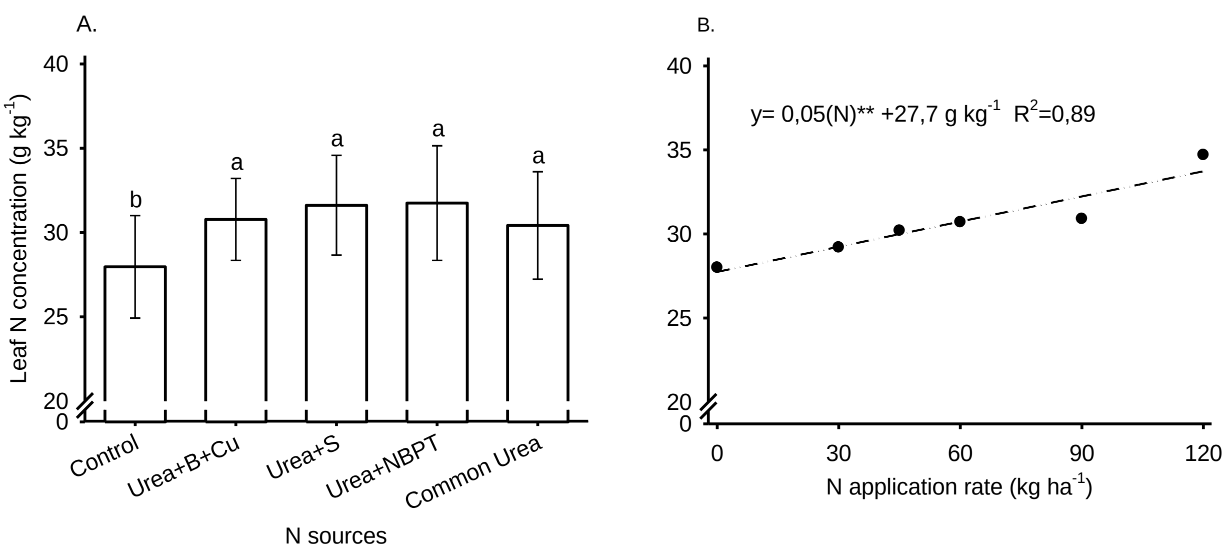

Figure 2. Leaf N concentration as a result of different sources (A.) and rates (B.) of N applied in topdressing via ureas in second-crop corn in rotation with soybean in an improved fertility *Latossolo*. ** significant at 1% of probability by the F test. Nazareno, MG, Brazil, 2011/2012 crop season.

Duarte (2014), who estimated a standard value of 15 kg t^{-1} of N exported through grain.

In the treatment that did not receive N in topdressing, 77 kg ha^{-1} of N was exported via the grain. This shows

Table 1. Grain N concentration (g kg^{-1}) in second-crop corn following soybean in an improved fertility *Latossolo*, as a result of sources of urea and N application rates in topdressing. Nazareno, MG, Brazil, 2011/2012 crop season.

N source	N application rate (kg ha^{-1})				
	30	45	60	90	120
Urea+B+Cu	13.7^A	14.3^A	15.1^A	14.7^A	14.8^A
Urea+S	13.5^A	14.0^A	14.3^A	14.8^A	15.1^A
Urea+NBPT	14.0^A	13.5^A	13.7^A	14.6^A	15.1^A
Common urea	12.9^B	13.8^A	14.0^A	14.1^A	14.9^A
Mean	13.5^c	13.9^c	14.3^b	14.5^b	15.0^a
CV %	2.5	3.2	7.2	2.4	4.3

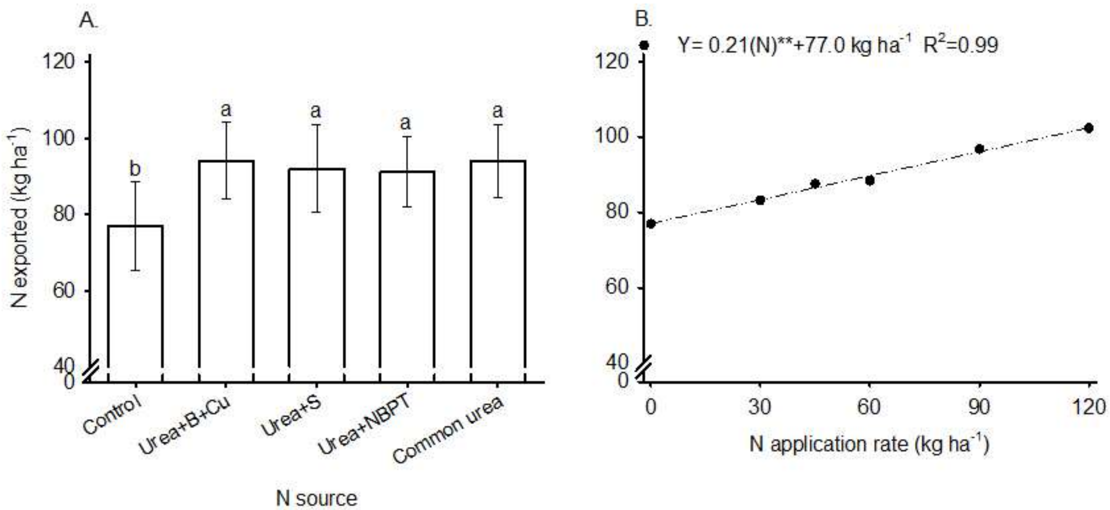

Figure 3. N exported as a result of different sources (A.) and rates (B.) of N applied in topdressing in second-crop corn in an improved fertility *Latossolo*. ** significant at 1% probability by the F test. Nazareno, MG, Brazil, 2011/2012 crop season.

that part of the N exported originated from mineralization of the organic matter in the soil. The other fraction of N that was exported originated from the 15 kg ha^{-1} of N supplied at sowing through application of the MAP fertilizer. This shows the importance of fertilization for maintaining the soil organic matter.

The interaction between N sources and rates applied in topdressing were not significant for mineral N available in the 0 to 10, 10 to 20, and 20 to 40 cm depth layers. The common urea and sulfur-coated urea sources had higher mineral N concentrations than the control treatment only in the 20 to 40 cm layer (Figure 4A). There were probably considerable losses through leaching because rainfall of 48 mm was registered 36 hours after the application of the ureas in topdressing.

The addition of different rates of N increased the mineral N concentrations in the surface layer, and an increasing linear model was fitted. In contrast, in the 10 to 20 cm layer, the N rates applied did not modify the mineral N concentrations. In the 20 to 40 cm layer, there was a quadratic fit between the application rates and the mineral N concentration available (Figure 4B).

From the increase in the mineral N concentrations in the soil, especially in the surface layer (0 to 10 cm), it can be deduced that high rates of N applied through fertilizer in topdressing provide a good supply of the nutrient in the corn cycle when the greatest amount of N is required, given that the evaluation was made at the beginning of tasseling.

Considering the apparent density of the soil of 1.0 kg dm^{-3} normally observed in the *Latossolos* of the Cerrado, the treatments that received N via ureas made a stock of around 24 kg ha^{-1} of mineral N available in each layer evaluated (Fernandes and Fernandes, 2009). This value can be considered significant in the 20 to 40 cm layer since the plant concentrates around 80% of the root system in the first 40 cm of the soil profile (Silva et al., 2012).

It should be noted that organic matter is important in making mineral N available to the crop. In the first 20 cm

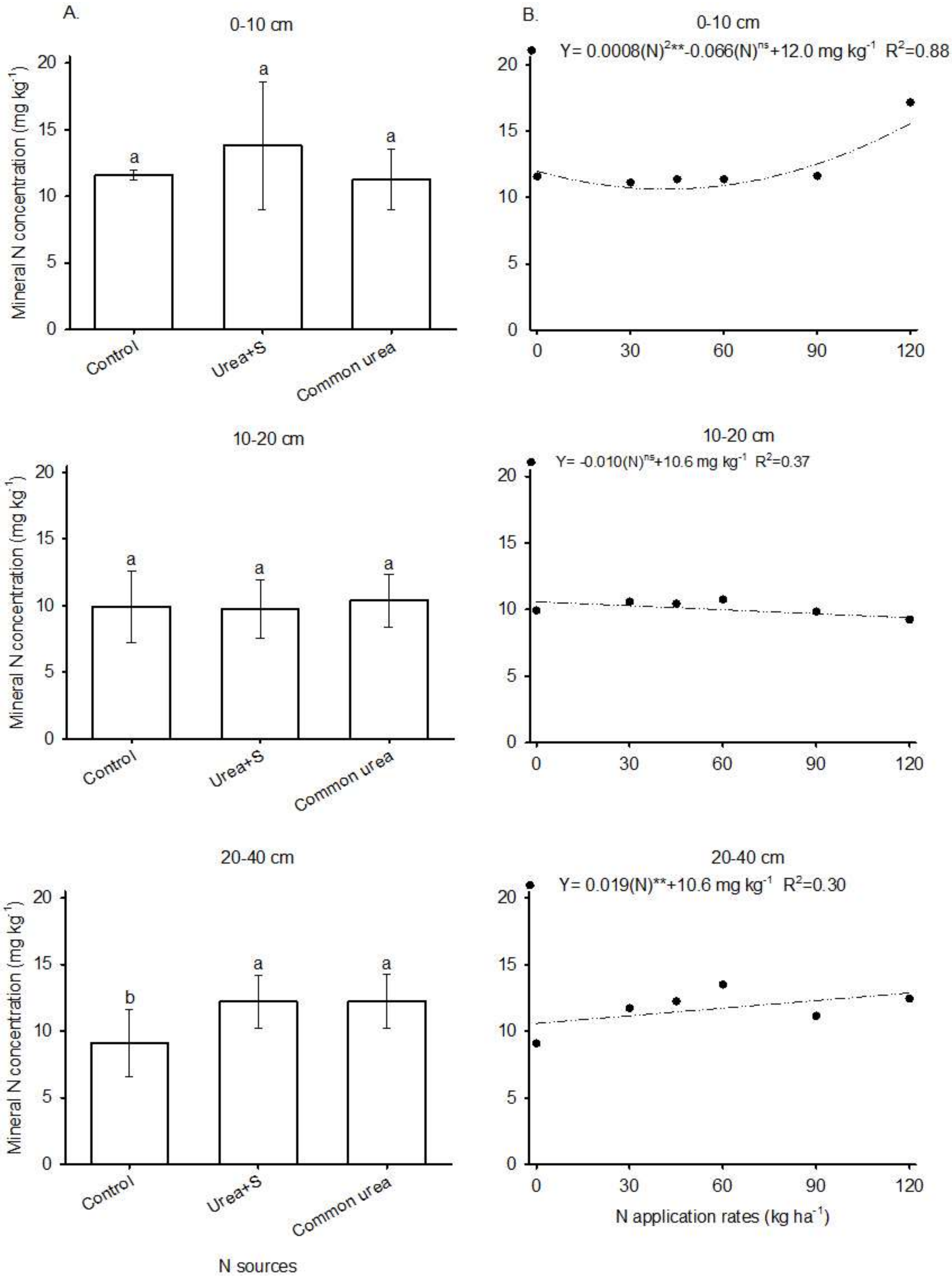

Figure 4. Mineral N (NO_3^- + NH_4^+) concentration in the 0-10 cm, 10-20 cm, and 20-40 cm depth layers, as a result of different sources (A.) and rates (B.) of N applied in topdressing in second-crop corn in rotation with soybean in an improved fertility *Latossolo*. ** significant at 1% probability by the F test. Nazareno, MG, Brazil, 2011/2012 crop season.

of soil depth, the control treatment made mineral N concentrations available equal to the treatments that had received N via ureas (Figure 4A). Another important aspect is the contribution of N originating from crop

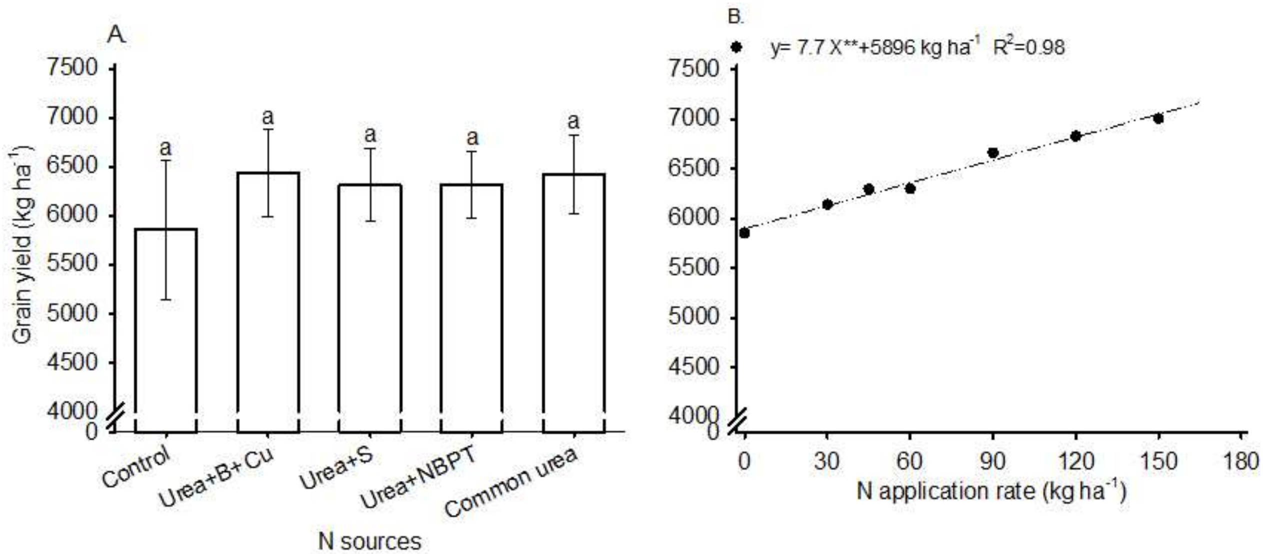

Figure 5. Grain yield under different sources (A.) and rates (B.) of N applied in topdressing in second-crop corn in an improved fertility *Latossolo*. ** significant at 1% probability by the F test. Nazareno, MG, Brazil, 2011/2012 crop season.

residues from previous crops, especially leguminous crops. These aspects indicate the fundamental importance of a suitable supply of N to non-leguminous species, with economic and environmental impacts, because of high response to the application of this nutrient and the high susceptibility to losses by the processes of volatilization and leaching (Aita et al., 2004; Ferreira et al., 2010).

There was no interaction between sources and rates of N applied in topdressing for grain yield. Grain yield ranged from 5853 kg ha^{-1} in the treatment that did not receive N (control) to 6430 kg ha^{-1} in the Urea+B+Cu treatment, and the sources evaluated did not exhibit significant difference (Figure 5A). Moreover, corn yield showed a linear increase as the N application rates increased. According to the fitted model, each kg of N supplied added 8 kg ha^{-1} of grain production (Figure 5B).

Studies that show increases in grain yield with increasing application of N via nitrogen fertilizers are well known in the literature (Mar et al., 2003; Santos et al., 2013) as well as the absence of response in the use of sources of different concentrations and chemical composition (Meira et al., 2009; Lange et al., 2014).

The final stand of plants showed significant lodging as a result of the action of wind at the end of the crop cycle. This factor probably led to the low agronomic performance of the cultivar evaluated. Another factor that may have led to low grain yield was the water deficit registered in the period between tasseling and grain filling (Figure 1). Bergamaschi et al. (2004) obtained reduction of 2000 kg ha^{-1} of corn grain in an experiment conducted in dryland arising from water demand of eight consecutive days when the crop was at 60 days after sowing (beginning of tasseling).

Studies performed in the Cerrado showed that second-crop corn responds in grain yield when rates from 120 to 160 kg ha^{-1} of N are applied in topdressing (Mar et al., 2003; Carvalho et al., 2011). These authors obtained yield of 10,7t ha^{-1} upon supplying 160 kg ha^{-1} of mineral N. This implies that in the present study, rates above the maximum tested (120 kg) would increase grain yield according to the fitted model.

Only considering the costs associated with application of N in topdressing in management of second-crop corn practiced on the Santa Helena farm in the 2012/2013 crop year, economic analysis confirmed that there was no advantage in applying nitrogen fertilization in topdressing (Table 2).

The high cost of the fertilizers, the low price received for the bag of corn, and especially the atypical climate conditions that producers confronted in the region for the season brought about the loss obtained from application of nitrogen fertilizers in topdressing. However, longer term studies that consider the production system as a whole are needed. The reason for this is that, without nitrogen fertilization, the sustainability of the systems may be compromised since the supply of N to the crops will be made through oxidation of the organic matter present in the soils (Duete et al., 2009).

Increases observed in relation to standard management of the farm (without application of nitrogen fertilization in topdressing for second-crop corn). Price per kg of nitrogen source: urea+B+Cu = R$ 1.46, urea+S = R$ 1.57, urea+NBPT = R$ 1.34, Urea: R$ 1.20. Cost of mechanized application of urea in topdressing: R$ 10.00 per hectare. Value of a 60 kg bag of corn: R$ 23.62. Exchange rate of U.S. dollar on August 18, 2013 = R$ 2.42. Source: CEPEA/ESALQ (2013); Heringer fertilizantes (2013).

The low efficiency of N use is another factor associated

Table 2. Profitability indicators and N use efficiency in second-crop corn production as a result of application rates and sources of N via ureas in topdressing in an improved fertility *Latossolo*. Nazareno, MG, Brazil, 2011/2012 crop season.

Source	Application rates	Grain yield	Increase				Efficiencyof N
			Grain yield	Income	Cost	Profit	
	………kg ha^{-1}.................			.... R$ ha^{-1}			kg kg^{-1}
Control	0	5853	-	-	-	-	-
	30	6166	313	122.00	438.00	-316.00	10
	45	6304	451	176.00	657.00	-482.00	10
Urea+B+Cu	60	6503	650	254.00	877.00	-623.00	11
	90	6597	744	290.00	1315.00	-1025.00	8
	120	7158	1305	509.00	1753.00	-1244.00	11
	30	5991	138	54.00	471.00	-417.00	5
	45	6165	312	122.00	707.00	-585.00	7
Urea+S	60	6409	556	217.00	942.00	-725.00	9
	90	6642	789	308.00	1413.00	-1105.00	9
	120	6816	963	376.00	1884.00	-1508.00	8
	30	6229	376	147.00	402.00	-255.00	13
	45	6064	211	82.00	603.00	-521.00	5
Urea+NBPT	60	6330	477	186.00	804.00	-618.0	8
	90	6685	832	324.00	1206.00	-882.00	9
	120	6723	870	339.00	1608.00	-1269.00	7
	30	6175	322	126.00	360.00	-234.00	11
	45	6345	492	192.00	540.00	-348.00	11
Common urea	60	6145	292	114.00	720.00	-606.00	5
	90	6769	916	357.00	1080.00	-723.00	10
	120	6650	797	311.00	1440.00	-1129.00	7

with the negative outcome obtained in final yield of the crop. The response in grain production clearly expressed the law of diminishing increases: fertilization increased production in the beginning and then decreased in yield per unit of N added. Probably the low utilization of the N provided in topdressing is connected with the period of water deficit that occurred in the phase of greatest demand for the nutrient by the crop (tasseling and flowering).

The results reveal that the stabilized ureas did not bring about the effect that aims at controlled release of N in synchrony with the demand required by the corn plant. As already discussed, accentuated losses probably occurred through leaching since rainfall of 48 mm was registered 36 hours after application of the ureas in topdressing, a condition that is unfavorable for the stabilized ureas to express their efficacy (Zavaschi et al., 2014).

Conclusions

The sources of N supplied via stabilized ureas does not increase the mineral N in the soil, the leaf and grain N concentration, the exported N, and grain yield. Supplying increased N rates increases the leaf and grain N concentrations, the exported N, grain yield, and mineral N available in the soil up to a soil depth of 10 cm. The application of N via stabilized ureas is not economically compensatory for second-crop corn in rotation with soybean when managed in unfavorable soil and climate conditions in a soil with improved fertility.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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