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Full Length Research Paper

Rice false smut and its management in major rice growing areas in Ashanti region of Ghana

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***Ustilaginoidea virens*, the pathogen that causes rice false smut (RFS) disease induces infertility in infected spikelets, reduces grain weight and caused up to 75% yield loss. Surveys on RFS disease were conducted from September to December, 2015 in 60 rice farms within three districts: Ejisu-Juaben, Ejura-Sekyedumase and Asante Akim-North, in the Ashanti region of Ghana. Incidence and severity, as well as farmers' perception of the disease were obtained using questionnaires. Symptomatic rice panicles were collected from farms for identification of associated pathogen in the laboratory. Effect of four inorganic fungicides: Mancozan super, Suncozeb, Nordox and Sidalco Defender on mycelial growth and sporulation of the RFS pathogen were studied using the food poisoning method. Fourteen rice varieties were evaluated for their response to the disease. The surveys revealed that most (60%) of the farmers had no knowledge of the disease. The highest incidence of RFS disease was observed at Duampompo (23.3%) in Ejisu-Juaben Municipal/District, Ntemaso (23.3%) in Ejura-Sekyedumase District, and Habitat (38.0%) in Asante-Akim North District. The highest severity was observed at Ntemaso (5.0) in Ejura-Sekyedumase and Habitat (7.6) in Asante-Akim North District, with Bomfa recording the highest severity (5.0) in the Ejisu-Juaben Municipal. *U. virens* was isolated from diseased rice samples collected from the surveyed fields. The four fungicides evaluated exhibited 100% inhibition on the growth of *U. virens* mycelium eight days after inoculation *in vitro* however, Nordox was the most efficient after 23 days inoculation and the Mancozan super was the least efficient. Evaluation on rice varieties response to *U. virens* should be repeated and the effectiveness of fungicides should be tested under the field-infected plants in order to sustain the present results.**

Key words: *Ustilaginoidea virens*, rice false smut, disease.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the dominant staple food and cash crop in Ghana (Danso-Abbeam, 2014). The crop is consumed daily and is the sole most essential basis of human calories. It is the third most cultivated crop worldwide, after maize and sugarcane (FAOSTAT, 2014). MoFA (2009) reported that urbanization,

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population increase and change in consumer preference account for the continuous increase in rice consumption in Ghana over the years. The annual per capita consumption of rice in Ghana have been increasing; from 17.5 kg during 1999 to 2001 to 24 kg during 2010 to 2011 (MoFA, 2012). The per capita/consumption of rice in 2012 to 2014 was estimated at 32 to 35 kg. Rice consumption in Ghana is projected to reach a milestone of about 63 kg in the year 2015 (MoFA, 2014).

Inspite of the technological advances in its production, diseases remain a major cause of yield losses and lower profits worldwide, as they cause reduction in quantity and quality and increase production cost of the crop (Ghini et al., 2008). According to ISSER (2008), Ghana's agricultural sector receives aid from several organizations (Farmer-Based Organizations, Non-Governmental) to increase rice production (yield), reduce poverty and increase farmers' income. Farmers receive training as well as high yielding crop varieties for production. Despite all these inputs received by the farmers, production remains low (Faltermeir, 2007).

Rice false smut (RFS) disease is caused by an Ascomycete, *U. virens* (Cooke) Takahashi. The chlamydospores of *U*. *virens* survive in the rice seeds as well as the soil throughout the cropping season and they serve as principal sources of inoculum for the disease (Ashizawa et al., 2010). The life cycle of the pathogen, infection and disease development are unclear (Fu et al., 2014). Also, characterization of the pathogen-host interaction and pathogen history is difficult (Fu et al., 2012). During infection*, U. virens* produces mycotoxins such as Ustilotoxins A and B which contaminate rice seeds and straw. These mycotoxins are harmful to man and livestock (Shan et al., 2013). According to Tanaka et al. (2008), RFS disease has become an important disease of rice, causing significant yield losses globally. The disease reduces yield, affects grain quality and imposes health hazards significantly in all rice producing areas. Rani (2014) reported that yield losses caused by RFS disease is attributed to both smut balls as well as chaffiness, reduction in grain weight and infertility of the spikelet near the smut balls. Reduction of yield by the disease is alarming in some major rice growing regions. Upadhyay and Singh (2013) reported that yield loss due to RFS disease from many rice growing areas ranges from 1 to 75%. The fungus enters the plant through the small opening between the lemma and palea and initial infection occurs in the grain which reduces seed germination (Ladhalakshmi et al., 2012). The RFS pathogen grows and contaminates the infected plant tissues, including the stamen and filament. Thus, this is regarded as the plant stamen-filament disease (Tang et al., 2013). Previously, the disease was considered a minor one due to its rare occurrence. However, it has now become a serious concern for rice production (Zhou et al., 2008).

Inorganic fungicides such as Simeconazole (Fluorophenyl) and 2.5% Wenquning (*Bacillus subtilis*) have been used to control the disease (Ashizawa et al., 2010). However, the use of some partial resistant plant genotypes such as Neixiangyou 8156, Zhongyou 177, Heyou 6, Nei5you 317, Suaiyoulianhe 2 and Nongfengyou 256 have proved more effective (Liang et al., 2014). The research seeks to identify intervention(s) for sustainable rice production and also study the RFS disease for effective management in order to minimize yield losses and thus, improving the livelihood of farmers.

MATERIALS AND METHODS

Survey and sample collections were conducted from September to December, 2015 to obtain information on RFS disease in three districts/municipalities and also to ascertain farmers' perception of the disease on 60 rice farms within three districts in the Ashanti region of Ghana namely Ejisu-Juaben, Asante-Akim North and Ejura-Sekyedumase (Table 1).

The Ejisu-Juaben District is located in the central part of the Ashanti region. It lies between latitude 1°15' N and 1°45' N and longitude 6°15' W and 7°00' W. It records very high relative humidity during rainy season and early mornings. The relative humidity is not stable; it records lowest during midday when weather is hot despite rainy seasons unlike other districts in the Ashanti region. The district has the major rainfall season starting from March to July with an average rainfall of 1200 to 1500 mm annually. Its shorter rainfall season starts in September and ends in November with an average rainfall of 900 to 1120 mm (Ghana Statistical Service, 2010).

Ejura-Sekyedumase District is situated within longitude 1°5' W and 1°39' W and latitudes 7°36' N and 7°9' N. It is located at the north of the Ashanti region. The district has two rainfall patterns: The bimodal pattern in the south and the unimodal pattern in the north. The major rainfall season starts from April to November. Annual rainfall ranges from 1200 to 1500 mm. Relative humidity is extremely high throughout the rainy season, recording 90% in June and 55% in February (International Telecommunication Union (ITU), 2012, Tacoli, 2012). Asante-Akim North District is situated at the eastern part of the Ashanti region and lies between latitude 6° 30' N and 7° 30' N and longitude 0° 15' W and 1°20' W. The district has a total annual rainfall ranging from125 to175 mm, with the major rainy season occurring from May to July and the minor season occurring from September to November. Relative humidity is generally high throughout the year in this district, ranging from 70 to 80% in the dry season and 75 and 85% in the wet season (Ghana Statistical Service, 2012).

Purposive and stratified sampling methods (Miles and Humber, 1994) were used to select five rice farmers in 12 communities within the three districts/municipality. Farmers were interviewed with the aid of a questionnaire to obtain information such as their knowledge of the RFS disease, sources of seeds, preferred varieties, types of fertilizer used, major diseases they encountered, as well as some management practices they employed. The selected fields were then assessed for incidence and severity of rice false smut disease. In each farm, five 5 m x 5 m plots were demarcated in four corners and one in the middle for assessment. Percentage disease incidence per plot was determined as a ratio of the number of diseased hills over the total number of hills in the plot. Visual scoring for severity in each plot was done using the International Rice Research Institute's Standard Evaluation System (IRRI, 1996) for rice on a scale of 0 to 9, where 0 (no disease), 1 (symptom on less than 1% of plant), 3 (symptom on 1-5% of plant), 5 (symptom on 6-25% of plant), 7 (symptom on 26-50% of plant) and 9

Table 1. Districts/Municipal surveyed with their communitie.

District/Municipal	Communities			
Ejisu-Juaben	Nobewam	Bomfa	Besease	Duampompo
Asante-Akim-North	Ohene-Nkwanta	Juansa	Habitat	Nyantokro
Ejura-Sekyedumase	Aframso	Kyere-adireagya	Ntemaso	Mawabamumum

Table 2. Inorganic fungicides with their corresponding active ingredients and sources.

Inorganic fungicide	Active ingredient	Company/country
Mancozan Super	Mancozeb 640 g/kg+Metalaxyl 80 g/kg WP	Louis Dreyfus Commodities/France
Nordox 75 WG	Copper fungicide	Nordox Industries/Norway
Suncozeb	80% WP Mancozeb	Zhejiang Xinan Co. Ltd./China
Sidalco Defender	435 g/l Copper Oxychloride	Sidalco Limited/UK

(symptom on 51-100% of plant).

In total 60 samples of rice panicles showing typical symptoms of RFS disease (smut balls) were collected from the fields, using an improved tissue segment method (Rangaswami, 1972). Diseased panicles identified in each plot were detached using a knife, and the total sample from each farm was carefully packaged in a plastic bag for further identification. Causal organism of the RFS disease was identified and the effects of different fungicides on the mycelium growth of the causal organism were evaluated using the food poisoning method in the Plant Pathology laboratory of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology (KNUST). Inorganic fungicides were obtained from Chinese Agro-chemical Shop, Kumasi, Ghana. The cultures were grouped, based on the district/municipality where infected rice panicles were collected. Isolates from one district/municipality but different communities were grouped. To clarify the particular identity shared by isolates from one district and communities, the cultures were mounted on the microscope for examination and identification. The cultures were then grouped, based on morphological characteristics such as nature of mycelium growth, colour and spore size. Mycelium growth and colour were characterized by visual assessments while spore sizes were characterized through the aid of micrometrics SE premium software mounted on the Leica (Leica Microsystem Company Ltd. Germany). Thus, the isolates were grouped into three separate groups. Table 2 shows the list of inorganic fungicides used in this study (evaluation against *U. virens*).

250 ml of potato dextrose agar (PDA) prepared in five separate Erlenmeyer flasks were amended with 0.8 ml of Sidalco Defender, 1.25 g of Nordox 75 WG, 1.2 g of Mancozan Super or 1 g of Suncozeb. Each rate was based on manufacturer's recommended rates. The PDA with no amendment served as control. Completely randomized design (CRD) with five replications was used.

Fungal growth from both amended and control plates were observed daily for growth and fungus characteristics. Measurement of mycelium growth was done when the growth of fungi in the control plate attained maximum growth at eight days after inoculation. Persistence of the four fungicides in terms of inhibition of mycelium growth, as well as sporulation of *U. virens* were determined. Growth inhibition of the isolates by the inorganic fungicides was determined using the radial growth method (Soad and Samir, 2005). This method involves measuring the diameter of mycelia in both the control and amended plates, when growth in the control plates had achieved maximum diameter. The corresponding percentage growth inhibition was calculated using the formula (Sundar et al., 1995):

$$\text{Inhibition (\%)} = \frac{Y-A}{Y}\ x\ 100$$

Where, Y is mean diameter of *U. virens* growth in control plate and A is the mean diameter of growth in amended plates.

Data were subjected to analysis of variance (ANOVA) using two-way analysis with Genstat Statistical Package (Genstat, 2007), 9th edition. Treatment means were separated by least significant difference test at 5% probability. Square root √(x + 1) transformation and Arc sine square root transformation were applied to data as many biological variables do not meet the assumption of parametric statistical test. Square root was used for count data while Arcsine was used for data in percentages.

RESULTS AND DISCUSSION

Farmers' perception of rice false smut disease in the surveyed areas

During the survey, it was observed that 80% of rice farmers were males; 33% of them had basic education, 13% had tertiary education while 27% had no formal education. About 45% of the farmers were between 41-50 years-old while 2% were below 20 years-old. About 33.3% of the farmers observed RFS disease on their fields during the harvesting stage while 13.3% observed the disease at the maturity stage of the crop. Some symptoms of the disease observed by farmers were yellowish (48.3%), greenish (20%) and black (31.7%) smut balls. The disease occurred mostly (70%) in the major growing season. About 32% of farmers reported RFS as the major disease affecting rice production in the surveyed areas. Other diseases of rice were identified during the study. Since most farmers had at least some basic education, they practiced good agronomic techniques resulting in high yields. The result agrees with findings of Hussain and Byerlee (1995) who reported that

farmers with some level of formal education adopt new technologies such as application of fertilizers, disease and pest management, and use of proper planting distance for rice cultivation faster thereby increasing yield. Diseases affecting rice production in the surveyed areas were RFS, rice blast, sheath rot, rice bacterial blight, and yellow mosaic virus. According to farmers, inadequate management of these diseases resulted in production failure. These results supports those by Nelson et al. (2001) where farmers from developing countries have significant difficulties in the management of crop diseases which often results in crop losses.

Incidence and severity of rice false smut disease in the surveyed areas

The incidence and severity of RFS disease in the Ejisu-Juaben municipality, Duampompo had the highest mean incidence whereas Nobewam recorded the lowest. The mean incidence of RFS disease recorded at the four communities were not significantly different at P>0.05 from each other.

Habitat recorded the highest (38.0) mean incidence of RFS disease while Juansa and Nyantokro recorded the lowest (15.6) mean incidence of the disease in Asante-Akim North District. No significant differences were found among other locations. In the Ejisu-Juaben Municipal, Bomfa recorded the highest (5.0) mean severity of RFS disease with Besease and Nobewam recording the lowest (3.5). In the Ejura-Sekyedumase District, Ntemaso recorded the highest (5.0) mean severity while Mawabamumu recorded the lowest (3.3). Also, mean severities of RFS disease recorded in Aframso, Ntemaso and Kyeredieagya were not significantly different (P>0.05) from each other.

Habitat recorded the highest (7.6) mean severity of RFS disease in the Asante-Akim North District with Juansa recording the least (1.7). There was no significant differences (P>0.05) between the mean severities recorded in Habitat and Ohene-Nkwanta.

Comparing the districts, Asante-Akim North District recorded the highest incidence (38.0) while Ejisu-Juaben Municipal and Ejura-Sekyedumase Districts recorded the lowest (23.2).

The presence of the alternative host of *U. virens, cylindrica* L in the district could be the possible reason for high incidence. According to Rani (2014), *U. virens* survives on the weed and cause disease thus, producing plenty chlamydospores as inocula for RFS disease on rice. It could also be attributed to environmental conditions such as rainfall, temperature and relative humidity experienced during production and exchange of planting materials (seeds). This is supported by Rao and Raju (1955) that environmental promote incidence and severity of RFS disease. There was no significant difference (P>0.05) between disease incidences recorded in at the four communities. Since these communities are within the same district, there was a higher possibility of exchange of infected rice varieties for planting among farmers in the communities. This may have resulted in the same incidences of disease recorded in the communities as reported by Fan et al. (2015) that exchange of planting materials are a possible cause of high incidence. Ntemaso recorded the highest (23.3) incidence of RFS disease in the Ejura-Sekyedumase District. The presence of weed such as *Dracaena marginata* Lam was observed on farmers' fields in the Ntemaso community. This weed has been reported as an alternative host of the RFS pathogen. High incidence of RFS disease in the community could be attributed to the presence of this weed on the fields. This is in support of the findings of Gohel et al. (2014) that RFS pathogen, *U. virens*, lives on alternative hosts in paddy fields to produce plenty of chlamydospores of which might act as the basis of infection and later infect the rice after planting. The lowest (21.9) incidence recorded at Aframso may be due to the use of moderately susceptible or tolerant rice varieties used by farmers. Farmers in this community may have used tolerant rice varieties. Tebeest and Jecmen (2012) reported that the number of smut balls or incidence of infection of rice false smut disease depends on the level of susceptibility of the varieties involved. Habitat community had the highest incidence of rice false smut disease in the Asante-Akim North District with Juansa recording the least (14.2). The weed *cylindrica* L was observed in most of the fields surveyed in habitat, and relatively fewer fields in Juansa. The presence of this weed in Habitat community might have caused the high incidence of the disease in the community as was reported by Rani (2014) who reported that *U. virens* causes disease in *I. cylindrical.* The higher severity of disease recorded in Ntemaso may be attributed to the application of higher dosage of nitrogen fertilizers by the farmers in the community. Though soil samples were not taken to determine the total nitrogen per site, some communities used nitrogenous fertilizers while other used manure and some used none. This result supports that of Mohiddin et al. (2012) that excess nitrogen makes the plant less fibrous and less resistant to RFS disease as observed in Habitat community. According to Fan et al. (2015), exchange of susceptible rice varieties to RFS and growing of diseased rice seeds could result in to high incidence and severity of RFS disease in farmers' fields. This is in agreement with report of Nessa et al. (2015) that severity of rice false smut disease depends on soil fertility and flood water depth.

Isolation and identification of the causal organism of rice false smut disease

The growth of the colonies from all the three districts/municipality were creamy-white flat or raised with

Plate 1. Front view of mycelia plated *U. virens* on PDA.

Plate 2. Back view of mycelia plated *U. virens* on PDA.

slight undulations, with the mycelia fluffy, compact and leathery (Plates 1 and 2 and Table 3). The spore sizes of fungal isolates varied from 33.90 to 35.13 µm. These characters identified through laboratory analysis from the diseased plant tissues collected from the surveys proved that the pathogen is *U. virens* shown in Table 4. In The description of *U. virens* by Joshi and Sharma (1975) and Verma and Singh (1988), the mycelia of the fungus appear whitish to creamy, with the spore size ranging from 30 to 40 µm in diameter.

Effect of four inorganic fungicides on growth and sporulation of *U. virens in vitro* using the food poisoning method

There was no mycelial growth of *U. virens* in plates amended with Mancozan super, Nordox, Sidalco defender and Suncozeb fungicides, while there was a mean of 8.5 cm growth in the control plates eight days after plating (Table 4). This treatment was effective in eight days after which some fungicides lost their potential. Nordox effectively controlled the mycelial growth of *U. virens* at 100% until 23 days while growth was observed on the three fungicides from the 10th day after inoculation. There was significant difference ($P<0.05$) between the control and the remaining treatments.

This indicates that all four fungicides used in the test were effective against *U. virens* since they inhibited the growth of fungus (Plate 3). The result supports that by Wagbe et al. (2015) who evaluated six different fungicides; SAA (Mancozeb 63% + Arbendazin 12%) 75 WP, Azoxystrobin 25 SC, Mancozeb 75 WP, Propiconazole 25 EC, Chlothalonil 75 and Heconazole 5 EC for their efficacy *in vitro* against *A. helianti.* Mancozeb at 2500 ppm showed the highest percent inhibition of 88.88% and is an active ingredient in Suncozeb.

Determination of persistence of the fungicides on *U. virens in vitro*

The persistence of four fungicides was assessed until 23 days of plating. All fungicides exhibited varying degrees of inhibition of *U. virens* mycelial growth. Even though some of them lost their potential eight days after, Nordox maintained its efficacy in controlling *U. virens (*mycelial growth) of by 100% for the entire 23 days, until the end of the experimental period (Table 5).

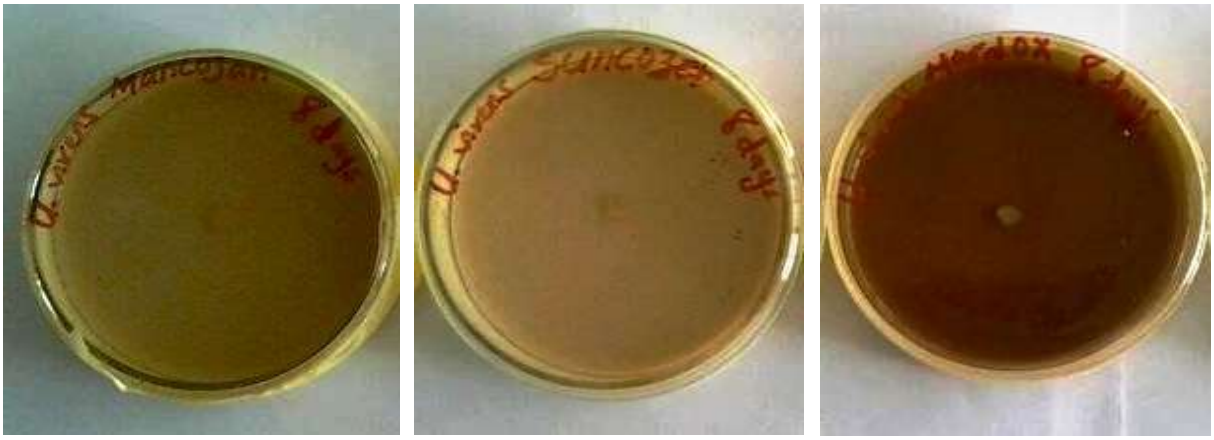
Nordox, with the most effective active ingredient (copper fungicide) completely controlled mycelial growth at 23 days. The results showed that Nordox had the highest persistence, followed by Sidalco defender (435 g/l copperoxycholoride) and Suncozeb (80% WP Mancozeb). Mancozan super (Mancozeb 640 g/kg and Metalaxyl 80 g/kg WP) had the lowest persistence. The result is in conformity with that of Hafiz et al. (2016) who evaluated six different fungicides namely Captan, Carbendaim, Tilt, Copperoxychloride, Mancozeb and Topsin against four strains of *Colletotrichum falcatum* and the highest inhibition percent was recorded in plate amended with Mancozeb (95, 90, 85 and 80% at 30% concentration) while the least inhibition percent was recorded in plate amended with Captan at 1% concentration (37.31, 32.31, 27.3 and 22.31 concentration).

Table 3. Morphological characteristics of fungal isolates from survey areas.

District	Colour of mycelia	Mean spore size(µm)
Ejisu-Juaben	Creamy-white	33.90
Ejura-Sekyedumase	Creamy-white	35.13
Asante-Akim North	Creamy-white	34.26

Table 4. Mean radial growth of fungal colonies on fungicide amended PDA plates, eight days after plating.

Treatment	Mean radial growth (cm)
Mancozan super	0.0[b]
Suncozeb	0.0[b]
Nordox	0.0[b]
Sidalco Defender	0.0[b]
Control	8.5[a]
CV (%)	7.0



A B C

D E

Plate 4. Growth of *U. virens* on Mancozan super (A), Suncozeb (B), Nordox (C) and Sidalco defender (D) fungicides, and the Control (E), eight days after plating.

Table 5. Mean radial growth of fungal colonies at 2 to 23 days after plating.

Treatment	Mean radial growth of mycelia (cm) at				
	2 days	8 days	14 days	20 days	23 days
Mancozan super	0.00	0.00	0.93	2.20	3.04
Suncozeb	0.00	0.80	1.15	2.10	2.50
Nordox	0.00	0.00	0.00	0.00	0.00
Sidalco defender	0.00	0.00	0.00	1.10	2.10
Control	1.85	8.49	9.00	9.00	9.00

Conclusion

The causal agent of rice false smut disease, *U. virens,* was identified from diseased rice panicles obtained from the surveyed districts/municipality in the Ashanti Region of Ghana. The present study revealed that farmers' knowledge of rice false smut disease was generally low. The fungicides evaluated exhibited 100% inhibition on the growth of *U. virens* eight days after inoculation *in vitro* in Nordox (copper fungicide), Mancozan super (Mancozeb 640 g /kg + Metalaxyl 80 g/kg), Suncozeb (80% WP Mancozeb) and Sidalco defender (435 g/l copper oxycholoride), however, after 23 days only Nordox inhibited mycelium growth. The highest (23.3) incidences of RFS disease were observed in Duampompo in Ejisu-Juaben Municipal and Ntemaso in Ejura-Sekyedumase District and Habitat in Asante-Akim North District. The highest severities of RFS were recorded in Ntemaso in Ejura-Sekyedumase, Bomfa community in the Ejisu-Juaben Municipal and Habitat in Asante-Akim North District.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Performance of the *Brachiaria* hybrid 'Mulatto II' under different doses and forms of limestone application in the Amazon

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Acid soils have been responsible for the poor performance of most plant species, and liming is an efficient way of correcting the pH of such soils. The aim of this study was to assess the performance and establishment of the *Brachiaria* hybrid 'Mulatto II' under different doses and forms of limestone application. The experimental design was of five doses of limestone (0, 0.5, 1, 2, and 4 t ha^{-1}) and two forms of application (broadcasting over the surface, and broadcasting followed by hoeing the top 20 cm of soil) with three replications, in 3 x 3 metre plots of the *Brachiaria* hybrid 'Mulatto II'. The greatest number of germinated seeds was at the dose of 4 t ha^{-1} limestone when incorporated into the soil. For height, the greatest values found were at the maximum dose of limestone when incorporated into the soil. Dry matter production was not influenced by the form of limestone application, however production increased with the supply of limestone. The hybrid variety proved easily adaptable to different soil and climate conditions.

Key words: Liming, tropical pasture, fodder availability, dry matter.

INTRODUCTION

One of the foundations of Brazilian agribusiness is cattle farming. According to the IBGE Automatic Recovery System (SIDRA), the current Brazilian cattle herd comprises 215.2 million herd. Between 1987 and 2013 in Brazil, the herd increased by 60%, while in the states of the Amazon region, it increased by 280%, as the activity was the cheapest form of occupying and using the deforested area (Barbosa et al., 2015). In the last ten

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years, the northern region has significantly expanded its agricultural frontier into animal production (Dias-Filho, 2010) as the number of cattle slaughtered in the region correspond to approximately 22% of the domestic total (IBGE, 2015). In Acre, beef farming accounts for approximately 40% of the state's gross domestic product (GDP), and is the activity with the highest economic importance of the agricultural sector (Sá et al., 2010).

Livestock farming takes up approximately 220 million hectares, of which 70 million are in the Amazon states (Barbosa et al., 2015). However, approximately 80% of the deforested area in the Amazon rainforest is used for livestock, with half of that area displaying a severe degree of soil degradation (Araújo, 2008). The Brazilian agricultural sector is now more aware of environmental issues, so the challenge is for more efficient production through the use of such technologies as soil and pasture management (Dias-Filho, 2010).

The genus *Brachiaria* was introduced to Brazil around the 1950s, and represents 85% of the 180 million hectares of pasture grown in the country (Macedo, 2004), as it adapts to the most varied of soil and climate conditions (Soares filho, 1994) and is resistant to the spittlebug (Valle et al., 2000). In the State of Acre (AC), the forage grass with the largest planted area is *Brachiaria brizantha* 'Marandu', also known locally as *Braquiarão* (Dias-Filho and Andrade, 2006).

The *Brachiaria* hybrid 'Mulatto II' is the second hybrid introduced as a result of the tropical grass program of the Centro Internacional De Agricultura Tropical (CIAT) started in 1989 and which resulted in a hybrid from crosses and selections of *Brachiaria ruziziensis*, *Brachiaria decumbens* 'Basilisk' and *Brachiaria brizantha* (Argel et al., 2007). The results of Argel et al. (2005) demonstrated the superiority of the Mulatto II hybrid compared to the Mulatto I, important being its good adaptation to acid soils of low fertility and a moderate adaptation to soil moisture. The variety is able to develop deeper roots, leading it to withstand long periods of drought of up to six months (CIAT, 2006). Guiot and Melendez (2003) pointed out its high adaptability, which is due to its perennial, vigorous nature, and profuse, decumbent and stoloniferous habit, it furthermore demonstrated great tolerance to the spittlebug and to the non-significant damage caused by caterpillars throughout years of study. Thus, this variety encompasses productivity, resistance and digestibility, considering also that it has wide adaptability to the various climatic and soil conditions (Santos et al., 2015).

Good pasture management guarantees good livestock production under grazing, and for the evaluation of these, some aspects are considered such as: animal performance, pasture support capacity, animal production per hectare, the botanical composition of pasture, and stability of the vegetation cover (Gomide and Gomide, 2001). Brazil stands out as a potential global livestock producer due to the management and exploitation of tropical grasses' potential. These species, when well managed, present a high rate of biomass accumulation, presenting nutritional value and structural characteristics compatible with good animal performance (Silva and Nascimento Júnior, 2007; Euclides et al., 2000).

One of the efficient ways of achieving good livestock productivity is genetic improvement. This process of using controlled hybrids is still poorly controlled in the genetic improvement of tropical forages, being the majority of germplasm banks used by direct selection of available genotypes (Pereira et al., 2001). This breeding process is only justified when the natural variability of the species has already been exploited enough to avoid undesirable traits (Cameron, 1983).

Acid soils limit the production of most crops and influence the availability and toxicity of elements, microbial activity, and root development that limits the absorption of nutrients and water by plants (Fageria and Baligar, 2003). High concentrations of toxic elements such as aluminum (Al) and manganese (Mn) inhibit root development, which consequently has a negative influence on the absorption of water and nutrients by plants, especially calcium (Ca) and magnesium (Mg) (Lathwell and Grove, 1986).

Liming is an effective and inexpensive way to neutralise soil acidity and improve crop productivity (Nolla et al., 2013). This practice reduces the toxicity of Al and Mn, and increases the availability of other elements such as potassium (P), calcium (Ca) and magnesium (Mg), increases the cation exchange capacity (CEC), promotes nitrogen fixation (N_2), and improves soil structure (Bermardi et al., 2012; Carvalho and Nascente, 2014).

Considering the importance of liming for the breeding and establishment of crops, the aim of this study was to evaluate the forage performance and establishment of the *Brachiaria* hybrid 'Mulatto II' under different doses and forms of limestone application in the Juruá Valley region, Acre, Brazil.

MATERIALS AND METHODS

The experiment was conducted in the experimental area of the Federal University of Acre, Floresta Campus, (UFAC), in the town of Cruzeiro do Sul, located at 07°37'52" S, 72°40'12" W, as shown in Figure 1. The work was carried out from December 2013 to February 2014. According to Cavalcante and Souza (2010), the Koppen classification of the climate in the region is type Af, tropical humid with well-distributed rainfall throughout the year and the absence of a dry season. The average altitude of the region is 170 m, with an annual average rainfall of 2074 mm.

Data for rainfall, average air temperature, evaporation and relative humidity measured during the experiment can be seen in Figures 2 and 3, respectively.

The soil of the experimental area was classified as a dystrophic Yellow Argisol with no evidence of a reduction zone (greyish). Soil samples were collected from 15 random points, at a depth of 0 to 20 cm (Figure 3), and sent to the Department of Soils and Fertilisers on the Jaboticabal Campus of the São Paulo State University, where a chemical analysis of the soil was performed. Recommended fertilisation was carried out according to the results

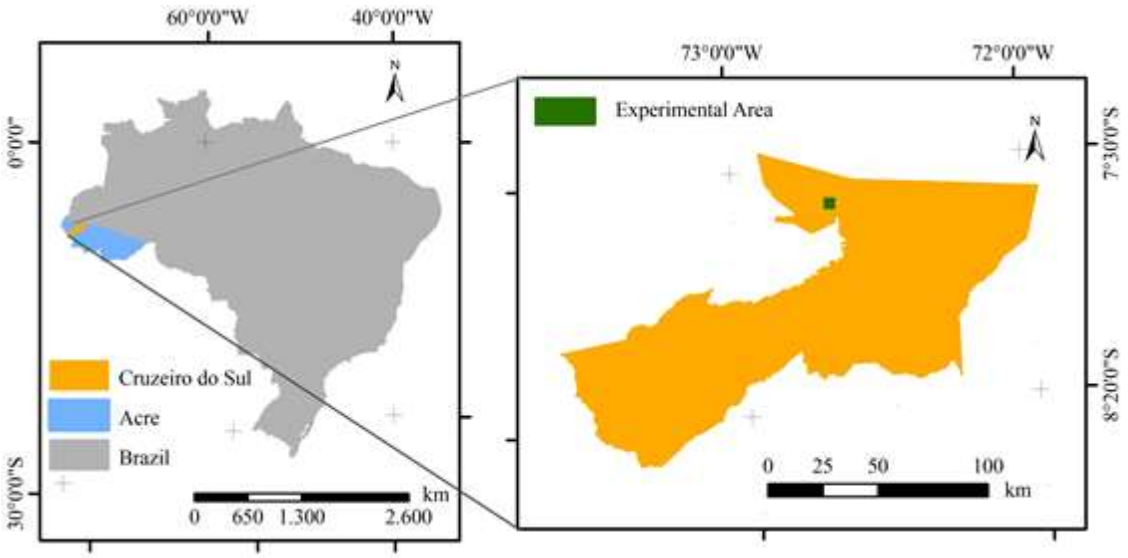

Figure 1. Location of the experimental area in the town of Cruzeiro do Sul, Acre, Brazil.

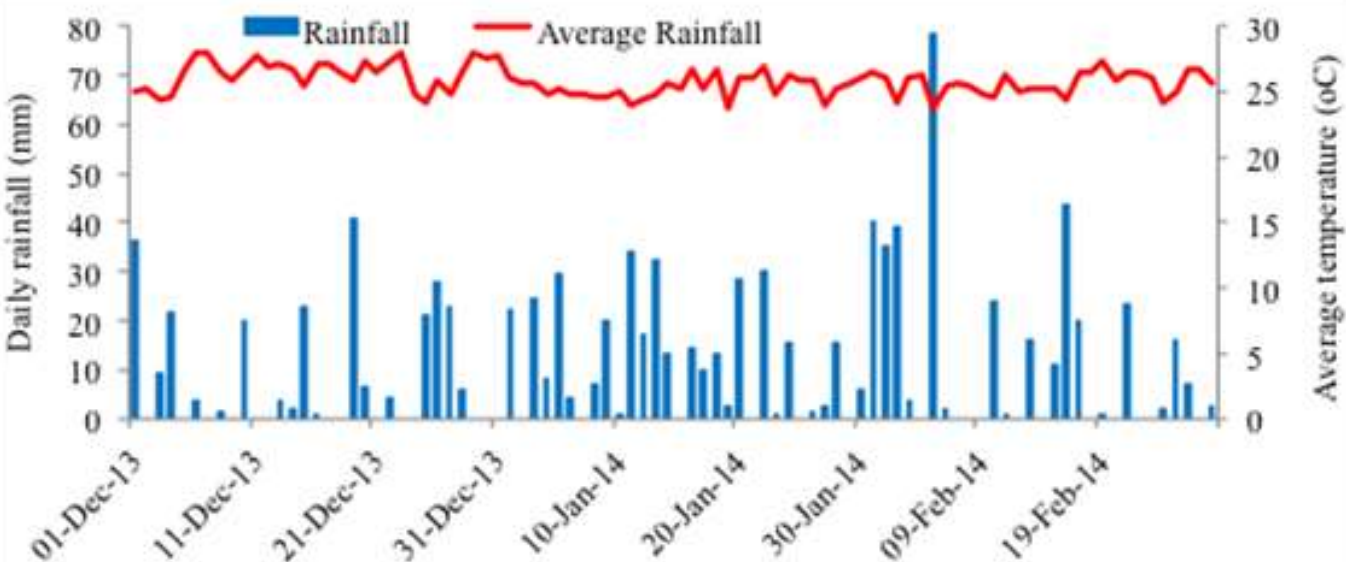

Figure 2. Average daily temperature and daily rainfall during the experimental period, in Cruzeiro do Sul, AC. Source: INMET (2017).

of the soil analysis (Table 1), to the technical circular with recommendations for the fertilisation and liming of pasture in Acre (Andrade et al., 2002), and to the Manual for Management and Fertilisation for the State of Acre (Wadt, 2005). Nitrogen fertilisation at 40 kg ha^{-1} was divided into three applications starting from the 21st day after planting.

The experimental design was of randomised blocks in a 5 × 2 factorial scheme, with five doses of dolomitic limestone filler at different concentrations (0, 0.5, 1, 2 and 4 t ha^{-1}) and two forms of application with three replications, in 3 m × 3 m plots of the *Brachiaria* hybrid 'Mulato II' (CIAT 36087). There were two blocks, one for each form of application, to test the differences between broadcasting over the surface and broadcasting followed by hoeing the top 20 cm of soil, as shown in Figure 4.

Agronomic evaluations of the forage were carried out from seed germination at 7, 14 and 21 days after planting, by a count of the germinated seeds. Plant height was determined with the aid of a tape measure from the average of five plants chosen at random in each plot, considering the height from the ground to the inflexion of the highest leaf.

Samples to determine dry matter production were obtained with the aid of a square metal structure, 0.5 m × 0.5 m (0.25 m^2) in size, which was randomly thrown three times within each experimental unit when the pasture reached 30, 50 and 70 cm. For each evaluation, forage biomass was collected, cut close to the soil, packed in plastic bags, which were identified for transportation to

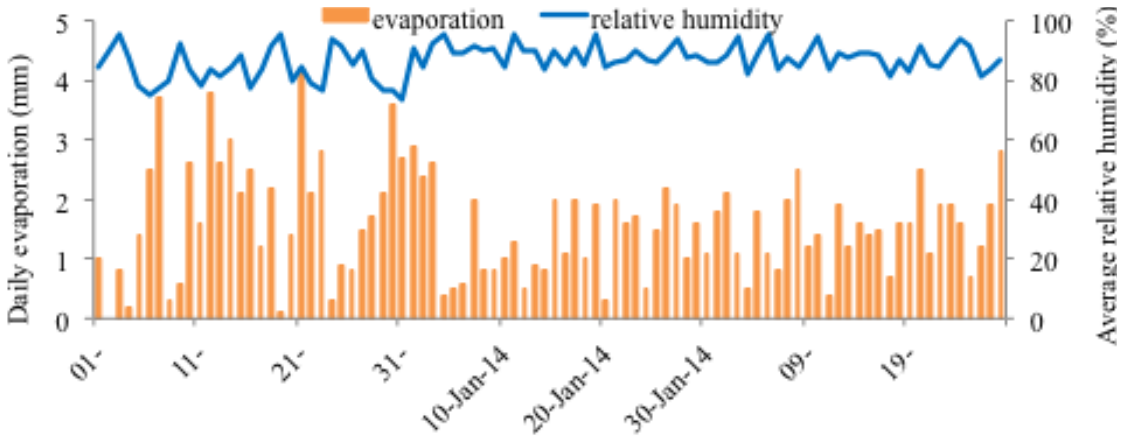

Figure 3. Daily evaporation and relative humidity during the experimental period, in Cruzeiro do Sul, AC. Source: INMET (2017).

Table 1. Chemical characterisation of the soil in the experimental area.

Depth (cm)	pH ($CaCl_2$)	OM (g/dm^3)	P (mg/dm^3)	K	Ca	Mg	H+Al	SB	T	(%)
				($mmol_c/dm^3$)						
0-20	4.2	25	4	1.3	7	4	52	12.3	64.3	19

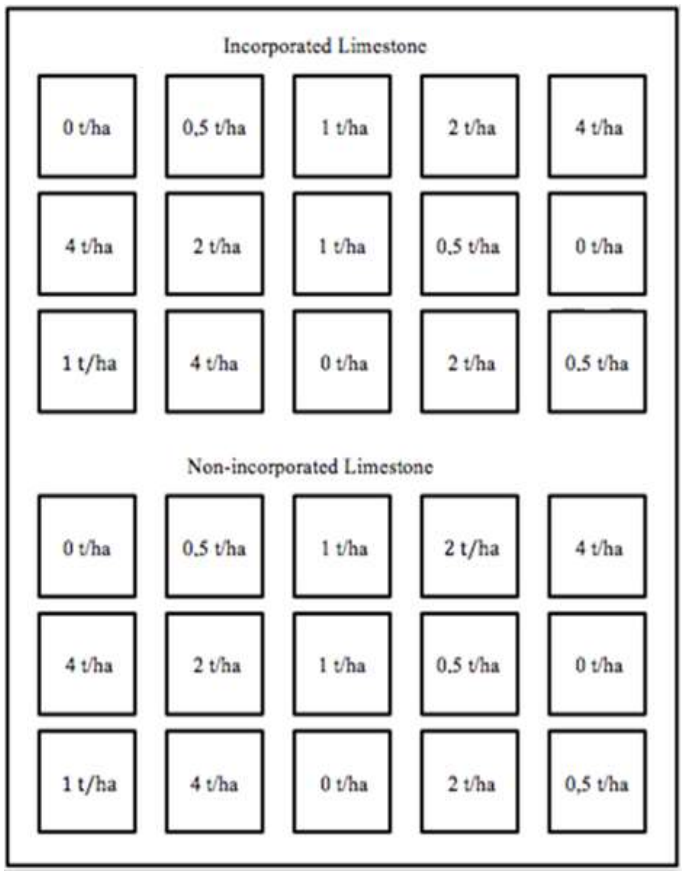

Figure 4. Sketch of the experimental area.

the laboratory, and weighed. The samples were then packed in paper bags and placed in a forced air ventilation oven at 65°C for 72 h.

The results were submitted to statistical analysis using the Analysis of Variance System for balanced data (SISVAR), described by Ferreira (2000). The data were submitted to analysis of variance for a completely randomised design in a 5 × 2 factorial scheme (Five doses of limestone and two forms of application). Interactions that were significant at 5% probability by F-test were properly broken down. The mean values were compared by Tukey's test at 5% probability.

RESULTS AND DISCUSSION

The number of germinated seeds was higher at the dose of 4 t ha^{-1} limestone when incorporated into the soil; in the treatment where no limestone was incorporated, the maximum applied dose gave the smallest amount of germinated seeds. In general, the treatment with the greatest number of germinated seeds was at a dose of 1 t ha^{-1} limestone with no incorporation of the $CaCO_3$ (Figure 5). Deminicis et al. (2004) and Pereira et al. (2004) found similar results in the production of seeds of *Brachiaria decumbens* Stapf under different strategies of limestone application.

The greatest values for height were found at the maximum dose of limestone when incorporated into the soil. However, it was found that the control treatment displayed mean values that were similar to the maximum doses, showing that there was no significant difference for the quantity of limestone applied, since it was possible

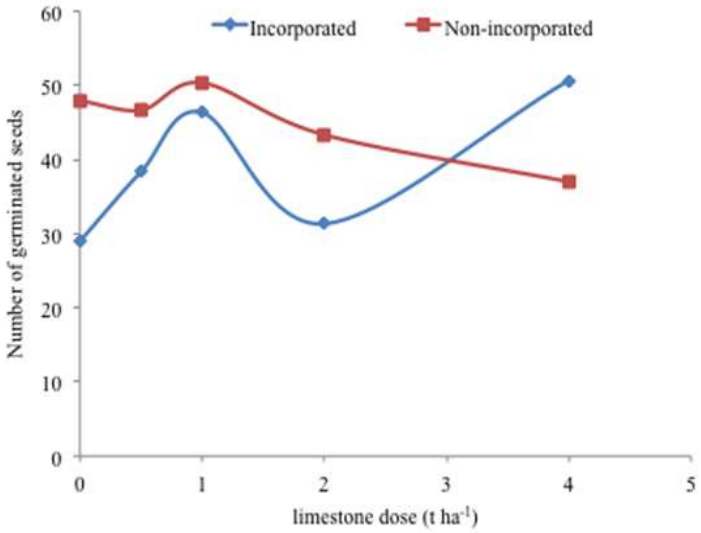

Figure 5. Effects of limestone doses (t ha^{-1}) and forms of application on the number of germinated seeds.

Table 2. Average height (cm) for the different treatments with incorporated and non-incorporated limestone in the three collections.

Treatment (t ha^{-1})	Incorporated			Non-incorporated		
	1st collection	2nd collection	3rd collection	1st collection	2nd collection	3rd collection
Control	35.67[a]	91.33[a]	114.11[a]	43.11[a]	86.55[a]	120.22[a]
0.5	40.66[a]	96.89[a]	117.55[a]	43.88[a]	100.33[a]	209.11[a]
1	51.88[a]	104.55[a]	132.33[a]	48.11[a]	105.55[a]	154.33[a]
2	45.00[a]	108.33[a]	119.89[a]	48.33[a]	100.77[a]	136.66[a]
4	54.22[a]	113.11[a]	133.00[a]	53.33[a]	83.89[a]	138.66[a]

* Mean values followed by the same letter in a column do not differ statistically. Tukey's test at 5% probability.

to achieve similar results even at a dose of 0 t ha^{-1} (control) (Table 2). This suggests that the effect may be closely related to the supply of Ca and Mg, since 90% of the value was achieved at the lowest dose of limestone.

Similar results were found by Guimarães (2000), where there was an increase in *B. humidicola*, *B. mutica*, *Echinochloa pyramidalis* and *E. polystachya*, despite the soil still presenting high acidity and high levels of exchangeable Al.

The method of application, with incorporated or non-incorporated limestone, together with the amounts applied, did not give significant results in relation to the amount of dry matter (DM) produced by the forage; even so, there was an increase in forage weight when doses of limestone were applied, as shown in Tables 3 and 4. Incorporating the limestone into the soil gave the greatest mean value for production.

Luz *et al*. (2000), obtained better results for DM production in Tobiata grass (*Panicum maximum* 'Tobiata') when limestone was incorporated into the soil. These results, showing an increase in dry matter even at low applied doses of limestone, are explained by both the tolerance of the genus Brachiaria to high concentrations of aluminium, and by the effects that limestone causes in the soil, such as the increased absorption of nitrogen, phosphorus, potassium and sulphur (Quaggio et al., 1993) and the supply of calcium and magnesium as nutrients (Mascarenhas et al., 1976).

The values for dry matter production in tonnes per hectare showed that incorporating the limestone into the soil gave the greatest values, where a production of 14,556 t ha^{-1} DM was achieved with the application of 2 t ha^{-1} limestone; comparable results for production were found in 2004 in Gualaca, Panama (15.6 t ha^{-1} DM) (IDIAP, 2006). Nevertheless, the values were not so expressive as to consider that the application of limestone should be able to increase production in the Mulatto II cultivar.

Table 3. Values for dry matter - DM (%) for different forms of limestone application, incorporated and non-incorporated, at different collection times.

Treatment (t ha^{-1})	Incorporated			Non-incorporated		
	1st collection	2nd collection	3rd collection	1st collection	2nd collection	3rd collection
Control	28.97[a]	26.50[a]	26.37[a]	27.68[a]	26.68[a]	33.18[a]
0.5	23.54[a]	22.94[a]	29.39[a]	29.10[a]	24.21[a]	29.53[a]
1	27.14[a]	26.72[a]	23.60[a]	26.08[a]	27.72[a]	33.78[a]
2	26.18[a]	25.76[a]	36.39[a]	23.66[a]	25.28[a]	31.40[a]
4	27.18[a]	23.91[a]	27.73[a]	21.92[a]	24.79[a]	30.49[a]

* Mean values followed by the same letter in a column do not differ statistically. Tukey's test at 5% probability.

Table 4. Mean values for dry matter (DM) production in kg ha^{-1} of the variety 'Mulatto II' as a function of the amount of limestone applied in the two forms of application in the three cuts.

Treatment (t ha^{-1})	Incorporated			Non-incorporated		
	1st collection	2nd collection	3rd collection	1st collection	2nd collection	3rd collection
Control	11.588	10.600	10.548	11.072	10.672	13.272
0.5	9.416	9.176	11.756	11.640	9.684	11.812
1	10.856	10.688	9.440	10.432	11.088	13.512
2	10.472	10.304	14.556	9.464	10.112	12.560
4	10.872	9.564	11.092	8.768	9.916	12.196

* Mean values followed by the same letter in a column do not differ statistically. Tukey's test at 5% probability.

Similar results were found by Sanzonowicz *et al*. (1987), where the application of different doses of limestone (0, 3 and 4.5 t ha^{-1}) in a pasture of *B. decumbens* did not increase dry matter production after three months of pasture or during succeeding years. This agreed with the results found in Rondônia by Gonçalves *et al*. (1984), where in Porto Velho there was no increase in forage production beyond the dose of 600 kg ha^{-1}; in Presidente Médice a dose of 400 kg ha^{-1} limestone achieved maximum production, and in Vilhena the pasture did not respond to liming.

According to the results, it was possible to establish a pasture of *Brachiaria* 'Mulato II' in the region of the Juruá Valley. Similar results were obtained in Lanos Orientales, Colombia, where the species showed good adaptation to various conditions of both soil and climate, demonstrating that the cultivar adapts easily, and is compatible with the quality and infrastructure of different environments (Centro Internacional De Agricultura Tropical (CIAT), 2004).

Conclusions

The doses of limestone and forms of application did not affect performance in the *Brachiara* hybrid 'Mulatto II' in which the application of limestone to pastures in Acre is only necessary at small doses, to renovate or maintain pastures that have low levels of calcium and magnesium in the soil. Additionally the introduction of new tropical pastures proved to be successful in Acre, irrespective of the dose of limestone and form of application.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Relative competitiveness of *Phaseolus vulgaris* with *Bidens pilosa*

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In agriculture, weeds tend to compete with the crop for scarce resources like water, light and nutrients, which incurs losses to farmers. Consequently, farmers must deal with weeds to derive maximum benefits for their crops and the environment. The aim of this paper was to assess the competitiveness of common bean crops in the presence of hairy beggarsticks (*Bidens pilosa*) at different population densities. The treatments were arranged in replacement series using five proportions (0:16, 4:12, 8:8, 12:4 and 16:0) of common bean and hairy beggarsticks in a fully randomized design, with four replicates. The analyzed variables were dry mass of the aerial part and height of plants. Competitive analysis was performed using diagrams applied to substitute experiments and indices of competitiveness. With regard to the two evaluated variables, the common bean was more resourceful than the hairy hairy beggarsticks.

Key words: Replacement series, competition, shoot dry mass, stature, *Bidens pilosa*, beans.

INTRODUCTION

Brazil is one of the world's leading producers of beans with a mean annual production of 3,500,000 tons (MAPA, 2016). The common bean is consumed mainly in the states of Paraná, Santa Catarina, Rio Grande do Sul and Rio de Janeiro. As one of the basic Brazilian food items, it is cultivated by small and large producers in all regions of Brazil (MAPA, 2016). This important component of the Brazilian diet is high in protein, carbohydrates, vitamins, minerals, fiber and antioxidant compounds that help reduce diseases. According to the Ministry of Agriculture and Supply, the MAPA (2016), seven out of ten Brazilians consume beans on a daily basis.

However, the productivity of this crop in Brazil is considered low and could potentially triple with the appropriate use of technology in farming. There are several factors that reduce the productivity of crops, including the interference of weeds, that is, the competition between species (Teixeira et al., 2009).

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According to the authors, the bean plant is one of the crops that provides less shade for the soil and suffers the most interference of weeds, thus generating losses in growth, productivity, and the operationalization of harvests.

Weeds can interfere with agricultural crops by competing for the resources they require for growth, such as water, light and nutrients, and by allelopathy (Pereira et al., 2011). One of the species of weed that is usually found in crops and may be causing losses is hairy beggarsticks (*Bidens pilosa*), which is a fast-growing erect herb, 20 to 150 cm tall, with high seed production, that grows year-round in favorable conditions (Kissmann and Groth, 1997). Considering that this weed usually infects annual crops in more than 40 countries, it can reduce productivity by 30%, as well as serve as a host to fungi, virus and nematodes (EMBRAPA, 2014).

The weed, *B. pilosa* is among the most predominant species in bean crops in the dry and rain seasons (Teixeira et al., 2009), and it can exhibit high competitiveness and significantly reduce the dry matter accumulation of crops.

Substitutive experiments are conducted to determine the competitive relationship among plants, the effects of the population, and the proportional difference of crops with weeds (Moraes et al., 2009). The replacement series includes the culture alone and in a co-culture mixture with weeds in variable proportions. The total amount of plants is constant in all the experiment treatments to indicate which species is the most competitive (Cousens & O'neill, 1993).

There is little knowledge on the interaction of common beans with black-jack. Given the inexistence of studies to shed light on this doubt, the aim of this paper was to assess the competitiveness of common bean crops in the presence of hairy beggarsticks in different population densities.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse at the experimental unit of the Universidade Tecnológica Federal do Paraná - UTFPR - Campus Dois Vizinhos, in February and March 2014. The adopted experimental design was random blocks with four replications.

The first experiment was installed in a monoculture of common bean and black-jack. Both species were planted in 8-L pots. The final constant production of dry mass in the aerial shoots of the plants was obtained from the average of both monocultures. The average population of 16 plants pot^{-1}, which is the equivalent of 400 plants m^{-2} (data not presented), was used to obtain the final constant production.

For the second experiment, seeds were planted in seedling production trays to ensure uniform germination and seedling emergence on the same day, thus preventing any advantage of one species over the other. Prior to sowing on the trays, it was observed that the difference of germination between the species was two days.

After five days of emergence, the seedlings were transplanted to 8-L pots. The replacement series experiments included different combinations per pot (0:16, 4:12, 8:8, 12:4, 16:0) of common bean plants and black-jack, respectively. The plants were irrigated as required. For both experiments, soil fertility was corrected according to the technical recommendation for bean crops.

Thirty days after emergence (DAE), the shoot dry mass and height of the common bean and hairy beggarsticks plants were recorded. To count the dry mass of the shoots, the plants were cut close to the soil and conditioned in a forced air oven at 60°C until constant weight. Height was measured using a graded ruler from the soil to the highest outstretched leaf.

Relative productivity (RP) and total relative productivity (TRP) data were analyzed using diagrams and species proportion. For RP analysis, the expected production is defined by the straight line that connects the production point of each species in pure stand (100:0) to point zero of the stand (0:100). When the RP results in a straight line, it means that one species has no effect over the other. However, when the RP results in a concave line, it implies some loss for one or both species, while a convex line implies benefits for one or both species. For the TRP, if the value is equal to 1 (straight line), there is competition for the same resources, if the value is higher (convex line), competition is avoided, and if the value is less than 1 (concave line), there are multiple losses in growth (Cousens, 1991).

The procedure to statistically analyze relative production was calculated using the difference for the RP values (DRP) from the proportions 25, 50, and 75% in relation to the values of the hypothetical straight line (Passini, 2001).

The indices of relative competitiveness (RC), relative clustering coefficient (K) and aggressiveness (A) were calculated as follows: RC represents the comparative growth of the X genotype in relation to Y, K indicates the relative dominance of a genotype over the other, and A indicates which genotype is the most aggressive. The genotype X is more competitive than Y when RC > 1, $K_x > K_y$ and A > 0, and the genotype Y is more competitive than X when RC < 1, $K_x < K_y$ and A < 0 (Hoffman and Buhler, 2002). To calculate these indices, the 50:50 proportions of the species were used with the following equations, as suggested by Cousens and O'Neill (1993):

$RC= RP_x/RP_y$, $K_x= RP_x/(1-RP_x)$, $K_y= RP_y/(1-RP_y)$, $A= RP_x – RP_y$.

The t-test was applied to test the differences in the DRP, TRP, RC, K and A indices (Hoffman and Buhler, 2002). To test the differences of DRP and A, it was considered that the null hypothesis would be the mean equal to zero ($H_o = 0$), for TRP and RC, that the means would be equal to one ($H_o = 1$), and for K, that the means of the differences between K_x and K_y would be equal to zero [$H_o = (K_x - K_y) = 0$]. The criterion to consider RP and TRP curves different from the hypothetical straight lines was that significant differences according to the t-test should occur in at least two proportions (Bianchi et al., 2006). Similarly, for the RC, K and A indices, a difference in competitiveness was considered when there was a significant difference according to the t-test in at least two indices.

The data obtained for shoot dry mass and height, expressed in means per plant, were subjected to analysis of variance (p in at least two indices. he t-teeatments were compared using Dunnett's test (p obtained for shoot monocultures were considered the control for comparison.

RESULTS AND DISCUSSION

Graphical analysis for the variable shoot dry mass of the plants showed that the RP (relative productivity) of the common bean has a convex line and the hairy beggarsticks

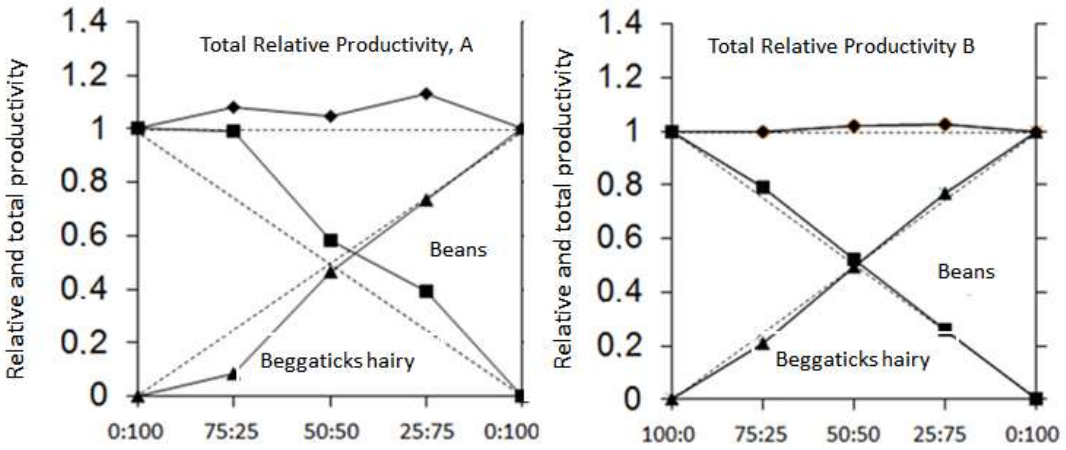

Figure 1. Diagram of relative mean production of the shoot dry mass (A) and height (B) of common bean and hairy beggarsticks plants according to variation of the ratio between the two species. UTFPR, Dois Vizinhos, PR, Brazil, 2014.

Table 1. Difference of relative productivity (DRP) and total relative productivity (TRP) of the variables shoot dry mass and height of the common bean and black-jack, 30 days after emergence. UTFPR, Dois Vizinhos, PR, Brazil, 2014.

Variables	Proportions of plants (bean: competitor)		
	75:25	50:50	25:75
Dry mass of the aerial part			
DRP common bean	0.24 (± 0.05)	0.08 (± 0.06)	0.14 (± 0.10)
DRP black-jack	-0.16 (± 0.03)*	-0.04 (± 0.10)	-0.02 (± 0.13)
TRP	1.08 (± 0.04)	1.05 (± 0.14)	1.13 (± 0.08)*
Leaf area			
DRP common bean	0.04 (± 0.05)	0.02 (± 0.05)	0.01 (± 0.03)
DRP black-jack	0.04 (± 0.07)*	-0.01 (± 0.02)	0.02 (± 0.02)
TRP	1.00 (± 0.05)	1.02 (± 0.05)	1.03 (± 0.01)

*Significant difference based on the t-test $p \leqslant 0.05$. Values in parentheses represent the standard error of the mean.

has a concave line, that is, the straight lines deviated from the expected production line. The common bean was more competitive than the weed since it captured the resources more effectively in all the assessed proportions (Figure 1A). In another study, Galon et al. (2015) conducted substitutive experiments with soybean and observed a reduction in the production of dry mass in all the tested proportions, which proves that this crop is more competitive than black-jack.

The greater RP of the common bean increased the production of the shoot dry mass of both species, that is, total relative productivity (TRP), suggesting that the common bean benefitted by growing with the weed (Figure 1A and Table 1). These results are directly associated with the fact that this crop has a greater capacity to quickly cover the soil and thus restrict the weed's search for light.

The radiation balance in the red and far-red range is perceived by the phytochromes that interconvert between the two forms, giving the plant its capacity to stretch and escape the shade to later assume a more generalized and homogenous growth with the accumulation of mass that is proportional to the size (Procópio et al., 2004).

The results of the RP and TRP of the height of common bean and hairy beggarsticks were similar to the results shown in Figure 1A and B and Table 1, although, in this case, the straight lines were close to the expected lines. The RP and the TRP showed no differences for the variables of the studied proportions (Table 1), since at least two of the proportions would have to show

Table 2. Indices of competitiveness between common bean and black-jack, expressed in relative competitiveness (RC), relative clustering coefficients (K) and aggressiveness (A), obtained in a replacement series of experiments. UTFPR, Dois Vizinhos, PR, Brazil, 2014.

Variable	RC	Kx (crop)	KY (competitor)	A
Shoot Dry Mass	1.38 (0.31)	1.52 (0.41)	0.98 (0.33)	0.12 (0.08)
Height	1.07 (0.05)	1.15 (0.23)	0.99 (0.09)	0.03 (0.07)

Table 3. Responses of bean crops and hairy beggarsticks expressed in shoot dry mass and height of plants 30 days after emergence. UTFPR, Dois Vizinhos, PR, Brazil, 2014.

Proportion (bean: competitor)	Shoot dry mass (g plant^{-1})	Height (cm)
Bean		
100:0 (T)	0.53	31.25
75:25	0.71	32.84
50:50	0.62	32.73
25:75	0.84	32.39
CV (%)	29.6	15.5
Competitor		
100:0 (T)	0.45	23.64
75:25	0.43	24.16
50:50	0.41	23.45
25:75	0.11*	19.93*
CV (%)	29.43	5.34

*Mean differs from control (T) according to Dunnett's test ($p \leq 0.05$).

significant differences for this to occur (Bianchi et al., 2006). Plant height is an important feature in the competitive processes because it has a direct influence on the plant's capacity to intercept and use light (McDonald, 2003), the higher the plant, the greater its capacity to create shade for the competing species. In a study conducted with soybean and red rice, Moraes et al. (2009) detected the influence of these crops in suppressing the competitor through shade due to the greater leaf area and quick establishment, which is similar to the findings of this study.

The common bean is a crop with low competitive potential that is classified as having low shading capacity and must therefore compete with weeds (Teixeira et al., 2009). However, some studies corroborate the results presented here where the common bean was more competitive than *Brachiaria plantaginea* (Passini, 2001) and *Amaranthus* sp. (Carvalho and Christoffoleti, 2008).

These results can be explained by the attributes of the crop, such as height, biomass accumulation, canopy architecture, and number and size of branches, that work together to better compete with the weeds (Pires et al., 2005, Bianchi et al., 2006). In this case, vigorous growth, stature, and greater leaf area of the common bean plants were the components that surpassed the vegetative characteristics of the black-jack.

The common bean proved being more competitive than the hairy beggarsticks for the shoot dry mass and height variables according to the established criteria, that is, RC > 1, $K_x > K_y$ and A > 0 (Table 2). These indices of competitiveness show which species is more competitive. In the same way, Hoffman and Buhler (2002) showed that sorghum was more competitive than *S. halapense,* soybean was more competitive than red rice (Moraes et al., 2009).

Relative growth verified using the shoot dry mass and height variables showed that both variables of the common bean culture differed from the control (monoculture) (Table 3). Both variables confirm that the bean plant prefers hairy beggarsticks in its vicinity than another common bean plant at least within the 30 days after emergence, that is, in this monoculture, the means of these variables were lower than the means found in the mixed crops. When compared with the control, shoot dry mass (36%) and height (4.5%) increased. In the 25:75 proportion, similar results were reported by Christoffoleti and Victória Filho (1996), who found that corn preferred pigweed in its vicinity than another corn plant.

For the competitor black-jack, there was no difference

in the lowest proportion of the competitor (25:75) in comparison with the control. This difference was represented by a 76% reduction for shoot dry mass and a 15.7% reduction for height in comparison with the control. The competitor in the monoculture had a higher production of shoot dry mass than when in competition, which suggests that it prefers to compete with an individual of the same species, unlike the common bean.

Species with similar growth habits will make similar demands on the limited resources for growth, but the differences in their efficiency in the utilization of these resources makes one species a better competitor than are the others (Tuor and Willians, 2002). Generally, intraspecific competition among crop plants is more severe than the interspecific effects of weeds on crop yield (Radosevich, 1987). Given the relative importance of weeds in the agricultural scenario, studies on the biology and the interference relationships of this species on different crops are fundamental (Wandscheer et al., 2013).

Regardless of the proportion of the species, bean plants were more competitive than hairy beggarsticks and had a greater relative productivity of shoot dry mass and height. Consequently, the common bean prefers hairy beggarsticks in its vicinity than another common bean plant.

Conclusions

It was concluded that regardless of the proportion of the species, the common bean showed gains in relation to the hairy beggarsticks for the analyzed variables.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Influence of pre-germination treatments on germination seed in *Melanoxylon brauna* Schott

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This study evaluated the presence of integument dormancy in *Melanoxylon brauna* seeds by testing the influence of nine pre-germination treatments on seed germination compared to a control (no pre-germination) treatment. Pre-germination treatments include; immersion in sulfuric acid for 5 min, 10 min, 15 min and 30 min, hot water at 80°C without soaking, hot water at 80°C with soaking for 30 min, 90 min, 24 h, and mechanical scarification. The experiment consisted of a completely randomized design, with four replicates and 25 seeds per experimental unit. Percentage germination, germination speed, number of normal and abnormal seedlings, and mortality rate were evaluated. Seeds began to germinate at four days, and germination varied from 33 to 89%, with the highest percentage found in hot water with or without soaking for 30 min, which not differed statiscally from control. Immersion in sulfuric acid for longer than 10 min reduced seed germination and increased mortality rate. We conclude that *M. brauna* seeds do not undergo seed dormancy, and there is no need to apply pre-germinating treatments to its seeds.

Key words: Dormancy, seed technology, Leguminosae.

INTRODUCTION

Melanoxylon brauna, popularly known as brauna, brauna-preta or garauna, is an arboreal species of the Leguminosae Family - Caesalpinoideae, endemic to Brazil and native to the Caatinga, Cerrado, and Atlantic Forest biomes. It occurs naturally in the states of Bahia, Goiás, Minas Gerais, Espírito Santo, Rio de Janeiro, São Paulo, and Paraná (Lorenzi, 2009; Carvalho, 2010). The species has very heavy and compact wood suitable for external and hydraulic works, fence posts and civil construction (Carvalho, 2010). Due to intense extractive exploitation of its wood for use in construction, the species is currently categorized as vulnerable on the endangered species list (Martinelli and Moraes, 2013). It has ornamental potential due to its intense yellow

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flowering and is thus used in landscaping projects and afforestation of squares/parks. It has symbiotic association with nitrogen-fixing bacteria (De Faria et al., 1984), however it is little used in environmental restoration projects due to the difficulty of obtaining its seeds and their slow growth during the seedling phase and in the field.

Understanding the main processes involved in germination is of vital importance for multiplying native species, considering that the seminal route is often the only form of propagating these species, as in the case of Brauna. Germination consists of a complex and orderly set of biochemical and physiological events which begin with water absorption by the seeds that activates metabolism culminating in the emergence of the embryonic axis (Labouriau, 1983). This process is influenced by several intrinsic and extrinsic factors which can act in isolation or in interaction with others.

Several species of the Leguminosae Family have waterproof seed coatings/integument, which causes physical or exogenous dormancy. This characteristic is determined by the presence of substances such as suberin, lignin, cutin and mucilage that can concentrate on different parts of the seeds such as its coating/integument, pericarp and nucellar membrane, which differ from one species to another (Mayer and Poljakoff-Mayber, 1982). The waterproof coating/integument can act in two ways on seed dormancy; inhibiting water absorption and preventing seed soaking, or by reducing oxygen availability to the embryo.

Dormancy is ecologically important for preventing germination when the environmental conditions for the species' growth are not adequate by increasing the prospects of success for its establishment and survival. Under natural conditions, physical dormancy can be broken by scarification processes, animal ingestion, microorganism activity, natural soil acidity and by burning (Mayer and Poljakoff-Mayber, 1982).

Seeking methodologies for analyzing forest seeds has a fundamental role in scientific research and is of diverse interest. For Brauna, the effects of temperature, substrate and seed size on germination and vigor have already been investigated (Flores et al., 2014a, b). Large dark seeds put to germinate on a paper roll substrate in temperatures ranging between 30 to 35.8°C showed better performance. However, no studies have addressed the influence of pre-germination treatments on the germination of this species. The objective of this study was to verify the influence of different pre-germination methods on seed germination and vigor in *Melanoxylon brauna*.

MATERIALS AND METHODS

The experiment was conducted at the Laboratory of Leguminous Forests, Embrapa Agrobiology, Seropédica, Rio de Janeiro.

Melanoxylon brauna seeds used in the experiment were harvested in July, 2015 in Leopoldina, Minas Gerais and remained stored in a cold room at 5ºC for one year. Then the moisture content of the seeds was determined by the drying oven method at 105 ± 3°C for 24 h, adopting two replicates of 5 g of each seed, and then 1000-seed weight was also determined, consisting of weighing eight samples of 100 seeds (Brasil, 2009).

For the germination test, seed asepsis was first performed by immersion in 5% (v/v) sodium hypochlorite for 10 min, followed by rinsing under running water. The treatments used to break dormancy were:

Chemical scarification

The seeds were immersed in sulfuric acid with 98% concentration for 5 min (T1), 10 min (T2), 15 min (T3) and 30 min (T4), and then rinsed in running water.

Thermal shock

The seeds were immersed in water at 80°C without soaking (T5), and with soaking for 30 min (T6), 90 min (T7) and 24 h (T8).

Mechanical scarification (T9)

The region opposite to the axis of the embryo was manually rubbed using sandpaper P150, until a slight change of color was obtained in that area of the coating/integument.

Control (T10)

Intact seeds without any treatments

A germitest paper roll was used as substrate, with three papers per repetition, moistened with distilled water 2.5 times its weight (47.5 ml per roll). The rolls were placed in transparent polyethylene plastic bags with dimensions of 40 cm x 60 cm with 0.033 mm thickness, which were then well tied with crochet thread to avoid drying out. The rolls of paper with plastic were kept upright in a BOD germinating chamber at a temperature of 25ºC, and a photoperiod of 12 h. The experimental design was completely randomized with four replicates and 25 seeds per experimental unit.

Counts were carried out daily in the first week until the first germinated seeds were observed. The evaluations were weekly from the second week on with the following characteristics evaluated: percentage of normal and abnormal seedlings, percentage of hard or non-germinated seeds and dead seeds. Germinated seeds were considered those whose radicles were equal to or greater than 2 mm. Also, the Speed Germination Rate (SGR) was calculated according to the formula proposed by Maguire (1962).

The experiment lasted 25 days, when all treatments presented a stabilized germination percentage. The data of the evaluated variables were subjected to analysis of variance (ANOVA) and the means that originated from the treatments were compared by the Scott-knott test, at 5% probability. There was a need for transformation in arc sin sen($\sqrt{x/100}$) of the normal seedlings variable values because they did not present a normal distribution or homogeneity of residue variance, which are necessary assumptions to perform ANOVA. Non-parametric Kruskal Wallis test was used for the variable percentage of abnormal seedlings, as the residues did not fit such assumptions even after transformation. Analyzes were performed with the help of SAEG 9.1 (SAEG, 2007),

Table 1. Summary of the analysis of variance with the sources of variation and probabilities of significance.

Source of variation	GL	G (%)			SGR			PLAN (%)			PLAA (%)			M (%)		
		QM	F	P	QM	F	P	QM	F	P	SQ	F	P	QM	F	P
Treatment	9	9384.4	12.43	0.0000	16.45	6.22	0.0001	1007.11	5.083	0.0003	18.71	1.823	0.1052	1042.7	12.43	0.0000
Error	30	2516.0			2.64			198.13			10.26			83.86		
CV (%)		13.33			14.23			50.27			188.48			20.26		

(P) for the analyzed variables corresponding to germination percentage (G), normal seedlings (PLAN), abnormal seedlings (PLAA), mortality (M) and speed germination rate (SGR).

Table 2. Germination percentage values (G%), speed germination rate (SGR), percentage of normal seedlings (PLAN%), percentage of abnormal seedlings (PLAA%) and percentage of mortality (M%) of *Melanoxylon brauna* seeds subjected to different pre-germination treatments after 25 days of testing under controlled conditions.

Treatments		G %	SGR	PLAN %	PLAA %	M %
T1	Immersion in sulfuric acid 5 min	73^{b}	13.43^{a}	33^{a}	0^{a}	27^{c}
T2	Immersion in sulfuric acid 10 min	70^{b}	12.70^{a}	27^{a}	3^{a}	30^{c}
T3	Immersion in sulfuric acid 15 min	51^{c}	10.09^{b}	4^{c}	1^{a}	49^{b}
T4	Immersion in sulfuric acid 30 min	33^{d}	6.84^{c}	1^{c}	0^{a}	67^{a}
T5	Hot water 80°C without soaking	80^{a}	12.16^{a}	33^{a}	4^{a}	20^{d}
T6	Hot water 80°C with 30 min soaking	89^{a}	13.81^{a}	42^{a}	0^{a}	11^{d}
T7	Hot water 80°C with 90 min soaking	73^{b}	11.58^{a}	42^{a}	6^{a}	27^{c}
T8	Hot water with 24 hours soaking	67^{b}	10.67^{b}	17^{b}	0^{a}	33^{c}
T9	Mechanical Scarification	53^{b}	10.55^{b}	34^{a}	0^{a}	31^{c}
T10	Control	82^{a}	12.37^{a}	47^{a}	3^{a}	18^{d}

Mean followed by equal letters in the column did not differ among each another by Kruskal-Wallis test (PLAA%) at 5% significance.

SISVAR (Ferreira, 2011) and R (The R Project for Statistical Computing, version 3.3.2.) software programs.

RESULTS AND DISCUSSION

The 1000 seed weight for *Melanoxylon brauna* was 136.70 g, meaning 1 kg corresponds to 7,135 seeds. The moisture content of the seeds was 7.42%. The 1000 seed weight reported by Flores et al. (2014) for the species was very close to what was found: 133.43 g (7,494 seeds per kilogram), with 13% humidity. Carvalho (2010) reported values of 7,800 to 30,000 seeds per kilo for the species, and Lorenzi (2009) found 30,000 seeds per kilo, values well above what we found.

The analysis of variance showed a highly significant difference between treatments for germination ($F = 12.433$; $p < 0.0000$), speed germination rate ($F = 11.42$; $p < 0.0001$), normal seedlings ($F = 5.083$, $p < 0.0003$), and mortality ($F = 12.433$, $p < 0.0000$). The only exception occurred for the abonormal seedlings ($F=1.823$, $p<0.1052$), which was not significant. Thus, it was possible to statistically distinguish the treatments for breaking dormancy (Table 1).

The highest percentages of germination were found in hot water treatment with 30 min soaking (T6), control (T10) and hot water without soaking (T5) (Table 2). Germination was 89%, 82% and 80%, respectively for these treatments, not differing among them. The second best results were obtained by treatments T1, T2, T7, T8, T9,

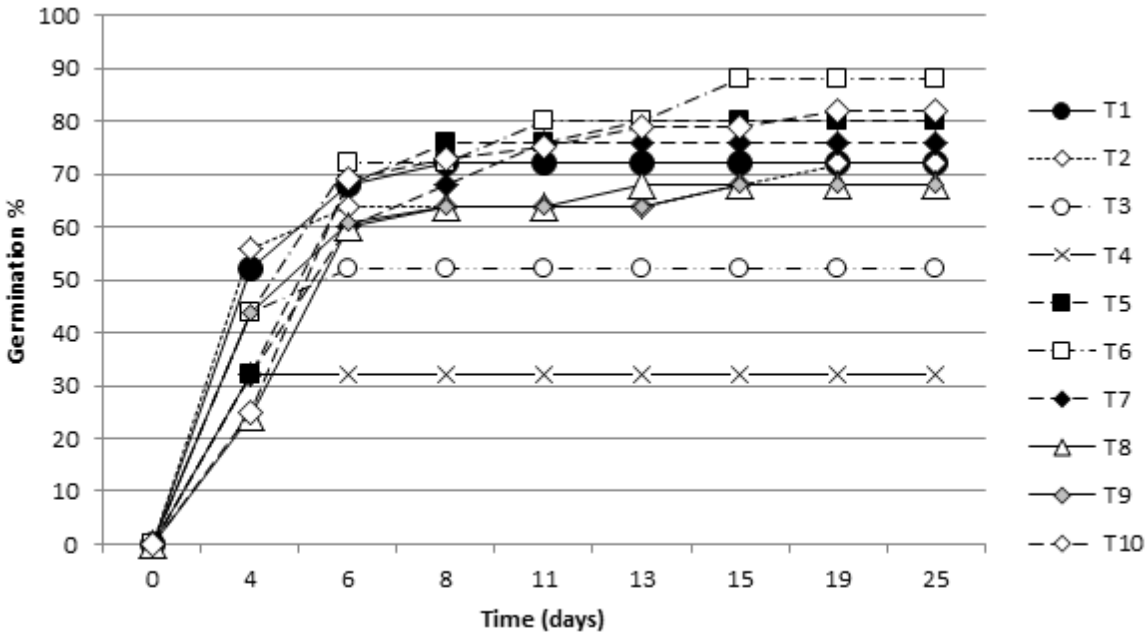

Figure 1. Germination time of *Melanoxylon brauna* seeds subjected to different pre-germination treatments under controlled conditions.

which presented germination varying from germination of 67 to 73%, respectively, with no statistical difference. The lowest percentage of germination was found for T4 - Immersion in sulfuric acid for 30 min (33%). The treatments of immersion in sulfuric acid for 15 min (T3) showed germination values of 51%. Speed germination rate formed a first group with treatments T1, T2, T5, T6, T7, T10, a second group with T3, T8, T9, and lastly the T4 treatment (Table 2).

The seeds began to germinate on the fourth day of the experiment for all treatments. All treatments reached a germination percentage greater than 50% at 6 days, except for immersion in sulfuric acid for 30 min (T6), which reached 32% persisting throughout the experiment period (Figure 1).

In general, the mortality of Brauna seeds was quite high, varying from 11% to 67%. The lowest value was found for T6 (seeds soaked in hot water 80°C by 30 min), not differing significantly from control (T10) and hot water without soaking (T5).

A high incidence of fungi in the seeds was observed and may have contributed to its high mortality, especially when combined with treatments that caused seed damage. Although fungal attack causes an increase in mortality, its presence is a factor that can positively influence the germination process, since it leads to deterioration of the coating/integument. It was not measured in this experiment, but have already been observed between *Alternaria*, *Aspergillus* fungi and *Astragalus utahensis* seed (Long et al., 2012; Eldredge et al., 2016) and between corn and *Fusarium subglutinans* (Rheeder et al., 1990).

Immersion in sulfuric acid for longer than 10 min impaired germination and increased seed mortality. Although, chemical scarification leads to integument/coating degradation allowing water to enter. Excessive immersion/soaking can cause the breakdown of essential cells, thereby inducing mechanical damage and fungi invasion, which in turn hinder the emergence of seedlings (Rolston, 1978).

Immersion in hot water for 24 h also impaired Brauna seed germination, reducing speed germination rate and increasing mortality. Excess water can impair the germination process by promoting pathogenic microorganism proliferation, restricting oxygen entry and absorption. When set to soak for an extended period, the seeds may suffer irreversible damage to the membrane system, and consequent leaching of cellular contents that negatively affects germination. Similar to Brauna, *Parkia pendula* seeds do not seem to tolerate long periods of soaking, and a reduction in germinability and percentages of normal seedlings can be observed when soaked for 24 h after the heat treatment (Pinedo and Ferraz, 2008). These authors found that a soaking greater than 20% of their mass after about 4h significantly reduced the emergence of seedlings. This reduction was observed in *Parkia multijuga* when soaking seeds exceeded 45.4% in water content (Calvi et al., 2008).

Variable results in relation to the same chemical treatments in different plant species can be observed due to the germination peculiarities of each species and the

characteristics of each integument/coating. *Colubrina glandulosa* Perk germinated well with sulfuric acid for 30 to 90 min, however germination losses were observed for 120 and 150 min (Brancalion et al., 2010). *Libidibia ferrea* (Mart. ex Tul.) LP Queiroz) had good results with sulfuric acid for 20 and 40 min (Matos et al., 2015). *Samanea tubulosa* (Benth.) Barneby & JW Grimes germinated with sulfuric acid for 5 and 10 min (Muniz Giachini et al., 2010). *Parkia panurensis* e *P. velutina* had a good performance with immersion in sulfuric acid for 30 min (Melo et al., 2011). *Enterolobium contortisiliquum* (Vell.) Morong germinated with immersion in sulfuric acid for 30 to 50 min without significant difference between immersion/soaking periods (Lozano et al., 2016). *Gledistchia amorphoides* Taub seeds subjected to chemical scarification for 1 or 2 h had germination increased by 70% and anticipated in 15 days (Bortolini et al., 2011).

Although mechanical scarification has been indicated as a good method to overcome seed dormancy in many Leguminosae species (Guedes et al., 2011; Dayrell et al., 2015), in this study it caused a decrease in brauna speed germination rate and percentage. Based on the results, it can be assumed that the seeds of Brauna do not have seed dormancy.

Conclusion

Treatments with seed immersion in 80°C hot water with or without soaking for 30 minutes show the highest germination, speed germination rate and lowest mortality values. These treatments are not statistically different from each other or the control group, concluding that brauna seeds do not undergo physical dormancy and do not require pre-germination treatments.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

The effect of vegetation covers on the physical properties of a red latosol

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In this study, the physical properties of a red latosol were assessed under Cerrado (a Savannah like vegetation type) and under of *Eucalyptus grandis* cultivation. Two contiguous sites of 14 ha each showing similar original vegetation cover, slope, topographic position, soil type, and sun exposure (aspect) were selected. Systematically, 20 sampling points were distributed in each site, from which soil deformed samples were collected to determine soil texture and non-deformed soil samples were collected to determine apparent density, volumetric soil moisture, and penetration resistance. Based on this study's results, it was observed that by changing land cover of Cerrado vegetation to cultivation, *E. grandis* provided no significant changes, Scott-Knott test (α = 0.05) of soil penetration resistance, density, and volumetric moisture of the red latosol.

Key words: Cerrado vegetation, *Eucalyptus grandis,* land use, land cover change.

INTRODUCTION

Anthropogenic pressure on the Cerrado biome has grown in recent decades due to the increase in population density in the region and the horizontal expansion of the agricultural frontier. The conversion of new areas into agricultural lands, pastures, and forestry causes destruction of large areas of native vegetation and major changes in the physical and biotic environment. In these regards, it is necessary to conciliate human needs with the conservation of natural resources by adopting alternative and more sustainable land uses. Hence, it is fundamental to assess the impact of these land use changes caused by several anthropogenic uses as observed by Effgen et al. (2012), Tavares Filho et al. (2014), Effgen et al. (2015) and Stone et al. (2015).

Agricultural soils, such as those in originally dense vegetation in the Cerrado regions, represent an important rural frontier in Brazil. According to current legislation, these soils may suffer alterations in their use and occupation by converting them to agricultural lands, pastures or silvicultural sites. Therefore, they are subject

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to modifications in their physical and chemical attributes depending on the type of land use and management systems adopted. Its degradation effects are, therefore, a great environmental concern (Effgen et al., 2012, 2015; Stone et al., 2015). Furthermore, if soil degradation can be reversed, its qualities are maintained or improved using appropriate management methods; the sustainability of the agroecosystem may become a reality. Knowing soil quality under natural conditions and comparing these conditions to those resulting from different uses are essential to determine strategies for sustainable management.

Among the anthropic uses to which areas have been converted in the Cerrado biome is silviculture with crops of homogeneous eucalyptus (*Eucalyptus* species). By comparing *Eucalyptus* plantations to other land use types, such as pastures and agricultural lands, which are more commonly observed and encompasses much larger spatial and temporal scale, forestry is considered a more important economic activity at the national scenario and historically in the Cerrado region. There is a growing demand in wood products by industries such as energy (firewood, wood chips and charcoal), construction (shoring, plywood, structures, etc.), farmo-chemical production (oils, essences, resin, rubber, etc.), livestock (forage and wood), agriculture (mentoring, substrate, etc.), and in the environmental area (CO_2 sequestration) (Silva et al., 2010; Soares et al., 2017).

Silvicultural activities generally occur in a longer cycle in relation to agricultural and livestock activities. They generally promote less demanding species in regards to soil chemistry and physics, since they are less dependent on pesticides; they minimize the action of erosive agents; they require reduced soil preparation and a long cycle between planting-harvesting-planting; they have a high soil nutrient cycling potential throughout the cutting cycle by litter deposition (Pinto et al., 2016); their cultural practices are less intense and use fewer machines or devices while planting and cultivating; when properly managed, they have the potential to provide shelter for fauna, allowing the integrated promotion of natural resource production and conservation (Soares et al., 2017). The evaluation of alterations in soil caused by changes in land use and occupation can become an important parameter to evaluate the sustainability of newer approaches that meet human needs (Silva et al., 2010).

Physical properties of soil generally reflect the positive and negative impacts of management on soil conservation and on the quality of the ecosystem involved (Silva et al., 2010). Since the physical properties of soil are easily and rapidly obtained specially the soil apparent density and penetration resistance, they are important measurements for the *in situ* assessment of management quality, as well as of the economic and environmental viability of forest production. Many within the scientific community focus on the physical properties of soils, since they evidence the negative impact of inadequate management through soil compaction. This can be aggravated by secondary problems and severely compromise the environmental quality of the production system (Effgen et al., 2015; Effgen et al., 2012).

This research hypothesized that land use conversion of Cerrado vegetation to silviculture with homogenous plantation of *Eucalyptus grandis* will significantly affect soil physical properties. Thus the study's objectives were to estimate changes in soil density, penetration resistance, and moisture as evidence of land use and land cover change in the study site.

MATERIALS AND METHODS

Study area

This study was carried out at Água Limpa Farm (FAL) at the University of Brasília (UnB), located in the southwestern quadrant of the Federal District, 25 km from the center of Brasília-DF. Água Limpa Farm, with a total area of 4,250 ha, is located in the Hydrographic Microbasin of Ribeirão do Gama, a contributor to Paranoá River which is part of the Paranaíba River Basin. The relief is smoothly undulating and the altitude varies between 1,005 and 1,200 m above sea level. The studied areas are located in the watershed between the Capetinga and Taquara streams, both tributaries of Ribeirão do Gama, at coordinates latitude 15°58'23" South and longitude 47°54'31" West, SAD (South American Datum) datum 69, at an average altitude of 1150 m (Figure 1).

According to the Köppen climate classification, the climate of the region is "Aw" (Tropical seasonal savanna), with well-defined rainy and dry seasons. The rainy season begins in September or October and lasts until April or May, with an annual rainfall of 1,453 mm. The wettest months are November to March, when 75% of the annual precipitation occurs on average. The dry season usually begins in May and lasts until September. The months of June, July and August are the driest, constituting a period of water deficits for most soils. The mean annual temperature is 22°C, with a 27°C maximum and a 15.4°C minimum. September and October are the hottest months, with a monthly average of up to 25.6°C. June and July are the coldest months, with average temperatures of around 20°C. Relative humidity is high during the summer and over a few months of spring and autumn. During this period, the averages recorded range from 73 to 79%. Between June and September, these averages vary between 50 and 61%, although periods with relative humidity of less than 20% are frequent. The annual mean of this climatic variable is 67.3%. Average daylight per year is 2,417 h, always exceeding 125 h per month. Between April and September, the sun shines more than 200 h per month. November, December and January are the months with the less amount of daylight hours (Felfili and Silva Júnior, 1993).

Experimental design

The experiment was carried out in two adjacent areas with Red Clay Oxisol (EMBRAPA, 2013, 2011). Both of them were originally covered by Cerrado vegetation (Felfiliand Silva Júnior, 1993). The first area has a natural vegetation cover, properly preserved Cerrado vegetation, with no history of recent fires, invasive plants or other signs of anthropic actions. This area represents the original form of the savanna physiognomy characterized by its soil cover. It is covered with a herbaceous layer composed mainly of grasses and a wood layer spaced of arboreal and shrub elements

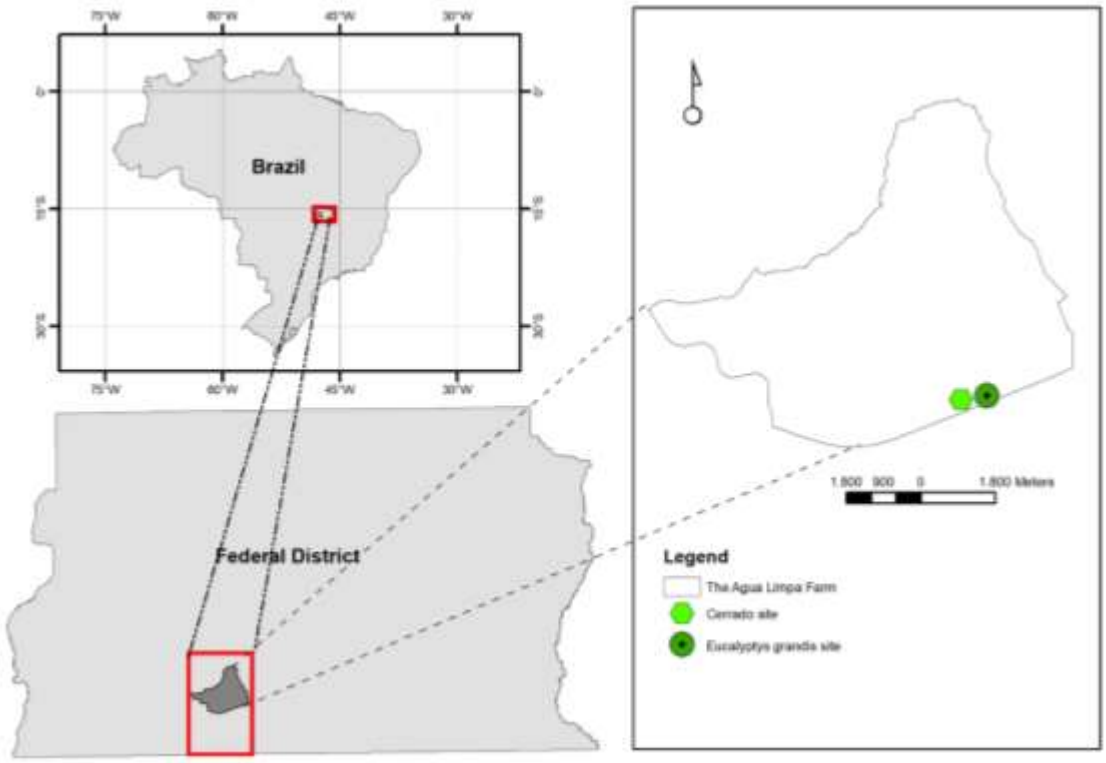

Figure 1. Studied area at Água Limpa Farm (FAL), University of Brasília (UnB), spatially located in the southwestern of the Federal District, Brazil.

(Ribeiro and Walter, 1998). Its tree cover varies from 10 to 60%, while its density ranges between 600 and 1200 wood plants (DAP at 30 cm of soil greater than 5 cm) per hectare (Felfili and Silva Júnior, 1993).

The second area was deforested and converted to a homogeneous forest stands of *Eucalyptus grandis* in 2009. The forest site was 7 years old at time of this study. Conventional soil preparation using a 26" harrow was adopted previously for *Eucalyptus* plantation. The spacing used for planting was 3 m × 3 m (1,111 plants/ha).

A plot of 1 ha (100 m × 100 m) was demarcated for data collection in each area. Four sets of undisturbed soil samples made of 8 pieces of 2.5 cm high were sequentially collected up to 20 cm deep for the verification of apparent density of the soil and volumetric humidity. This was collected with Uhland type sampler in rings of 80 cm^3 of internal volume. Twenty deformed soil samples were randomly collected in each plot, using a 2" Dutch type test, to a depth of 20 cm in order to perform the particle size analysis of soil particles for texture determination. The method used to determine soil granulometric composition is described in EMBRAPA (2011). The samples were analyzed and the results used to determine soil texture through the textural triangle method; thus classified as clay textured.

Penetration resistance in each plot of up to 30 cm depth was evaluated using Stolf impact penetrometer (M = 3,985 kg, A = 1,2767cm^2 and m = 3,506 kg) up to a depth of 30 cm in each plot. The calculation of penetration resistance was performed as described by Stolf et al. (2014).

$$RP = \left[\left(\frac{Mgh}{10A}\right) \times \left(\frac{M}{M+m}\right) \times N\right] + \frac{(M+m) \times g}{A} \quad (1)$$

where RP is the penetration resistance ($kgf.cm^{-2}$); M is the impact mass (kg); g is the gravity acceleration ($m.s^{-2}$); h is the mass displacement height of impact (m); A is the penetration cone base area (cm^2); N is the necessary impacts to penetrate soil by 1 dm ($impacts*dm^{-1}$); and m is the penetrometer body mass (kg).

The acceleration of gravity (g) was calculated according to the methodology proposed by Lopes (2008) for correction of the 15.973° latitude and the 1150 m altitude at the experiment site. The value found was g = 9.7842 ms^{-2}. For the transformation of RP in $kgf.cm^{-2}$ to MPa the RP result is multiplied by g × 100^{-1} (0.09784).

A regular mesh of resistance to the penetration in the studied areas was obtained with the data taken from the field.

Statistical analysis

The edaphic variables under a vegetative Cerrado vegetation cover and *E. grandis* cultivation were compared using the Scott-Knott test at a 5% probability level. This test was chosen because of its power and robustness for non-parametric distributions, as was recommended by Borges and Ferreira (2003) in comparison with other statistical tests. The statistical software SISVAR of the Federal University of Lavras (Ferreira, 2009) was used to perform the mean contrast test. This software is of public domain and was freely downloaded at the Federal University of Lavras (UFLA) website.

RESULTS

Tables 1, 2 and 3 show that according to the Scott-Knott test at 5% probability level, there were no significant

Table 1. Grain size composition of red latosol on Cerrado vegetation and Eucalyptus grandis crops.

Soil cover	Granulometric composition (g.kg^{-1})		
	Area*	Silt*	Clay*
Cerrado vegetation	250[a]	175[a]	575[a]
Eucalyptus grandis	225[a]	200[a]	575[a]

*Results followed by the same letter in the same column did not differ statistically according to the Scott-Knott test with a 5% probability level.

Table 2. Statistical moments of the soil's volumetric moisture in the 0-20 cm deep layer of red latosol on Cerrado vegetation and Eucalyptus grandis crops.

Soil cover	Volumetric moisture (cm.cm^{-3})				CV (%)
	Mean*	Standard deviation	Minimum	Maximum	
Cerrado vegetation	0.28[a]	0.02	0.23	0.34	8.37
Eucalyptus grandis	0.28[a]	0.03	0.18	0.33	10.55

*Results followed by the same letter in the same column did not differ statistically according to the Scott-Knott test with a 5% probability level.

Table 3. Apparent density according to the sampled depths of red latosol in the Cerrado vegetation and *Eucalyptus grandis* plantation.

Depth (cm)	Apparent density (g.cm^{-3})		
	Cerrado vegetation*	*Eucalyptus grandis**	CV (%)
0 - 2.5	0.87[a]	0.92[a]	10.91
2.51 - 5	1.04[a]	1.08[a]	9.55
5.01 - 7.5	0.99[a]	1.14[a]	2.26
7.51 - 10	1.05[a]	1.15[a]	3.11
10.01 - 12.5	1.09[a]	1.15[a]	4.31
12.51 - 15	1.11[a]	1.16[a]	7.19
15.01 - 17.5	1.06[a]	1.18[a]	4.45
17.51 - 20	1.10[a]	1.16[a]	5.81
Mean	1.04[a]	1.12[a]	3.18
	Penetration resistance (MPa)		
	Cerrado vegetation*	***Eucalyptus grandis****	**CV (%)**
0 - 10	1.15[a]	1.30[a]	13.01
10 - 20	1.93[a]	2.17[a]	12.13
20 - 30	2.44[a]	2.51[a]	10.09
Mean	1.84[a]	1.99[a]	11.73

Results followed by the same letter in the same column did not differ statistically according to the Scott-Knott test with a 5% probability level.

differences in variables texture, volumetric moisture, apparent density and resistance to penetration, in red latosol on Cerrado vegetation and *E. grandis* crops.

The two study sites showed the same soil type and granulometric composition, which indicates homogeneity in edaphic conditions.

The Cerrado vegetation is composed of herbaceous, shrub and small tree stratus, with open canopy, unique and great species diversity. The *E. grandis* plantation showed only one stratum, even-aged stand, homogenous, arboreal with closed canopy. Despite of the large structural differences in the vegetation between the two studied sites, there were no statistically significant differences in soil volumetric moisture.

Heavy machines were used to convert (clean and prepare) land cover from Cerrado vegetation to *E. grandis* plantation. Consequently, an increase in apparent density and soil penetration resistance were expected. Based on the results, the expected soil physical changes were not observed.

DISCUSSION

As shown in Table 1, there were no statistical differences between the soil textures of the two areas thus, showing that one silvicultural cycle (7 years) is not enough to differentiate soil textures between these two types of uses. In fact, the change in granulometric composition of soil is only evidenced on a much longer time scale, from decades or even centuries, as described by Anjos and Liesenberg (2002).

Soil volumetric moisture did not differ statistically in the 5% probability level by the Scott-Knott test in the studied areas. The mean depth at 0 to 20 cm for the Cerrado vegetation and *E. grandis* plantations was 0.28 cm^{-3}. During the 30 days prior to collection, 50.5 mm of accumulated rain were recorded for the Federal District. The results are to be interpreted in terms of soil texture (57.5% clay), which contributes to a higher water retention (Resende et al., 2007), so that roots, requires higher osmotic pressure to absorb water. The volumetric moisture content in the soil coincides with the values (28%) observed by Carneiro et al. (2009) in a Cerrado vegetation under similar soil conditions in the southwest of the state of Goiás.

The data analyses did not indicate a significant statistical difference between *E. grandis* and the Cerrado vegetation. It may be inferred that in the local biomass and evapotranspiration conditions, *E. grandis* did not modify the soil water regime in the 0 to 20 cm layer.

The mean values of apparent density were statistically the same in the soil under Cerrado vegetation and *E. grandis* at 5% level of significance according to the Scott-Knott test. For a red latosol in either type of soil cover, soil density did not reach the value determined as limiting for root development of 1.33 $g.cm^{-2}$ proposed by Klein et al. (2009), at any depth.

The apparent density in the first sampled layer (0 to 2.5 cm depth) was about 20% lower in both types of soil cover. This can be attributed to higher organic matter content in the soil surface and/or to greater difficulties while sampling in more superficial layers given the greater root density. Dedecek and Gava (2005) attributed the recovery of apparent density in the 0 to 10 cm layer to of soil drying-wetting cycles. According to the authors, the cycles reorganize soil particles in order to recover the original density in the layer directly in contact with machines' wheels by the action of organic matter and biological activity thus restoring the physical properties of the soil after 7 years of *Eucalyptus* growth.

In the present study, the physical properties of soil remained the same in the 0 to 30 cm layer as there were no significant differences found between the Cerrado vegetation and the 7-year-old *E. grandis* cultivation. This result is similar to that obtained by Dedecek and Gava (2005), Oliveira et al. (2008) and Effgen et al. (2015).

The mean apparent density observed at 20 cm depth in the Cerrado vegetation and *E. grandis* crop was 1.04 and 1.12 $g.cm^{-3}$ each. Apparent density increased with soil depth in both soil covers up to 12.5 cm, and remained stable at the maximum depth of 20 cm. This was probably due to the gradual decrease in organic matter content in the soil. Further studies are needed to prove this hypothesis.

The mean apparent density did not differ statistically between the two soil used at the 5% level in the soil under Cerrado vegetation or *E. grandis* crops as can be observed in Table 3.

The study of penetration resistance up to 30 cm can identify impediments to root development in areas of greater fine roots concentration, since they are responsible for the absorption of water and nutrients used by the plants both in the Cerrado vegetation and *E. grandis* crops. In both types of soil cover penetration, resistance increased with depth increment, exceeding 2 MPa in the 20 to 30 cm layer. This is considered by many authors as restrictive for root development of large tree species.

The occurrence of the same phenomenon in the Cerrado vegetation area discards the hypothesis that an increase in penetration resistance takes place in deeper soil layers due to the traffic of machines used for planting of *E. grandis*. It is therefore considered a natural situation in this environment.

The average resistance to penetration in the 0 to 10 cm, 10 to 20 cm and 20 to 30 cm depth layers did not differ statistically at 5% level of significance according to the Scott-Knott test between soil cover types. The averages in the 0 to 10 cm layer were 1.15 and 1.30 MPa, respectively for the Cerrado vegetation area and *E. grandis* crops (Table 3). Penetration resistance greater than 2 MPa implies restrictions of root development occurring in the superficial layer of the soil. Values surpassing this criterion were observed in the 20 to 30 cm soil depth in both studied areas.

The effects of land preparation using heavy machinery adopted for the cultivation of *E. grandis* compared to the undisturbed Cerrado vegetation did not cause significant soil impacts at the three analyzed soil depths. The study results suggest that silvicultural activity in latosols is an alternative land use that causes lesser impacts to soil physical properties compared to those subject of agricultural croppings (Dedecek and Gava, 2005; Oliveira et al., 2008; Tavares Filho et al., 2014; Effgen et al., 2015; Stone et al., 2015). However, complementary and spatially larger studies should be conducted to achieve more detailed results in this regard.

Conclusion

There were no significant differences (Scott-Knott test at α=0.05) between the edaphic variables of grain size or granulometry, humidity or moisture, density and penetration resistance assessed in a medium-textured red latosol under a vegetative Cerrado cover and *E. grandis* plantation. It indicates that changing land cover from Cerrado vegetation to *E. grandis* plantation did not substantially impact the assessed soil physical properties of red latosols in the study sites. Further studies, however, should be conducted to better understand broader soil impacts by forestry plantations in the Cerrado region.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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The effects of interest rates on access to agro-credit by farmers in Kaduna State, Nigeria

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This study examined the effect of interest rates on access to agro-credit by farmers in Kaduna State, Nigeria. This study employed survey research methodology which covered the three agricultural zones in the study area. The data generated were analyzed using descriptive statistics, multiple regression and 4-point likert scale rating. It was shown that, majority (40%) were aged between 31 and 40 years and about 41.20% had no formal education while 16.7% had secondary certificate. The study further revealed that about 48.3% of the respondents had farming experience of 20 years and above and majority (41.67%) sourced a total amount of between ₦100, 000 and ₦400, 000 from formal or informal sources. Age, level of education, interest rate, credit awareness and farm income were the major determinants of (p<0.05) credit sourced by the farmers in the study area. Majority of the farmers obtained their credit more from informal sources than formal sources. Inability to receive the amount applied for, risk of repaying the money and problem of getting guarantors were among the major problems under informal sources while high interest rate and inadequate collateral security were for formal sources. Recommendation was made for government to reduce the high interest rate charged on credit facilities.

Key words: Interest rate, agro- credit access, sources, Kaduna, Nigeria.

INTRODUCTION

With an estimated 140 million inhabitants and a population growth rate of 2.5% annually, Nigeria is the most populated country in sub-Saharan Africa and one of the most populated countries in the world (National Population Commission [NPC], 2006). The agricultural sector is the mainstay of the majority of Nigerian rural poor, with over 70% of the active labour force in rural areas employed in agriculture and the sector contributing over 23% of the gross domestic product (GDP) in 2006 (World Bank, 2007).

Agricultural credit plays a critical role in agricultural development (Duong and Izumida, 2002). Farm credit has for long been identified as a major input in the development of the agricultural sector in Nigeria. The decline in the contribution of the sector to the Nigeria economy has been attributed to the lack of a formal national credit policy and paucity of credit institutions.

The provision of credit or loanable fund (capital) is viewed as more than just another resource such as labour, land, equipment and raw materials (Rahji and

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Adeoti, 2010). It determines access to all of the other resources which farmers require.

Agricultural credit access has particular salience in the context of agricultural and rural development in Nigeria. Some 70% approximately of Nigeria's farm households live in the rural areas with their main source of livelihood being agriculture. Credit constraint to these farm households thus imposes high cost on the society. This is in terms of rural unemployment, rural poverty, and distortion of production and liquidation of assets. Government over the years has continued to seek the avenues in both developed and developing countries attempt to overcome these problems by subsidizing credit, setting up credit guarantee fund schemes such as Agricultural Credit Guarantee Fund Scheme [ACGFS] in Nigeria, 1977) and specialized agricultural credit banks like Nigeria Agricultural and Cooperative Bank [NACB], 1973 now Bank of Africa [BOA], 2010) and stimulating institutional innovations in the financial system (e.g. People's Bank, Community Bank, Rural Banking Schemes) (Rahji and Adeoti, 2010).

The Nigerian agricultural sector is among the most heavily regulated sector of the Nigerian economy. The special interest of government in the agricultural sector is due to its relevance in the provision of raw materials for industries and most importantly the provision of food for the teaming Nigerian population and also serving as a source of foreign exchange for the economy (Adofu, Abula and Audu, 2010).

Anyanwu et al. (1997) opined that commercial banks encourage savings. Since investments are made out of savings, the establishment of commercial banks especially in the rural areas makes savings possible hence economic development is accelerated. The government most often thinks it is necessary to intervene in the operation of the banking system with the intention of correcting the short comings of the price fixing mechanism to ensure that what is commercially rational for an individual bank is approximately rational for all (Adofu et al., 2010).

According to Akiri and Adofu (2007), the existence of externalities and imperfection in the financial markets of most developing economies has often called for intervention by the government through its appropriate agent (the Central Bank of Nigeria in the case of Nigeria) to encourage investment and to re-channel credit to those economic units with high social rate of returns but low commercial rate of returns. Under the deregulated interest rate system, the market forces of demand and supply play a very prominent role in the determination of interest i.e. banks and their customers are free to negotiate to arrive at a suitable interest rate on both deposit and loans.

Interest in an amount charged to a borrower for the use of a lender's money over a period of time. From the lenders' perspectives, the money the lender is investing is changing over time due to the interest being added. For this reason, interest is sometimes referred to as the time value of money. According to Organization for Economic Cooperation and Development (2013), interest can be said to be the price paid by the borrower for the use of funds saved by the lender and the compensation to the lender for his deferring expenditures. This compensation comprises two elements, namely a payment equal to the loss of purchasing power of the principal during the term of the loan and a balance that represents the real interest accruing to the lender. However this simplicity does not extend into the area of rate determination since rates vary not only because of inflation, as implied above, but also because of a number of other influences, including the amount, purpose and period of the transaction; the credit-worthiness of the borrower; the collateral offered and/or other guarantees/guarantors available; the competition for the transaction; and government policy.

Interest rates charged on loans to farmers in developing countries like Nigeria have generally being a contentious issue since the spring review of small farmer credit sponsored by the United States Agency for International Development (USAID) in 1973. Interest rate is an important economic price. This is because whether seen from the point of view of cost of capital or from the perspective of opportunity cost of finds, interest rate has fundamental implication for the economy.

Socially, interest rate charged by banks could be regulated to encourage savings mobilization, ensure and foster adequate investment for rapid growth and development, bearing in mind the view of Goldsmith (1969) that the financial superstructure of an economy accelerates economic performance to the extent that it facilitates the migration of funds to the best user, i.e. to the place in the economic system where the funds yield the highest social return.

In Nigeria, there is a wide gap between owned and required capital for financing most agricultural activities of farmers due to increase in the cost of borrowing (Iroh, 2012). The lack of access to capital due to high level of interest rate is one of the major factors which hinder the development of agriculture (Tefera, 2004). One of the major problems responsible for inadequate credit facilities required by farmers for their agricultural activities is constant and persistent increase in the cost of borrowing, despite the fact that these farmers produce the bulk of the food consumed in the country.

Among the studies reviewed, little or none has successfully investigated the effects of interest rate on farmers' access to agro credit especially in Kaduna State, Nigeria. Few of these studies concentrated on the impact of interest rate variability on the entire economy of Nigeria without any particular reference to agriculture. For instance, Wasser and Kuoteiner (1994), Fahrer and Rohling (1990) and Bono (1995) only used interest rate as one of the tools of monetary policy with no particular interest in agriculture, thus this work tends to fill this gap

in literature.

These gaps then raise the questions on the effects of interest rate on farmers' access to agro credit in Kaduna State as interest rate variability can determine the level of investment, consumption, production and the growth of output.

The speculative movement of funds into/out of Agricultural activities depends on the level of interest rates. There is however an apparent lack of information regarding the effects of these variations in interest rates that may help to determine to what degree government should modify her interest rate policy especially with respect to agro credit. There is also the need to understand the effects of interactions of high/low interest rates and how they affect credit supply to farmers. It is expected that this study will help to widen the knowledge of farmers on the available credit and proper interest rate level that will enable them to achieve the best level of agricultural practices and thus improving their means of livelihood and nations' food security status. The output of the study will be invaluable to policy makers and governments agencies interested in food security and agricultural development.

The study specifically sought to:

(i) Identify the socio-economic characteristics of farmers in Kaduna State.
(ii) Determine the sources of credit used and amount of credit sourced by the farmers.
(iii) Determine the factors affecting the volume of credit sourced, and
(iv) Determine the problems encountered in obtaining loans from formal and informal sources.

MATERIALS AND METHODS

The study was conducted in Kaduna State in Nigeria. Kaduna State occupies part of the central position of the Northern part of Nigeria (with Kaduna as its capital) and shares common borders with Zamfara, Katsina, Niger, Kano, Bauchi and Plateau State. To the south-west, the state shares a border with the Federal Capital Territory, Abuja. The global location of the state is between latitude 90 and 140 north of the equator and longitude 70 and 100 east of the Greenwich meridian. The state occupies an area of approximately 48,473.2 sq km and has a population of more than six (6) million (NPC, 2006) with a population density of 130 people per sq km that accounts for 4.3% of Nigerians total population.

The state has 23 local government areas (LGAs). A large populace of the state practice agriculture as their major economy means. The 23 LGAs in the study area were grouped into three agricultural zones, namely; Kaduna Central (zone one); Lere, Kubau, Soba, Sabon-gari, Zaria, Ikara, Kudan, Makarfi; Kaduna North (zone two); Kaduna north, Chukun, Kajuru, Kaduna south, Giwa, Igabi, Birnin-gwari; Kaduna South (zone three); Jama'a, Sanga, Jaba, Kagarko, Kauru, Kachiya, Zango kataf, Kaura.

A three level multistage random sampling method was use for this study. At the first stage, two LGAs were randomly selected from each of the three agricultural zones making a total of six LGAs. At the second stage, a random selection of two wards from each LGA making a total of 12 wards. Lastly, 10 farmers were randomly selected from each of the wards giving a total of 120 respondents to be used for the study.

Data for this study were collected from primary sources. The data were generated by the use of well structured, validated and pretested questionnaire.The data were analysed using descriptive statistics and ordinary least square model. Descriptive statistics was used for the description of the socio-economic characteristics of the farmers, the sources of credit used, amount of credit sourced by the farmers and determination of the problems encountered in obtaining loans from formal and informal sources. Ordinary least square (OLS) estimation technique was used to determine the factors affecting the volume of credit received by farmers in Kaduna State, Nigeria. The linear model can be stated implicitly as:

$$Y = f(X_1+X_2+X_3+X_4+X_{5+}X_{6+}X_{7+}X_8), e$$

Where: Y = Volume of credit sourced (₦); X_1 = Age (years); $X_{2=}$ marital status (dummy); married = 1; single = 0; X_3 = Level of education (years); X_4 = Farming experience (years); X_5 = Interest rate (%); X_6 = Credit awareness (dummy); aware = 1, not aware = 0; X_7 = Farm income (₦); X8 = Co-operative membership (dummy); member = 1; not member = 0; e = error term.

In addition, Likert type scale rating of 4-point was applied to assess the problems encountered in obtaining loans from formal and informal sources. This was carried out by asking the respondents their opinions about the problems they encounter in obtaining loans from both formal and informal sources. The 4- point scale was graded: very serious, serious, undecided and not serious, which have values of 4, 3, 2 and 1 respectively. Thus, the mean score of the respondents was obtained as follows:

$$4+3+2+1 = 10$$
$$\Sigma fx/\Sigma x = 10/4$$
$$\bar{X} = 2.50$$

Using the interval scale of 0.05, the upper limit cut-off point is 2.50+0.05=2.55, while the lower limit cut-off is 2.50-0.05=2.45. For a given view the mean score is computed by taking the sum of the products between the number of responses and the grade point and then divided by the total number of responses

RESULTS AND DISCUSSION

Socio-economic characteristics of the farmers

The socio-economic characteristics of the farmers are shown in the Table 1. It shows that majority (57.5%) of the respondents were males while 42.5% of them were females. The implication is that men dominate the production of crops and animals in the area. This is an added advantage to the area, since men have more opportunity to obtain credit than females' counterparts due to issue of collateral required by most of the financial institutions. The result equally shows that (40%) of the farmers were between the ages of 31 and 40 years. About 5% were 51 years and above, while those within 21-30 years and 41-50 years constituted 32.5 and 18.33% of the farmers, respectively. This means that majority of the farmers were middle aged. These categories of farmers could be considered to be the economically active population, as the age of the farmers dictates and affects the amount of credit he or she will

Table 1. Distribution of respondents according to their socio-economic characteristics.

Variables	Frequency	Percentage
Gender		
Male	69	57.5
Female	51	42.2
Total	120	100
Age		
≤20years	5	4.2
21-30	22	18.33
31-40	48	40.0
41-50	39	32.5
51 and above	6	5
Total	120	100
Marital Status		
Married	78	65
Single	19	15.83
Widowed	15	12.5
Divorced	08	6.7
Total	120	100
Educational level		
No Formal	50	41.2
Primary Education	41	34.2
Secondary education	20	16.7
Tertiary Education	09	7.5
Total	120	100
Farm size (Ha)		
≤1.0	30	25
1.0-1.9	24	20
2.0-2.9	41	34.2
3.0-3.9	18	15
4.0 and above	07	5.83
Total	120	100
Experience (years)		
1-5	04	3.3
6-9	14	11.67
10-14	23	19.2
15-19	21	17.5
20 and above	58	48.3
Total	120	99.97
Type of farming		
Crop farming	32	26.7
Animal farming	17	14.2
Both crop and animal	71	59.2
Total	120	100
Annual Income		
≤₦40,000	24	20

Table 1. Contd.

41,000-60,000	52	43.3
61,000-80,000	22	18.3
81,000-100,000	10	8.3
101,000 and above	12	10
Total	120	100

Source: Field Survey, 2014.

source at a particular interest rate. This finding agrees with Olarinde et al. (2005) who found that old people tend to be risk averse than young people.

The study further showed that most (65%) of the farmers in the area were married, 15.83% were single and 12.5% were widowed while only 6.7% of them were separated. This shows that the contribution of the farmers in the study area towards agricultural development should be favourable as a reasonable number of them were married and were expected to be able to attract support from their children. This result supported the findings of Ojo and Jibowo (2008) who reported that married people are responsible individuals whose views are highly respected within rural communities in Africa.

Farmer's educational attainments showed that (41.2%) of the farmers had no formal education; while about 34.2% of them attained primary education. Also, 16.7% attended secondary education while only 7.5% of them attended tertiary institutions. The above result evidently indicated that most of the respondents lack formal education, by implication it would be difficult for them to obtain credit from financial institutions as this requires formalities such as filling forms as well as being rational enough to select the financial institution that offers the best interest rate at a given time. Less than 25% of the respondents had less than or equal to 1hectare of land, 20% had between 1.0-1.9 hectares, while (34.2%) of them had between 2.0-2.9 hectares of land. Also, the result further showed that 15% and only 5.83% of the sampled respondents had a farm size of between 3.0-3.9 hectares and 4.0 and above hectares of land respectively. This implies that most of the farmers were small holders and subsistence farmers, a situation that may not allow them to engage in large production, have access to bigger credit facilities. The small farm size by the farmers could be attributed to the high capital intensive nature of agricultural production.

Furthermore, it was observed that 3.3% of the respondents had years of farming experience between 1-5 years, 11.67% indicated between 6-9 years and 19.2% had between 10-14 years. More so, majority (48.3%) of the sampled respondents had a farming experience of 20 years and above while about 17.5% had farming experience between 15-19 years. This implies that the farmers in the study area had been engaged in one form of agriculture or the other which means that they must have acquired good farming experience. This indicates active participation of the respondents in agricultural production in the area. Majority (59.2%) of the respondents were fully engaged in both crop and animal farming, 26.7% of the farmers were engaged in crop farming only while 14.2% of them engaged in animal farming as their primary occupation.

The annual income level refers to the farmer's legitimate financial income. The result shows that majority (43.3%) of the respondents earned between ₦41, 000 - 60,000; 20% earned less than ₦40, 000. Also, about 18.3% of them earned between ₦61, 000 and 80,000; 8.3% earned between ₦81, 000-100,000. Only 10% earned above ₦101, 000. The implication of the finding is that farmers in the study may not have limited access to credit facilities. This is because access to credit is enhanced by high income than earning capacity. This finding shares a common view with Alabi et al. (2007) who reported that a farmer with a profitable supplementary income could become an early adopter of new technology that may require demanding for credit facilities.

Sources of credit used and amount of credit obtained by farmers

Sources of credit used by farmers

Table 2 shows the sources of credit used by farmers in agricultural production in the area.

It is evident that most farmers found it difficult to obtain agricultural credit. Various sources of credit by the farmers in the study area were identified. Table 2 disclosed that majority (65% and 52.5%) of the farmers obtained credit from Personal Savings and Rotating Savings and Credit Association (RoSCAs) respectively. Also, 45% and 50% of the respondents obtained credit from friends and money lenders respectively, while only 32.5% of them sourced their credit from relatives. More so, 15% of the farmers secured credit from commercial banks, 19.2% from co-operative banks and majority (42.5%) secured their credit from development bank e.g Nigerian Agricultural Cooperative and Rural Development Bank (NACRDB), while only 6.7% sourced from merchant banks.

It is obvious that majority of the farmers depend on informal creditors who charge exorbitant interest rate. This means that they have not been able to exploit the

Tables 2. Distribution of respondents according to the sources of credit used.

Sources	Types	Frequency	Percentage
Formal	Commercial banks	18	15
	Co-operative banks	23	19.2
	Development banks (NACRDB)	51	42.5
	Merchant bank	08	6.7
Informal	Friends	54	45
	Relatives	39	32.5
	Personal Savings (Adashi)	78	65
	Moneylenders	61	50.8
	RoSCAs	63	52.5

Source: Field Source: Field Survey, 2014. **Multiple responses.

Table 3. Distribution of respondent according to the amount of credit obtained.

Amount of credit obtained (₦)	Frequency	Percentage
≤ N100,000	31	25.83
100,001-400,000	50	41.67
400,001-700,000	13	10.83
700,001-1,000000	18	15
>1,000000	08	6.67
Total	120	100

Source: Field Survey, 2014.

low interest rate charged by the formal credit institutions. This agrees with the survey carried out by Krain (1998) who observed that credit from formal financial institutions meet only a small portion of the total credit demand of the agricultural sector. He found out that credit from the formal financial sources accounted for only 9.9% of the total credit available to the agricultural sector.

The remaining 90.1 percent is from the informal financial sources mainly comprising loans from relatives, friends, rotational savings groups and one's superior at work and other sources. This could be that poor farmers in the area lacked title deeds for pieces of land they own and as a result they do not qualify for bank credit where collateral are mostly required.

This was further reinforced by the findings of Steel et al. (1997) who reported that reliance on collateral by banks often however, exclude many otherwise credits worthy small-scale farmers in many African countries where land title are not well documented or readily transferable. This implies that agricultural practices in such areas suffer setbacks because of insufficient amount of credit since majority of the farmers depends mainly on informal sources.

Amount of credit obtained by farmers

The amount of credit obtained by farmers in the area is shown in Table 3.The study indicates that 41.67% of the respondents obtained credit at the range of ₦100,001-400,000 and 25.83% obtained credit less than or equal to ₦100,000. Also, 10.83%, 15%, and 6.67% borrowers had obtained credit to the tune of ₦400,001-700,000, ₦700, 000 - 1,000,000 and more than ₦1,000,000 respectively. This shows that most of the borrowers obtained credit less than ₦500, 000. It may be that majority of farmers in the area are peasant farmers with small land holdings who need small amount of money mainly for production. Also, it could be because of the exorbitant interest rate charged by most financial institutions especially in the informal sector.

Factors affecting the volume of credit sourced by farmers

The result of regression analysis is presented in Table 4. The multiple regression analysis was used to predict the factors affecting the volume of credit sourced by farmers. Output of the regression analysis showed a co-efficient of multiple determination R^2 value of 0.65. This implies that about 65% of the total variations in volume of credit sourced by farmers were accounted by joint actions of the independent variables. The overall regression result was significant as F-Statistic value of 4.28 was statistically

Table 4. Determinants of credit volume sourced by farmer.

Variables	Coefficient	Standard error	t-value	Significant
Constant	3.029	0.316	9.577	0.00
Age	-0.117	0.058	-1.995	0.048
Marital status	-0.192	0.040	-4.817	0.324
Level of education	0.080	0.044	1.838	0.069
Farming experience	0.01	0.014	0.052	0.958
Interest rate	-0.012	0.019	-0.644	0.052
Credit awareness	0.021	0.024	0.855	0.001
Farm income	-0.034	0.041	-0.841	0.024
Co-operative membership	0.059	0.042	1.410	0.161
F-statistics=4.28				
R^2=0.65				

Source: Field survey, 2014.

significant at 1% level of probability which shows the goodness of fit on the estimated model.

Five out of eight predicators, namely; age, level of education, interest rate, credit awareness and farm income was statistically significant at various levels of probabilities.

Age (X_1)

The result indicated that age had negative sign but statistically significant effect on the volume of credit sourced by farmers from either formal or informal financial institutions. This relationship is in consonance with the a *priori* expectation of the study, because older people are always risk averse and would not like to enter into debt obligations. In addition, the older people find it difficult to understand the operations and conditions of formal and informal financial institutions and are also afraid of credit conditions.

Marital status (X_2)

The co-efficient of marital status was found negative and not statistically significant. This finding suggests that being married or single does not matter in terms of the volume of credit sourced by farmers in the area either from formal or informal financial institutions.

Level of education (X_3)

The variable level of education was positively signed and statistically significant at 10% level of probability. This agrees with the *a priori* expectation, because it was believed that chances to obtain credit from formal or informal financial institutions improve with increase in the level of education. This implies that majority of the credit beneficiaries in the area were the educated farmers.

Farming experience (X_4)

The co-efficient was positively signed and found not statistically significant. This implies that the volume of the credit sourced by the farmers does not depend on the number of years of farming experience a farmer has acquired in agricultural production. This finding disagreed with Smeeding and Weinberge (2001) that farmers with higher level of farming experience which is an indication of entrepreneurial skills acquired and the ability to diversify production enterprises will manage credit facilities more efficiently and generate more income.

Interest rate (X_5)

The relationship between interest rate charged and the volume of credit sourced by farmers from either formal or informal financial institutions conforms to *a priori* expectation of the study. That is, the lower the interest rate charged by financial institutions, the higher the volume of credit sourced by farmers and vice versa.

Credit awareness (X_6)

Awareness to credit availability had a positive and significant relationship at 1% level of probability with the volume of credit sourced by farmers from either formal or informal financial institutions. The positive relationship was expected because those individuals who are aware of the credit availability in the financial institutions have better chances to obtain more credit than those who are not aware. This finding agrees with Kashuliza et al. (1998) who found that gender, level of education and awareness of farmers of the available credit facilities in

Table 5. Distribution of respondents according to problems encountered in obtaining credit from formal sources.

S/N	Problems	Mean score
1.	A lot of time is spent on getting the credit	2.58
2.	Procedures are complicated	2.71
3.	Interest rates are high	2.80
4.	The cost of transaction is high	2.43
5.	One is not given the full amount applied for	2.02
6.	Inadequate collateral security to obtain credit	3.00
7.	Transportation cost from home to source of credit is high	2.38
8.	Problem of collateral cheques	2.44
9.	Repayment time is short	2.55
10.	Illiteracy	2.98
11.	Lack of good information about agro-credit	2.81
12.	Lack of presence of banks in the rural areas	2.68

Source: Field survey, 2014.

their areas are important factors in determining access to credit.

Farm income (X_7)

The relationship between farm income and volume of credit sourced by farmers was statistically significant at 5% level of probability, but negatively signed. The negative co-efficient does not conform to *a priori* expectation of the study. Nevertheless, the implication of this result is that most of the credit was made available to those with low farm income. Also, most of the available credit scheme had eligibility criteria favouring people with relatively low income in rural areas.

Co-operative membership (X_8)

The co-efficient was found positive but statistically not significant. The *a priori* expectation was not met, because being a member of co-operative societies is an advantage for sourcing more credit especially in informal financial institutions where familiarity and guarantors are always considered. Meanwhile, the implication of this result is that, farmers being a member of co-operative or not has nothing to do with the volume of credit sourced from either formal or informal financial institution in the area.

Problems encountered by farmers in obtaining credit from formal and informal financial institutions

Problems encountered by farmers through formal financial sources

Table 5 shows the problems encountered by farmers in obtaining credit from formal financial institution Farmers in the area encountered some problems which hindered them from access to both formal and informal financial institutions to boost agricultural production. However, the mean score of 2.55 and above was used as a decision rule, which implies that any problem equal to or greater than 2.55 was considered a serious problem in the area.
From formal financial institution perspectives, this problem includes the following with mean score: A lot of time is spent on sourcing the credit (2.58); procedures are complicated (2.71). Interest rates are high (2.80), Inadequate collateral security to obtain credit (3.00). Agnet (2004) opined that complex mechanism of commercial banking is least understood by the small scale farmers and thus limit their access. Also, among the problems are lack of awareness of credit packages (2.63) and lack of presence of banks in the rural area (2.68).

Problems encountered by farmers obtaining credit through informal financial sources

The problems encountered by farmers in obtaining the credit from informal financial are shown in Table 6. The problems encountered by the respondents in sourcing credit from informal sources were; lack of trust to pay back the credit (2.89), one is not always given the full amount he/she applied for (2.93), risk of not paying back because of crop failure (2.84), difficulties before getting the credit (2.63) and problem of getting guarantors (3.00).

Conclusion and recommendations

The decline in the contribution of Agricultural sector to the Nigeria economy has been attributed to the lack of a formal national credit policy and paucity of credit

Table 6. Distribution of respondents according to the problems encountered in obtaining credit from informal sources.

S/N	Problems	Mean score
1.	Lack of trust to pay back the credit	2.89
2.	Transportation cost is high from home to source	2.08
3.	One is not always given the full amount he applied for	2.93
4.	Risk of repaying the credit because of crop failure	2.84
5.	Time in repaying the credit is short	2.24
6.	Difficulties before getting the credit	2.63
7.	Problem of getting guarantors	3.00
8.	Illiteracy	2.43

Source: Field survey, 2014.

institutions. Commercial interest rate and collateral requirement charged by both formal and informal financial institutions, largely restricted farmers from seeking credit from these sources. However, Farmers secured credit from informal financial institutions than formal sources. The interest rate, age, level of education, credit awareness and farm income were identified as the major determinants of the volume of credit source.

Interest rate charged on credit facilities should be reduced to motivate the farming communities to source for credit and finally credit policy for rural and micro enterprise lending needs to be formulated in order to mobilize savings and maximise the availability of credit to the population in rural and urban areas.

It is also important that Agricultural extension agents and other relevant agencies should intensify effort in educating farmers on the sources of credit facilities available to them.

Complicated application procedures adopted by most financial institutions should be modified to enable more farmers to source for credit.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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