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African Journal of Agricultural Research

Full Length Research Paper

In-vitro bioavailability of selected minerals in dry and green shelled beans

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Mineral deficiency especially that of iron and zinc has continuously emerged as a public health issue in developing countries, probably due to the over dependence on plant food sources, which contain more than enough minerals to meet the daily requirement but have a low bioavailability for physiological purposes. Experiments on *in-vitro* bioavailability were carried out on dry and green shelled beans. *In-vitro* bioavailability of iron and zinc in bean samples was determined by HCl-pepsin (HCl-P) and pepsin-pancreatin (P-P) method. The amount of the proxy bioavailable minerals were obtained by atomic absorption spectrophotometry. In both minerals there was a small but significant (P=0.009) and (P=0.0003) increase in *in-vitro* bioavailability after cooking. The average increase for all the varieties was 3.2 to 3.4% for iron and 1.3 to 1.6% for zinc. The two minerals were more available in cooked green shelled beans compared to dry ones. The highest difference for iron bioavailability was observed in Maharagi soja (12.9%) while lowest was in TY 3396-12 (1.4%). The highest observed for zinc was 3% in G59/1-2. Vulnerable groups who suffer from iron and zinc deficiency should be encouraged to consume green shelled beans more often in comparison to dry beans to improve their mineral uptake.

Key words: In-vitro bioavailability, green, shelled, dry beans, minerals.

INTRODUCTION

In-vitro bioavailability of a mineral is generally defined as a measure of proportion of the total minerals in food or a meal that is utilized for normal body functions. For most minerals the amount that is absorbed from the gastrointestinal tract, is the major determinant of bioavailability but this varies greatly between minerals (Sandberg, 2002). Absorption is affected by a range of factors including interactions with other dietary components in the gastrointestinal tract, for example vitamin C enhances iron absorption while tannins and phytates have an inhibitory effect. Several antinutritional factors have been implicated as the main cause of reduced micronutrient availability such as phytic acid and tannins although phytic acid has a more pronounced

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effect (Zhou and Erdman, 1995; Zdunczyk et al., 1996; Antony and Chandra, 1998; Manary et al., 2000).

The quantification of bioavailability has been done by complex processes comprising isotopic elemental digestion. However, various techniques have been established by nutritionists to determine bioavailability. For instance, *In-vitro* studies range from measurements of solubility, extractability, and fractional dialysability to studies of the nutrient uptake in experimental animals (Miller et al., 1981; Sripriya et al., 1997; Mamiro et al., 2001). The nutrients are incubated in intestinal preparations to simulate the processes that take place in the gastrointestinal tract (Blenford, 1995). Contemporary developments have used cell culture called the Caco-2 as an *in-vitro* method to assess iron bioavailability in human beings (Glahn et al., 2000; Kim et al., 2011). When compared with other *In-vitro* methods used previously by other scientists a significant correlation (r=0.97 and P=0.0001) was found (Yun et al., 2004). The results obtained from the above methods are used as proxy to estimate bioavailability (Watzke, 1998).

Beans are naturally low in fat, with little saturated fats. The average lipid content is only 1.5% of the dry bean and unsaturated fatty acids make up 75% of the lipid material. Beans consumption does not improve only micro and macronutrient status but also they play a role in other health parameters such as improving glycemic control (Kabagambe et al., 2005), decrease the risk of coronary heart disease and lowers cholesterol levels (Bazzano et al., 2011).

Minerals and trace elements play essential roles in numerous biochemical and physiological processes in animals and man. A deficiency, an overdose or imbalances between minerals or trace elements will exert a negative effect on health or nutritional status of an individual. Generally, it is not the ingested dose of minerals and trace elements that is important to maintain balance, but rather the amount that is bioavailable (available for biological and biochemical processes in the organism). Several food components are able to form soluble or insoluble complexes with minerals and trace elements under gastrointestinal conditions. These food components thereby increase or decrease the availability for absorption in the small intestine, and thus the bioavailability of minerals and trace elements. Due to the complexity of food products, however, the relative contributions of food components to the bioavailability of minerals and trace elements are often not clear.

Although *in-vivo* experiments (using actual animals or human beings) are the best way to study the bioavailability of minerals and trace elements, *In-vitro* methods offer an appealing alternative because they are relatively simple, rapid and inexpensive (Mamiro et al., 2001). Therefore, there is a great need in human nutrition and animal nutrition for an *In-vitro* method, which predicts the bioavailability of minerals and trace elements *in vivo*. The aim of this study therefore was to compare in-vitro bioavailability of selected minerals in dry and shelled green beans for raw and cooked samples.

METHODOLOGY

Bean samples

Bean seeds of 38 varieties were brought from University of Nairobi and multiplied on experimental plots at Sokoine University of Agriculture Morogoro. The objective was to harvest enough beans to perform a number of laboratory experiments on each variety. A one acre plot was cleared and seed-bed prepared. Each variety was planted on four lines 50 cm apart and 20 cm from seedling to seedling (one stand per hill). This gave on average about 4 kg per variety. All analyses were done in the Food Science and Technology Laboratory in collaboration with the Department of Soil Science. *In-vitro* bioavailability of minerals was determined on raw and cooked dry and shelled bean samples.

Total *In-vitro* bioavailable minerals

Total *in-vitro* bioavailable Iron and Zinc of the raw and cooked dry and green shelled bean samples was carried out by AOAC method No 968.08 and determined by atomic absorption spectrophotometry method No AOAC method 970.12, (AOAC, 1995).

In-vitro HCl-pepsin and pepsin-pancreatin mineral bioavailability

In-vitro bioavailability of iron and zinc by HCl-pepsin (HCl-P) was carried out by a method described by Kumar and Chauhan (1993). Two grams of the dried bean samples were weighed and 25 ml of HCl-Pepsin solution was added in a 100 ml conical flask. The pH was adjusted to 1.35 and the mixture was incubated at 37ºC in a metabolic shaker water bath for 90 min. At the end of 90 min, the digest was centrifuged at 3000 rpm for 45 min and the supernatant filtered through whatman filter paper no 41. The filtrated was subjected to Pepsin-Pancreatin (P-P) method as described by Miller et al. (1981). Fifteen milliliters of the filtrate was mixed in 10 ml of pancreatin bile in tyrode buffer and pH adjusted to 7.5 and incubation continued for 2 h. The digest was centrifuged at 10,000 g for 20 min and then filtered through Whatman filter paper No 41. Analysis of the filtrate for soluble iron and zinc was performed using the Atomic Absorption Spectrophotometer (Shimadzu UNICAM 919, England).

Statistical analysis

Data for the *In-vitro* solubility were entered in excel office 2010 computer software. Descriptive statistics was used to compare the solubility's in raw and cooked samples and Students t-test was used to test for significant differences among the treatments at 95% confidence interval.

RESULTS

In-vitro bioavailability of iron and zinc in raw and cooked dry beans are presented in Figures 1 and 2. In both minerals there were a small but significant (P=0.009) and (P=0.0003) increase in mineral bioavailability after

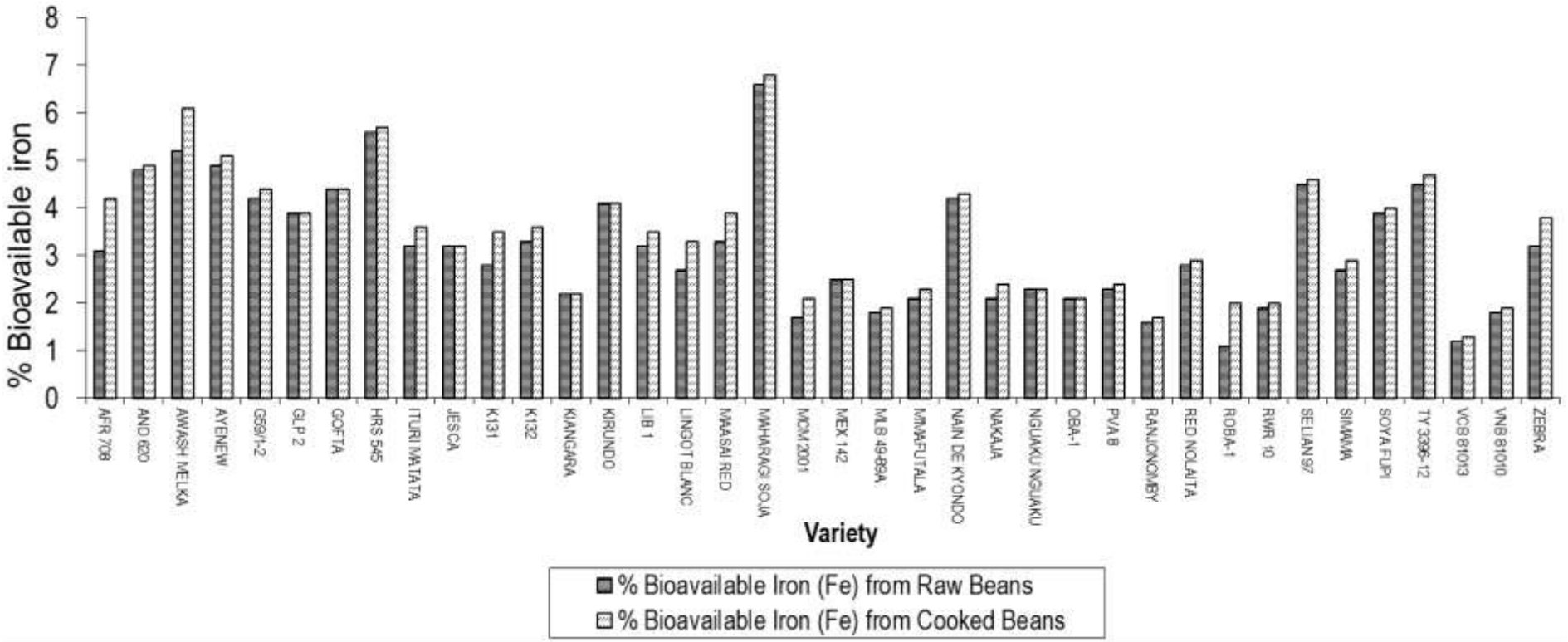

Figure 1. *In-vitro* bioavailability of iron from raw and cooked beans.

cooking. The average increase for all the varieties was 3.2 to 3.4% for iron and 1.3 to 1.6% for zinc.

A similar trend was observed in the *In-vitro* bioavailability of iron and zinc in raw and cooked shelled beans (Figures 3 and 4). A relative wider gap is observed for iron and zinc bioavailability in shelled beans. In both minerals, there was a significant (P=0.000) increase in bioavailability after cooking the shelled beans. The average increase for all the varieties was 4.9 to 7.4% for iron and 2.4 to 3.6% for zinc. The highest difference for iron bioavailability was observed in Maharagi soja (12.9%) while lowest was shown by TY 3396-12 (-1.4%). The highest observed for zinc was 3% in G59/1-2.

DISCUSSION

Variety of beans displays a diverse variation in mineral bioavailability. This might probably be brought up by the variation in the content of antinutritional factors such as oxalates, lectins, hemaglutins, tannins and phytates (Sandberg, 2002). The most important antinutritional factors in the dietary minerals bioavailability are the phytates and tannins.

The bioavailability of iron, which is the amount absorbed from food can be less than one percent to over 50%. Iron is found in food in two different forms, either as heme iron, found in the haemoglobin and myoglobin of meat, poultry and fish, or as non-heme iron found in plant products. Heme iron is better absorbed (about 15 to 40%) than non-heme iron (1 to 15%) (Roughhead and Hunt, 2000). Thus, although heme iron contributes

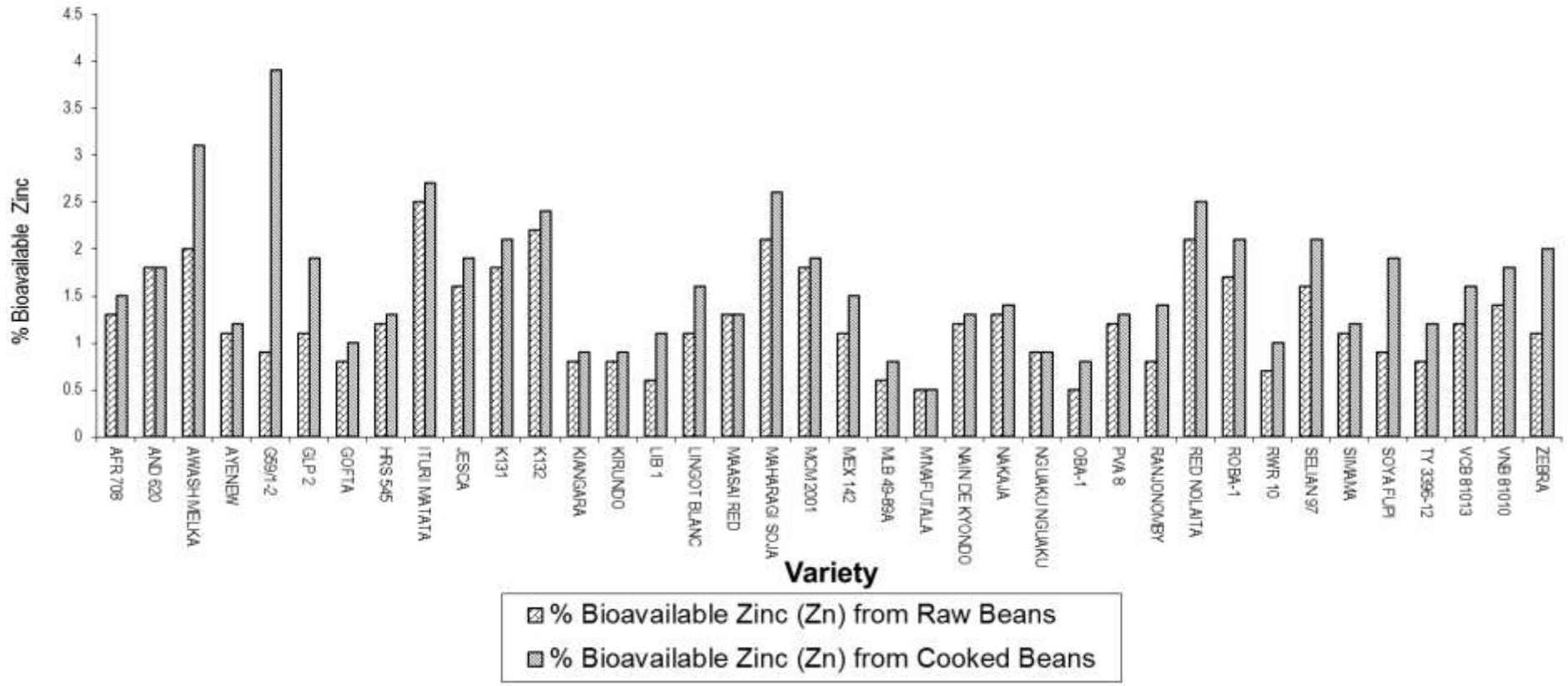

Figure 2. *In-vitro* bioavailability of zinc from raw and cooked beans.

only about 10 to 15% of total iron intake but may provide substantial amount of total iron absorbed (Allen and Ahluwalia 1997, EFSA, 2010). Non-heme iron is relatively consumed in much greater quantities, but is greatly affected by both inhibitors and enhancers in the diet such that there can be up to ten fold variations in absorption rates (Gropper et al., 2005). Non-heme iron absorption from a meal containing enhancers of absorption, such as meat, fish, or chicken, is about four times greater than it would be if the major protein sources were eggs or pulses. The addition of even small amounts of meat or a source of vitamin C (ascorbic acid) substantially increases the non-heme iron absorption from the entire meal (Lynch and Cook, 1984; Baech et al., 2003; Nielsen et al., 2013). In contrast, tea, coffee or eggs decreases the absorption of non-heme iron from a meal.

Low bioavailability diets (5% of the total iron absorbed) are based mainly on cereals and root vegetables with only very small quantities of meat, fish or vitamin C-containing foods (Baech et al., 2003). Such diets often contain foods that inhibit iron absorption (maize, beans, whole-grain flour) and are dominant in many developing countries. Intermediate bioavailability diets (10% of the iron absorbed) consist mainly of cereals and root vegetables but contain some meat and some foods containing vitamin C. High bioavailability

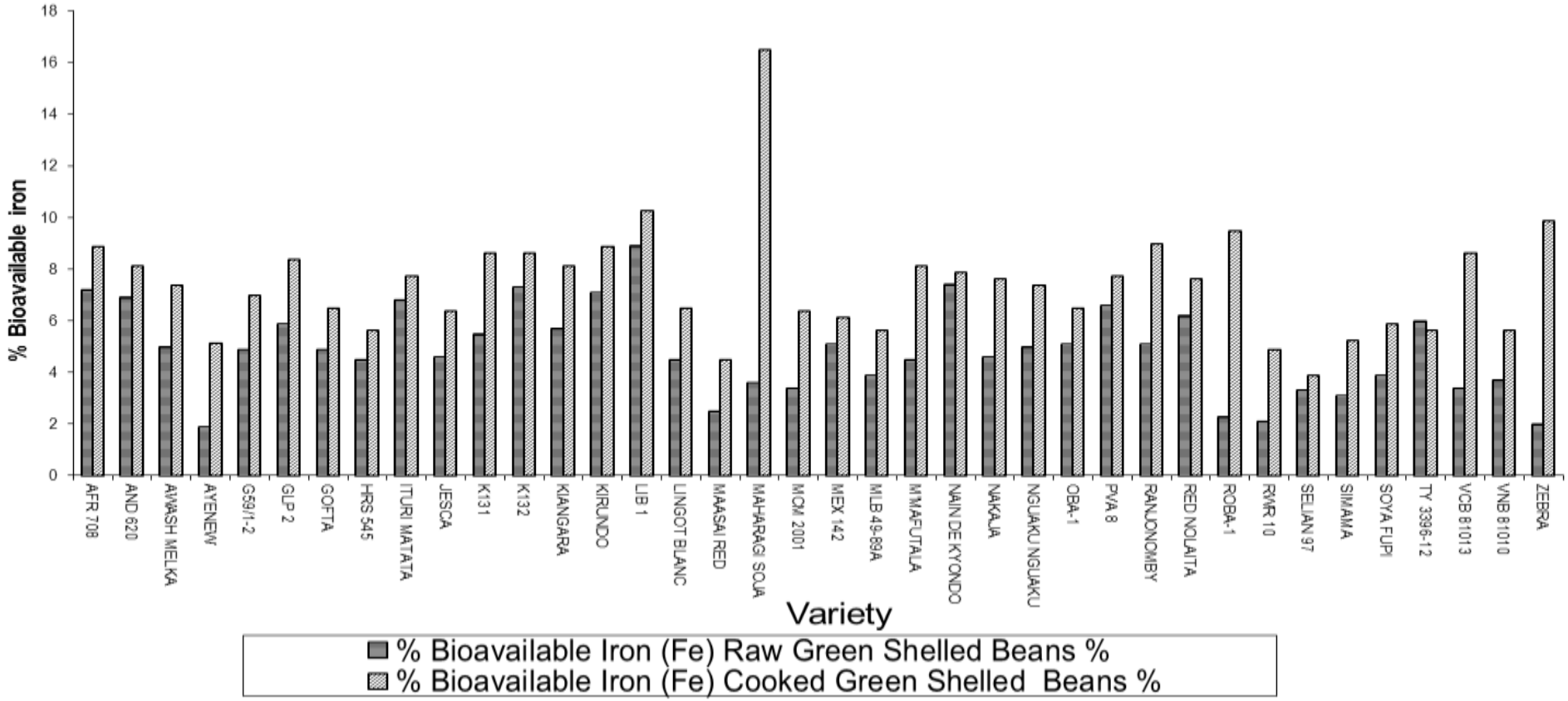

Figure 3. *In-vitro* bioavailability of iron from raw and cooked green shelled beans.

diets (15% of the iron absorbed) contain regular intakes of meat, poultry and fish (Baech et al., 2003). They also contain vitamin C-rich foods such as citrus fruits and some vegetables. A high bioavailability diet containing inhibitors of iron absorption, such as tea, coffee, cereal fibre, and dairy foods with main meals, would become an intermediate bioavailability diet.

In legume seeds, phytate is located in the protein bodies in the endosperm (Sandberg, 2002). Phytate occurs as a mineral complex, which is insoluble at the physiological pH of the intestine. It is considered antinutritional, causing reduced uptake in the human intestine of essential dietary minerals such as Fe, Zn and Ca. A dose-dependent inhibition of Fe, Zn and Ca absorption by phytate has been demonstrated in humans(Hallberg et al., 1989; Brune et al., 1992; Hurrell et al., 1992; Fredlund et al., 2002; Petry et al., 2010; La Frano et al., 2014). Inositol pentaphosphate has also been identified as an inhibitor of Fe and Zn absorption (Sandstrom and Sandberg, 1992; Sandberg et al., 1999). Furthermore, it was found that inositol tri and tetra-phosphate contribute to the negative effect on Fe absorption of processed foods containing a mixture of inositol phosphates (Sandberg et al., 1999), probably by interactions with the higher phosphorylated inositol phosphates.

Fe absorption from soya beans and soya protein

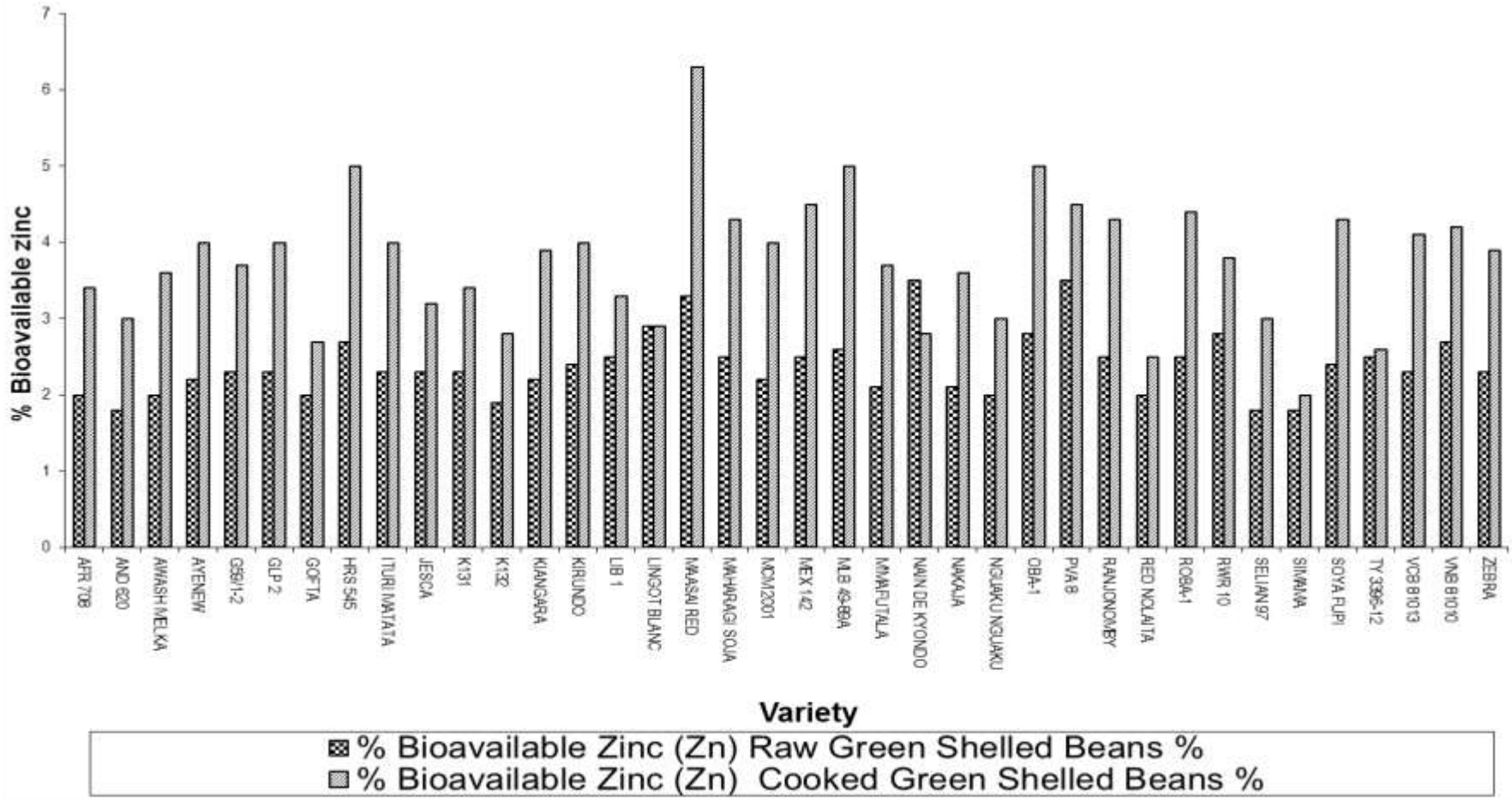

Figure 4. *In-vitro* bioavailability of zinc from raw and cooked green shelled beans.

products studied in single meals, using extrinsic labeling of meals with radioactive isotopes or studied by a stable isotope technique, was found to be low (Cook et al., 1981; Hurrell et al., 1992; Davidsson et al., 1994). Fe absorption from single meals based on black beans, lentils, mung beans, split beans and from two bean phenotype varieties was found to be very low, ranging from 0.8 to 1.9% (Lynch et al., 1984; Donangelo et al., 2003). Legumes contain varying amounts of polyphenols and generally the amounts are considered higher in the coloured seeds. Beans of the species *Phaseolus vulgaris* were found to contain high amounts of polyphenols (Paredes-Lopez and Harry, 1989), whereas the content of polyphenols in peas (*Pisum sativum*) was very low. Another study which used *In-vitro* digestion/human Caco-2 model reported high bioavailability of iron in white compared to colored beans which was explained by presence of flavonoids in colored beans (Hu et al., 2006).

For shelled beans the percentage *In-vitro* bioavailability was comparatively higher than that observed in the dry beans. This is probably because the seeds were still maturing and therefore the antinutritional factors were not fully formed with regard to quantities and so the amount that was required to bind the minerals was not sufficient. Consuming green shelled beans might be rather beneficial with regard to mineral uptake than the dry beans.

Conclusion

Minerals from green shelled beans have been observed to be more bioavailable compared to dry beans. Vulnerable groups who suffer from micronutrient deficiencies especially iron and zinc, such as children below five years of age, pregnant and lactating mothers and the sick, should be encouraged to consume green shelled beans more often to improve their mineral uptake.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Educational value of managerial and productive support of a cooperative of small-scale livestock producers

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The objective of this paper was to study the productive situation of a producers' cooperative of small animals. This paper is based on the experience of partaking in the management of a cooperative of small-scale livestock producers that created an opportunity for scientific learning for the students of zootechnics at the Alagoas State University-UNEAL. The results of this study revealed that through exposure to the production culture of every business unit in the cooperative, the students confronted a range of economic and administrative aspects, a valuable addition to the educational process for the students involved. They faced the challenge of giving concrete answers to the needs of the community under their management, both individuals and as a collective, in this way cooperating with small-scale livestock producers. Furthermore, the process of performing diagnostics during university extension courses in collaboration with the members of the cooperative led to an understanding of the real information technology needs of the producers and the knowledge of the real challenges of managing and planning. It is concluded that instating programmes of collaboration in the areas of management and planning between Universities and Cooperatives can significantly promote the goal of regional development.

Key words: Cooperation, education, management, production diagnostics.

INTRODUCTION

Few cooperatives have been successful in the state of Alagoas, and those that have were managed non-democratically in an authoritarian style, thus exhibiting characteristics more typical of a private business. The cooperative under study was one of the latter, governed primarily by its president. The main development project of the cooperative was the construction of a dairy plant built for bottling goat milk for direct sales, taking advantage of food distribution programmes of the Federal Government of Brazil. This project was one of the main

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reasons for the discontent of the members of the cooperative. Neither sales, nor production had commenced at the time of study, despite the construction of the building itself having been completed. Alleged errors in the logistics of the construction led to a lack of authorization from the supervisory bodies of the state of Alagoas (ADEAL, 2015).

Carney and Watts (1990) stresses the importance of considering the implications of elaboration of autonomous strategies on behalf of the family farmers. A complex learning process of the conjunct of activities new to family farmers is at work. In addition to the exploration of new technologies and new forms of collective organisations, it includes development management, knowledge and capacity to work under market conditions, encounter and negotiate with financial organisations, manage the relationships with intermediary organisations, such as NGOs. Pereira et al. (2006) reported that this combination results in new learning patterns that need to be implemented and institutional forms of facilitating the process that need to be established. The series of initiatives arising throughout the country need to be synthesised and analysed to facilitate progress in the area. Findings by Ying Xiong et al. (2013) showed that the new requirements of markets can promote gains to consumers with the production of a safer food, but also can make it difficult for some producers are able to sell in many markets. Thus, the cooperative production allows even small farmers can adopt standards production required by the markets and especially with a technical guidance that is offered by the professionals of cooperatives, since the state in many situations demonstrates little producers in technical assistance and rural extension.

Deficiencies of the cooperative caused by the spread of punitive levels of bureaucracy enacted by the state agencies seeking to control the liberation of the industry functions within the confines of the policies established by the animal control agency restricts the possibility of assistance and development of the cooperative which would have benefited a variety of producers in the region (Pereira et al., 2006; Ying Xiong et al., 2013).

This paper aims to bring to light a discussion about the learning process afforded by the practice of participating students. The interaction of the faculty and students could be instrumental in transforming the social realities and could generate collective knowledge, leaving as the main legacy the experience accumulated by the students in their practice area, which in turn empirically positively reflects on their quality of work post-graduation. The inside knowledge of the challenges of a fragile cooperative society combined with the possibility of participating in an empowering capacity promotes effective learning, undoubtedly resulting in newfound understanding of the practice of management and of overcoming the daily challenges, thereby generating scientific knowledge.

METHODOLOGICAL PROCEDURES

This paper is based on a study of a Cooperative of Small Livestock Producers in the city of Santana do Ipanema in the region of Alagoas in north-eastern Brazil. The main produce of the cooperative is comprised of goats and sheep. However, it also includes poultry, cattle and some members are beekeepers, majority of them employing agro-ecologic production methods. Participants of this study were teachers and students of the State University of Alagoas, Brazil.

Data were collected between January and April 2014 from individual interviews. The study involved a total of 64 members in the cooperative; all of them small-scale family farmers in the municipalities of Maravilha, Agua Branca and Santana do Ipanema. While the headquarters were based in the latter, every rural property formed a production unit, a nexus of the cooperative society. Santana do Ipanema, where the study took place, is located in the semiarid climate of northeastern Brazil, a region that unites nine states with diverse cultures, marked local expressions and knowledge, thereby resulting in a more individualistic tradition of management of rural properties.

Initially, the study aimed to promote the education of students undertaking formal courses in the State University of Alagoas, supplementing the curriculum of the disciplines of Rural Extension, Rural Sociology, Rural Economy, Technologies of Intervention in Nutrition, and Nutrition of Animals and Humans, Environmental and Applied Sciences.

This was achieved through the informal education of students as participants in the cooperative. They became researchers of the everyday life of the common men, learning to be a citizen of the world, placing oneself into the willingness to participate in a collective process of construction of local reality, of intervention in adversities and from there deriving lessons of citizenship and other collective and personal objectives, learning to be an administrator, manager, student and teacher. The data presented in the results was collected in interviews and participatory research, intervention in activities of rural extension, together with members of the cooperative in the city of Santana do Ipanema. Of the set of 60 members, 20 were interviewed, constituting a sample of 33.33%. The research also involved posterior intervention, employing formal knowledge of the university to respond to the necessities of the members of the cooperative, not merely with the intent to educate the students to enter into workforce, but also to create professionals knowledgeable of reality capable of being a transformational social actor.

RESULTS AND DISCUSSION

The results showed that the main difficulty of the cooperative of small producers of livestock in the city of Santana do Ipanema was mainly associated with the “lack of cooperation” and this was cited as a response by 85% of the sampled respondents while 75% showed that “lack of water” as the major problem. Similarly, 75% claimed that “lack of help from the government” was another obstacle while 20% showed that “lack of labour” 5% as “other reasons” of the producers. The absolute frequency (the absolute number of the interviewed that responded in the specified way) and the relative frequency of the responses (relevant percentage) are presented in Table 1.

These results are similar to those reported by Pike et al. (2015) that attributes both economic and social

Table 1. Responses to the question: What is the main difficulty of the Cooperative? Research conducted with members in general, n = 20.

Answer	Absolute frequency	Relative frequency, %
Lack of cooperation	17	85
Lack of water	15	75
Lack of government support	15	75
Lack of labour	4	20
Others	1	5

Source: Producers of small livestock of the Cooperative – The sum is greater than 100% to reflect multiple responses given by the same producers.

success of cooperatives to the democratic culture propagated within, arguing that it promotes a high-trust culture, do lowering transaction costs. Recognition of lack of cooperation as a major difficulty by the greatest proportion of cooperative members, in light of the dominant role of the president in the cooperative under study provides supports this view, providing empirical evidence, and indicates the significant potential positive impact of improved forms of management that could be instilled through collaboration with the University.

In this study, the idea that the semiarid condition was directly correlated with low productivity of small livestock was not vividly surface, and there was no shortage of examples to demonstrate this in Santana do Ipanema. In the process of undertaking research for this paper, the producers seemed to mitigate or cope successfully with the dry conditions in the region. The technologies applicable to dry climates have been developed and often effectively applied. Similar results have been reported by Silva (2003), in his study states that agricultural yields for all major crop categories are lower in the tropics.

Formation of a cooperative had been instrumental in defying the dry conditions and other problems encountered in everyday life by the producers, whereby together they were able to instate better forms of planning, administer their collective knowledge and seek more qualified labour. However, this is not reflected in the reality encountered by those who were surveyed, many complained of the lack of support from the government, incentives, unions and the commitment of the producers to the cooperative. Silva et al. (2014) indicated that the most effective way to overcome the drought in northeastern Brazil and lack of resources, is undoubtedly the cooperative. The union of small farmers can break through major barriers in production.

Technical assistance support

The question of existence of technical assistance was also posed to the producers, referring to the forms offered by the management of the cooperative or supplied by the producer support agencies of the government of the State of Alagoas, Brazil. It was noted that 75% of the respondents that were not in agreement with the whole idea of existence of technical assistance to the cooperation among the producers, indicating the apparent shortcomings in the development of the cooperative, which in turn hinder production and stall internal communication along the lines of production and commercialisation of the various products in the cooperative.

Similar findings were reported by Neto (2007), who showed that organizations offering help to the cooperatives were inefficient, large and costly structures, centralized in their decision-making processes and slow in attending to the immediate needs of the members of the cooperatives.

Although it is recommended in Brazil that technical assistance for small producers is obligation of the Brazilian state, the technical assistance offered to the cooperative was the University, through its extension project.

The response ‘Yes’ was given by 20% of the members, demonstrating that there is a small number of members who receive this service. However, it was not specified whether this be provided by the cooperative itself or by governmental organs, university or others. It also demonstrates that the search for technical assistance was more successfully implemented by the limited number of the most knowledgeable members, or those with better connections in the management of the cooperative or with organs of technical assistance of the regions in the proximity.

Finally, the answer ‘Yes’, but with limitations was given by 5% of those interviewed. Similar results obtained by Pina (2007) in Cape Verde, said that despite the discontent of members, the study universe was unanimous on continued membership perspective in the organization and thus recognize its important role in community development in various sectors. Therefore, 80% of the members are discontent with the technical assistance provided, disturbing results for the management of the cooperative. This data is represented in Figure 1. There clearly exists the need for direct intervention on part of the university as a governmental organ

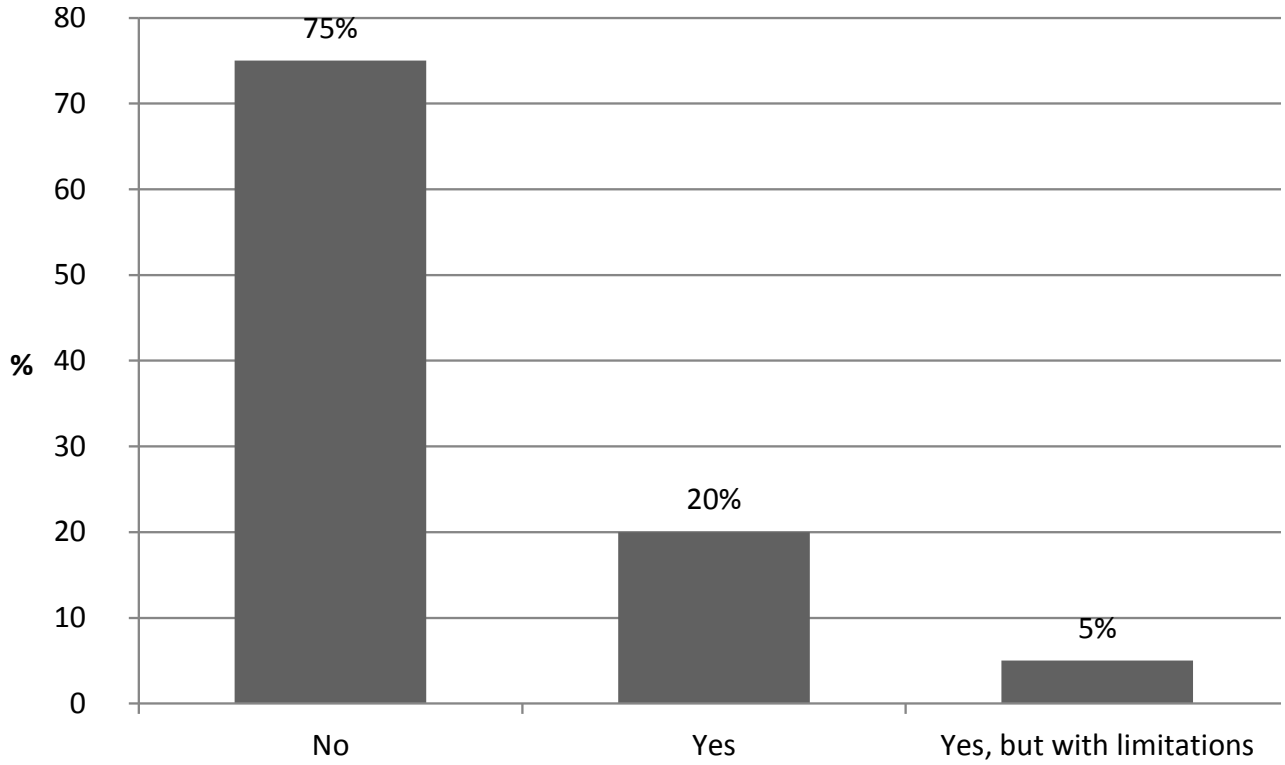

Figure 1. Response to the question: Does help with technical assistance exist? As a percentage of interviewed. Source: producers of small livestock in the Cooperative.

organ responsible for the accumulation of acquired knowledge in the region. This could change the situation, depending on the particular programmes of professor and student assistance to the society implemented, while being an aspect informal education, but at the same time concrete and necessary. However, lack of financial resources leads to considerable limitations of the universities in Brazil, with their functions currently restricted to limited research and repetitive teaching of old theories without aspects of creativity that could transform the reality.

The producers of small livestock under study view themselves as confronting various limitations in terms of management and adequate technology for its operations. At this point, it is imperative to create a presence of qualified technicians who would make periodic visits to the property, exchanging knowledge and enabling the producer to work more productively.

For Peixoto (2008), technical assistance and rural extention are of fundamental importance in the process of implementation of new technologies generated through research, essential for the rural development in the broad sense of the word and, specifically, for the development of agricultural, forestry and fishing activities.

In general, these producers encountered various difficulties in keeping their business viable, the limitations confronted by them can be observed in diverse stages of the production process, due to the great shortage of responsible technicians.

The model of production most often employed is described as antigenic and of low quality. At the moment, the fight for qualifications in this production chain is won by the large businesses competing with the cooperatives. However, this is not inevitable and depends upon the form in which the mobilizations and negotiations take place. The agro industrial appropriation is facilitated through miniaturization of the technologies- as is the case for mini pasteurizers of milk, and through differentiation by quality, which permits the segmentation of the market (Galerani, 2003).

According to Scopinho and Martins (2003), it has to be taken into account that the rural brazilian producer is not prepared, formally or otherwise, for self-managed cooperation, due to the organization and management of rural work historically having been undertaken in the form of either large agricultural businesses or small subsistence farms.

The collaboration between University and Cooperatives

The members of the cooperative were asked “in what ways could the university collaborate with the cooperative?”

The most common responses were the following: organization of internships in the cooperative to provide assistance; help with insemination and calculation of feed; facilitation of governmental assistance to the producers; continuation with the covenant between the producers and the university; periodic visits to the property, exchange of technical knowledge; sending interns to assist the management; collaboration with the interns; improvement of production processes; orientation of the producers in management of the feed during the period of weaning.

In addition to exchanging professional experiences with the producers, the university provides them with the possibility to improve their life expectancy and work conditions through the development of projects taking into the account the dry conditions in the region, utilizing relevant technologies, knowledge of their proper use in farming activity. This forms an effective collaboration with the economy of the city and those who know the reality and the society that surrounds them, together participating in interlocutions and collective changes. Boost the management, directly or indirectly, of new jobs created and of the income of the small producers, promoting their (re)inclusion both socially and economically (Prezotto, 2002).

Conclusions

It can be concluded that, the assistance provided by Universities to cooperatives of producers could be instrumental in positive learning, could be used to align formal and informal education, bringing benefits to the productive sector, the academia and to the students. Also, there was a large gap found to exist among the cooperatives, that can be filled through extension courses, with the University bringing benefits to all those involved.

It is further recommended that the university gives greater attention to small producers, collaborating with their appropriate technology development needs of local conditions, organization of internships in the cooperative to provide assistance; help with insemination and calculation of feed; facilitation of governmental assistance to the producers; continuation with the covenant between the producers and the university; periodic visits to the property, exchange of technical knowledge; sending interns to assist the management; collaboration with the interns; improvement of production processes; orientation of the producers in management of the feed during the period of weaning.

The conclusions reached from the analysis of the results of the interviews with the members conducted are presented and discussed, resulting in a conjuncture of cooperative performance and of the experience for educational purposes through a more thorough study of local reality, through education of the collective economy and solidarity with cooperativist principles.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Management of a rural estate using a multi-criteria tool to support decision making

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The global population increase associated with an increase in purchasing power has caused an increase in food demand greater than productivity. This global context has generated demand for scientific development in agriculture and the collection of practical results from experimental farms and research institutes. The objective of this study was to build a process, illustrated by a model, to support the management of an experimental farm by highlighting, organizing and measuring what, in the view of the manager, are the most relevant factors in management and performance; in this way, the aim was to expand its current performance and re-examine its goals and practices to move from the current state to the new design. This is a case study: the source of data collection was unstructured interviews with the experimental farm manager through which primary traits were identified. The methodological approach is classified as both qualitative and quantitative and the logic of the research is thus both inductive and deductive. The intervention instrument used was the multi-criteria decision aid - constructivist tool, which allowed us to identify, organize and measure operationally, tactically and strategically the aspects judged as necessary and sufficient by the key decision maker to monitor and improve the performance of the experimental farm in a transparent way that is scientifically substantiated. Although this work has contributed to the development of a model that takes into account variables such as infrastructure, results and restrictions in the workplace, the model presented only qualitative data. In this sense, for future work it is recommended the use of cardinal scales for the measurement, which allows quantifying the degree of compliance of the objectives outlined by the decision-maker in a localized and holistic way.

Key words: Management, experimental farm, means of production.

INTRODUCTION

Business organizations are generally continuously asked for results, both in the form of sustainability in the long term and economically in the short term. In addition to these demands, there are demands for experimental farms and agricultural research institutes to yield scientific results in the form of creative innovations, such as increases in productivity, but also in the form of disruptive innovations, such as the development of new

varieties and products. Thus, the management of experimental farms is challenged to improve the strategic, tactical, operational and academic outcomes. The strategic results concern sustainability and image, and social and environmental responsibility; the tactical results are associated with the dissemination of work processes and the bringing of more competitive products to the business community; operating results are related to the financial results and to the business and academic outcomes that result from teaching, research and extension (Meinke et al., 2001).

The management of experimental farms and conventional rural estates have certain variables in common, such as selection, training, coaching and people management, available area, input management, maintenance of machinery and implements, crop selection and marketing (Brozová et al., 2008), and soil nutrient depletion (Pendera et al., 2004); all these variables are controlled by the decisions of the managers. To ensure that decisions take into account all these variables simultaneously to achieve the sustainability and profitability of the property is the challenge of their managers.

Based on this, it is found that the management of an experimental farm involves multiple variables, many actors, conflicts between objectives, the management of scarce resources and on-going demands for improved performance; however, managers commonly have little knowledge of how to make decisions. This set of characteristics inherent in experimental farms makes the context complex (Ensslin et al., 2010).

Thus, the following research question emerges: What are the criteria for performance management and how should they be organized and measured in the process of managing an experimental farm? The overall objective of this work for this environment is to identify, organize and measure the criteria, judged by the manager in charge as critical for the success of the experimental farm, evidencing the current performance and goals of the farm in each criterion and how to use this model to support the process generating and monitoring strategic alternatives for improvement. By taking into account these considerations, the specific objectives of this work are: i) to describe the actors in the context and in particular the decision maker who determines key values and preferences; ii) to identify and organize the criteria that the decision maker considers necessary and sufficient to assess the management of the farm; iii) to construct ordinal scales to measure the criteria according to the perceptions of the decision maker; iv) to evidence the status quo of the experimental farm management to facilitate its monitoring.

MATERIALS AND METHODS

This article describes a case study in which a performance management process was built, illustrated by a customized model for the manager of an experimental farm located in Florianopolis, Santa Catarina. This experimental farm belongs to the Universidade Federal de Santa Catarina – UFSC. To develop such a model, the study employed the multi-criteria decision aid - constructivist (MCDA-C) method. The data comprise primary traits obtained directly at the study site with the decision-maker through unstructured interviews conducted with the experimental farm manager in May to November, 2011 and authenticated in March and April, 2012. In this work, it is understood as primary data those aspects considered necessary and sufficient for the experimental farm management, such as: Classroom, food quarters, laboratories, storage, shelter, support area road network (Figure 7). The methodological approach is classified as qualitative in terms of the identification of criteria and quantitative in terms of the building of ordinal scales to measure to what extent each objective is being achieved. The logic of the research is therefore inductive. Non-structured interviews progressed from an initial list of the decision maker on relevant aspects to the context for the use of cognitive maps that allow structuring the information into means-end forms.

RESULTS AND DISCUSSION

Construction of the MCDA-C model

The MCDA-C methodology has as its main purpose the expansion of the knowledge of the decision maker in relation to complex, conflicting and uncertain contexts. This methodology makes use of tools to structure information that might allow explicit understanding of the consequences of decisions for aspects that the decision maker considers relevant (Bortoluzzi et al., 2010, 2011a, b; Ensslin et al., 2010, 2012; Giffhorn et al., 2010; Grzebieluckas et al., 2011; Lacerda et al., 2010, 2011a, b; Moraes et al., 2010; Tasca et al., 2010; Vianna and Ensslin, 2011; Zamcopé et al., 2012). So, MCDA-C is characterized as essential in this research for allowing, in a structured and systematic way, the conditions required for the evolution of knowledge about the problem in question to identify those aspects considered as necessary and sufficient for the decision maker. The model was set up in an initial phase that identified the subsystem of actors and the ascribing of labels representing what is sought in terms of values and preferences. Further, the objectives judged by the decision maker as necessary and sufficient to evaluate the context in accordance with the actors' values and preferences were identified, organized and measured

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Table 1. Subsystem of actors.

Parameter	Description
Stakeholders	
Decision maker	Professor at the Centre for Agricultural Sciences (Centro de Ciências Agrárias), UFSC and supervisor of the farm
Speakers	Rector and Pro-Rectors Professors Director of the Centre for Agricultural Sciences Research students
Facilitators	Authors
Actors	Other students Farm staff Society

following a particular order (Bortoluzzi et al., 2011a; Ensslin et al., 2012; Grzebieluckas et al., 2011; Lacerda et al., 2011a; Moraes et al., 2010; Tasca et al., 2010; Vianna and Ensslin, 2011).

Context, subsystem of actors and labelling

The experimental farms are seen as the centre of creation, development and dissemination of innovations and knowledge in the field of agricultural production. To meet demand for their innovations and knowledge, the experimental farms promote teaching, research and extension activities, qualifying professionals for the labour market (Nagaoka et al., 2012). In consequence, the performance of the experimental farm management may have an impact on the training of scholars, the evaluation of courses and the image of the university in society. In this example, the supervisor has limited time for managing the farm, which complicates the management process. Moreover, because it is a public experimental area, the farm is subject to laws and regulations that restrict its operations. The manager is aware that he will be asked about his performance but has not had an instrument to support him in his management activities, leaving him in a vulnerable position. Based on these considerations, we identified the supervisor as the person with whom the decision aiding tool would be implemented, which actors had power to intervene in the process and those with an interest in the decisions to be taken. This group of involved actors is presented in Table 1. Later, we assigned a label that represented the major concerns of the decision maker to the decision context to be analysed. The label of the case study was defined as: support for the decision-making process of Ressacada Experimental Farm - UFSC.

Table 2. Five identified PAEs.

PAE	Description
1	Control experimental unit
2	Skilled operational labour
3	Days in the field
4	Excellence in teaching
5	Excellence in research

Primary evaluation elements, concepts and areas of concern

To obtain data relating to the value system, open interviews with the decision maker were recorded. His statements were analysed, allowing identification of the primary assessment elements (PAEss; Ensslin et al., 2001). These are the first aspects, references, actions, desires, goals and constraints of the problem externalized by the decision maker (Grzebieluckas et al., 2011; Keeney, 1992; Lacerda et al., 2011a; Moraes et al., 2010; Rosa et al., 2012; Tasca et al., 2010; Vianna and Ensslin, 2011; Zamcopé et al., 2012). By means of interviews with the decision maker, 127 PAEs were identified, of which five are presented in Table 2.

By starting with the PAEs, the MCDA-C methodology extends the knowledge of the decision maker with the construction of concepts. The concepts have both a preference pole (positive), which indicates the preferred direction of the decision maker, and an opposite psychological pole (negative), which concerns the (unwanted) consequence(s) of not achieving the objective underlying the preference pole. Table 3 presents the concepts for the first three PAEs, where the ellipsis (...) should be read as "instead of", representing the psychological opposite

Table 3. The First Three Concepts.

PAE	Concept
Control experimental unit	Being the control experimental unit ... Compromising those involved and failing to contribute to a good course evaluation
Skilled operational labour	Requiring and developing skills of operational labour ... Presenting poor work and compromising those involved
Days in the field	Ensuring opportunities for days in the field ... Missing the opportunity of revealing the farm to society

of the concept. The concepts that represent strategic concerns can be clustered in areas of concern. This brings together the first concepts that explain the values of the decision maker and the properties of the context taken into account when evaluating this area of concern (Bortoluzzi et al., 2010; Ensslin et al., 2000, 2012; Grzebieluckas et al., 2011;Lacerda et al., 2011a; Moraes et al., 2010; Vianna and Ensslin, 2011; Zamcopé et al., 2012).

The names given to the areas should be those that best reflect the main concern of the decision maker when expressing the concepts belonging to the group. It should be noted, however, that the concepts determine the name given to the area of concern (Bortoluzzi et al., 2011a; Ensslin et al., 2012; Lacerda et al., 2011b; Zamcopé et al., 2010).

Means-end maps and tree of fundamental points of view

The next step is the construction of maps of means-end relationships by using the concepts initially identified and grouped into categories for the model of fundamental points of view (FPVs). These maps detail the hierarchical relationships and influences between the concepts in terms of ways to discriminate the strategic objectives in terms of tactical and operational goals (Bana et al., 1999; Bortoluzzi et al., 2011b; Ensslin et al., 2000, 2010, 2012; Grzebieluckas et al., 2011; Lacerda et al., 2011a; Moraes et al., 2010). This process was repeated for each concept until the cause and effect relationships between them were identified. To facilitate analysis and understanding, the means-end maps are divided into clusters. The clusters are formed by grouping the branches for which the arguments reflect the same concerns of the decision maker. By investigating the branch, the decision maker follows a line of argument that leads to a particular means concept and thence to the goal expressed by the label of the problem. The name of each cluster is given in terms of the target focused on by the decision maker and expressed by the branches that compose it. Figures 1, 2 and 3 illustrate knowledge transfer from the means-end maps for “fixed” FPVs. This process yielded four clusters: i) full use of the infrastructure; ii) use conditions of the infrastructure; iii) full land use and iv) staff.

The “full use of infrastructure cluster” can be explained by the following sub-clusters: i) academic support infrastructure, ii) infrastructure logistics, and iii) the means of production infrastructure. The “use conditions of the infrastructure” cluster is explained by the sub-cluster maintenance. The “complete land use” cluster is explained by the sub-clusters i) design and ii) master design. The “staff” cluster is explained by the sub-clusters i) skills, ii) functions, and iii) update. The representation of the label, areas of concern and its respective FPV, is given the name hierarchical structure of value, as shown in Figure 4 for the model built for the study case. In the transition process of converting the Means-end maps into a hierarchical structure of value, each cluster is related to a point of view of the hierarchical structure of value as shown in Figure 4.

One concern to be considered is that the initial clusters should be tested to ensure that they represent aspects of the context in order to be essential, controllable, complete, measurable, operational, isolatable, not redundant, concise and understandable (Keeney, 1992; Ensslin et al., 2001, 2010).

Hierarchical structure of value and descriptors

The sub-clusters should follow the same properties as the first clusters and their initial transformation process is equivalent to that used for FPVs and these sub-criteria are called elementary points of view (EPV). This decomposition process continues until an EPV that represents a property of the context is attained and can be measured in an objective and unambiguous fashion (Ensslin et al., 2010). The hierarchical structure is shown in Figure 4.

The ordinal scales are constructed in an interactive process with the decision maker and should be those that best represent what the decision maker sees as relevant. In this process, one must identify the reference levels, or anchors: the “good level”, which represents the level

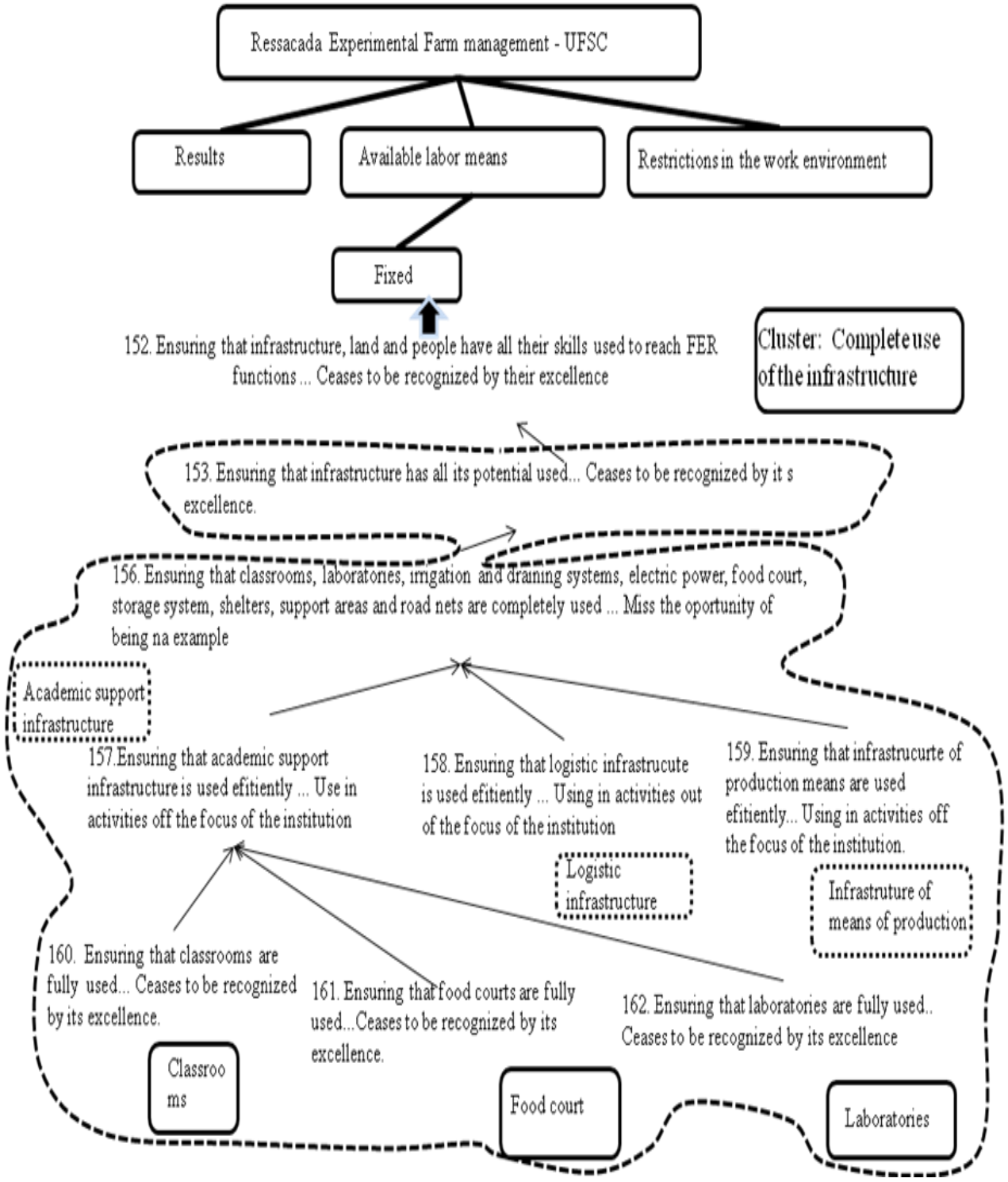

Figure 1. Means-end map for the “complete use of infrastructure cluster”

above which the decision maker judges the performance to be excellent, and the “neutral level”, below which performance is compromised. Between these two points, the performance represents challenges (Ensslin et al., 2010). Ordinal scales were constructed for the “fixed” EPVs and comprised 16 descriptors, which can be seen

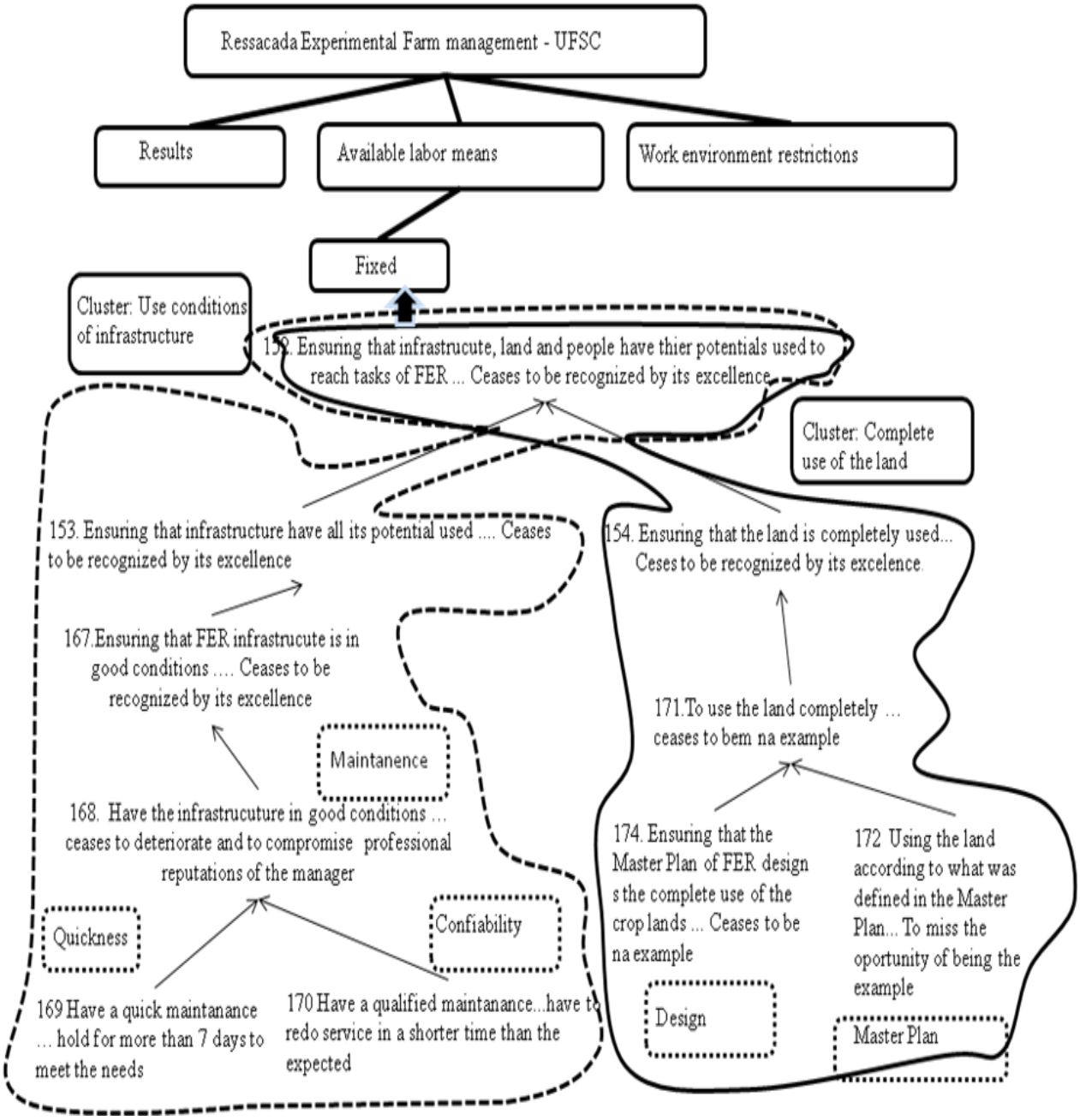

Figure 2. Means-end map for the “use conditions of the infrastructure” and “complete land use” clusters

in Figures 5, 6, 7 and 8. Good and neutral levels are displayed in these four figures for each descriptor of the EPV considered.

Depiction of the status quo of the experimental farm management for the FPVs considered

Upon completion of the construction phase of the descriptors, the MCDA-C methodology enables the ordinal profile of the current situation to be visualized in relation to each aspect considered relevant by the manager (Bortoluzzi et al., 2010). This profile represents the diagnosis of the current situation, presented concisely but completely according to the manager’s perceptions (Lacerda et al., 2010); this is aimed at enabling a monitoring function in the management task. Figures 5, 6, 7 and 8 illustrate the performance profile of the “fixed”

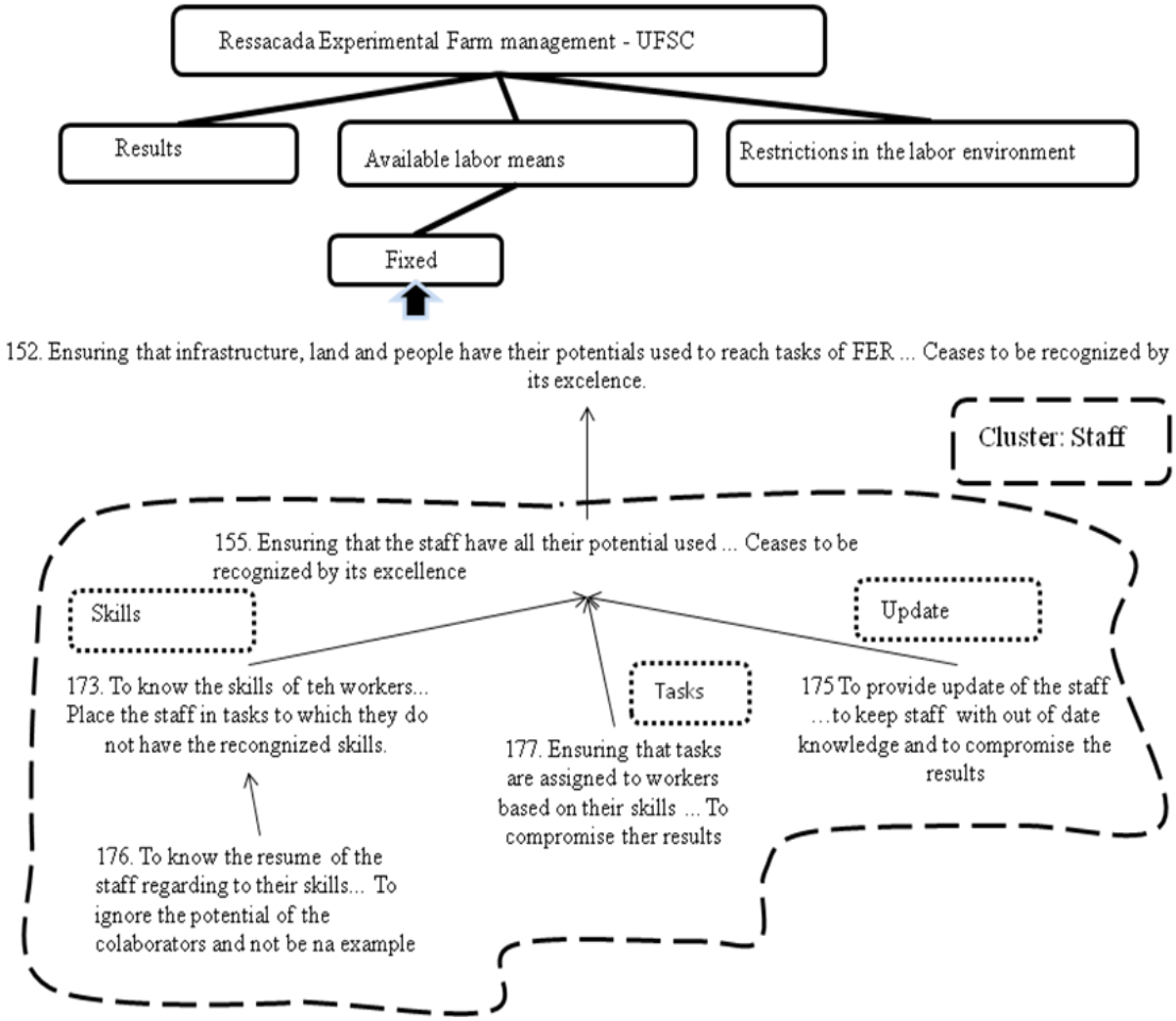

Figure 3. Means-end map for the “staff” cluster.

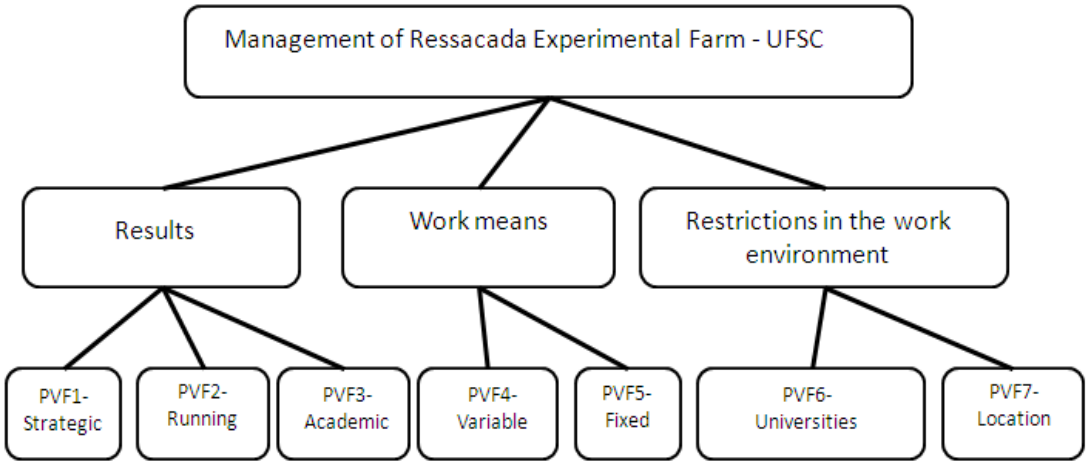

Figure 4. Hierarchical structure of value.

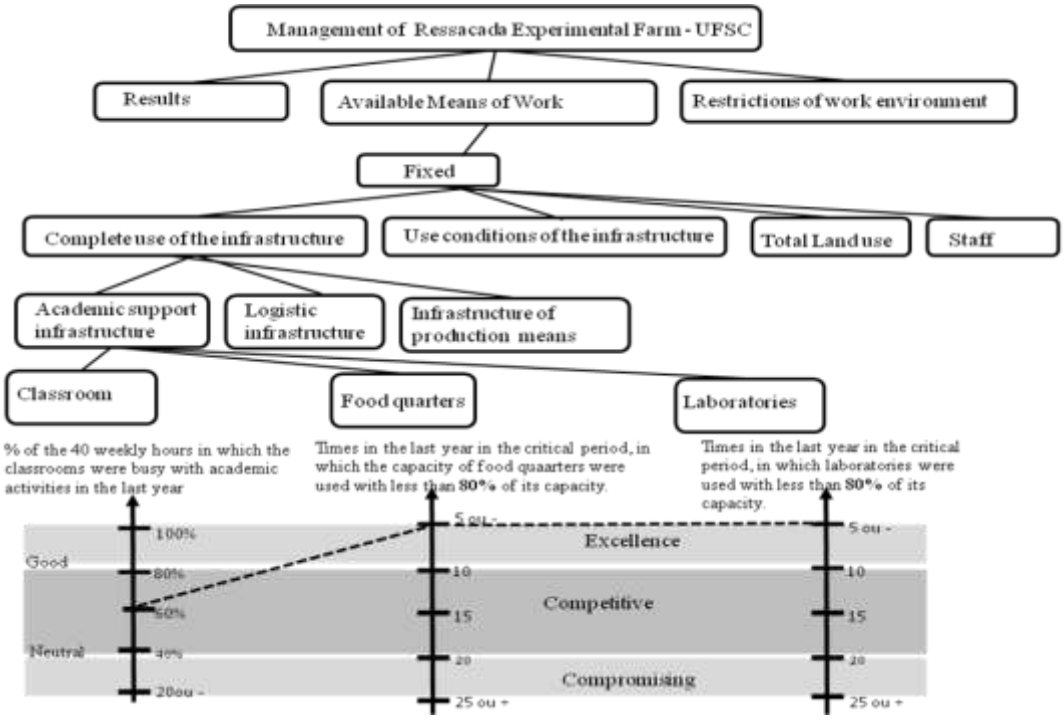

Figure 5. Profile of the status quo impact for FPVs for descriptors (1 to 3).

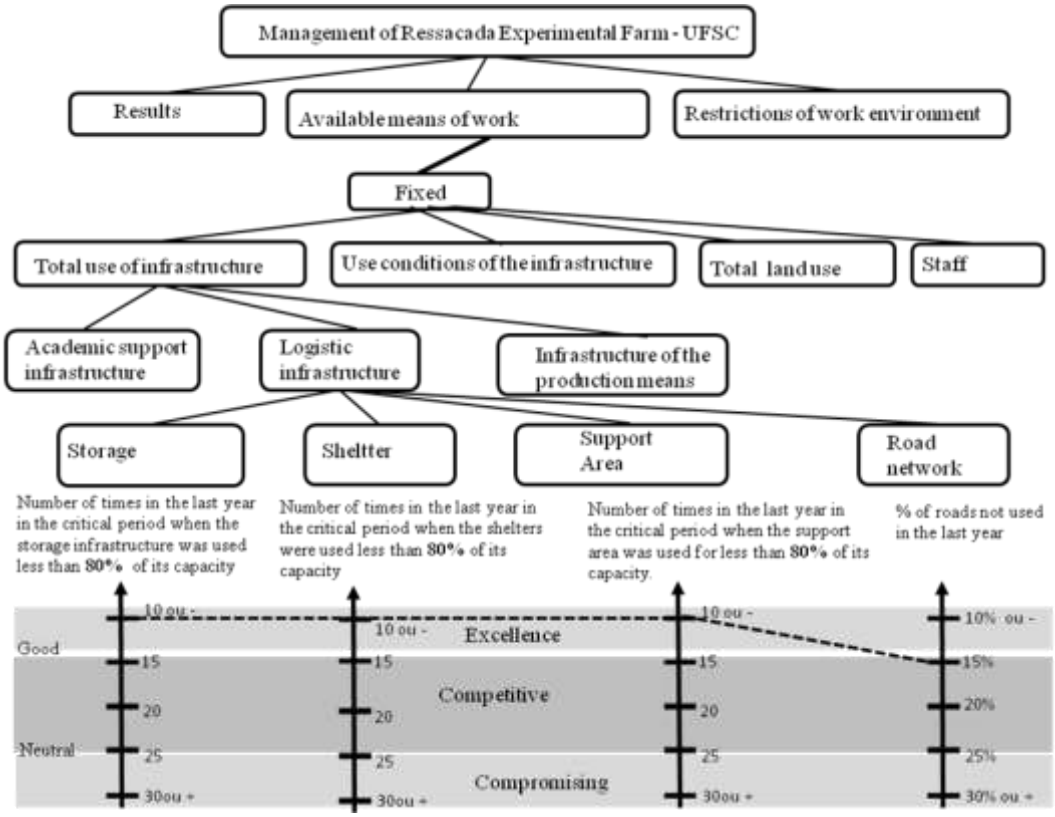

Figure 6. Profile of the status quo impact for fixed the FPVs for descriptors (4 to 7).

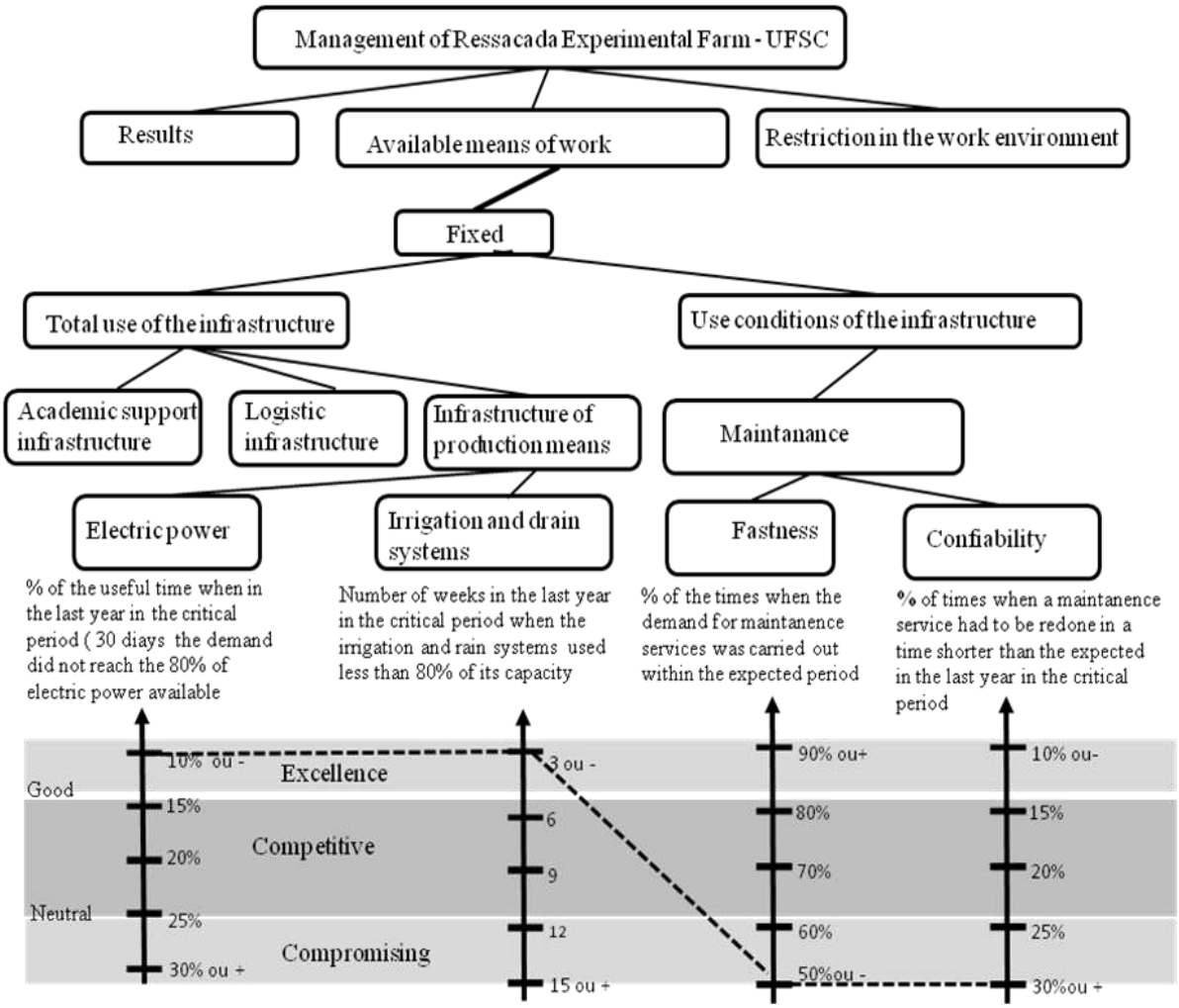

Figure 7. Profile of the status quo impact for the fixed FPVs for descriptors (7 to 10).

FPVs for the experimental farm analysed. We can see that the farm has excellent performance in relation to the following categories: feeding area, laboratories, storage, shelters, support area, electricity power, drainage and irrigation system, and updates. However, the classrooms and road networks present challenges in terms of performance and the others present compromised performance.

The model, built on the values and preferences of the decision maker, allows visualization of the impact of management on what the manager considers it necessary and sufficient to take into account, as shown in Figure 8. This understanding helps the decision maker to identify where the main competitive advantages and opportunities for improvements.

It should be noted that the scales constructed are simply semantic descriptions or alpha-numeric symbols (Barzilai 2001; Bortoluzzi et al., 2011a; Ensslin et al., 2001, 2012; Grzebieluckas et al., 2011; Lacerda et al., 2011a; Moraes et al., 2010; Tasca et al., 2010). Therefore, it would be wrong to use these scales for any function involving arithmetic operations (sums, means, etc.) since they are not numerical. The MCDA–C recognizes the differences between ordinal scales and cardinal and to accomplish the transformation between the two, the participation of the decision maker is again required to provide information concerning the differences in attractiveness among the levels of each scale. This activity can be performed using various methods, such as direct scores, bisection or the Macbeth approach, among others (Bortoluzzi et al., 2011b, Ensslin et al., 2001; Grzebieluckas et al., 2011; Lacerda et al., 2010; Vianna & Ensslin 2011; Zamcopé et al., 2010, 2012). However, discussing the process of transforming ordinal scales into cardinal scales is beyond the scope of this paper.

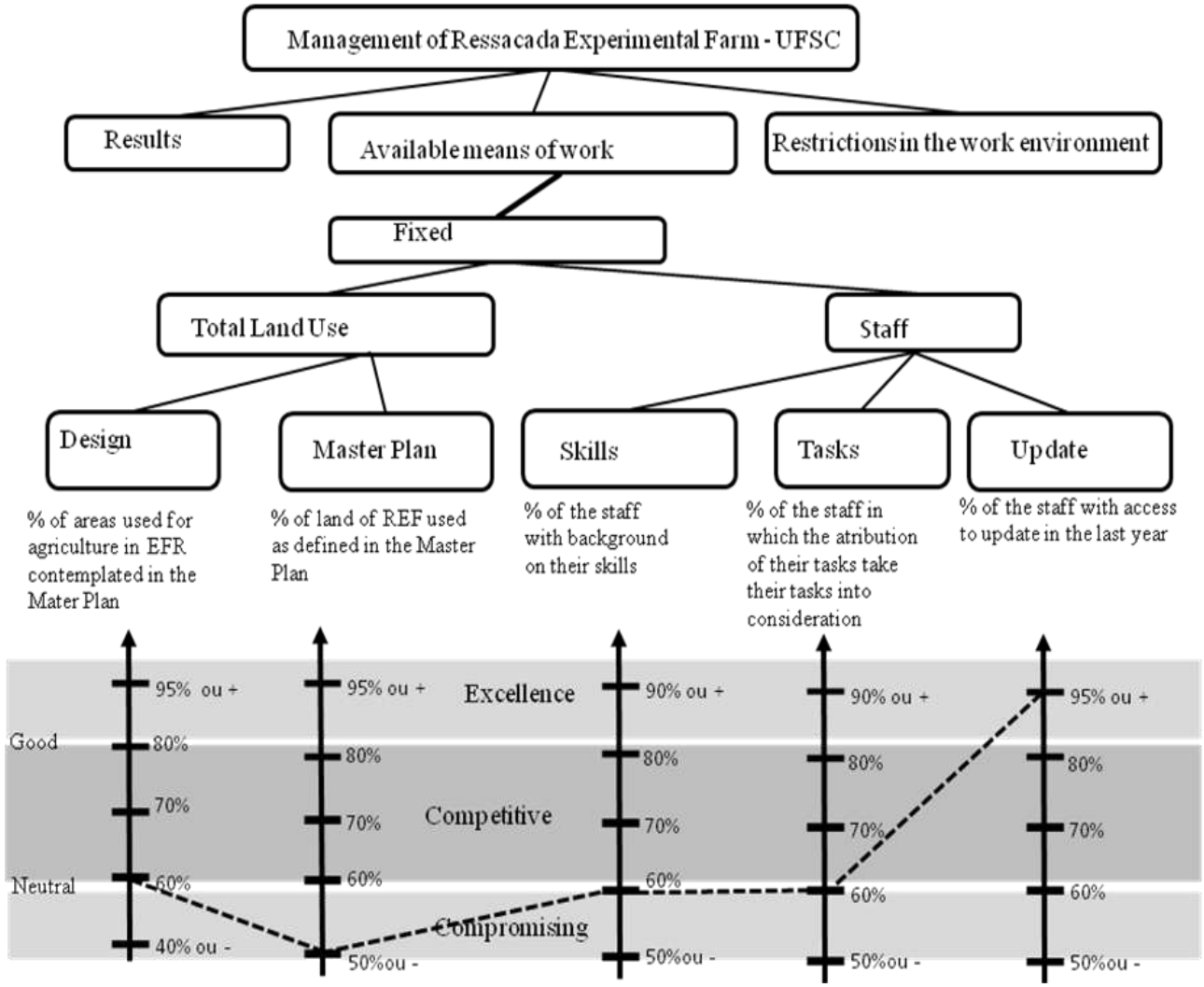

Figure 8. Profile of the status quo impact for the fixed FPVs for descriptors (11 to 15)

Conclusions

The objective of this study was to construct a process, illustrated by a model, to support the management of an experimental farm so as to highlight, organize and measure aspects of performance that, in the view of the manager, are the most relevant, then extending the current goals, practices and performance by moving from the current status to that designed. This is a study of a specific case. The data comprise primary traits obtained through unstructured interviews with the manager of the experimental farm. The intervention instrument employed was the multi-criteria decision aid - constructivist (MCDA-C) tool, which allowed us to identify, organize and measure the aspects judged necessary and sufficient by the decision maker to monitor and improve the performance of the experimental farm in a transparent and scientifically based fashion. The model constructed allowed the manager: i) to identify those aspects of performance necessary and sufficient to evaluate current management of performance and ii) to evidence current strengths and opportunities for improvement. Armed with this understanding, provided by the model constructed, the manager was provided with the necessary elements to seek alternatives to improve performance in those categories that present compromising performance, such as the master plan and the reliability plan.

This study was carried out in a real environment. The experimental farm is located in Florianopólis, Santa Catarina and belongs to the Universidade Federal de Santa Catarina - UFSC; it is used as an agricultural enterprise, school, and experimental and research centre. The research allowed the manager to explicate the management model to facilitate the setting of goals,

performance monitoring, and the formulation of alternatives to achieve the goals set.

The study began by contextualizing and describing the actors involved, as well as labelling the case study, thus fulfilling objective (i). As described in the following sections, the decision maker engaged in an interactive process with the facilitator to identify, organize and clarify those criteria that must be taken into account in the management ofperformance, namely: strategic, operational, academic, fixed, variable, university and location. Thus objective (ii) to identify the criteria that the decision maker considers necessary and sufficient to evaluate management - was met. This also answered the research question: What are the criteria to be considered in the management process of an experimental farm?

Figures 5, 6, 7 and 8 present the ordinal scales constructed and the status quo for these scales, meeting the specific objectives (iii) and (iv) for the FPVs considered “fixed”. Among the contributions of this work, the following stand out: i) the research has a practical aspect in terms of providing a model that illustrates, organizes and measures in an orderly manner those aspects considered by the decision maker to be necessary and sufficient for full compliance with all his or her duties as manager of the experimental farm; ii) the model allows the manager to justify his or her decisions to other stakeholders, based on specific values (accountability); iii) the model constrains the amount of information in terms of what is necessary and sufficient for management in the particular context. This process created the conditions for disseminating the practices and performance sought by the decision maker, how these are to be measured and the goals among all those involved in the experimental farm. Thus, they in turn can base their decisions specifically on the strategic options adopted.

The limitations of this and other such studies relate to the long-term nature of the process and also the level of participation required of the decision maker. Finally, it should be noted that although the model is customized - that is, the model represents the values and preferences of a specific decision maker – the process employed is generic and can be used by other managers.

Conflict of interests

The authors have not declared any conflict of interest

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Full Length Research Paper

Relationship on the incidence of *Thrips tabacci* and spacing of garlic plantation

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Thrips, *Thrips tabaci* Lind. (Thysanoptera: Thripidae), is a key pest of garlic in Brazil. This study aimed to evaluate the influence of spacing on *T. tabaci* infestation of a garlic crop. The experiment was conducted at the experimental farm of the Goiano Federal Institute (Instituto Federal Goiano – IF Goiano) - *Campus* Urutaí. The experimental design was a randomized block with nine treatments and spacing in single rows (0.20 × 0.10 m, 0.25 × 0.10 m and 0.30 × 0.10 m) and double rows (0.20 × 0.10 × 0.10 m; 0.20 × 0.15 × 0.08 m; 0.25 × 0.10 × 0.10 m; 0.25 × 0.15 × 0.08 m; 0.30 × 0.10 × 0.10 m; and 0.30 × 0.15 × 0.08 m). The Chonan 15 genotype was used in three replicates. At 30, 50 and 70 days after emergence (DAE), evaluations on the following features were carried out: leaf length, number of leaves, angle between the two central leaves, damage and number of thrips per plant. At the end of the crop cycle, the plants were harvested. Individual cured bulb mass, estimated commercial yield, number of cloves per bulb and bulb diameter were also evaluated. Spacing influenced the angle between the central leaves, with spacing of 0.30 × 0.15 × 0.08 m, among the least dense spacing, producing the widest angle (26.96°), suffered one of the highest degrees of insect damage. A spacing of 0.25 × 0.10 m had the highest number of thrips per plant (2.99). Spacing influenced production, with the highest yield occurring with a spacing of 0.25 × 0.15 × 0.08 and 0.30 × 0.10 × 0.10 m (14.37 and 13.51 t/ha, respectively). The least dense spacing produced the largest bulb diameter (42.80 mm) and mass (30.66 g).

Key words: *Allium sativum*, insect, Thrips, plant architecture, non preference.

INTRODUCTION

Thrips tabaci Lindeman 1889 (Thysanoptera: Thripidae) is a key pest of garlic in Brazil, due to the dry climate, which encourages the occurrence of this insect. The pest can reduce crop yield by up to 61 percent if not controlled

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(Maranhão and Menezes, 1991; Silva et al., 2003; Gonçalves and Vieira Neto, 2011). The attacked plants develop lesions on leaves that cause yellowing and premature dryness, highly infested leaves appear twisted, as if they were burned, before subsequently falling (Souza and Macêdo, 2009). This pattern occurs because the thrips scrape the leaf surface to feed on the sap, facilitating the emergence of various diseases, including those caused by viruses (Gallo et al., 2002).

The most widely used control method is chemical control, which promotes biological imbalance, increases the risk of environmental contamination, insect resistance and increases production costs. Alternative controls such as changes in plant arrangement, spacing and planting density are viable ways of reducing losses and may contribute to the integrated management of thrips in the garlic crop (Gallo et al., 2002; Loges et al., 2004).

Structural characteristics such as plant architecture, angle between the two central leaves and leaf length influence the population of *T. tabaci* in onion crops (Loges et al., 2004). Plants with a greater central angle are resistant to thrips by antixenosis, but few studies conducted confirms, whether that smaller number of insects on plants with a higher central angle is due to more efficient control effected by natural enemies, insecticides or abiotic agents (Loges et al., 2004). The aim of this study was therefore to determine the influence of plant spacing in single and double rows on the thrips population density in a garlic crop.

MATERIALS AND METHODS

The experiment was conducted at the experimental farm of the IF Goiano – Campus Urutaí in Urutaí, Goias State, Brazil (17° 19'13'' S, 48° 12'37' 'W. 697 m altitude). During the experiment, the cumulative rainfall was 12 mm, the maximum temperature reached 36°C, and the minimum temperature was 8°C. The planting of Chonan 15 genotype cloves was done in May, 2012, with nine treatments adopted at different spacings: in single rows (0.20 × 0.10 m, 0.25 × 0.10 m and 0.30 × 0.10 m) and in double rows (0.20 × 0.10 × 0.10 m, 0.20 × 0.15 × 0.08 m, 0.25 × 0.10 × 0.10 m, 0.25 × 0.15 × 0.08 m, 0.30 × 0.10 × 0.10 m and 0.30 × 0.15 × 0.08 m). The experimental design was conducted in randomized block design with three replicates. The experimental plot (2.5 m × 1.2 m) had a working area of 0.25 m^2, comprising the central row. Irrigation was performed by a conventional sprinkler, and other cultural practices proposed by Filgueira (2008) were adopted, with the exception of use of chemicals for pest control after planting.

Evaluations were performed 30, 50 and 70 days after emergence (DAE), with five plants per plot randomly selected to evaluate the following features: leaf length (LL), corresponding to the length of the sheath to the apex of the largest leaf, expressed in centimeters; angle between the two central fully developed leaves (ANG), taken from the central axis of the plant using a protractor and expressed in degrees; total number of leaves (TNL); damage caused by thrips attack (DAMAGE), using a rating scale for the lesions caused by thrips, with a score of 0 indicating leaves with no attack symptoms, score 1: leaves with a few chlorotic spots, score 2: leaves with many chlorotic spots, score 3: leaves with chlorotic spots and early desiccation, and score 4: leaves with chlorotic spots and advanced desiccation (adapted from Albuquerque, 2004); and number of thrips on the two fully developed central leaves (NYMPH).

To perform the insect count, garlic plants were cut close to the ground, placed in a labeled plastic bag, brought to the Agricultural Entomology Laboratory and stored in cold storage to reduce thrips movement. The number of insects per plant was then counted. For identification of the adult Thrips the methodology proposed by Monteiro et al. (2001) was adopted.

At the end of the crop cycle, the plants were manually harvested. The harvested plants were submitted to a curing process, in the shade, for a period of 20 days. Subsequently, the bulbs were cleaned, the shoots were cut to 1.0 cm, and the roots were removed. Regarding features associated with production, the individual mass of the cured bulbs (IMB), estimated commercial yield (ECY), cloves per bulb (CPB) and diameter of bulb (DIA) were all evaluated. The data were transformed into $(X + 0.5)^{1/2}$ for analysis. The results were submitted to an analysis of variance using the F-test, and the treatment means, when significant, were compared using the Duncan test at 5% probability. A correlation analysis among the number of *T. tabaci* and the angle between the two central leaves in the different planting arrangements was performed. Statistica software version 7.0 (Statsoft, 2004) was used.

RESULTS AND DISCUSSION

The TNL means relating to the different spacings were not significantly different from each other, and spacing did not affect the number of leaves per plant (Table 1). Regarding evaluation periods, there was no difference between 30 and 50 DAE, but at 50 and 70 DAE, there were significant differences, with a mean increase of 0.46 leaves per plant. The values found for the number of leaves were below those obtained by Mota et al. (2005), who evaluated morphological similarities of different cultivars of garlic, with the Chonan cultivar exhibiting a mean of 7.83 leaves per plant.

With regard to damage caused by *T. tabaci*, in the first evaluation at 30 DAE, significant differences were not observed between treatments due to the absence of leaf symptoms, but from 50 to 70 DAE, there was an increase from 0.81 to 3.24 in terms of damage (Table 1). This increase was due to the longer period of plant exposure to pest attack. There was also a difference in damage score for the different spacings, with the 0.20 × 0.15 × 0.08 m and 0.30 × 0.15 × 0.08 m spacings obtaining the highest scores and the 0.30 × 0.10 × 0.10 m spacing obtaining the lowest score (Table 1).

Leite et al. (2004) observed an increase in the percentage of leaf area damaged by *T. tabaci* in different onion cultivars. In the Aurora cultivar, the percentage varied among 1.04, 6.07 and 17.98 percent in June, July and August, respectively. These observations coincide with the tendency toward increasing damage values in the garlic plant. The number of thrips per plant increased from 0.72 to 3.50 thrips per plant between 30 and 50 DAE, but there was a drop in population between 50 and70 DAE, reducing to 1.16 thrips per plant (Table 1). These data contradict Ramiro's (1972) report that the

Table 1. Leaf length (LL), angle between the two central leaves (ANG), total number of leaves (TNL), number of *T. tabaci* nymphs on the two central leaves (NYMPH) and damage score (DAMAGE) in the garlic genotype. Urutaí, Goias State, Brazil, 2012.

Spacing (S)	LL	ANG	TNL	Nymph	Damage[1]
0.20 × 0.10	50.74	20.77[b]	4.51	2.03[ab]	2.00[ab]
0.25 × 0.10	46.90	21.00[b]	4.48	2.99[a]	2.11[ab]
0.30 × 0.10	50.49	22.44[ab]	4.44	1.29[b]	1.83[ab]
0.20 × 0.10 × 0.10	49.33	20.62[b]	4.29	1.85[ab]	2.21[ab]
0.20 × 0.15 × 0.08	46.44	23.88[ab]	4.48	1.88[ab]	2.33[a]
0.25 × 0.10 × 0.10	48.55	21.00[b]	4.44	1.63[ab]	2.11[ab]
0.25 × 0.15 × 0.08	51.44	20.92[b]	4.48	1.48[ab]	1.77[ab]
0.30 × 0.10 × 0.10	49.12	21.44[b]	4.48	1.00[b]	1.66[b]
0.30 × 0.15 × 0.08	48.07	26.96[a]	4.33	2.00[ab]	2.22[a]
F (S)	1.13[ns]	1.67*	0.13[ns]	1.43*	1.53*
Epoch (E)					
30 DAE	39.57[b]	24.06[a]	4.14[b]	0.72[b]	-[2]
50 DAE	53.48[a]	23.92[a]	4.35[b]	3.50[a]	0.81[b]
70 DAE	53.98[a]	18.37[b]	4.81[a]	1.16[b]	3.24[a]
F (E)	88.43**	11.59**	9.80**	33.63**	113.92**
F (S × E)	0.23[ns]	1.21 [ns]	0.90[ns]	1.52[ns]	0.72 [ns]
CV (%)	8.96	22.01	13.96	28.19	11.06

[1]Means in the column followed by the same letter do not differ according to Duncan's test. P < 0.05. **Significant at 1% probability. *Significant at 5% probability. [NS]Not significant. [2]Damage quantification results not obtained due to lack of symptoms in the leaves.

incidence of *T. tabaci* in the onion crop is initially uneven and grows gradually, with the largest population at the end of the crop cycle. This finding can also be observed in a study by Leite et al. (2004), who obtained a gradual increase in the thrips population on Conquista onions, varying among 0.00, 2.13 and 6.35 insects in the months of June, July and August, respectively. Zamar et al. (2007) also found an increase in the thrips population of garlic plants as the end of the crop cycle drew near.

There was no difference in pest population with regard to spacing, with the largest infestation in the 0.25 × 0.10 m spacing, at 2.99 thrips per plant, and the lowest in the 0.30 × 0.10 × 0.10 m and 0.30 × 0.10 m spacings, 1.00 and 1.29 thrips per plant, respectively. These results corroborate those of Leite et al. (2007) who evaluated the incidence of insects and disease in onion cultivars and found mean values of 2.88 thrips per leaf. In this study, the spacing with the largest thrips populations did not coincide with the spacing that had the greatest damage caused by thrips.

Plant spacing affected the angle between the central leaves, with less dense spacing, such as 0.30 × 0.15 × 0.08 m, having larger angles and denser spacing, such as 0.20 × 0.10 × 0.10 m and 0.20 × 0.10 m, having smaller angles (Table 1). The angle values found are similar to those found by Mota et al. (2005), who evaluated morphological similarities of different garlic cultivars and found an angle of 19.76° in the Chonan cultivar.

An interaction between central angle and number of thrips per plant was observed in the 0.25 × 0.10 m spacing, which had one of the smallest angles and showed the highest infestation of thrips per plant. The spacing of 0.30 × 0.15 × 0.08 m, which had the largest angle also had the higher thrips population. These data corroborate those of Silva (2011), who noted the same central angle and same thrips population in different onion cultivars. Using linear regression analysis to compare the number of thrips and the angle of the central leaves (Figure 1), a significant difference can be observed with a positive linear correlation, indicating that a reduction in the former factor involves an increase in the latter. The relationship between central angle and thrips number is not well established in the literature on *T. tabaci* infestation, but the data corroborate those of Loges et al. (2004), who found higher thrips infestations in onion plants with smaller leaf angles. Higher *T. tabaci* infestation in treatments with lower leaf angles may be due to better shelter for the insects, protecting them from natural enemies and the action of insecticides also

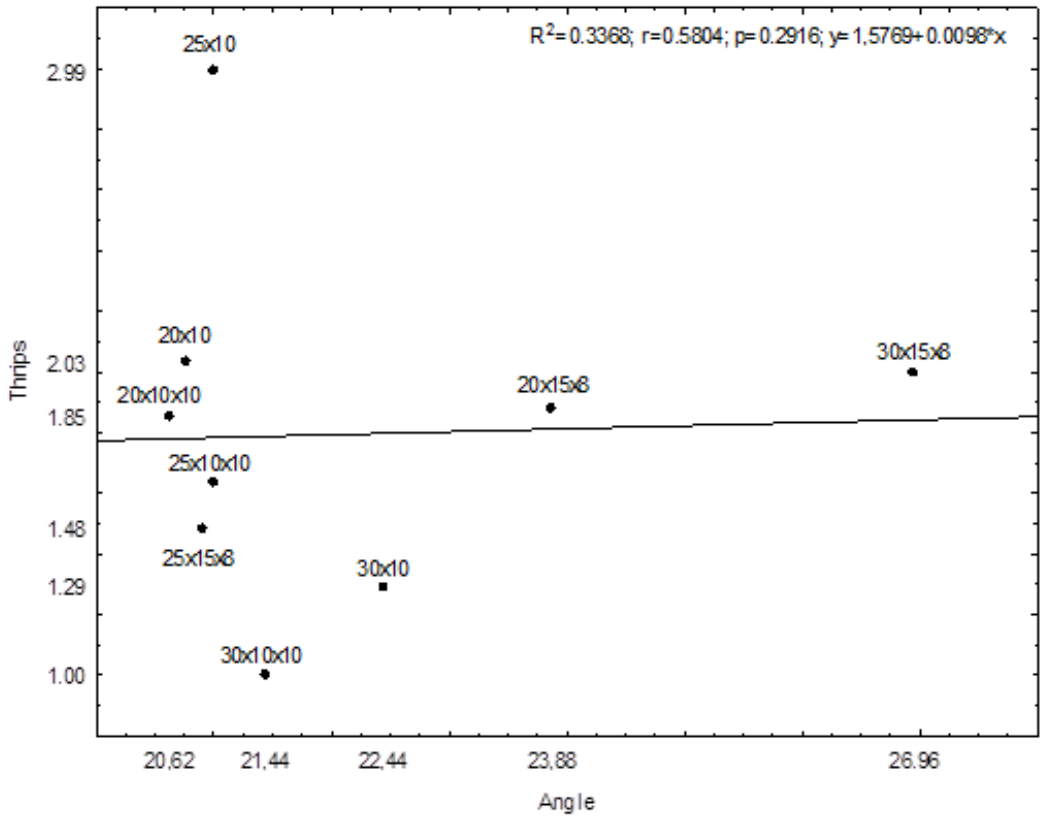

Figure 1. Correlation between the number of *T. tabaci* and the angle between the two central leaves in different garlic crop planting arrangements. Urutaí. Goias State. Brazil. 2012.

minimizing adverse environmental conditions (Jones et al., 1935; Loges et al., 2004).

There was a reduction in the angle between the central leaves in the different evaluation periods, with a significant reduction from 23.92° at 50 DAE to 18.37° at 70 DAE (Table 1). This reduction may be due to the increased total number of leaves per plant, thereby reducing the angle between the central leaves. This finding is in accordance with those of Loges et al. (2004), who found a reduction in angle due to an increase in number of onion leaves.

Another variable that spacing did not affect was leaf length (LL), with no significant differences (Table 1). Resende et al. (2013), evaluating morphological aspects of garlic clones under field conditions, found a leaf length of 51 cm in the Chonan cultivar, which is similar to that found in the present study. Loges et al. (2004) suggested there was a relationship between plant height and numbers of thrips, as taller plants have heavier leaves and thus a larger angle between the central leaves, but this was not observed in the present study due to the similarity of leaf length. Regarding the different evaluation periods, there was a difference between 30 and 50 DAE, with leaf growth of 13.91 cm, but there was no significant difference between 50 and 70 DAE.

Production components and number of cloves per bulb were not affected by spacing (Table 2) because these are characteristics linked to the cultivar and not to planting arrangement (Silva and Silva, 2009). Bulb diameter was influenced by spacing, with one of the least dense spacings of 0.30 × 0.10 m having the largest bulb diameter, 42.8 mm, and one of the most dense spacings, 0.20 × 0.10 × 0.10 m, having one of the smallest diameters.

Average bulb mass was also influenced by spacing. One of the least dense spacings had the highest individual bulb mass, which was the spacing of 0.30 × 0.10 m with a mass of 30.66 g. One of the most dense spacings, 0.20 × 0.15 × 0 08 m, yielded one of the lowest masses. These results suggest that a less dense planting arrangement produces bulbs with greater mass and larger diameter. In relation to yield, the spacings that stood out were 0.25 × 0.15 × 0.08 m and 0.30 × 0.10 × 0.10 m, with yields of 14.37 and 13.51 t/ha, respectively. Souza and Carmo (2012) found that the best spacing for garlic crop planting was 0.25 × 0.10 m and 0.25 × 0.15 m,

Table 2. Estimated commercial yield (ECY. t/ha). number of cloves per bulb (CPB). bulb diameter (DIA. mm) and average bulb mass (IMB. g) of garlic. depending on the evaluated spacings. Urutaí. Goias State. Brazil. 2012.

Spacing (S)[1]	ECY	CPB	DIA	IMB
0.20 × 0.10	9.12^{b}	11.90	39.00^{ab}	23.79^{ab}
0.25 × 0.10	10.87^{ab}	12.26	39.06^{ab}	23.80^{ab}
0.30 × 0.10	11.38^{ab}	11.13	42.80^{a}	30.66^{a}
0.20 × 0.10 × 0.10	12.63^{ab}	11.20	37.73^{b}	22.92^{ab}
0.20 × 0.15 × 0.08	11.17^{ab}	11.13	37.00^{b}	22.06^{b}
0.25 × 0.10 × 0.10	12.75^{ab}	11.26	39.20^{ab}	25.18^{ab}
0.25 × 0.15 × 0.08	14.37^{a}	11.00	38.86^{ab}	25.48^{ab}
0.30 × 0.10 × 0.10	13.51^{a}	11.60	40.40^{ab}	26.51^{ab}
0.30 × 0.15 × 0.08	11.40^{ab}	12.00	39.80^{ab}	27.32^{ab}
F (S)	1.50*	0.42^{ns}	1.89*	1.24*
CV (%)	18.62	10.92	5.35	16.13

[1]Means in the column followed by the same letter do not differ according to the Duncan Test. P < 0.05. *Significant at 5% probability. ^{NS}Not significant.

with yields of 11.52 and 11.73 t/ha, respectively, values lower than those found in this study.

The yield achieved in this study was higher than that found by Resende et al. (2013), who achieved an average Chonan cultivar yield of 6.7 t/ha, except when using 0.20 × 0.10 m spacing. The spacings with the highest yields coincide with those with the lowest thrips populations. Spacing influenced the angle between the two central leaves, a feature associated with plant insect resistance. Production was not influenced by the number of thrips per plant due to the low insect population, which was influenced by spacing. In larger spacings, larger bulb diameters and mass were obtained, but the number of cloves per bulb was the same in all spacings.

Conflict of interests

The authors have not declared any conflict of interest

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Full Length Research Paper

Metabolic profile of Brazilian pine embryos and megagametophyte of stored seeds

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Changes in availability of metabolites during seed deterioration might damage processes of synthesis and energy release for embryonic growth. This research aimed to determine which alterations occur in metabolic profile over storage of *Araucaria angustifolia* seeds and how these alterations are related to viability loss. Metabolic profile of samples stored at 60, 120, and 180 days, at ambient temperature, refrigerator (5°C), and freezer (-18°C), was analyzed by Fourier transform mid infrared (FTIR) spectroscopy. Additionally, soluble proteins of embryos and soluble carbohydrates and starch of megagametophytes were also quantified and related to dry matter and seed germination. Presence of primary and secondary metabolism compounds was identified in embryos (starch, proteins, lipids and phenolic). Both embryos and megagametophytes are composed principally of carbohydrate and starch. At 180 days of storage, only freezer-stored samples maintained a metabolic profile similar to freshly harvested samples, but seed viability was dramatically reduced. Storage in refrigerator can be an alternative to control the catabolism of reserve compounds in *A. angustifolia* seeds, retaining about 70% germination.

Key words: *Araucaria angustifolia*, germination, Fourier transform mid infrared (FTIR), metabolic profile, seed deterioration.

INTRODUCTION

Species *Araucaria angustifolia* (Bert.) O. Kuntze (Brazilian pine) is a native gymnosperm from Brazilian Atlantic Rain Forest, and has an emergent status in upper forest canopy (Korndörfer et al., 2008; Elbl et al., 2014). Because of high economic value of its wood, natural populations of *A. angustifolia* have been a target of progressive exploitation (Eira et al., 1994), and species has been classified as critically endangered by International Union for Conservation of Nature and Genetic Resources (IUCN, 2013).

A. angustifolia seed or pinion contains an embryo with two cotyledons, and reserve tissue called megagametophyte (Ferreira, 1981), which quickly lose physiological potential after harvest because they are

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recalcitrant (Espindola et al., 1994; Panza et al., 2002; Balbuena et al., 2011). Therefore, its use in seedlings production for areas recovery and commercial plantations, as well as human consumption, is difficult, being restricted to a few months per year. Although there are several means of clonal propagation of conifers, such as somatic embryogenesis, rooting of cuttings, and organogenesis, there are risks due to lack of genetic diversity in clonal populations (Bonga, 2015). Storage conditions must be adequate to minimize seminiferous metabolic activity and extend seed longevity, but even under optimal storage conditions, conifer seeds will deteriorate with time, especially for particular species which appear to be peculiarly susceptible to deterioration (Terskikh et al., 2008).

Considering importance of seed quality evaluation for a successful production (Oliveira et al., 2014), some studies have investigated a reduction of physiological quality of *A. angustifolia* seeds during storage (Piriz Carrillo et al., 2003; Caçola et al., 2006; Amarante et al., 2007; Garcia et al., 2014), and has been reported cell death and loss of viability caused by freezing of recalcitrant seeds.

Seed deterioration is accompanied by biochemical changes which affect the supply of energy required for germination. In fact, some authors studied chemical composition of *A. angustifolia* seeds, which may have from 2 to 7% lipids, 4 to 9% protein, 68 to 88% starch (Ramos and Souza, 1991; Piriz Carrillo et al., 2003; Astarita et al., 2003; Leite et al., 2008). However, researches on chemical composition of *A. angustifolia* seeds, in general, aim to assess its potential use as food, and there are few studies concerning metabolic profile changes during storage, including damage from freezing to metabolism of *A. angustifolia* seeds, but it is known that seeds starch content can be reduced from 73 to 22% after 18 months of storage in polyethylene bags, at 4°C (Piriz Carrillo et al., 2003).

Understanding variations in metabolic profile in function of viability loss may indicate strategies for maintaining quality of *A. angustifolia* seeds for long storage periods. Based on three popular forms of seed storage among regional producers (use for seedlings production) and consumers (use for food) of *A. angustifolia* seeds, the aim of this study was to determine which alterations occur in metabolic profile over storage time and how these alterations are related to viability loss.

MATERIALS AND METHODS

Seed sampling, storage and periodicity of assessments

A. angustifolia mature cones (megastrobili) containing seeds were collected from a natural population located in the region of Painel (27° 55' of latitude south, 50° 06' of longitude west and an average altitude of 1144 m), southern Brazil. Cones were collected from 25 mother trees randomly selected with approximately 50 m away from each other, with a total of 80 cones. Seed sample was homogenized and divided into four replicates, from which a fraction was removed for each storage condition: ambient temperature (laboratory), refrigerator (5 ± 1°C and 45 ± 5% of humidity relative), and freezer (-18 ± 1°C and 90 ± 5% of relative humidity), in sealed transparent plastic bags with porosity of 0.015 µm. As a reference, for storage period of samples at ambient (laboratory) conditions, variations in temperature and relative humidity to city of study ranged from -3°C and 33%, until 30°C and 99%, respectively, with average temperature and relative humidity of 15°C and 80% between months of July and December (Epagri/Ciram, 2013). Analyses were performed in freshly harvested seeds and every 60 days during storage over 180 days. As a control, viability and dry matter were conducted using whole seeds; mid-infrared vibrational spectroscopy (FTIR) and soluble proteins were conducted with embryos tissue, since embryo reserves are the first hydrolyzed during deterioration process; soluble carbohydrates and starch, major compounds of *A. angustifolia* seeds were extracted from megagamethophytes in order to compare them with FTIR results.

Dry matter analysis

Dry matter content was determined with four replicates of three seeds for each storage time and storage condition, where were transversely cut, then weighed (wet weight), dried in an oven at 105°C ± 3°C, for 24 h and reweighed to determine dry matter.

Germination test

Four replicates of 25 seeds were surface-decontaminated with sodium hypochlorite solution (2%, v/v) for three minutes and subsequently sown in trays containing moist sand up to 60% of field capacity, deposited in germination chamber at 25°C, with constant luminosity. Germination evaluation was performed after 65 days, considering germinated seeds with root protrusion (at least 10 mm of primary root).

Fourier transform infrared mid spectroscopy (FTIR)

A pool of 10 embryos/replicate (dry weight) were macerated into liquid nitrogen in a mortar with pestle, and analyzed by an infrared spectrometer, equipped with a single reflection ATR (Golden Gate) system in potassium bromide matrix. 128 scans/sample were collected in spectral window of 4000 to 500 cm^{-1}. Spectra were normalized, baseline corrected in the region of interest (3000 to 600 cm^{-1}) and processed with the aid of OPUS software (Bruker Corporation). Analyses were performed in triplicate.

Biochemical analysis

Total soluble proteins were extracted from a pool containing 10 embryos/replicate. Embryos were macerated with liquid nitrogen and homogenized with 20 mM of sodium phosphate dibasic buffer (pH 7.5), 1 mM ethylenediaminetetraacetic acid (EDTA), 50 mM NaCl, 10% (v/v) glycerol, 1 mM phenylmethylsulfonyl fluoride (PMSF) and 1.5% (v/v) β-mercaptoethanol (Steiner, 2005). Proteins were precipitated by adding absolute ethyl alcohol (2:1, v/v) and resuspended in a solution of 20 mM sodium phosphate dibasic buffer (pH 7.5). Soluble proteins contents were determined

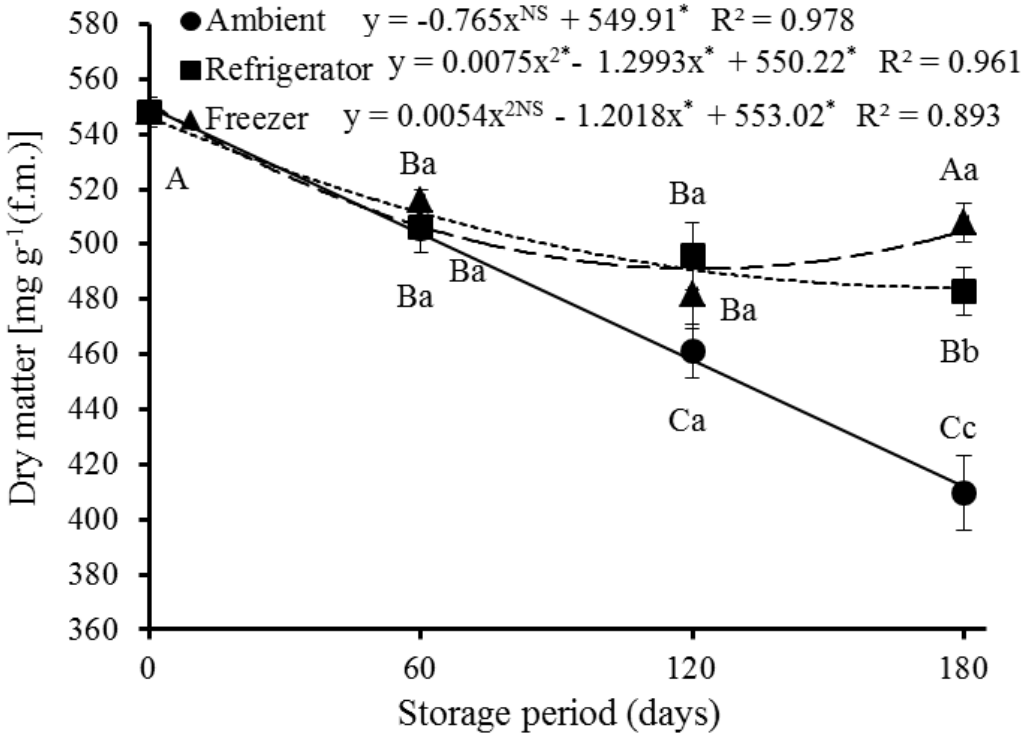

Figure 1. Dry matter during storage of *Araucaria angustifolia* seeds at ambient temperature (-3 to 30°C), refrigerator (5°C), and freezer (-18°C). Uppercase letters compare storage periods and lowercase letters compare storage conditions (Tukey's test, P ≤ 0.05). *Vertical bars* denote standard error of the mean. *Significant at 5% probability.

spectrophotometrically by Bradford method (1976) using bovine serum albumin as a standard (BSA 0 to 800 µg/ml, $R^2 = 0.9845$, y = 2078.7x – 29.82), in triplicate.

Soluble carbohydrates and starch were extracted through methodology described by McCready et al. (1950), using a pool containing megagametophytes from 10 seeds per replicate. 1 g of dry biomass was macerated in mortar and pestle with liquid nitrogen, followed by triple extraction with ethyl alcohol 80%. Supernatants were collected for quantification of soluble carbohydrates and residue was used for starch extraction by adding perchloric acid (52%). After filtering aliquots of soluble carbohydrates and starch in fiberglass filter, quantification was proceeded by colorimetric analysis using a spectrophotometer in range of 490 nm by phenol-sulfuric method (Dubois et al., 1956), with D-glucose as standard (Glucose 0 to 100 µg ml^{-1}, $R^2 = 0.9873$, y = 0.0214 x + 0.0839), in triplicate.

Experimental design and statistical analysis

Experiment was conducted in a completely randomized design, in split plot, with three storage conditions (ambient, refrigerator and freezer) and four storage periods (0, 60, 120 and 180 days). Analysis of regression and variance was performed, and test of means by Tukey test at 5% probability using statistical program SAS 2009 (SAS Institute Inc.). Total set of data of processed spectra was subjected to multivariate statistical analysis, by applying methods of principal components (PCA), using statistical package The Unscrambler 9.1 (CAMO Software Inc.).

RESULTS

Dry matter content

Dry matter content of freshly harvested seeds was 548 mg g^{-1}, with a reduction for all storage conditions. More pronounced discrepancies among storage conditions were detected after 120 days of storage, with a greater reduction in dry matter in seeds stored at ambient temperature (Figure 1).

Seeds germination

Freshly harvested seeds showed 92% of root protrusion (Figure 2). Regression analysis showed a significant decreasing tendency in germination percentage, especially for samples stored in freezer, for which there was complete loss of viability at 60 days of storage. Samples maintained at ambient temperature showed complete loss of viability at 180 days of storage.

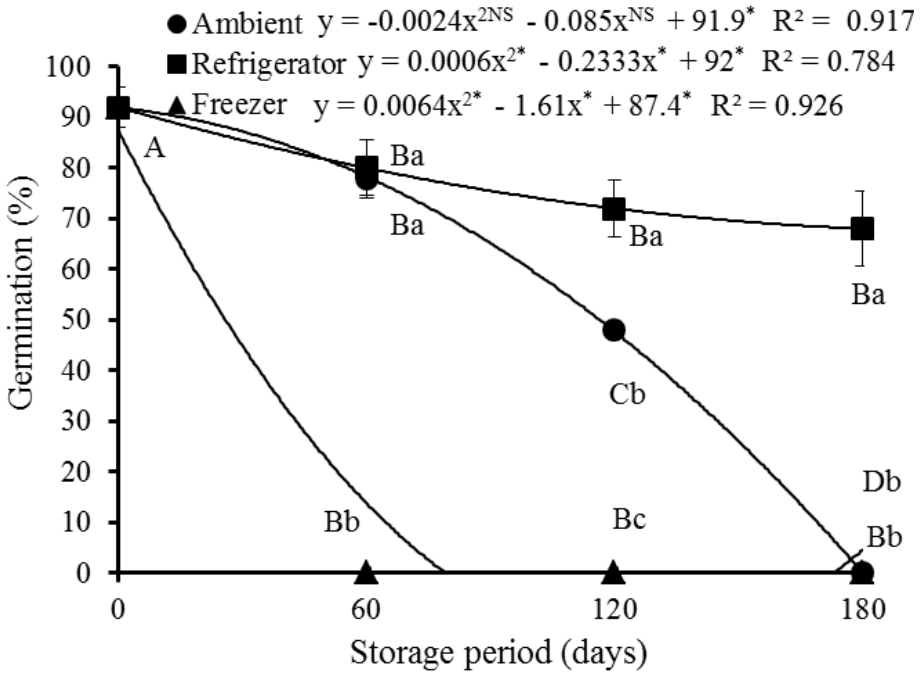

Figure 2. Germination during storage of *Araucaria angustifolia* seeds at ambient temperature (-3 to 30°C), refrigerator (5°C), and freezer (-18°C). Uppercase letters compare storage periods and lowercase letters compare storage conditions (Tukey's test, P ≤ 0.05). *Vertical bars* denote standard error of the mean. *Significant at 5% probability.

Refrigerator condition was superior in maintaining seed viability, showing 70% germination at 180 days of storage.

FTIR spectroscopy analyses

FTIR spectroscopy allows detection of 19 to 22 relevant peaks in spectral window between 3000 to 600 cm^{-1} (Figure 3). Bands with higher intensities for all samples were detected in spectral window 1200 to 800 cm^{-1}, which is associated with occurrence of typical carbohydrates signals (Cerná et al., 2003; Kuhnen et al., 2010). In this spectral region, bands are primarily due to axial deformation of links C-O, C-C, and C-O-C and the presence of COH groups (Schulz and Baranska, 2007; Kuhnen et al., 2010). Particularly, peaks were detected in band 1022 cm^{-1}, related to amylose, and 1016 cm^{-1}, related to amylopectin.

Protein constituents in *A. angustifolia* embryos were mainly observed by band in 1648 cm^{-1}, since region between 1650 and 1500 cm^{-1} resulted from axial deformations of C = O group and angular deformations of NH_2 group regarding the amines (Lambert et al., 2001; Schulz and Baranska, 2007; Kuhnen et al., 2010). Lipids constituent in *A. angustifolia* embryos were identified by presence of bands in 2926, 2856 and 1742 cm^{-1}. These metabolites are associated to axial deformation of functional group C = O typically found in fatty acids in 1740 and 1440 cm^{-1} (Silverstein, 1994; Schulz and Baranska, 2007), as well as signals between 3000 to 2800 cm^{-1}, related to axial and angular deformation of methyl group ($-CH_3$) and/or methylene (CH_2) (Lambert et al., 2001; Kuhnen et al., 2010).

Various signals in spectral range 900 to 690 cm^{-1} were observed in samples, suggesting the presence of compounds having aromatic rings in their structure, such as (poly)phenols, which may result from deformation of link = CH of aromatic compounds (Lambert et al., 2001). As for the bands observed in spectral window 1140 to 1150 cm^{-1}, they can represent the presence of terpenoids (Schulz and Baranska, 2007).

Principal components 1 (PC1) and 2 (PC2) revealed a clear discrimination of samples, being effective to explain 97% (96% explained by component PC1 and 1% by PC2) of variance in spectral data of FTIR (Figure 4).

Biochemical changes during storage

Protein content of embryos form freshly harvested seeds

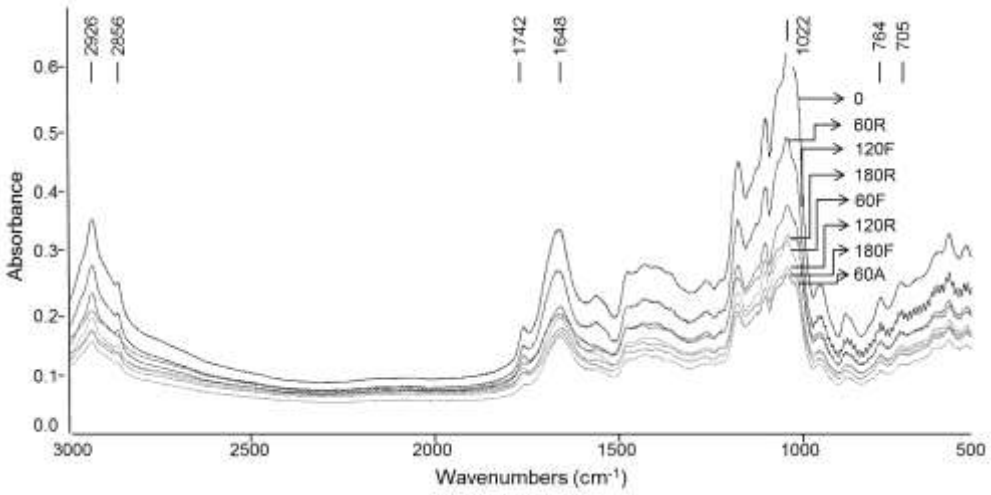

Figure 3. FTIR spectra (3000 – 600 cm^{-1}) of samples of *Araucaria angustifolia* embryos during storage period at ambient temperature (-3 to 30°C), refrigerator (5°C), and freezer (-18°C). 0 – freshly harvested; 60A – 60 days of storage without thermal control; 60R – 60 days of refrigerator storage; 60F – 60 days of freezer storage; 120R – 120 days of refrigerator storage; 120F – 120 days of freezer storage; 180R – 180 days of refrigerator storage; 180F –180 days of freezer storage.

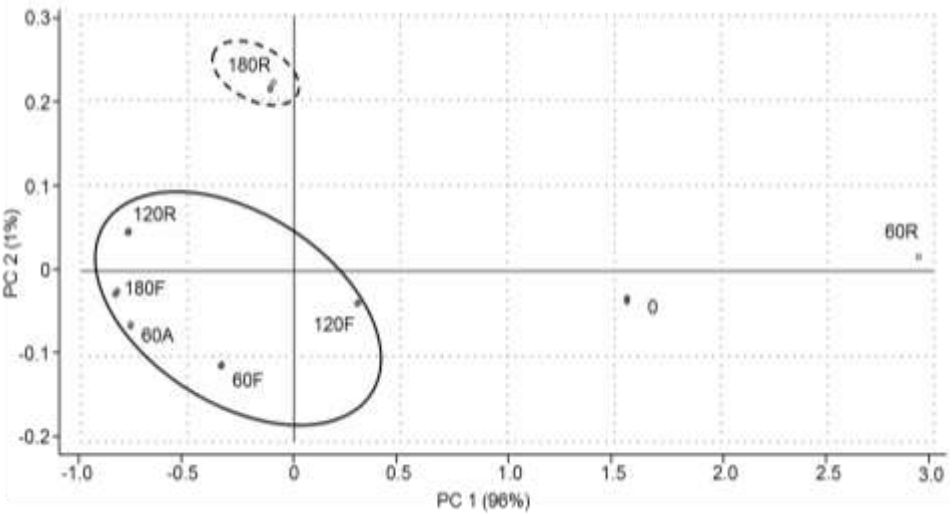

Figure 4. Principal component analysis scores scatter plot of FTIR dataset (3000 – 600 cm^{-1}) of *Araucaria angustifolia* embryos during storage period at ambient temperature (-3 to 30°C), refrigerator (5°C), and freezer (-18°C). 0 – freshly harvested; 60A – 60 days storage without thermal control; 60R – 60 days of refrigerator storage; 60F – 60 days of freezer storage; 120R – 120 days of refrigerator storage; 120F – 120 days of freezer storage; 180R – 180 days of refrigerator storage; 180F –180 days of freezer storage.

was 13.6 mg g^{-1}, which was significantly reduced over 180 days of storage at ambient (1.2 mg g^{-1}) and refrigerator (4.8 mg g^{-1}) (Figure 5). However, storage in freezer was efficient in maintaining soluble protein levels, which remain similar ($P \leq 0.05$) to freshly harvested samples until the end of experiment (180 days). Content of soluble carbohydrates in megagametophyte of freshly harvested seeds was 58 mg g^{-1}, and this amount remained stable ($P \leq 0.05$) up to 180 days of storage only for freezer condition (Figure 6A). At 180 days, soluble

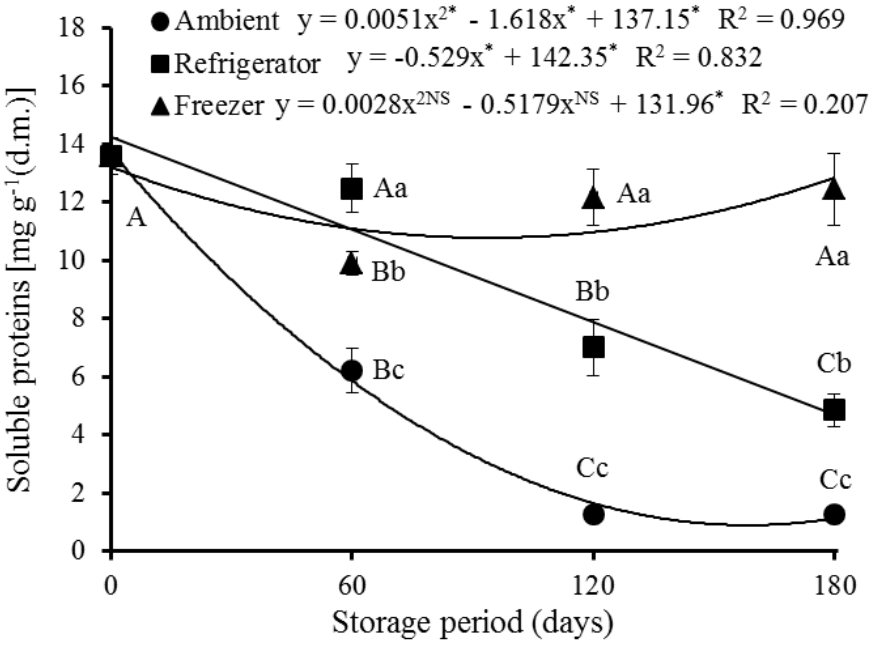

Figure 5. Soluble proteins content of *Araucaria angustifolia* embryos during storage period at ambient temperature (-3 to 30°C), refrigerator (5°C) and freezer (-18°C). Uppercase letters compare storage periods and lowercase letters compare storage conditions (Tukey's test, P ≤ 0.05). *Vertical bars* denote standard error of the mean. *Significant at 5% probability.

carbohydrates content of samples stored in freezer (47 mg g^{-1}) was similar (P ≤ 0.05) to that observed for refrigerator (40 mg g^{-1}). Freshly harvested seed showed 509 mg g^{-1} of starch (Figure 6B). At 180 days, only samples stored in refrigerator showed similar starch content (P ≤ 0.05) to that observed in freshly harvested samples and there was a significant reduction of 28% in starch content of samples stored in freezer for 180 days. For ambient condition, the megagametophyte tissue was fully consumed at 120 days, precluding analyses of soluble carbohydrates and starch; therefore, it is inferred that soluble carbohydrates and starch content of samples was 0 mg g^{-1} at 120 days and 180 days of storage at ambient condition.

DISCUSSION

Germination results showed refrigerator storage favored retention of seeds viability for 180 days, while storage in freezer leads to a rapid loss of cell viability since freezing causes embryos death (Garcia et al., 2014), and ambient condition favored a continuous decrease in viability over time. Lower temperatures such as those in refrigerator (5°C) contributes to viability maintenance, as observed by other authors, with 61% germination in *A. angustifollia* seeds stored under 4°C (Fowler et al., 1998), with low respiratory rates when stored at temperatures ranging from 2 to 10°C (Amarante et al., 2007).

Starch and lipids are among compounds stored in greater quantities in embryos of mature seeds of *A. angustifolia* (Farias-Soares et al., 2013), but the FTIR spectroscopy results demonstrated that proteinaceous compounds are, quantitatively as important as lipids, and phenolic constituents are also present in large quantities. Regardless of condition, storage resulted in changes in metabolic profile compared to freshly harvested samples. FTIR and chemometric analysis showed these changes resulted from structural differences conferred, especially by presence of carbohydrates represented by starch (1021 cm^{-1}), proteins (1649 cm^{-1}), and lipids (2930 cm^{-1}). Sample distribution along PC2 was responsible for explaining only a small part of sample variance, with a greater factor contribution of phenolic compounds of *A. angustifolia* embryos, represented by presence of signals at 971 cm^{-1} throughout experimental period. These and similar methods, including high-resolution nuclear magnetic resonance (NMR) spectroscopy provided a wealth of information on a variety of primary and secondary metabolites of conifer seeds (Terskikh et al., 2005).

Construction of a descriptive model based in principal

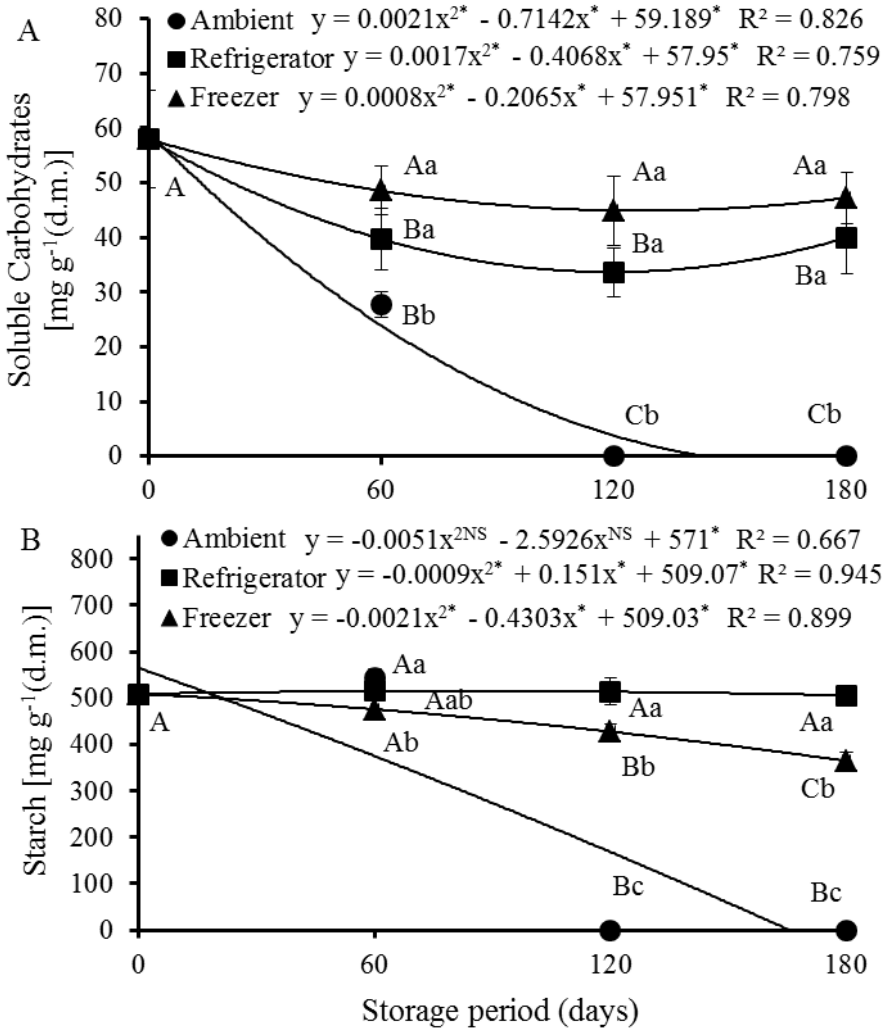

Figure 6. Content of soluble carbohydrates (A) and starch (B) of *Araucaria angustifolia* megagametophytes during storage period at ambient temperature (-3 to 30°C), refrigerator (5°C) and freezer (-18°C). Uppercase letters compare storage periods and lowercase letters compare storage conditions (Tukey's test, $P \leq 0.05$). *Vertical bars* denote standard error of the mean. *Significant at 5% probability.

components analyses allowed identification of profiles of greater metabolic similarity between storage periods and conditions. A standard for samples grouping in intermediate storage periods (60 and 120 days) was detected, indicating minor metabolic discrepancies. Such clustering suggests samples stored for 60 days at ambient temperature are similar, in metabolic composition level, to those samples stored in refrigerator for 120 days and in freezer for 180 days. In fact, further analysis demonstrated protein, carbohydrates and starch contents decreased, in first moment, for ambient samples; in a second moment, protein content decreased for refrigerator samples; and for freezer samples, there was no reduction of protein and carbohydrate contents during storage period, that is, these compounds were not deteriorated or neither hydrolyzed in a preparatory germination metabolism.

Soluble protein is accumulated in *A. angustifolia* embryos, especially in final stages of embryogenesis in embryonic axis region (Astarita et al., 2003; Silveira et al., 2008). However, during seed deterioration after harvest protein degradation occurs (McDonald, 1999; Murthy et al., 2003), which may impair early development of seedlings and subsequent field establishment. Except by freezer samples, whose death was caused by freezing, soluble proteins availability during storage seems to play an important role for embryonic viability maintenance, since the reduction of proteins levels (Figure 5)

followed same pattern as the reduction observed in seed germination (Figure 2).

A progressive decline in seed viability may also be caused by peroxidation of storage lipids due to the reduction of nutrient reserves, and also because of the generation of toxic products of peroxidation (Terskikh et al., 2008). Soluble carbohydrates are also essential to seed viability maintenance during storage, acting in soaking water mechanisms and in embryo protection against desiccation and pathogen attack (Barbedo and Marcos Filho, 1998). Although high, carbohydrates content in freshly harvested seeds was 32% and 20% lower than observed by Ramos and Souza (1991) and Piriz Carrillo et al. (2003), respectively, but chemical composition can vary as a function of factors such as genotype, maturity stage, climatic conditions of collection site, and nutrition of mother plant.

There was no degradation of starch in seeds stored in refrigerator (5°C), despite other authors have reported the reduction of 23 and 12% in starch content after storage of *A. angustifolia* seeds for a period of 180 days at temperature of 5 and 4°C, respectively (Ramos and Souza, 1991; Piriz Carrillo et al., 2003). But in seeds of forest species *Caesalpinia echinata* (brazilwood), both contents of soluble carbohydrates and starch decrease during storage (Hellmann et al., 2008). It has been reported that viability loss of *A. angustifolia* is accompanied by a decrease in starch content during artificial aging (Ramos and Carneiro, 1991) and natural aging in storage (Ramos and Souza, 1991). Starch is an important compound in both megagametophyte and embryo of *A. angustifolia* seeds, since this component is present in higher quantity (quantitative analysis) and because glycidyl components were most important for sample separation (chemometric analysis).

Changes observed in seeds reserve compounds directly reflected in dry matter content. In freshly harvested seeds, dry matter content was similar to that observed when seeds reach maturity (500 mg g^{-1}) (Astarita et al., 2003). As mentioned, ambient condition reflected earlier the changes in protein and carbohydrates (reduction at 60 days), and starch contents (reduction at 120 days), which were also reflected in a lower dry matter content shown at 180 days. These changes probably are associated to early germination events, when they occur in the beginning of reserve digestion and assimilation as energy for posterior embryonic development during germination process. On the other hand, storage in freezer proved to be more adequate to maintain protein and carbohydrates content of *A. angustifolia* seeds. This fact may be important for feeding purposes.

Seeds maintained in refrigerator showed a reduction in both protein content, carbohydrate content and germination during experimental period, suggesting an important positive relation between reserve availability and seed viability. However, after storage for 180 days at 5°C, some authors found no relation between reduction of viability (from 99% to 18% approximately), and protein content of seeds, which remained unchanged during storage (Ramos and Souza, 1991). Ultimately, results presented here demonstrated metabolic changes begin later during storage at controlled conditions (refrigerator and freezer) indicating that the higher the average temperature during storage, the higher speed of biochemical changes in both embryos and megagametophytes tissues of *A. angustifolia*.

In summary, analyses performed were effective to characterize the presence of primary (starch, proteins and lipids) and secondary metabolism compounds (phenolic) in *A. angustifolia* embryos. Changes in metabolic profile were reflected in seed viability, varying according to storage condition. Seed storage at -18°C (freezer) delayed hydrolysis of reserve metabolites after seed harvest, and this preservation of some compounds is vital for human as these seeds are edible, but this storage condition did not retain seed viability. Therefore, storage at 5°C (refrigerator) favored prolongation of seeds biochemical quality, minimizing damage to viability and proving to be a viable alternative to storing *A. angustifolia* seeds for 180 days. These results may aid further research aiming at characterizing other metabolic events that occur during deterioration of *A. angustifolia* seeds, such as those involving ultrastructural changes and consequences of cellular oxidative stress.

Conflict of interest

The authors have not declared any conflict of interest

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Gender gap and female workforce participation in agriculture in Andhra Pradesh, India

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Women's participation in the agricultural labour force (38.87 and 55.67%) in India and the State of Andhra Pradesh, India (Census of India, 2001) plays a distinctive role in earning a livelihood for the family. The objective of the study was to examine the pattern of women work force in agricultural activities in Andhra Pradesh (AP), India and is based on secondary data taken from the census of 2001 and 2011 and primary survey undertaken in six selected districts of Andhra Pradesh. The proportion of women agricultural labour is more than male labour in all the districts. With respect to gender gap, the participation gap has been narrowed but remuneration and advancement gap between male and female workers still exists. The OLS regression was employed to estimate the various factors which affect the female work force participation in Andhra Pradesh. At the district level a high inter district variation has been observed for the work force participation for men and women. With the emerging commercialization of agriculture and introduction of new technologies, capacity building of women workforce is important for achieving sustainable agricultural growth and improving the rural livelihood security.

Key words: Women's participation, agricultural labour, gender gap, livelihood security.

INTRODUCTION

Women are 48.5% of the general population of India and agricultural sector is the largest employer of women. According to official statistics (National Sample Survey 68th round), in the rural areas, 59% men work in agriculture, but the figures are 75% for women. Women's participation in agriculture has been growing relative to men who not only implies increased dependence of women on agriculture but also reiterates their crucial role in the sustainable growth and future of this sector. Mahapatra (2002) highlighted that women's economic productivity is a critical factor, as the dependence of the family on their contribution to household resources increases with the poverty status of the household. Valipour (2014, 2015) also used the important indices of rural population to total population and total economically active population in agriculture to total economically active population to estimate the values of area equipped for irrigation.

Agriculture is the main occupation and 66% of population is engaged in agriculture and related activities in Andhra Pradesh, India. Rice is the major food crop and staple food of the state. Other important crops

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are Jowar, Bajra, maize, ragi, small millets, pulses, tobacco, cotton and sugar cane. Women agricultural workers constitute a large majority of the work force in Andhra Pradesh, India. The main agricultural operations performed by women in paddy cultivation are transplanting, weeding harvesting, sowing, harvesting and threshing of other crops like sorghum, ground nut, cotton and maize. Except for ploughing all the agricultural work is carried out by women labour.

The movement of men out of agriculture has led to an increase in women's share of the agricultural workforce and an expansion of their role in the sector. However, with labour absorption in agriculture on the decline, particularly in terms of paid jobs, more than two thirds of women workers are self-employed, working as managers and helpers on the family farm without any remuneration. Those who continue to work as casual labour earn wages less than the statutory minimum. Women in agriculture face increasing responsibility for ensuring household food security under adverse economic conditions and an intensification of their work burden (Aruna, 2010).

Closing gender gaps is thus not only a matter of human rights and equity; it is also one of efficiency (Global Gender Gap Report, 2012). The Global Gender Gap Index examines the gap between men and women in four fundamental categories (sub indexes): economic participation and opportunity, educational attainment, health and survival and political empowerment. In the present study one variable each under first three categories of the sub indexes were analysed in terms of female work force participation, female literacy rate and sex ratio for the state of Andhra Pradesh.

The need for gender statistics in formulating policies and programmes can hardly be over-emphasized. To understand women's work force participation in agriculture and the gender gaps this paper analyses the data from the census reports of 2001 and 2011 with the following main objectives. The Census of India is a veritable mine of information on demographic, social and economic aspects of population. It is the only source of population characteristics at the lowest administrative levels; village in rural areas and ward in urban areas (Census of India, 2011).

Objectives

1. Understand the gender gap and trends and pattern of women's workforce participation in agriculture at the district level in Andhra Pradesh between 2001 and 2011.
2. Identify the determinants of female labour force participation in Andhra Pradesh.

METHODOLOGY

Sampling design

The present study is based on both secondary data taken from the census of 2001 and 2011 and primary survey undertaken in purposively selected six districts, Nalgonda, Mahbubnagar, Warangal, West Godavari, Guntur and Kurnool representing the three regions of Andhra Pradesh, namely Coastal, Rayalseema and Telangana having high participation of women agricultural labour especially in the rice sector. Data was collected from 420 farmers on labour requirement and availability especially for rice cultivation. The analysis of data from the 2001 and 2011 census was undertaken to gain an understanding of the increasing or decreasing trends of women agricultural workers and what would be its implications for the rice sector. The State Primary Census Abstract 2011, Figures at a Glance-census 2011 of the Directorate of Census Operations AP were primarily referred to arrive at the different male and female work participation rates used in the study.

The variables in the study have been defined and derived in the following manner:

1. Worker: Based on the definition of work in census 2011, a worker is a person who has participated in any economically productive activity with or without compensation or profit.
2. Work participation rate: Is defined as the number of workers per hundred population

Female Work Participation Rate and Male Work Participation Rate was worked out in the following manner:

$$\textbf{Percentcultivator} = \frac{\text{main cultivators} + \text{marginal cultivators}}{\text{Total workers(Male \& Female)}} \text{X } 100$$

$$\textbf{Percent agricultural labour} = \frac{\text{main agric. labour} + \text{marginal agricultural labourers}}{\text{Total workers(Male \& Female)}} \text{X } 100$$

$$\textbf{Percent Household industry} = \frac{\text{Main household worker} + \text{marginal household worker}}{\text{Total workers(Male \& Female)}} \text{X } 100$$

$$\textbf{Percent other worker} = \frac{\text{main other worker} + \text{marginal other worker}}{\text{Total workers(Male \& Female)}} \text{X } 100$$

3. Gender gap: The difference between the female – male participation was calculated to find the gap between the sexes.
4. Sex ratio: Defined as the number of females per 1000 males in a population.
5. % Scheduled caste population: Percent of scheduled caste persons to total population.
6. Gender gap index: Examines the gap between men and women in four fundamental categories (sub indexes): economic participation and opportunity, educational attainment, health and survival and political empowerment. In the present study one variable each under first three categories of the sub indexes were analysed in terms of female labour force participation, female literacy rate and sex ratio for the state of Andhra Pradesh.
7. Economic participation and opportunity: This sub index is captured through three concepts: the participation gap, the remuneration gap and the advancement gap. The participation gap is captured using the difference in labour force participation rates.
8. Educational attainment: In this sub index, the gap between women's and men's current access to education is captured through ratios of the female literacy rate to the male literacy rate
9. Health and survival: This sub index provides an overview of the differences between women's and men's health and uses the variable sex ratio at birth and political empowerment was not included in the present study.

In order to analyse the determinants of female labour force participation OLS regression was worked out. Sex ratio, female literacy rate, percent scheduled caste population and male work participation rate were the independent variables and female labour force participation was dependent variable. Time was taken as a

Table 1. Proportion of total workers, main workers and marginal workers in Andhra Pradesh 2011.

Total/male/female	Total workers	Main worker	Percentage	Marginal workers	Percentage
Total	3,94,22,906	3,30,37,378	83.80	63,85,528	16.20
Males	2,41,85,595	2,14,60,081	88.73	27,25,514	11.27
Females	1,52,37,311	1,15,77,297	**75.98**	36,60,014	**24.02**

Source: State Primary Census Abstract of AP-2011 (Anuradha ,2011).

Table 2. Work Participation Rate in Andhra Pradesh in 2001 and 2011.

Residence	Sex	2001	2011	Change
Total	Persons	45.79	46.61	+0.82
	Males	56.23	56.98	+0.75
	Females	35.11	36.16	+1.05

Source: Primary Census Abstract-2011, Directorate of Census Operations, Andhra Pradesh.

continuous dummy variable. Ordinary least square method (OLS) was employed because of its unique advantages/characteristics such as the possibility of negative and positive residuals getting cancelled can be avoided by using OLS. The regression line passes through the sample means and is as close as possible to the data points. The mean of the residuals is zero. The residuals are uncorrelated with the predicted Y and also uncorrelated with the observed values of independent variables.

The OLS model fitted was as follows:

$$Yi=\beta o+ \beta iXi+Dt+U$$

Where, Yi = FWFP; βo = Coefficient for the constant/intercept; Xi are the independent variables/regressors; βi = coefficients of the respective independent variables / regressors; Dt = 0 for 2001; Dt = 1 for 2011, and U = Constant variance disturbance term.

RESULTS AND DISCUSSION

Proportion of workers in AP

In AP according to 2001 census, the population of the state was 762.10 lakhs of which women were 376.82 lakh and it has increased to 846.65 lakh in 2011 with 421.55 lakh women (Census 2001 and 2011) and 66.6% population living in rural areas is depending on agriculture and allied activities. Table 1 shows the distribution of workers into main, marginal and total workers in AP. It can be observed that majority (83%) of the overall population and also the male (88%) and female (75%) fall in the main worker category. However the proportion of females is more in the marginal workers category as compared to males. Women agricultural workers constitute a large majority of the work force in AP. The main agricultural operations performed by women in paddy cultivation are transplanting, weeding harvesting, sowing, harvesting and threshing of other crops like sorghum, ground nut, cotton and maize. Except for ploughing all the agricultural work is carried out by women labour. The figures speak and indicate there is an increase in total women agricultural labour from 2001 to 2011 census year. It was 7179601 persons in 2001 which has increased to 8837732 persons according to 2011 census.

Work participation rate in Andhra Pradesh in 2001 and 2011

The findings in Table 2 show the rural female work force participation rates in AP in 2001 and 2011. The female work participation rate was 35.11 in 2001 and it is 36.16 in 2011 indicating an increase in 1.05% over the last decade which is twice as that of male work participation rate. This may be due to the change in the definition of work, which according to the 2011 census defines a worker as a person who has participated in any economically productive activity with or without compensation or profit and the work participation rate is defined as the number of workers per 100 population (Primary Census Abstract, 2011). The work participation rate for females has been showing an increasing trend. District wise work participation rate in AP (Table 3) indicated that Vizianagaram and Mahbubnagar recorded the highest work participation rate in 2001 with a slight fall in both the districts in 2011. Districts like Hyderabad, Vishakapatnam and Khammam recorded increase probably due to their commercial status.

Sex wise distribution of workers and percentage of cultivators, agricultural labour, household industry and other workers in India and AP in 2001 and 2011

The numbers of agricultural cultivators (Table 4) has gone down by 7.8 million, that is, from 103.6 million in

Table 3. Districts by work participation rate in Andhra Pradesh- 2001 and 2011.

District	WPR 2001	WPR 2011	Change
Adilabad	45.15	48.29	**3.14**
Nizamabad	49.44	49.43	-0.01
Karimnagar	49.02	49.70	0.68
Medak	48.45	47.55	-0.90
Hyderabad	29.24	35.84	**6.60**
Rangareddy	40.21	41.46	1.25
Mahbubnagar	51.89	51.38	-0.51
Nalgonda	49.10	49.92	0.83
Warangal	48.25	48.56	0.31
Khammam	48.25	50.41	2.16
Srikakulam	47.36	47.73	0.37
Vizianagaram	52.20	49.39	-2.81
Visakhapatnam	41.82	44.05	2.23
East Godavari	39.58	40.62	1.04
West Godavari	44.13	45.04	0.91
Krishna	43.97	45.36	1.38
Guntur	49.05	48.73	-0.33
Prakasam	50.26	50.05	-0.20
Sri Potti Sriramulu Nellore	45.41	44.36	-1.05
Y.S.R.	44.80	45.81	1.01
Kurnool	49.45	50.07	0.62
Anantapur	48.83	49.89	1.06
Chittoor	46.80	46.32	-0.48

Source: Primary Census Abstract-2011, Directorate of Census Operations, Andhra Pradesh.

Table 4. Percentage of workers in different occupational groups, 2001-2011 in India.

Residence	Category	2001	2011	Change
Workers (Main + Marginal)				
	Total workers	100.0	100.0	
	Cultivators	31.7	24.6	-7.1
All Areas	Ag. labourers	26.5	30.0	**+ 3.5**
	HHI workers	4.2	3.8	-0.4
	Other workers	37.6	41.6	+ 4.0

Primary Census Abstract, Census of India, 2011.

2001 to 95.8 million in 2011, that is, a decrease of 7.1%. At the same time the number of agricultural labourers has increased by 3.5% only. The neglect of the agriculture sector and the limited employment opportunities it has are further shown through the decrease in the number of total workers by 3.6% in agriculture and allied activities. Another interesting fact that comes to light from this analysis is that most of the agricultural labourers who are classed as 'marginal workers,' or people getting work for less than six months in a year, are males whereas about 40% of the female agricultural workers are classed as 'main workers' who get more than six months of work in a year. These figures reiterate the fact of feminization of agriculture in India. Women are mainly wage labour they are also as main workers, marginal workers in agriculture (Vepa, 2005). This pattern is also reflected in the overall employment trend where the total number of male workers getting employment for more than six months in a year has declined by five percent between 2001 and 2011. In sharp contrast, the overall pattern of female work is that the number of female workers getting employment for more than six months a year has gone up by 2.3%. Thus the move towards the expansion of the informal sector is gendered in character.

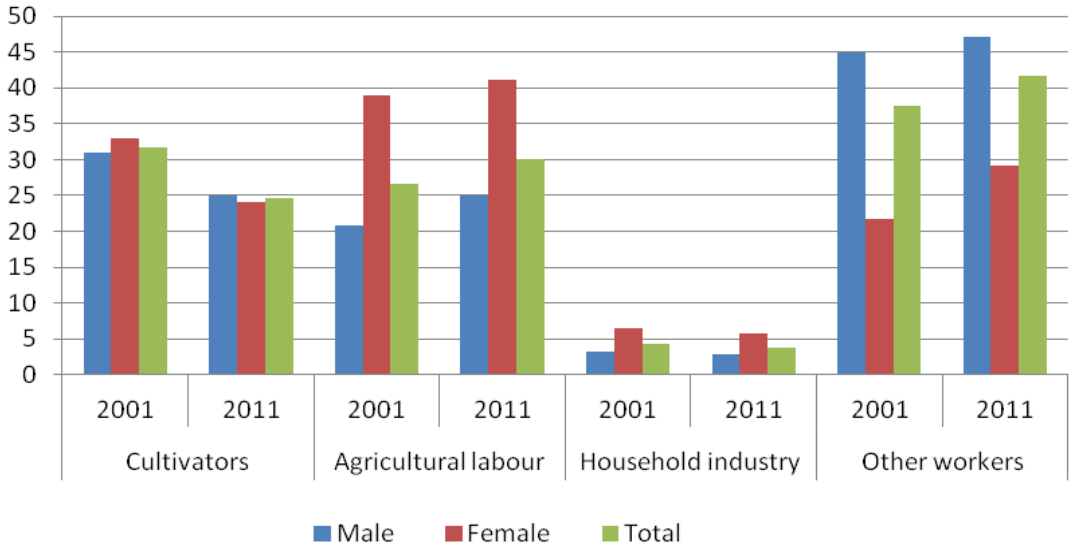

Figure 1. Sex wise distribution of workers and percentage of cultivators, agricultural labour, household industry workers and other workers in India during 2001 and 2011 census.

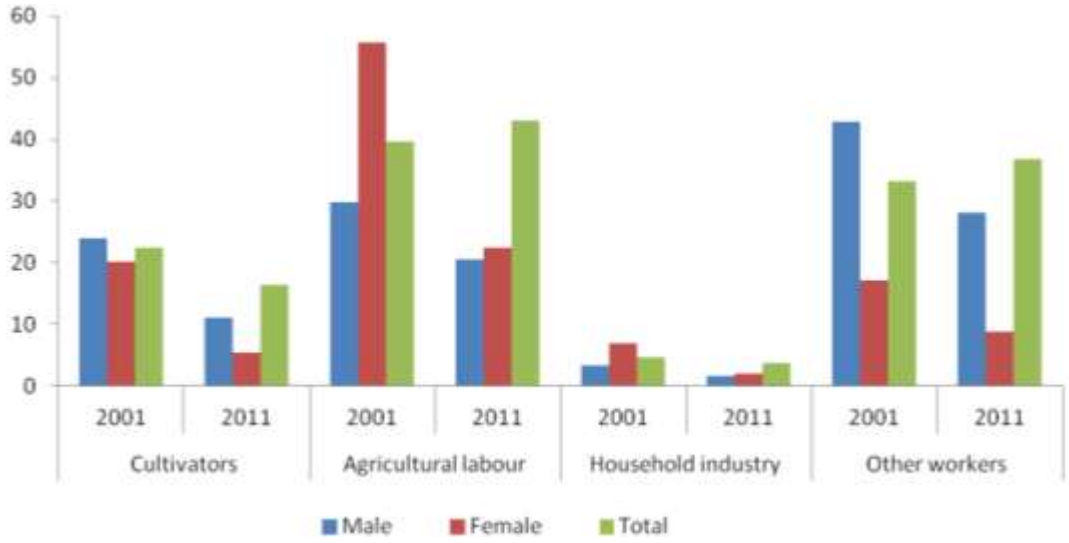

Figure 2. Sex wise distribution of workers and percentage of cultivators, agricultural labour, household industry workers and other workers in AP during 2001 and 2011 census.

From Figure 2, we can observe that the proportion of male cultivators in AP in 2001 was 24.01% and it has decreased to 11.05% in 2011 and female cultivators in 2001 were 20.08% and it is 5.41% in 2011. It shows that the proportion of both male and female cultivators has decreased in 2011. The female agricultural labour which was 55.67% in 2001 has decreased to 22.42% in 2011. The reduction in the women agricultural labour force is consistent with the overall reduction in the agricultural work between the census periods of 2001 and 2011. There is a marked decline in the cultivators and agricultural labour category of workers for both males and females. This is in conformity with the fact that India is witnessing the phenomenon of fewer farmers' every day (Sainath, 2013). It can be observed from the table that there is a shift from cultivators to agricultural labour in AP. This shift at all India level is 24.60 in 2011 from 31.65 in 2001 (Figure 1). An increase in the workers in the other category can be observed both at all India and AP level from 2001 to 2011 census year which is not a healthy sign for an agrarian country like India.

Table 5. Sex wise distribution of workers and percentage of cultivators, agricultural labour, household and industry workers and other workers in selected Districts of AP during 2011 census.

Districts	Cultivators		Agricultural labour		Household, industry		Others	
	Male	Female	Male	Female	Male	Female	Male	Female
Guntur	14.99	9.16	39.64	69.85	1.96	2.03	43.39	12.34
Kurnool	17.65	12.19	40.29	65.66	2.55	3.59	39.50	18.55
Warangal	26.58	19.63	30.58	62.32	2.35	5.27	40.47	15.23
Mahbubnagar	31.40	22.39	32.27	59.76	2.56	3.05	33.77	14.79
Nalgonda	22.48	13.80	35.41	67.61	2.62	2.55	39.48	16.03
West Godavari	11.79	2.42	52.68	74.94	1.58	2.59	33.95	20.04

Calculated from State Primary Census Abstract-2011.

Sex wise distribution of workers and percentage of cultivators, agricultural labour, household industry and other workers in selected districts of AP in 2011

The proportion of female cultivators is less than males in all the districts of the study area the probable reason may be that land is still in the names of the male member of the household. The best performing district for female cultivators is Mahbubnagar with 22.39%. The percentage of female agricultural labour is higher than that of male agricultural labour in all the districts of the study area. For men agriculture is not the only avenue for wage earning and other casual work provides more wages than agriculture, therefore they seek work as construction labour, and other such skilled and unskilled work. Whereas women have the responsibility of family care and therefore seek work close to their homes and thus continue to work as agricultural labour. The percentage of male workers in household industry is less than the females in all the districts of the study area which is in contrast for the other workers category where males outnumber females in all the districts. The reasons that can be attributed are the casualisation of the workforce and men are still considered as the bread winners of the family so their participation in wage earning is high. The drop in agricultural employment shows that the agricultural workers have been compelled to seek work in the casual labour market (Archana, 2013).

From the findings in Table 5 we can infer that women form the major agricultural labour work force in all the selected districts of the study area. Moreover if we combine the percentage of women agricultural labour and the cultivators they constitute about 77 to 82% of the agricultural work force where as men constitute 54 to 64%. The movement of men out of agriculture as reflected in their higher participation 33 to 43% in the other category of workers in all the districts of the study area probably has led to an increase in women's share of the agricultural workforce and an expansion of their role in the sector. Women agricultural workers are finding it harder to shift out of agriculture than men, and their stake is increasing in a sector that is riddled with adverse economic conditions and where they have little rights, authority, access to or control of resources required for enhancing production and household income (Aruna, 2010).

District wise female and male agricultural labour and gender gap in AP in 2001 and 2011

From the Table 6 it can be seen that among all the districts of AP, West Godavari recorded the highest work participation rate for females 74.72 in 2001 and 74.94 in 2011 followed by Krishna 71.61 in 2001 and Khammam 72.89 in 2011. The overall participation of women as agricultural labour in AP is 53.34 and 58% compared to 46.65 and 33.61 for males with a female male gender gap of 6.69 and 24.39% in 2001 and 2011 respectively. It can be seen that agricultural work is wholly dependent on the services of the female labour force. Similarly, most of the districts of AP have a high female agricultural labour force participation ranging from 33 to 74% with only six districts showing a percentage below 40.

From the findings in Table 6, we can observe a wide, 18 to 35% female to male gender gap in agricultural labour force in all the districts reiterating the fact that women make up a considerable work force in agriculture in AP. An analysis was undertaken in the selected districts for understanding the labour availability for rice sector and data was collected from 420 farmers from six major rice growing districts of Andhra Pradesh representing all the three Coastal, Rayalseema and Telangana regions. Farmers' in the study area reported a high dependence on hired women labour for activities like transplanting, weeding and harvesting. Though the figures in the table indicate a high availability of women labour, but certain factors like competing demands for labour in rice cultivation and cotton and of late the availability of work under MGNREGA scheme there is scarcity of labour being faced by the rice cultivators. This phenomenon has provided a better bargaining power to the women agricultural labour with serious repercussions for the rice cultivators.

Table 6. District wise Female and Male Agricultural labour and Gender gap in AP in 2001 and 2011.

District	Work participation rate of agricultural labour(Main +Marginal)					
	2001			2011		
	Female	Male	Gap	Female	Male	Gap
Adilabad	42.23	22.40	19.83	47.23	28.35	18.88
Nizamabad	33.84	26.28	7.56	38.71	32.88	5.83
Karimnagar	43.91	25.11	18.80	50.11	32.62	17.49
Medak	50.85	27.84	23.01	52.45	30.33	22.12
Hyderabad	1.27	0.49	0.78	2.25	13.97	-11.72
Rangareddy	39.45	12.18	27.27	28.38	9.96	18.42
Mahbubnagar	59.53	28.99	30.54	59.76	32.27	27.49
Nalgonda	61.22	27.60	33.62	67.61	35.41	32.20
Warangal	56.09	25.61	30.48	62.32	30.58	31.74
Khammam	67.50	36.71	30.79	72.89	45.08	27.81
Srikakulam	61.27	36.05	25.22	69.35	44.04	25.31
Vizianagaram	54.15	29.60	24.55	62.61	37.91	24.7
Visakhapatnam	39.81	19.57	20.24	44.40	23.40	20.64
East Godavari	66.34	45.37	20.97	66.66	48.96	17.70
West Godavari	74.72	48.31	26.41	74.94	52.68	22.26
Krishna	71.61	35.75	35.86	67.65	39.09	28.56
Guntur	66.99	37.36	29.63	69.85	39.64	30.21
Prakasam	58.78	32.99	25.79	69.53	39.97	29.56
Sri Potti Sriramulu Nellore	64.69	33.83	30.86	67.66	36.94	30.72
Y.S.R.	57.49	28.62	28.87	59.29	30.10	29.19
Kurnool	62.27	34.15	28.12	65.66	40.29	25.37
Anantapur	54.50	26.80	27.70	58.62	32.63	25.99
Chittoor	48.61	28.30	20.31	51.19	31.09	20.10
AP	53.34	46.65	6.69	58.00	33.61	24.39

Calculated from State Primary Census Abstract-2011.

The findings in Table 7 indicate that female work participation is higher than males in both the census years. Moreover there is substantial improvement in the socio-economic factors like female sex ratio and female literacy rate which is a good indicator towards the gender equality in these factors. Though the participation gap has been narrowed but it should not mislead one to believe that all is well with women agricultural workers as a wide remuneration (wage) gap exists between males and females both in agricultural and non-agricultural wages. From the primary survey in the selected districts a wide wage differential was reported by women labour where the rates for men were as high as Rs.500 per day while the highest being paid to women for transplanting rice was Rs.300 per day. In the rural areas, wages earned per day by a regular wage/salaried employee is Rs 322 for men and Rs 202 for women (Kumar, 2013).

The male-female disparity in wages has widened and the disparities continue to be highest for operations in which women specialize (Aruna, 2010). The advancement gap for women workers has not improved due to the fact that the movement of men out of agriculture has led to an increase in women's share of the agricultural workforce and an expansion of their role in the sector. However, with labour absorption in agriculture on the decline, particularly in terms of paid jobs, more than two thirds of women workers are self-employed, working as managers and helpers on the family farm without any remuneration.

Determinants of female labour participation

In the agricultural sector, there is a negative relationship between literacy and rural female labour participation as literacy enhances their employability and aspirations for better jobs and to shift from agriculture to non-farm work. The factors like sex ratio, percentage of male agricultural workers to total agricultural workers, percent of scheduled caste population and female literacy percentage are expected to have a direct effect on female rural work participation. To study the relationship between rural work participation rate and the socio-economic factors the OLS regression was worked out.

Table 7. Gender Gaps in work participation and selected socio-economic indicators in Andhra Pradesh during 2001 and 2011.

Districts	2001		2011		2001	2011	2001	2011	2001	2011
	MWPR	FWPR	MWPR	FWPR	Sex ratio	Sex ratio	Female literacy rate	Female literacy rate	%SC Population	%SC Population
Adilabad	22.40	42.23	28.35	47.23	989	1002.78	40.30	51.31	18.54	17.82
Nizamabad	26.28	33.84	32.88	38.71	1017	1038.08	39.48	51.54	14.84	14.54
Karimnagar	25.11	43.91	32.62	50.11	998	1009.27	42.75	54.79	18.62	18.8
Medak	27.84	50.85	30.33	52.45	974	989.17	38.66	51.37	17.58	17.73
Hyderabad	0.49	1.27	13.97	2.25	933	942.60	73.50	79.35	8.02	6.29
Rangareddy	12.18	39.45	9.96	28.38	944	955.33	56.49	69.4	14.55	12.31
Mahbubnagar	28.99	59.53	32.27	59.76	972	975.41	31.89	44.72	17.1	17.49
Nalgonda	27.60	61.22	35.41	67.61	966	981.52	44.68	54.19	17.73	18.27
Warangal	25.61	56.09	30.58	62.32	973	994.41	45.09	55.69	16.99	17.54
Khammam	36.71	67.50	45.08	72.89	975	1010.30	47.44	57.44	16.55	16.55
Srikakulam	36.05	61.27	44.04	69.35	1014	1013.88	43.68	52.08	9.05	9.46
Vizianagaram	29.60	54.15	37.91	62.61	1009	1016.38	39.91	49.87	10.58	10.57
Visakhapatnam	19.57	39.81	23.4	44.4	985	1002.97	50.12	59.34	7.6	7.68
East Godavari	45.37	66.34	48.96	66.66	993	1004.94	60.94	67.52	17.99	18.34
West Godavari	48.31	74.72	52.68	74.94	991	1004.28	68.99	71.36	19.17	20.62
Krishna	35.75	71.61	39.09	67.65	978	996.64	63.19	69.18	17.83	19.28
Guntur	37.36	66.99	39.64	69.85	984	1002.85	53.74	60.09	18.32	19.59
Prakasam	32.99	58.78	39.97	69.53	971	980.90	45.08	53.11	21.29	23.19
Sri Potti Sriramulu Nellore	33.83	64.69	36.94	67.66	984	986.32	56.38	61.99	22.00	22.49
Y.S.R.	28.62	57.49	30.1	59.29	974	983.66	49.54	56.77	15.74	16.16
Kurnool	34.15	62.27	40.29	65.66	965	983.52	40.03	49.78	17.81	18.21
Anantapur	26.80	54.50	32.63	58.62	958	977.46	43.34	53.97	14.14	14.29
Chittoor	28.30	48.61	31.09	51.19	982	1001.66	55.78	63.28	18.75	18.82

Calculated from State Primary Census Abstract-2011.

The relationship between the female literacy rate and female labour participation is negative. It is clear that that the female labour participation is affected by literacy and it is found to be significant at 0.01% level of significance with a P value of 0.002184 (Table 8). It means that higher the level of education, lower the level of women's participation in agriculture. Similar findings have been reported by Mazumdar and Guruswamy (2006), Kaur and Kaur (2012) and Shilen (2012).

Another variable, which is considered as the determinant of Female Labour Force Participation rate is the sex ratio which was found to be significant at 0.01% level of significance. The relationship between sex ratio and female labour force participation rate is negative and significant with a P value of 0.017966 at 0.05% level of significance. This means to say that, the districts with higher sex ratio have fewer women available to join labour force and low female participation in economic activities.

Male work participation rate is the important variable included in the model to capture the inter district variations in female labour force

Table 8. OLS estimation of regression equation.

Variables	Coefficients	t-Ratio	p-Values
Constant	177.3358	2.6196	0.0124**
FL	-0.3393	-2.9204	0.0057*
SR	-0.1610	-2.3743	0.0225**
%SC	0.4481	1.4908	0.1439
MWFP	1.4958	9.8426	3.0457E-12*
Dummy	0.6716	0.2707	0.7880
Adjusted R square	0.8230		
F-statistics	42.86		
p-value (t)	4.96E-15		

**0.05 %Level of significance; *0.01%Level of significance.

participation in Andhra Pradesh. The sign of co-efficient of variable percent scheduled caste population is positive, which implies that higher workforce participation of scheduled caste population is more likely to bring about high level of female workforce. Earlier studies have indicated that the scheduled caste women workers have a significantly higher odds ratio of being an agricultural labourer. Similarly, in the districts selected for the study the proportion of scheduled caste population is high (20.62%) especially in West Godavari district which has the highest percentage of women agricultural labour (74.94%).

The adjusted R for the OLS model fitted for the study was found to be 0.8275. The equation is found to be a good fit as it explains as much as 82% variation in rural female labour participation. However among the explanatory variables, sex ratio, female literacy rate and percent Scheduled Caste population were found to be statistically significant.

Conclusion

In the present study it was observed that the proportion of both cultivators and agricultural labour has fallen for males and females in 2011. The proportion of women agricultural labour is higher than males in all the selected districts of the study area.

One of the reasons could be that more males have moved out of the agricultural labour force but women still tend to be employed as wage labour in agricultural activities. It is imperative therefore, to provide technical knowledge and skills to build capacity of women agricultural labour to harness their potential to contribute towards sustainable agricultural growth. The variables like sex ratio, female literacy rate were found to be negative and significantly correlated with female work participation rate whereas percent scheduled caste population was positive indicating that the presence of a large population of scheduled caste provides more women to the work force.

Strategies for improving position of women labour

1. The generation of productive and gainful employment to absorb our growing women labour force must form a critical element in the strategy for achieving inclusive growth,
2. In order to promote gender equity, steps have to be taken to increase women's participation in the labour force with necessary skill development, labour policies and also the social security framework,
3. Giving women farmers' equal access to equipment and services such as seeds, tools, credit and land will help in achieving sustainable agricultural growth,
4. Labor demands in agriculture are high and competing for sowing, transplanting and harvesting, Women Self-Help Groups as contractual labor could be trained and promoted to provide labor for peak activities.

Conflict of interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Allelopathic effect of irrigation with different concentrations of leaf extracts of *Jatropha curcas* L. on growth *Brassica oleracea*

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The competition for sunlight, nutrients or space makes many plants from releasing toxins that can harm the growth and development of competing plants. This work aims to measure the allelopathic effect of the physic nut leaf extract on the cabbage plantation growth. The experiment was conducted in the Missal city, state of Parana, Brazil. It was used 6 different concentrations of extract *Jatropha*. curcas *L.*, as follow: 0, 5, 10, 20, 40, 80%. After 30 days of cultivation it was performed analysis of the following parameters of the crop development: Stalk diameter, stalk length, leaf area, root length, fresh and dry matter of root, fresh and dry matter of air portion, and the evaluated parameters varied in accordance with different levels of *J. curcas* extract.

Key words: Purging nut, alellochemicals, allelopathy, foliar extracts, irrigation.

INTRODUCTION

Allelopathy term was used for the first time in 1937 by Hans Molisch, and it was defined as a malefic or benefic influence of a chemical substance released by plants or microorganisms named alellochemicals. The most part of them come from a secondary metabolism of the plant working against microorganisms, virus, insects and other pathogens and predators action in order to inhibit them or to stimulate the growth or development of plants, and they can be released from leaves, root or by the decomposition of plant remains (Ferreira and Aquila, 2000).

The competition between one plant and another usually happens by a contest for limited resources as light, water and nutrients. Regarding to allelopathy it can be considered a strategy in an ecological competition because it concerns of a toxic effect of substances produced by other plants. Through this mechanism, a plant may interfere in the growth of another. However, the allelopathy is also known as an alternative to use of agrochemicals (Moreira et al., 2011).

Regarding to cabbage (*Brassica oleracea* capitata var.) it is Brassica *oleracea* subspecie, Capitata group that is

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composed by the most used vegetables in human feed. It is a biannual and herbaceous plant that belongs to the Brassicaceae family. It has rounded and waxy leaves, and they create a compact “head”. With time, it was obtained adapted cultivars in different temperatures leading to an increase in the plantation and harvest period (Filgueira, 2007).

The cabbage cultivation, as others herbaceous, requires a high nitrogen fertilizer level in its cycle that is in a short period. After the harvest, a few crop residue remains at cultivation local, leaving the soil with a lower amount of nutrients available, and it forces the producers to use nitrogen fertilizers, which has a high cost, and leave the producer depending on the industry (Zotarelli, 2000).

Physic nut (*Jatropha curcas L*.) is a plant that belongs to the Euphorbia family. This specie is well known by its high oil productivity that may be used to produce biodiesel. It is native from South America, but it is being explored in Central America, India and Africa too. The physic nut cultivation may produce about 2 tons of oil per hectare in regions of sandy and not very fertile soils where the weather is unfavorable for the most part of the plantations, and it is considered an excellent option to familiar agriculture (Saturnino, 2005).

Silva et al. (2012) reported that the aqueous extract of *J. curcas* root generates a allelopathic effect on some crops, showing the presence of chemical substances that may influence the growth and development of certain plants, and it may cause some positive or negative effects on the germination time and average speed and the maximum length of the root, and it can be observed a phytotoxicity of its residues on soil, and the most part of the residues come from the decomposition of leaf tissue (Wang et al., 2009).

As a function of what have been told, the main purpose of this work is to evaluate the allelopathic effect of the leaf tissue of *J. curcas* on the growth and development of *B. oleracea* capitata variety crop, and to analyze the following parameters: Stalk diameter, stalk length, leaf area, root length, fresh and dry matter of root and fresh and dry matter of air portion.

MATERIALS AND METHODS

The present study was performed in the Missal city, state of Parana, at 25º05’29” of latitude south and 54º14’52” of longitude west and 317 m of altitude. The date of the study was April 28 to May 27 of 2013. The weather is mesothermal humid subtropical. Summer is hot with a tendency of concentrated rainfall and the average temperature is 22ºC. Winter has not frequent frost and its average temperature is 18ºC. There is not a completely dry season. The annual average precipitation index is 1.788 mm (KAEFER, 2007).

The plantation was performed in an expanded polystyrene tray, specific to the vegetables seedlings production, being composed by a total of 200 cells, with a system of 10 × 20 cells, each one with a area of 14 cm² and a depth of 5.5 cm. The study was conducted in a greenhouse. The soil type is Red Hapludox.

The sowing in the tray was performed at a depth of 5 mm from the surface of soil. The treatment with substratum was performed starting at the first day of sowing, in randomized blocks. It was evaluated 6 different levels of physic nut leaf extract in concentrations of 0, 5, 10, 20, 40 and 80%. The sprinkling was performed with a manual sprinkler in three equal parts per day using a volume of 5 ml per cell, totalizing 100 ml per day for the period of 30 days till the harvest.

To obtain the leaf extract it was performed a crush of 200 g of leaf tissue of physic nut from the experimental field of the University, Cascavel campus, in 1 L of distilled water using a blender, and then filtering the material using a 40 mesh sieve that results in the crude extract. This was diluted again in distilled water to obtain different concentration ranges: 0, 5, 10, 20, 40 and 80%. The stock solution extract was stored in recipient 2 L, and refrigerated at 5ºC.

To perform the analysis, it was withdrawn the most representative plants of each treatment and the analysis was carried out right after the plant harvest, in order to preserve its characteristics. The analyzed parameters were: Stalk diameter, stalk length, root length, leaf area, fresh and dry matter of root, fresh and dry matter of air portion.

A caliper rule was used to measure the stalk diameter, stalk length and root length. The leaf area was estimated using graph paper. To measure the fresh matter of the root and of air portion it was used analytical balance with a precision of 0,0001 g. To analyze the dry matter of the root and of the air portion, they were placed in a industrial oven at 65ºC and they were keep in there till they do not change their weight. Then it was measured again its weight in an analytical balance to obtain the dry matter mass.

The statistical analysis of data (ANOVA) was performed using the software ASSISTAT version 7.6 beta. It was verified the representativeness of the data, it was calculated the average, the variation coefficient and regression at 5% of probability.

RESULTS AND DISCUSSION

It can be observed in Figure 1 that the increase of the aqueous extract of *J. curcas* concentration influenced significantly ($p < 0.01$) the stalk diameter, the root length, the stalk length, the leaf area, the dry and fresh matter of the root and the dry and fresh matter of the seedling area, in a linear decreasing way.

It can be observed that the stalk diameter (Figure 1A) adjusted linearly in a decreasing way, indicating a negative effect of the extract of *J. curcas*. The root length (Figure 1B) also decreased as function of the concentration. Similar results were found by Lemos et al. (2009), in a work carried out with aqueous extract of *J. curcas*. The authors verified that the concentration inhibited the root development in lettuce seedlings, with morphologic changes in the root. In a study carried out by Pillati and Boiago (2012) using root extract of *J. curcas* it can be also observed a negative allelopathic effect to the root growth *Brassicanapus L.* However, contradictory results were observed by Sanderson et al. (2013) in lettuce, but with lower concentrations (0, 1, 5, 10 and 15%) than in this study.

Reichel et al. (2013) verified that aqueous extract of *J. curcas* in concentrations of 20, 25, 30 and 35% stimulated the root growth in the wheat plantation. Abugre and Sam (2010) observed an inhibition of the

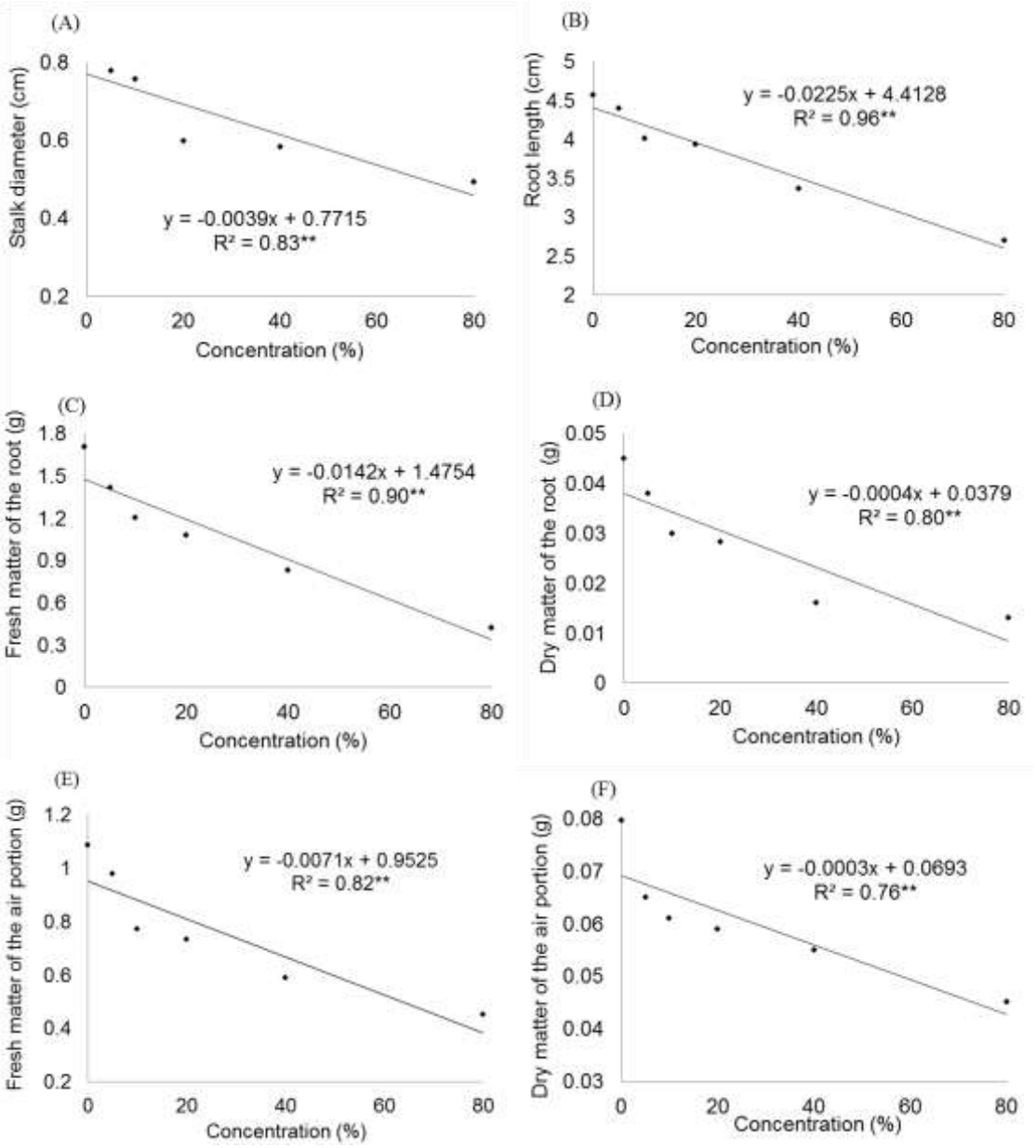

Figure 1. Stalk diameter (A); Root length (B); Fresh matter of the root (C); Dry matter of the root (D); Fresh matter of the air portion (E); Dry matter of the air portion (F). ** = significant at 1% of probability.

seedlings growth of *Z. mays* when they were submitted to high temperatures of *J. curcas* root extract. Bonamigo et al. (2009) reported an allelopathic effect of root aqueous extract on the early development of the soybean and canola. Abugre and Sam (2011) in a research with aqueous extract of J. curcas observed that the *J. curcas* specie was the one that most inhibited the okra seed germination (*Abelmoschus esculentus (L.) Moench).*

The fresh and dry matter of the seedling root (Figure 1C and D) suffered negative interference as a function of the concentrations. Rejila and Vijayakumar (2011) in a study performed with leaf extract of *J. curcas* on the *Capsicum annum L.* crop verified a significant reduction on the root development. Wang et al. (2009) reported in their studies an allelopathic effect of the *J. curcas* leaves on the *Tagetes erecta L*. seedlings development.

Regarding to the fresh and dry matter of the seedling air portion (Figure 1E and F) it can be observed that the *J. curcas* concentrations lead to an allelopathic effect. Similar effects were observed by Abugre and Sam (2010) with aqueous extract of root and leaves of the physic nut on the *Phaseolus vulgaris* crop. Reichel et al. (2013) observed in a study with extract of physic nut leaves (*J. curcas*) on the early development of wheat (*Triticum*

aestivum L.), with concentrations of (5, 10, 15, 20, 25, 30 and 35%), an allelopathic inhibition.

Conclusion

The application of aqueous extract of *J. curcas* leaf tissue showed a negative effect on the cabbage crop, with a reduction in the root length, stalk diameter, fresh and dry matter of the air portion and fresh and dry matter of the root as a function of the concentrations.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Characterization of farming systems in Jammu region of J&K State and its policy implications

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Farming systems of households in the Jammu region of Jammu and Kashmir State have been analyzed based on the primary data collected through a total sample of 450 farmers in 2010-2011. The cereal based farming system and livestock based farming system has been found mostly in the study area except in Rajouri district where only cereal based farming system was predominant. Livestock and cereals only have been found to be the main sources of farm income in all the districts, whereas maximum contribution to their income was from non-farm. The study has indicated that credit has no impact on farm income as none of the sample farmers has taken credit from any sources, whether it is institutional or non-institutional sources. It was also observed that cross-bred breeding programme has not marked headway in the sample area. As far as resource use efficiency was concerned, Cobb-Douglas production was used and it was observed that the elasticity coefficient was highly significant for area under cereals (AUC) in Reasi and Doda districts whereas for area under other crops (AOTH) it was found to be highly significant in Kathua and Doda districts. Doda district was found highly significant for both DA and EI also.

Key words: Farming system, livestock, cereal.

INTRODUCTION

India accounts for some 2.4% of the world's landmass but is home to about 17.52% of the global population (Anonymous, 2011). The Indian economy is predominantly agrarian and agriculture is a primary source of livelihood providing employment directly or indirectly to 58% of its population. Due to the rapid increase in the population and the decrease of agricultural land, no single farm enterprise is likely to be able to sustain the small and marginal farmers without resorting to integrated farming systems for the generation of adequate income and gainful employment year round (Mahapatra, 1994). The declining trend in size of average area operational holding from 2.28 ha in 1970-1971 to 1.33 ha during 2000-2001 and 1.23 ha in 2005-2006 poses a serious challenge to the sustainability and profitability of farming (Anonymous, 2012). In view of the decline in per capita availability of land from 0.5 ha in 1950-1951 to 0.15 ha by the turn of the century and a projected further decline to less than 0.1 ha by 2020, it is imperative to develop strategies and agricultural

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technologies that enable adequate employment and income generation, especially for small and marginal farmers who constitute more than 80% of the farming community (Jha, 2003). To meet the multiple objectives of poverty reduction, food security with improved productivity, reduced income imbalance between agricultural labourer and urban factory worker, competiveness and sustainability, several researchers have recommended the farming system approach to research and development. According to National Commission on Farmers (2005), introduction of appropriate farming systems have been proposed as one of the approaches to achieve better growth in agriculture and livelihood.

In Jammu and Kashmir State, the share of agriculture and allied sectors in the Gross State Domestic Product stands at 25.81%. While as nearly 70% of the population in the state derives its livelihood directly or indirectly from this sector (Anonymous, 2009). The predominant cropping systems in Jammu region of J&K State are rice-wheat (59.92%) and maize-wheat (73.09%) in irrigated and rain fed areas, respectively. Other farming activities may comprise any one or combination of mono or multiple cropping, horticultural crops, agro-forestry, livestock, poultry, fishery, goat/sheep rearing etc. So far studies conducted on farming systems in the Jammu division of Jammu and Kashmir State are negligible. As farming system approach is gaining lot of importance in recent years, a need was felt to work out the predominant farming systems, their economics and resource productivity of crop and non-crop enterprises in this region so that, it enables the academicians and policy makers to make policies instead of blanket recommendations, a region specific, appropriate and tailor-made recommendations.

METHODOLOGY

A multi stage random sampling was adopted for the selection of samples, with districts, blocks, villages and farmers as the first, second, third and fourth stage sampling units. Out of 10 districts of Jammu region, five districts namely Doda, Rajouri, Jammu, Kathua and Reasi (50% of total number of districts) were randomly selected. Then three blocks from each district were selected and from each block three villages were selected. The ultimate units, that is, farmers were selected randomly from each village so as to constitute a total sample of 450 (10 from each village) farmers from the whole area under study. The required information was collected through personal interview method, using well-designed and pre-tested schedules. The farmers were divided into four groups: marginal (0.01-2.50 acres), small (2.51-5.00 acres), medium (5.01-7.50 acres) and large (above 7.50 acres). The data was collected and farming systems were identified based on the major contribution to income of farm enterprises.

Education index

Education of the households was measured by education index using the formula given below (Singh, 2009):

Education Index = $\sum_{i=1}^{n} wifi / \sum fi$, i=0,1,2,…, 4

Education attained, that is, illiterate = 0, below high school = 1, high school = 2, intermediate = 3, graduation and above = 4.

Gross Income was computed by adding the income from all the sources including livestock, cereal, service and business.

Resource use efficiency

To analyze the resource productivities of different farming systems for improving the economic conditions of the farmers and to measure the contribution of specific factor in combination with other factors which are responsible for the change in the level of output, multiple regression analysis was used. The Cobb-Douglas production function in below form was fitted to the data:

$Y_i = b_0 X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} u_i$

Where Y = Gross farm income in Rupee; X_1 = Area under cereals in hectare (AUC); X_2 = Area under other crops in hectare (AOTH); X_3 = No. of dairy animals per farm (DA); X_4 = Expenditure on seeds in (`); $X_5$ = Expenditure on fertilizer and chemicals in ` (TFC); X_6 = Education index (EI); I = 1, 2, 3, 4, ……., n farms; b_0 = Constant; b_i = Regression coefficient, and U_i = Random variable.

RESULTS AND DISCUSSION

Socio-economic characteristics of households

The study of the socio-economic status of sample households in different farming systems of different districts of Jammu region indicated in Table 1 revealed that 52 (57.78%), 62 (68.89%), 76 (84.44%), 37 (41.11%) and 90 (100%) sample farmers (X_1) were following cereal based farming system in Jammu, Doda, Kathua, Reasi and Rajouri district, respectively whereas 38 farmers (42.22%), 28 farmers (31.11%), 14 farmers (15.56%) and 53 farmers (58.89%) were following livestock based farming system, respectively except in Rajouri district wherein all the 90 farmers were following cereal based farming system. Farmers were earning about 79% of their gross income (X_2) from livestock in the livestock based farming system in Kathua district followed by Doda (75%), Reasi (69%) and Jammu (62%). In cereal-based farming system farmers were earning about 95% income from cereals in Rajouri district followed by 93% in Kathua district, 89% in Jammu district and 81% in Reasi district. The data further revealed that except for Doda district, the rest of districts Jammu (7.80), Kathua (10.20) and Reasi (8.00) had higher family size in livestock based farming system. The education index has been found 1.30 in livestock based farming system as compared to 1.38 in cereal based farming system. The size of farm was more in livestock based farming system in all the districts except for Doda district. It was 1.83, 1.32, 4.40 and 2.01 ha in livestock based farming system and 1.72, 1.51, 2.40 and 1.23 ha in cereal based farming system for Jammu, Doda, kathua and Reasi districts, respectively. The cereal based farming system had more

Table 1. Socio economic characteristics of sample households of different districts of Jammu region.

Particulars	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
Jammu																	
Livestock based farming system	38.00(42.22)	61.72	7.80	1.30	2.26	189.00	1.83	0.00	0.00	0.00	0.00	0.05	0.48	0.65	37.21	38.41	187079.35
Cereal based farming system	52.00(57.78)	88.67	6.07	1.38	2.11	232.00	1.72	0.00	0.00	0.00	0.00	0.18	0.28	0.59	46.90	47.93	218367.86
All farming system	90.00(100.00)	100.00	6.85	1.34	2.24	220.00	1.77	0.00	0.00	0.00	0.00	0.12	0.37	1.61	42.38	43.49	204257.35
Doda																	
Livestock based farming system	28.00(31.11)	74.92	6.68	1.16	3.80	196.00	1.32	0.00	0.00	0.00	0.00	0.76	0.04	0.00	4.15	4.94	156105.26
Cereal based farming system	62.00(68.89)	93.16	6.83	1.15	1.83	199.00	1.51	0.00	0.00	0.00	0.00	0.67	0.10	0.02	4.27	5.07	210264.15
All farming system	90.00(100.00)	100.00	6.79	1.16	2.64	201.00	1.46	0.00	0.00	0.00	0.00	0.69	0.09	0.02	4.24	5.04	195972.22
Kathua																	
Livestock based farming system	14.00(15.56)	79.45	10.20	1.00	1.75	170.00	4.40	0.00	0.00	0.00	0.00	0.05	0.25	1.10	1.05	2.45	147200.00
Cereal based farming system	76.00(84.44)	92.92	7.32	1.72	1.62	200.00	2.40	0.00	0.00	0.00	0.00	0.13	0.24	0.16	0.34	0.83	257738.24
All farming system	90.00(100.00)	100.00	7.64	1.67	1.82	215.00	2.51	0.00	0.00	0.00	0.00	0.12	0.24	0.73	0.39	0.99	250167.12
Reasi																	
Livestock based farming system	53.00(58.89)	69.49	8.00	0.90	2.42	191.00	2.01	0.00	0.00	0.00	0.00	0.20	0.24	0.75	2.47	3.66	146044.88
Cereal based farming system	37.00(41.11)	80.69	6.69	0.76	2.17	207.00	1.23	0.00	0.00	0.00	0.00	0.34	0.11	0.50	0.45	1.41	74222.25
All farming system	90.00(100.00)	100.00	7.49	0.84	2.56	226.00	1.97	0.00	0.00	0.00	0.00	0.25	0.19	0.66	1.70	2.81	133946.22
Rajouri																	
Cereal based farming system	90.00(100.00)	95.00	8.85	1.44	3.09	291.00	2.22	0.00	0.00	0.00	0.00	0.95	0.24	0.05	7.55	8.80	240565.50
All farming system	90.00(100.00)	95.00	8.85	1.44	3.09	291.00	2.22	0.00	0.00	0.00	0.00	0.95	0.24	0.05	7.55	8.80	240565.50
Overall districts																	
Livestock based farming system	133(29.56)	65.25	5.72	1.05	1.85	189	1.91	0.00	0.00	0.00	0.00	0.27	0.35	0.64	12.25	15.75	159107.40
Cereal based farming system	317(70.44)	91.47	7.45	0.92	1.48	207	1.82	0.00	0.00	0.00	0.00	0.23	0.29	0.31	9.87	11.80	198231.60
All farming system	450(100.00)	100.00	7.15	1.02	1.80	209	1.87	0.00	0.00	0.00	0.00	0.24	0.33	0.50	10.35	12.75	175742.75

X_1 = Sample Size (No.), X_2 = Gross Income (%), X_3 = Family Size (No.), X_4 = Educational Index of head of the family, X_5 = Family labour engaged in agriculture/farm (No.), X_6 = Employment mandays/ year, X_7 = Farm size (ha), X_8 = Total farm credit (`/ha), X_9 = Institutional credit, X_{10} = Non Institutional credit, X_{11} = Kisan Credit Card (No.), X_{12} = Desi Cows (No./ha), X_{13} = Cross bred cows (No./ha), X_{14} = Dairy buffaloes (‘No./ha), X_{15} = Other animals (No./ha)-Poultry, goat etc., X_{16} = Total animals (No./ha), X_{17} = Off-farm ncome (`). Figures within the parentheses are percentages to total.

employment generation potential as compared to livestock based farming system with 232.00, 199.00, 200.00 and 207.00 man days for Jammu, Doda, Kathua and Reasi districts, respectively with 291.00 man days in Rajouri district where not a single farmer had livestock based farming system. The livestock population varied from 1.14/ha in livestock based farming system to 0.83/ha in cereal based farming system with an overall average of 1.04/ha. Farming system wise combination of dairy buffaloes varied from 0.63/ha in livestock based farming system to 0.26/ha in cereal based farming system with an overall average of 0.76/ha. The data further revealed that neither of the farming systems had either borrowed

credit for agricultural purposes or had Kissan Credit Card which is a matter of concern to bankers. The findings are in conformity with those of Singh et al. (2009) who had also reported that only 19% farmers were holders of KCC.

As regards the combination of cross-bred cows in the farming system, it was found that cross-bred breeding programme has not marked headway in the area and were 0.25 and 0.19/ha in livestock and cereal based farming systems, respectively with an overall average of 0.40/ha. As far as desi cows were concerned, they were merely 0.27/ha in livestock based farming system and was more in cereal based farming system (0.45/ha) as compared to livestock based farming system. The off-farm income in livestock based farming system was less (`159107.37/annum) as compared to cereal based farming system (`198231.60) with an overall average of (`175742.75).

Area under different crops across farming systems

The distribution of cropped area under different crops in Jammu region has been presented in Table 2. The cropping intensity was found to be more in cereal based farming system in all the districts like Jammu (178.97%), Doda (113.72%), Reasi 9183.95%) except Kathua district wherein it was 119.41% in cereal based farming system and 139.00% in livestock based farming system.

Cost on crop production and livestock maintenance

Table 3 represented the annual cost on crop production and livestock maintenance. In general, the overall average cost of production was found to be `21845.65 in livestock based farming system and `23253.61 in cereal based farming system. In livestock based farming system, it was found to be highest (`24566.67/ha) in Reasi district whereas in cereal based farming system (`18914.53) in Kathua district. The overall human labour was found highest (`8542.75) in cereal based farming system and bullock labour (`36565.35) in livestock based farming system. Overall expenditure on seed was highest in cereal based farming system (`1475.19) followed by livestock based farming system (1095.76). Kathua district with an expenditure of `2350.86 on seed in cereal based farming system is at top of the list whereas in livestock based farming system Jammu district tops with an expenditure of 1119.16. Expenditure on machinery was also found the highest in livestock based farming system (`8195.29) followed by cereal based farming system (`7850.65).

The per hectare cost of livestock maintenance was found to be maximum on the livestock based farming system (`21988.55/ha) followed by cereal based farming system `14408.05. Expect in Doda district the per hectare cost of livestock maintenance was found to be highest in livestock based farming system whereas in Doda district it was found to be highest in cereal based farming system (`17576.97).

Resource productivities of major farming systems of various districts

The Cobb-Douglas production was used to find out resource use efficiency of major farming systems of various districts of Jammu region and have been represented in Table 4. The elasticity of production indicated that one per cent increase in area under other crops (AOTH) in overall districts increase gross income ranging from 0.098%, in the case of livestock based farming systems, to 0.360% for the cereal based farming systems. As far as Jammu, Doda and Reasi district is concerned, it was found positively significant in all the farming systems whereas in kathua and Rajouri it was found to be non-significant. The elasticity coefficients for cereal based farming system in overall districts were found positive and non-significant (0.201) indicating that there is no contribution of dairy animals in increased gross income whereas in livestock based farming system it was found to be negative and non-significant (-0.03).

The contribution of different sources towards farm-family income for livestock based and cereal based farming systems has been shown in Table 5. On an average household in the region received `74492/farm as farm-family income out of which 41238.27 was from non-farm income followed by livestock (`20201.45) and crops (`13055.20). District wise analysis indicated that non-farm income contributed a major share to farm-family income except in Doda and Kathua where major contribution is from crops. The share of livestock was recorded highest (`18765.50) in livestock based farming system and `12055.10 in cereal based farming system in Reasi district.

DISCUSSION

The study revealed that livestock based farming system was rarely followed by the sample farmers of Kathua district but was major farming system followed by the sample farmers of Reasi district. Farmers from Kathua district were earning major portion of their gross income from livestock in the livestock based farming system whereas in cereal-based farming system farmers of Rajouri district were earning major portion of their gross income from cereals. The size of farm was more in livestock based farming system in all the districts except for Doda district. From the data, it was further observed that livestock was the major component of the existing farming system and neither of the farming systems had either borrowed credit for agricultural purposes or had

Table 2. Farm size-wise percentage area under different crops and cropping intensity under different farming systems.

Particular		Vegetables	Cereals	Fodder	Others	Fruit crops	Gross cropped area (ha)	Cropping intensity (%)
				Jammu				
Livestock based farming system	Marginal	0.00	97.77	2.23	0.00	0.00	1.12	182.67
	Small	0.00	88.09	11.19	0.72	0.00	2.31	179.87
	Medium	0.00	85.39	14.61	0.00	0.00	3.65	151.79
	Large	0.00	88.34	9.52	2.14	0.00	5.19	160.38
	All farms	**0.00**	**88.97**	**9.83**	**0.92**	**0.00**	**2.72**	**164.76**
Cereal based farming system	Marginal	0.00	98.25	0.17	1.58	0.00	1.27	192.21
	Small	0.00	95.90	3.52	0.59	0.00	2.27	164.43
	Medium	0.00	97.93	2.07	0.00	0.00	2.62	140.48
	Large	0.00	98.18	1.82	0.00	0.00	3.11	166.67
	All farms	**0.00**	**97.34**	**2.23**	**0.43**	**0.00**	**2.75**	**178.97**
				Doda				
Livestock based farming system	Marginal	0.00	100.00	0.00	0.00	0.00	1.00	126.76
	Small	0.00	100.00	0.00	0.00	0.00	1.71	118.10
	Medium	0.00	100.00	0.00	0.00	0.00	2.10	84.00
	Large	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	All farms	**0.00**	**100.00**	**0.00**	**0.00**	**0.00**	**1.49**	**112.55**
Cereal based farming system	Marginal	0.00	98.48	0.00	1.52	0.00	1.28	146.50
	Small	0.00	100.00	0.00	0.00	0.00	1.72	115.08
	Medium	0.00	100.00	0.00	0.00	0.00	3.14	120.77
	Large	2.54	97.46	0.00	0.00	0.00	1.97	53.64
	All farms	**0.16**	**99.45**	**0.00**	**0.38**	**0.00**	**1.72**	**113.72**
				Kathua				
Livestock based farming system	Marginal	0.00	63.64	36.36	0.00	0.00	2.20	314.29
	Small	0.00	100.00	0.00	0.00	0.00	2.80	186.67
	Medium	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Large	0.00	57.02	23.25	19.74	0.00	7.60	128.09
	All farms	**0.00**	**61.87**	**21.94**	**16.19**	**0.00**	**5.56**	**139.00**
Cereal based farming system	Marginal	0.00	99.21	0.59	0.20	0.00	1.21	177.27
	Small	0.00	92.26	5.35	2.39	0.00	3.29	195.75
	Medium	0.10	61.54	3.96	34.41	0.00	4.59	189.29
	Large	0.00	90.85	6.71	2.20	0.23	8.94	190.97
	All farms	**0.02**	**88.02**	**4.58**	**7.30**	**0.09**	**4.32**	**119.41**
				Reasi				
Livestock based farming system	Marginal	0.00	97.02	2.98	0.00	0.00	1.32	208.12
	Small	0.00	96.70	3.30	0.00	0.00	2.90	188.89
	Medium	0.00	92.78	7.22	0.00	0.00	3.74	153.88
	Large	0.00	83.39	1.71	1.20	13.70	6.49	173.29
	All farms	**0.00**	**90.49**	**3.72**	**0.53**	**5.27**	**3.38**	**168.24**
Cereal based farming system	Marginal	0.00	93.78	6.22	0.00	0.00	1.13	187.53
	Small	0.00	96.59	3.41	0.00	0.00	2.03	167.09
	Medium	0.00	100.00	0.00	0.00	0.00	3.75	163.04
	Large	0.00	97.87	2.13	0.00	0.00	5.88	106.82
	All farms	**0.00**	**97.94**	**2.06**	**0.00**	**0.00**	**3.52**	**183.95**

Table 2. Contd.

				Rajouri				
Livestock based farming system	Marginal	0.00	99.12	0.00	0.88	0.00	1.08	126.50
	Small	0.00	98.80	0.00	1.20	0.00	2.12	105.08
	Medium	0.75	99.25	0.00	0.00	0.00	2.95	112.77
	Large	0.00	98.55	0.00	1.45	0.00	2.80	96.46
	All farms	**0.24**	**99.15**	**0.00**	**0.85**	**0.00**	**2.25**	**103.25**
				Overall districts				
Livestock based farming system	Marginal	0.00	90.42	1.98	0.00	0.00	1.13	201.25
	Small	0.00	86.89	5.67	0.16	0.00	2.35	178.83
	Medium	0.00	92.54	9.81	0.00	0.00	2.21	123.37
	Large	0.00	85.24	4.25	4.23	2.78	4.31	154.56
	All farms	0.00	88.90	6.75	2.71	1.12	3.42	149.78
Cereal based farming system	Marginal	0.00	95.56	0.97	0.83	0.00	1.16	151.23
	Small	0.00	92.37	2.12	0.89	0.00	2.35	175.72
	Medium	0.21	94.57	1.72	5.17	0.00	3.72	139.78
	Large	0.45	95.02	4.25	1.89	0.05	5.02	141.76
	All farms	**0.19**	**95.14**	**3.98**	**3.76**	**0.01**	**3.63**	**152.25**

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Rice-Wheat and Maize-Wheat were found to be the major cropping systems in the Jammu region in both the farming systems. Also Kathua district had large percentage area under fodder crop under livestock based farming system whereas Doda and Rajouri districts has no area under this crop. In general, the overall average cost of production was found to be `21845.65 in livestock based farming system and `23253.61 in cereal based farming system.

The elasticity coefficient was found highly significant for area under cereals (AUC) in Reasi and Doda districts whereas for area under other crops (AOTH) it was found to be highly significant in Kathua and Doda districts. Doda district was found highly significant for both dairy animals and education Index also. The elasticity of production indicated that one per cent increase in area under other crops (AOTH) in overall districts increase gross income ranging from 0.098%, in the case of livestock based farming systems, to 0.360% for the cereal based farming systems. As far as Jammu, Doda and Reasi district is concerned, it was found positively significant in all the farming systems whereas in kathua and Rajouri it was found to be non-significant. The elasticity coefficients for cereal based farming system in overall districts were found positive and non-significant indicating that there is no contribution of dairy animals in increased gross income whereas in livestock based farming system it was found to be negative and non-significant. The regression coefficient of fertilizer and chemicals was highly significant in cereal based farming system indicating that farmers were getting positive impact for the input whereas in livestock farming system it was negative and non-significant indicating no impact of this input. The negative and non-significant coefficient for seed and education index in both cereal based and livestock based farming system indicated that these inputs did not contribute significantly to the output of these farming systems.

Conclusion

The educational index has been found highest (1.30) for livestock based farming system in Jammu district and for cereal based farming system it has been found highest (1.72) in Kathua district. The study has revealed that both the farming system, that is, livestock based farming system (189 man days per year) and cereal based farming system (207 man days per year) provides large employment but cereal based farming system provides the 56.71% employment. The per farm per year cost analysis of livestock maintenance has indicated that churi/concentrate, family labour and green fodder are the major components of livestock maintenance in all the districts. The regression analysis has indicated that one percent increase in area under other crops (AOTH) in overall districts increase gross income ranging from 0.098%, in the case of livestock based farming systems, to 0.360% for the cereal based farming systems.

Policy implications

1. Symphasis should be given in cereal based farming system which includes wheat, rice, jowar, maize etc.
2. Each zone of Jammu region being rich in location specific biodiversity needs to be explored, so that it may

Table 3. Annual input cost under different farming systems in various districts of Jammu region (`/ha).

Particular	Cost on crop production							
	Seed	Fertilizer	Plant protection	Irrigation charges	Human labour	Bullock labour	Machinery	Gross cost (Rs)
				Jammu				
Livestock based farming system	1119.16	1798.56	58.08	597.79	4352.87	4140.33	1032.78	**13099.57**
Cereal based farming system	866.00	1160.22	166.18	762.29	4894.73	1248.49	9231.75	**18329.66**
				Doda				
Livestock based farming system	334.41	721.29	86.49	511.71	11895.50	0.00	0.00	**13549.40**
Cereal based farming system	366.87	678.37	93.28	462.50	7991.51	0.00	3860.63	**13453.16**
				Kathua				
Livestock based farming system	1040.99	2092.63	158.43	877.28	5091.38	0.00	464.75	**9725.46**
Cereal based farming system	2350.86	2238.20	266.26	561.20	9521.40	970.12	3006.49	**18914.53**
				Reasi				
Livestock based farming system	861.81	749.16	15.37	210.31	2419.53	3933.34	16377.15	**24566.67**
Cereal based farming system	801.12	1076.18	36.06	143.25	2291.47	3485.68	8902.89	**16736.65**
				Rajouri				
Cereal based farming system	1138.67	1227.73	42.01	120.05	4296.72	4827.99	701.14	**12354.31**
				Overall				
Livestock based farming system	**1095.76**	**1589.65**	**90.15**	**519.55**	**6789.90**	**3565.35**	**8195.29**	**21845.65**
Cereal based farming system	**1475.19**	**1675.50**	**145.98**	**526.67**	**8542.75**	**3036.87**	**7850.65**	**23253.61**

Livestock maintenance

Particular	Churi/ concentrate	Dry fodder	Green fodder	Mineral mixture	Labour	Miscellaneous	Gross cost (Rs)
				Jammu			
Cereal based farming system	5199.07	3348.32	3882.90	822.12	4934.68	1140.55	19327.64
Livestock based farming system	6749.70	6268.97	3949.20	695.93	3580.27	6704.98	27949.05
				Doda			
Cereal based farming system	2190.09	5310.00	9524.96	551.92	0.00	0.00	17576.97
Livestock based farming system	837.35	3119.46	3522.72	476.58	0.00	375.77	8331.88
				Kathua			
Cereal based farming system	856.86	760.86	145.81	710.03	660.23	2000.21	5134.00
Livestock based farming system	1589.79	1701.03	1039.97	636.64	3872.30	203.47	9043.20

Table 3. Contd.

Reasi							
Cereal based farming system	2152.78	3693.16	1648.18	332.76	6766.11	1029.52	15622.52
Livestock based farming system	2830.49	2492.69	1152.61	473.30	13036.97	430.61	18560.61
Rajouri							
Cereal based farming system	2355.49	3495.87	3262.01	226.63	14456.02	313.42	24109.44
Overall							
Cereal based farming system	2485.39	3099.17	3159.69	841.43	2945.01	1854.32	14408.05
Livestock based farming system	3686.96	5862.61	4819.88	1031.73	10220.53	1889.68	21998.55

Table 4. Farming system-wise regression results for different farming systems in Jammu region of J&K state.

District	Farming system	Intercept	Regression coefficients						R^2 Adj	F ratio	Returns to scale
			AUC	AOTH	DA	Seed	TFC	EI			
Kathua	Cereal based	-0.245	1.219	-0.076	0.084	0.299	0.951*	-0.167	0.390*	8.147	2.308
	Livestock based	3.040*	0.000*	-0.157*	0.000*	1.479*	-0.211*	-0.520	1.000*	5.127	0.591
Jammu	Cereal based	-0.159	6.293*	0.440***	0.249	-0.160	0.123	-5.938*	0.243*	3.950	1.006
	Livestock based	4.099*	-0.892	0.252**	-0.158	-0.147	0.675	0.867	0.007	1.054	0.598
Reasi	Cereal based	4.511**	0.454***	1.181*	-0.478	-0.177	0.263	3.355	0.169***	2.087	4.598
	Livestock based	4.818*	0.400***	0.003	0.096	-0.067	-0.096	0.024	0.036	1.250	0.361
Doda	Cereal based	4.318	4.941***	1.164***	0.363	0.217	-0.866	1.459***	0.038	1.419	7.277
	Livestock based	2.291	1.054***	0.000***	0.795***	-0.919**	1.004	0.051***	0.355	9.268	1.985
Rajouri	Cereal based	1.155	1.159	-0.388	1.674**	-0.190	0.350	-2.919	0.149***	2.021	-0.315
Overall	Cereal based	1.763*	1.367**	**0.360***	0.201	-0.123	0.427***	-0.327	0.104*	5.934	1.912
	Livestock based	5.207*	0.027	**0.098****	-0.03	-0.070	-0.026	0.072	0.057	0.944	0.073

AUC, Area under cereals; AOTH, area under other crops; DA, dairy Animals; TFC, total fertilizer and chemicals; EI, Educational index; *Significant at 0.01 los; **Significant at 0.05 los, ***Significant at 0.1 los.

be beneficial for the farmers to adopt the farming system related to that particular area.
3. There should be government strategy for marginal and small farmers.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Crude glycerol co-digestion associated with swine manure in biogas production: A study in Brazil

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This study aimed to evaluate the crude glycerol efficiency, from biodiesel production, biogas production with co-digestion of swine manure. The process was conducted with several concentrations of glycerol 0, 5, 10, 20, 30 and 40% (w/w) and swine manure with a concentration of 20, 40 and 60% (w/w) with pH 7.2 and 35°C. The fermentation periods were 21 and 30 days. Fifty ml of micro-reactors were used airtight coupled to a 10 ml syringe best condition to evaluate the production of biogas. Analysis was also performed to evaluate total solids reduction of solids mass in proposed treatments. Using a digestion system on a laboratory scale, is constituted by a 20 L reactor total volume, a gas meter and a reservoir for storage thereof, biogas production was evaluated for the sample with 5% of glycerol and the control sample (0% glycerol). With the aid of a gas chromatograph analyzed the methane content thereof. It was observed that the amount of swine manure has great influence on the production of biogas and the concentration in the sample yield was better with 60%. The crude glycerol together to swine manure at a rate of 5% w/w can be used as a supplement in anaerobic digestion, providing a significant increase in the production of biogas in its content of methane and removal of total solids. Moreover, it has been found that concentrations of 20, 30 and 40% (w/w) of glycerol were inhibitory at all studies, difficulties occur and little production of biogas. Chromatographic analysis of the sample with 5% glycerol was satisfactory in relation to methane content, showing 58.87% of CH4 in the biogas.

Key words: Anaerobic digestion, methane, crude glycerol, swine manure.

INTRODUCTION

Environmental concerns about climate change in recent years have gained international significance, taking place on the development agenda. Being cited as the main factor responsible for this fear with the environment, emissions of greenhouse gases have been the target of environmental policies of different countries (Nyko et al., 2010).

The political and economic crisis in oil-producing

countries has led importing countries to seek investment seriously in research and development of alternative solutions to reduce its dependence on this ore. One alternative has been the use of vegetable oil, which are bio-fuels, instead of diesel oil. In seeking the reduction of dependency of petroleum and reducing environmental impacts, there were alternatives like biodiesel, leveraged by the National Program and Production and Use of Biodiesel (PROBIODIESEL). The law no. 11,097, of January 13, 2005, introduced the biodiesel in the Brazilian energy matrix (Brazil, 2005).

However in the production of biodiesel through any trigly ceride is a by product generated approximately 10 kg of glycerol generated for each100L of produced biodiesel (Santibanez et al., 2011). Due to its composition rich in carbon and easy degradation, glycerin has properties conducive to an aerobicco-digestão being susceptible toits association with swine manure, which is are sidue of the digestion wide spread technology. The growth of pig production in southern Brazil, has made the country alcançace the third in the world (ABIPECS, 2012). The intensification of pig farm because of its large geographic concentration, leads to a high concentration of manure, even with its high content of nutrients, it can become a dangerous pollutant both terrestrial as aquatic (Segat et al., 2015). The intense deposition in the soil of swine manure can cause leaching of the following nutrients P, K, Cu and Zn (Scherer et al., 2010).

The practice of co-digestion has benefits as increased load easily degradable organic matter, dilution of toxic substances, improving the mixing buffer capacity, increased biogas production, a better quality of a digested product, and reduced cost, better balance nutrients and a possible synergistic effect of microbial consortia on the efficiency and yield offer mentation (Alvarez et al., 2010; Ashekuzzaman and Poulsen, 2011; Rao and Baral, 2011; Khalid et al., 2011; Esposito et al., 2012; Wang et al., 2012; Zheng et al., 2015; Pagés-díaz et al., 2015; Khoufi et al., 2015).

The Program and Biodiesel Production and National use determined the addition of biodiesel to diesel in incremental scales in 2010 reached 5% in 2015 and rose to 7% (Brazil, 2015; ANP, 2015). This increase results in a large increase in the supply of a co-product generated in the production of biodiesel, which is glycerin. This will generate a surplus that the current market cannot absorb, reflecting the need for alternatives to the use of this co-product in a sustainable way, both economically and environmentally (Siqueira, 2012).

Given the earlier explanation and in order to avoid future problems arising from the accumulation of glycerol and to make it more competitive, biodiesel production justifies the search for the utilization of alternative crude glycerol generated in this production. Therefore, this study aims to evaluate the efficiency of crude glycerol, from the production of biodiesel, in obtaining biogasco-digestion pig manure. Thus, it becomes necessary to improve the different operating parameters involved in the anaerobic fermentation process for obtaining biogas from the crude glycerol producing clean, renewable energy and contributing to the Brazilian energy matrix.

MATERIALS AND METHODS

The experiment was conducted in the Development Center and Technology Dissemination (CEDETEC) Faculty of Assis Gurgacz (FAG) in the city of Cascavel Paraná State, Brazil. The crude glycerol was courtesy of a biodiesel plant, also the city of Toledo, its origin comes from soybean oil of methyl trans esterification.

The swine manure were provided by Granja Scheid, located in Sanga Line Guarani, in the Good Principle district of the city of Toledo - PR. The property has about 600 pigs and produces an average of 3 m^3 / day of waste. Pigs are raised in pens and these facilities are housed in collective cages, with about 30 animals each. The pen is made of brick and was built in such a way as to facilitate the management of waste, with concrete floors sunken directed to a collection box, avoiding thus contamination of neighboring areas. The waste was collected and preserved in fresh thermal polystyrene box (STYROFOAM) until they are needed.

In order to analyze the samples, micro-reactors made with glass containers with a volume of50mLand equipped with airtight 10mLsyringe, whose function was to measure the volume of produced biogas (Azevedo, 2010) were used. In micro-reactors added to the swine manure in concentrations of 20, 40and 60%, the culture medium comprisingly cerol in concentrations of 0, 5, 10, 20, 30 and 40% w/w and minerals solution (nutrient), as can be seen in Figure 1a. The micro-reactors were placed in 21 days-culture green house, as can be seen in Figure1b. The biogas volume was assessed daily by observing the displacement of the syringe plunger.

The culture medium was composed of crude glycerol ($C_3H_8O_3$) in concentrations of 5, 10, 20, 30 and 40% w/was a carbon source and mineral salts solution (nutrients). The solution of mineral salts followed Azevedo methodology(2010), where in 1 L of distilled water diluted to 2 gdi basic potassium phosphate (K_2HPO_4), 20 g monobasic potassium phosphate(KH_2PO_4) and 3.5 gurea (((NH_2) 2CO). The experiment was conducted without variation in pH. For the pH no variation in the samples was added3 mlKOH10Ninthe original culture medium yielding pH 7.2. The experiments were placed in the culture oven at 35°C for21 days. Total solids (TSs), refers to the remaining waste material into the container after evaporation and drying of the sample. The analysis of total solids (TSs) was determined according to the methodology described in American Public Health Association-APHA (1992).

First were measured capsules porcelain leaving them in oven at (55±50°C) for 1 h, followed by cooling in desiccator and weighing to the nearest 0.1 mg. Then transferred to10 ml of capsules pig manure, the culture medium comprisingly cerol (at concentrations of 0, 5, 10, 20, 30 and 40% w/w) and the solution mineral salts (nutrients) being subsequently placed in a greenhouse at a

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A B

Figure 1. Micro-reactorsused in their production and micro-reactors conditioned in the greenhouse (a. Micro-reactors used in the production packaged of biogas; b. Greenhouse with micro-reactors).

Figure 2. Biodigesterinlaboratory scale.

temperature of 103 to 105°C for about 24 huntil constant weight. Withdrawal greenhouse was placed in a desiccator to cool and the capsules were re-weighed, thus obtaining the final weight (dry) (mp). After 21 days at 35°C was used the methodology described for monitoring the remaining waste material in the micro-reactors. The total solids content was determined by Equation 1:

$$TS = \frac{Iw - Fw}{Iw}$$

Equation 1: Determination of total solids, wherein: TS=Total Solids; Iw=Initial weight (wet) (g); Fw = Final weight (dry) (g).

After evaluating the performance of micro-reactors was producing a digestion system from laboratory scale to assess the best result. As a reactor used a plastic jug of mineral water to volume of 20L, the mouth was sealed with a rubber stopper with a hole, into which was inserted a hard iron pipe connected to a transparent tube polyurethane for biogas outlet (Figure 2).

After passing through the gas meter, the biogas was stored in a gas sampler (bag). The biogas obtained was evaluated in relation to the produced volume. Methane proportions were analyzed by agas chromatograph. After 30 days, the same procedure described earlier was used, but there actor was fed with only manure and mineral salts solution.

RESULTS AND DISCUSSION

Figures 3, 4 and 5 show the behavior substrate at concentrations of 0, 5 (w/w), 10 (w/w), 20 (w/w), 30% (w/w) and 40% (w/w) crude glycerol in concentrations of

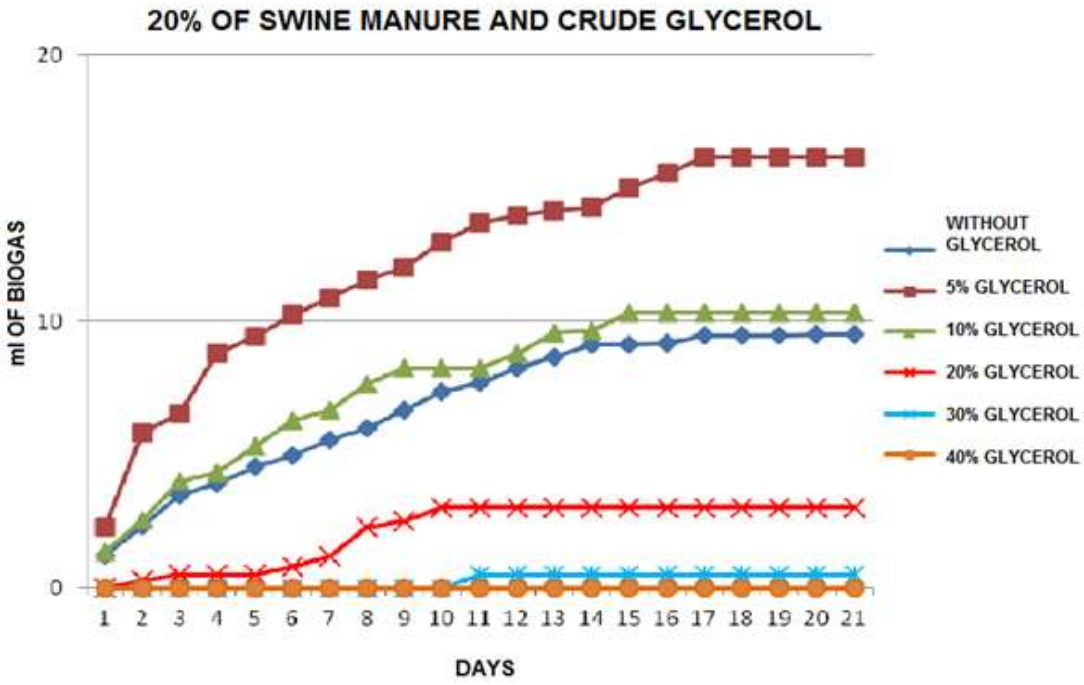

Figure 3. Concentration of 20% swine manure.

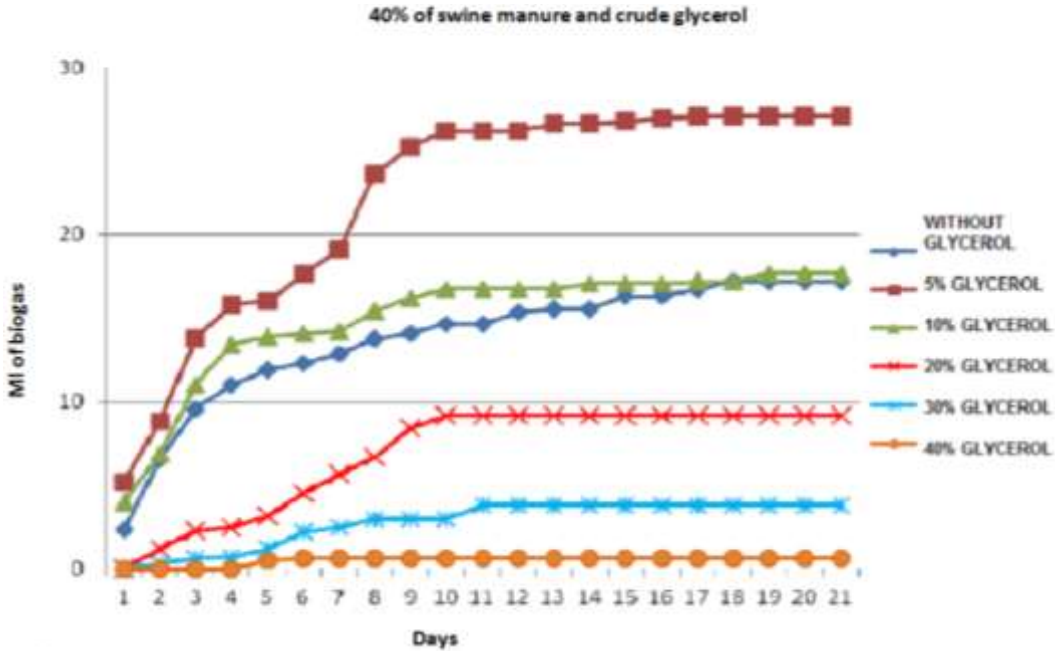

Figure 4. Concentration of 40% of swine manure.

20, 40 and 60% swine manure on the accumulated biogas production.

Looking at Figures 3, 4 and 5, it is seen that the sample With 5% glycerol when added in concentrations of 20, 40 and 60% swine manure significantly increased the volume of produced biogas, reaching the twentieth first day with 16.17 ml to 20%, 27.13 ml of 40% and 52.52 ml for 60% of swine manure.

Samples with 10% glycerol concentration biogas obtained a slightly higher, reaching a volume of 10.33 ml

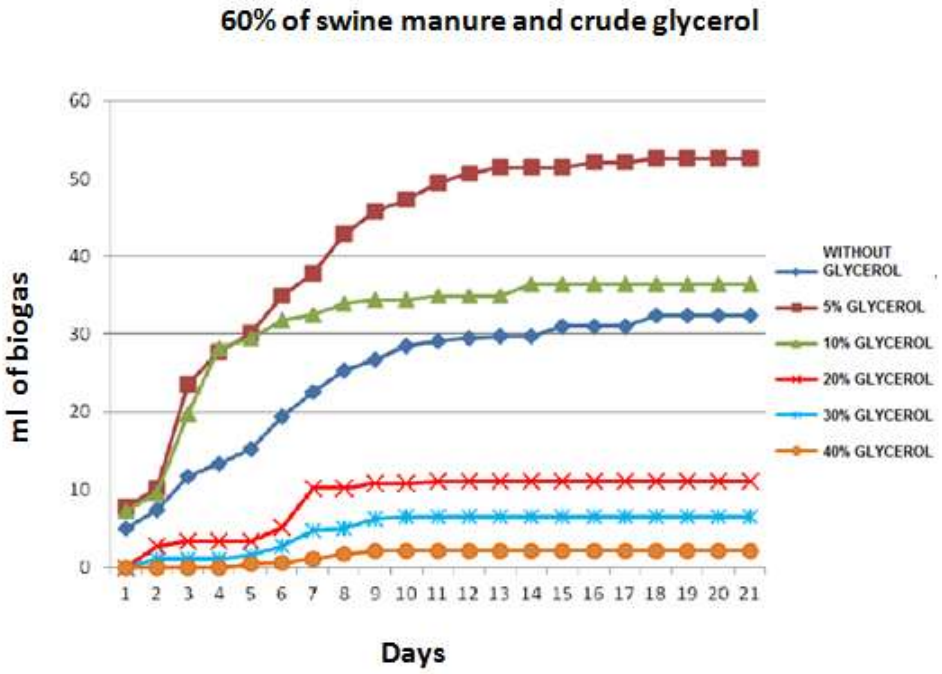

Figure 5. Concentration of 60% of swine manure.

Table 1. Total solids (TSs) and their respective reduction ratios after 21 days.

Total solids (21days)			
Glycerol concentration (%)	**Affluent(g)**	**Effluent(g)**	**Reduction (%)**
0	60.47	42.09	30.40
5	60.88	43.43	28.70
10	60.76	46.72	2311
20	60.55	50.63	16.38
30	61.42	55.35	9.88
40	58.75	56.70	3.49

for 20%, 40% to 17.68 ml and 36.45 ml of 60% swine manure. However, the samples without glycerol (0%) yielded 9.51ml, 17.19 and 32.39 ml respectively for each sample of pig manure. Analyzing the concentrations of 20, 30 and 40% (w/w) of glycerol can be seen that for other concentrations there was little production of biogas. The process of the daily biogas production in these concentrations was slower, indicating an inhibitory substrate trend. Azevedo (2010) in his studies on the effect of the concentration of glycerol for the production of biog as also found that the concentration of 40% (w/w) was inhibitory in all experiments.

Fountoulakis et al. (2010) comment on their work that inhibitory trend in the biogas at high concentrations of glycerol can be associated with contamination of glycerol for biodiesel residues or an organic over loading the digester. The results show that at this stage anaerobic digestion with the addition of 5% glycerin and 60% swine manure becomes viable for production of biogas. Backes (2011) in his experiment added 6% crude glycerol in swine manure and noted a significant increase in biogas production, obtaining average production of biogas at about $0.0121m^3$ and was significantly higher when compared to control ($\pm 0.0035m^3$) and treatment with 3% glycerol ($\pm 0.0065m^3$).

Analyzing the data in Table 1 (21 days of treatment), it is observed that the percentages add glycerol in concentrations of 5, 10, 20, 30 and 40% per swine manure removal rate total solids (TSs) declined over the treatments, with the greatest reduction in the control treatment, without glycerol(0%), reaching 30.40%. Since treatment with 5% glycerol reduction was 28.70%. Thus

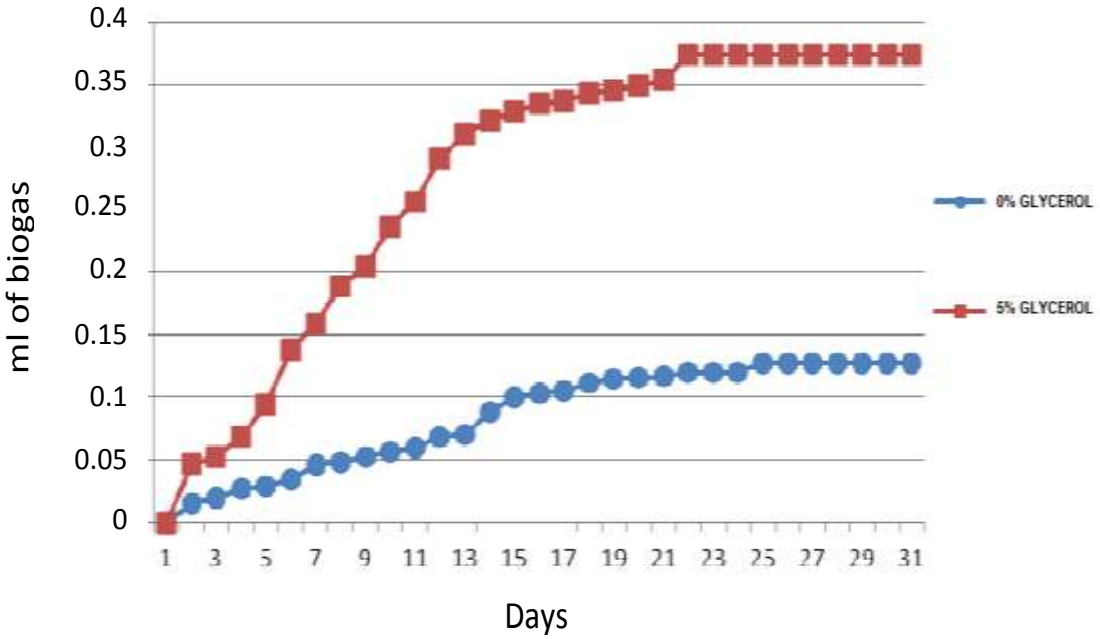

Figure 6. Production of biogas.

the treatment without glycerol (0%) and 5% glycerin, after 21 days at 35°C. They showed almost the same performance in reducing the mass of solids.

The results presented here show that the topical use of5% glycerol in anaerobic digestion of swine manure is effective in removing total solids (TSs). Backes (2011) in his study of anaerobic digestion noted that reductions in total solids of cattle manure after the procedure decreased to almost all treatments(control, 6 and 9%), with the largest reduction occurred in the control treatment, reaching 28%, and treatment with 9% glycerin to15%. Konrad (2010) in relation to the generation of biogas, obtained in the control sample (0% glycerol) a production of biogas 0.0024m^3, while the sample with 3% glycerin, production amounted to about 0.01292m^3 of biogas, which it represents an increase of 81.4% over the control sample. Since the biogas production with the addition of6% glycerin resulted in a total yield of 0.0058 m^3, representing 59.2% increase relative to the control sample.

From the results, the study came to the conclusion that the anaerobic digestion with the addition of 5% crude glycerin and 60% of swine manure is feasible for biogas production. Thus, it played up a laboratory reactor, and it was possible in order to analyze the volume of produced biogas and compares it with the control treatment. The test results are shown in Figure 6. Treatment with addition of 5% crude glycerin was increase in biogas production compared to the control treatment. The total gas production in this treatment was 0,373m^3 of biogas while in the control treatment (0% glycerin), was 0,127$m^3$of biogas. Figure 7 illustrates the chromatogram of the samples containing 0 and 5% (w / w) of glycerin. The chromatogram shows peaks corresponding to air, methane and carbon dioxide, respectively.

The retention times of methane and carbon dioxide of samples showed similar behavior to the standards. Since the peak of the air samples as compared to standard, they showed lower values being positive for the process. The air is lethal to anaerobic bacteria. If oxygen in the atmosphere, anaerobic bacteria paralyze their metabolism and cease to grow, they are responsible for the production of methane. By chromatographic analysis (Figure 7) it was possible to quantify the existing methane content in the samples studied. The results of this experiment showed that the sample methane percentage with 5% glycerin and control samples (0% glycerol) with 60% swine manure have similar values, and the sample with 5% glycerol obtained a value stronger than the control sample, reaching a plateau with content of 58.87% methane, while the control sample has reached 58.45%, as shown in Figure 8.

According to Souza et al. (2007), the biogas composition varies depending on the material from which it originated, but its basic composition is 40 to 70% methane (CH_4), 30-40% carbon dioxide (CO_2), nitrogen traces, hydrogen and gas hydrogen sulfide. Oliveira and Higarashi (2006) reported values between50 to 70% methane. Thus, the values found in this study are consistent with the values found in the literature. Konrad (2010) in their experiments with sludge treatment plant to quantify the biogas in the control sample (0% glycerol) had levels of methane of 68%. In the sample in which 3% glycerol added methane values reached 72% being

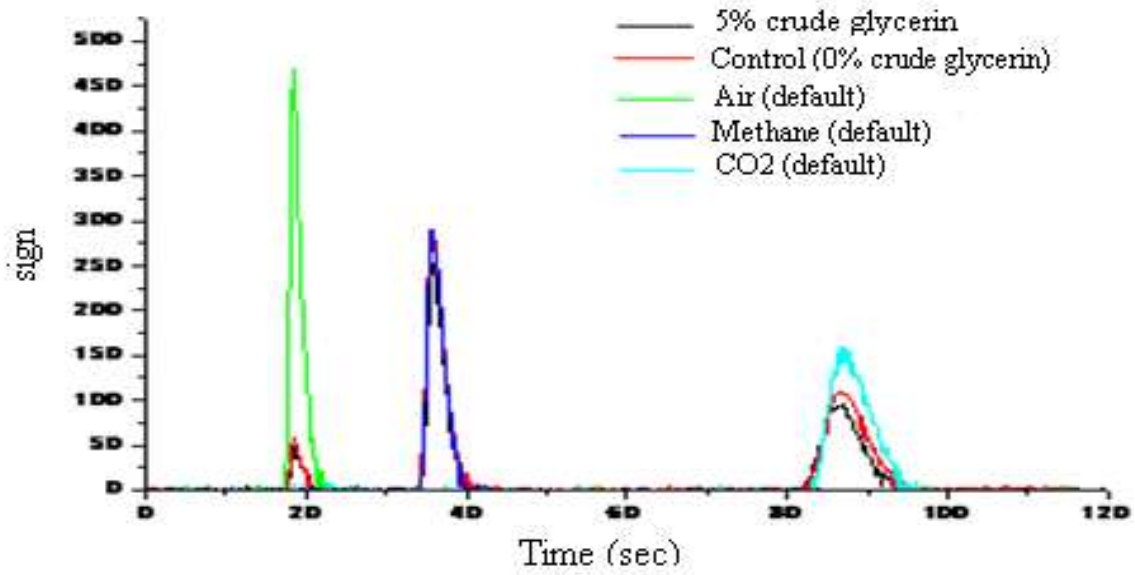

Figure 7. Gas chromatography analysis.

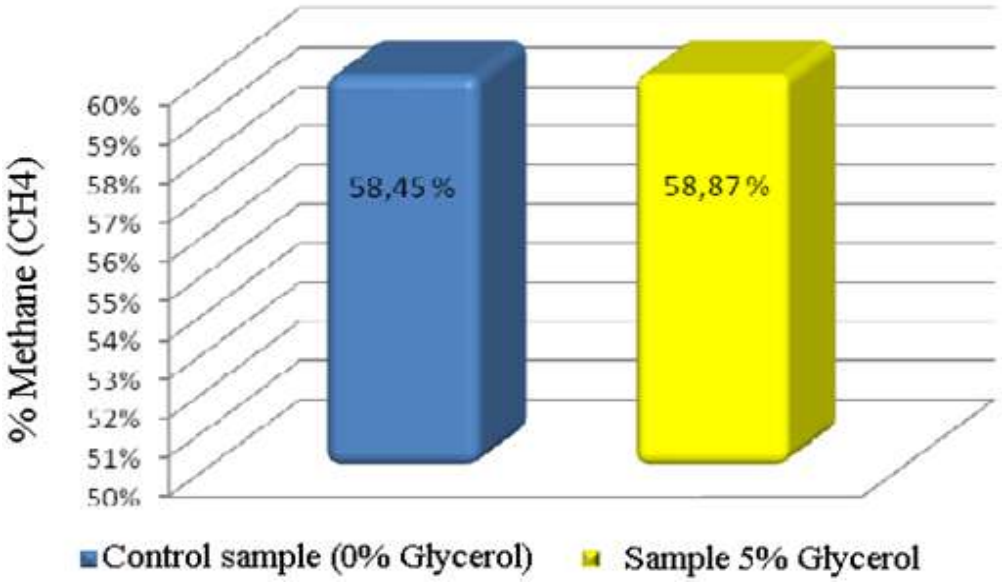

Figure 8. Content of methane.

satisfactory for energy purposes.

Since methane percentage with the addition of6% glycerol was 61%. Backes (2011) adding 3% glycerol swine manure obtained an average of 68% methane. In the control sample, 60% methane content was obtained. In the sample with 6%, glycerin value was around 90% methane. In his studies Chen et al. (2008) added glycerol to the manure and there was increased production of biogas and methane. The average content of methane in the biogas was 63to 70%.

Conclusion

The results showed that the amount of swine manure has great influence on the production of biogas. In this study, the concentration with higher yields in biogas production was the sample with60% of swine manure. The crude glycerol associated with the manure in a ratio of 5% w/w can be used as a supplement in anaerobic digestion, providing a significant increase in the production of biogas.

By increasing the concentration of glycerol were observed difficulties and little production of biogas. The process was slower, indicating an inhibitory substrate trend. It follows that the amount of glycerol added to the anaerobic digestion should have a limiting level of concentration and time to adapt to the biocenose, by avoiding an organic overhead in the process. The addition of 5% glycerol in the anaerobic biological treatment system with pig manure was efficient in reducing total solids, the read aptation of micro-organisms involved in anaerobic digestion process with the substrate. The biogas composition was not altered by the presence of 5% glycerol methane which aspect ratio remained virtually unchanged compared with the control sample.

Conflict of Interests

The authors have not declared any conflict of interests

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