African Journal of Agricultural Research

Volume 13 Number 6 8 February, 2018
ISSN 1991-637X

Academic Journals

ABOUT AJAR

The African Journal of Agricultural Research (AJAR) is published weekly (one volume per year) by Academic Journals.

African Journal of Agricultural Research (AJAR) is an open access journal that publishes high-quality solicited and unsolicited articles, in English, in all areas of agriculture including arid soil research and rehabilitation, agricultural genomics, stored products research, tree fruit production, pesticide science, postharvest biology and technology, seed science research, irrigation, agricultural engineering, water resources management, marine sciences, agronomy, animal science, physiology and morphology, aquaculture, crop science, dairy science, entomology, fish and fisheries, forestry, freshwater science, horticulture, poultry science, soil science, systematic biology, veterinary, virology, viticulture, weed biology, agricultural economics and agribusiness. All articles published in AJAR are peer- reviewed.

Contact Us

Editorial Office: ajar@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/AJAR

Submit manuscript online http://ms.academicjournals.me/

Editors

Editorial Board

African Journal of Agricultural Research

Table of Contents: Volume 13 Number 6, 8 February, 2018

ARTICLES

academicJournals

Vol. 13(6), pp. 281-287, 8 February, 2018
DOI: 10.5897/AJAR2017.12364
Article Number: C294C1355895
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Characterization of livestock farming in Jacaré dos Homens, Alagoas, Brazil

Cristian Cavalcante Félix da Silva[1*], José Crisólogo de Sales Silva[2], André Maia Gomes Lages[3], Sandrine Cíntia Amorim de Barros White[4] and Marília Ferro Marques Cavalcante[1]

[1]Departamento de Esportes de Rio Real, State University of Alagoas – UNEAL, Santana do Ipanema – AL, Brazil.
[2]Center for Nuclear Energy in Agriculture - CENA/USP, State University of Alagoas – UNEAL, Campus II, Santana do Ipanema – AL, Brazil.
[3]Faculty of Economics, Management and Accounting, Federal University of Alagoas - UFAL. Maceió, Brazil.
[4]State University of New York – SUNY ESF, USA.

Received 6 April, 2017; Accepted 7 November, 2017

Dairy farming is one of the most significant activities for Brazilian agribusiness, especially for its diversity and breadth. This study aimed to analyze the characterization of dairy farming activity developed in the Baixas community, in the city of Jacaré dos Homens-AL, Brazil, raising information about the production system adopted and considering the relevance of this activity to the locality. The research was conducted between September and October, 2011, through a questionnaire applied to 31 milk producers in the region. We used data tool software Microsoft Excel® 2010 and the results were analyzed in a descriptive statistical way, presented as absolute and relative frequency in charts. Conventional technique interviews were adopted. It can be concluded that despite the low level of school education, the majority of farmers are over 10 years in business and over half of them have incomes of less than 1 minimum wage. Despite the good production average 10 L/cow/day, the number of animals is small and for this reason, the income is low. Moreover, 45% of the producers do not have any type of economic and zootechnical control. However, barriers in the areas of management, nutrition, sanitation and genetics, combined with the implantation of technology and public policies focused on livestock, must be addressed so that this region can optimize its development.

Key words: Agribusiness, regional development, dairy farming.

INTRODUCTION

In 2014, the European Union ranked first among the world's largest milk producers and had an estimated production of 38.2 billion gallons, followed by India with 37.3 billion gallons. The United States came in third place with 24.6 billion gallons and China in fourth place with 10.2 billion gallons. Brazil is in the fifth position, with 8.8 billion gallons, an increase of 3.7% over the previous year (USDA, 2014).

*Corresponding author. E-mail: cristian.cfs@hotmail.com.

In this context, in 2014 the South region was in first place among the large Brazilian regions, holding 34.7% of the national production. However, Minas Gerais remained as the main producer state, with a production of 2.5 billion gallons, which corresponds to 77% of all the production in the Southeast region and 26.6% of the national production (Portal Brasil, 2015).

The milk production chain is among the most significant areas for Brazilian agribusiness, mainly due to its diversity and breadth. Brazil had a cattle herd of 212.3 million head in 2014, an increase of 569 thousand animals compared to 2013. The country still had the second largest herd in the world, being surpassed only by India, despite the several mishaps faced in the regional context, more specifically due to the strong drought and its consequences (IBGE, 2015).

The dairy sector is fundamental to the economic development of family-based farming in many regions of Brazil (Eurich et al., 2016). The breeding of dairy cattle developed at the semi-arid region of Northeastern Brazil is mostly composed of family establishments, with low level of technological innovation and seasonal production, due to the rainy and dry periods of the year (Guimarães Filho and Soares, 1999). The predominant breeding regimes are the extensive and the semi-intensive, in which the animals use the native vegetation of the Caatinga biome (exclusive to Brazil) for their maintenance and production (Alves et al., 2009). The Caatinga has the characteristics of a savannah, with xerophytic plants, and rare rainfall (around 12 to 31.5 inches per year), occupying 10% of the territory of Brazil.

In the extensive system, investments in facilities are reduced, having food support based on native pastures. When concentrated and mineral supplementation is available, they are not always adequate to the nutritional requirements of the herd. Another relevant aspect is the low reproductive and sanitary control, which leads to the limitation of milk yield per animal (LIMA, 2011).

The information from this study was generated through the program Alagoas Mais Leite, from the State Department of Agriculture of the State of Alagoas that hired Empresa Pecuária Intensiva de Consultoria, which with EMBRAPA is allowed to execute the methodology of the Projeto Balde Cheio. The project assisted 500 milk producers in several cities in Alagoas, organized in associations and productive groups. The program began in the second half of 2011 and ended in the second half of 2016.

The municipal HDI is adapted from the world famous version of HDI. It evaluates well-being from the geometric mean of three dimensions: income, health and education. Jacaré dos Homens is a city located in the State of Alagoas, Brazil. The country had 5507 municipalities in the 2000s. According to PNUD data, available in Wilkipedia, out of the 101 municipalities of Alagoas at the time, Jacaré dos Homens ranked 56th in terms of municipal HDI in Alagoas (PNUD, 2010). This corresponded to the 5098th position at the national level, holding a mHDI of 0.571. It is worth remembering that this indicator goes from 0 to 1. The closer to 1, the better the performance. In this context, it should be noted that Maceió, the capital of the state, is the city with the best ranking in Alagoas, with a mHDI of 0.739, occupying the 2180th position among the Brazilian municipalities.

When using PNUD official data for 2010, Maceió ranked 1266th. As the city is a capital of a Brazilian State, this position was still far below the expected, with an HDI of 0.721. The numbers fell, but the relative position of that city improved even with the increase in the number of municipalities during that period of time. Thus, in 2010, there would be 5565 Brazilian municipalities. At that same time, Jacaré dos Homens jumped to 4562th position, holding a HDI of 0.583. It is very interesting to note that it performs really well on the health dimension, well above its index aggregate value.

The HDI does not capture the income distribution aspect. This information is provided by the GINI index. The closer to 1 the value of the municipal GINI index, the worse the income distribution. In the case of Jacaré dos Homens, its GINI index was 0.505. Maceió, in the same period, had the value of 0.6378. That means a lot worse than Jacaré dos Homens. For comparative purposes only, the municipality of São Paulo, the largest in Brazil in population, had the GINI of 0.6453. Meanwhile, Chapecó, in the countryside of the State of Santa Catarina, had 0.4819. The capitals seem to present lower results when compared to countryside cities, since Florianópolis, capital of Santa Catarina, had the value of 0.5474. This situation is similar to Maceió. From everything that has been analyzed, it can be concluded that Jacaré dos Homens presents a relative adverse situation in social terms.

The objective of this study was to characterize the dairy cattle production system in the community known as Baixas, in the city of Jacaré dos Homens in Alagoas, based on social, economic and zootechnical aspects, aiming to contribute to the maintenance and improvement of the dairy production in the region, as it is the main economic activity of the municipality.

MATERIALS AND METHODS

The present study was carried out in the municipality of Jacaré dos Homens, located in the southwestern region of the State of Alagoas, Brazil, a mesoregion of Sertão Alagoano, which is characterized by the presence of the caatinga biome, a savanna that only exists in Brazil. The city is located approximately 122 miles from the capital of the State of Alagoas, Maceió, at an altitude of approximately 443 feet and geographic coordinates 9°38' 08'' S and 37°12' 17'' W. The climate is semi-arid tropical, with dry season, with irregular rainfall and low relative humidity, and has an average annual rainfall of 17 inches (DB-City, 2016).

The research was carried out with the use of a structured questionnaire used for the initial diagnosis and characterization of properties used by the Balde Cheio program, from EMBRAPA Pecuária Sudeste. This public company stands out in Brazil for the generation of new technologies in the agricultural sector. The objective of this study was to collect information about the social aspects of producers, obtainment of rural financing, types of economic activities practiced on rural properties, herd management practices (food, productive, reproductive, genetic and sanitary) and property rentals, besides the factors considered more important for the producers regarding the development of rural activities.

Interviews were done with families of milk producers, at their properties' headquarters. In some cases, more than one member participated. 31 questionnaires were elaborated with structured questions, where 10 relevant aspects were selected among the questions in the standard questionnaires by the Balde Cheio program. It is important to mention that the 31 interviews represent the total statistical population of the city. The software Microsoft Excel® 2010 was used, and the results were analyzed in a descriptive statistical way and presented as absolute and relative frequency in charts.

The research is descriptive and exploratory. For the first case, it is description of the studied phenomenon and its characterization and for second case, to show information about the production system at the Caatinga biome for a public that may not know it.

For convenience, this is the case of a non-probabilistic sample, which selected the accessible producers that were part of the project mentioned above. The research is descriptive and exploratory. In the first case, it describes the phenomena studied and their characterization and in the second case, it opens some information about the production system in the Caatinga biome to an audience that would probably ignore it.

The formula used to calculate the productivity would be: the standard daily milk production in liters / number of dairy cows) *365 days = milk production in liters/cow/year. This formula led to the results analyzed below.

RESULTS AND DISCUSSION

In this study, when the socioeconomic profile of the interviewees was analyzed, it was found that these individuals are, on average, 45 years old and have a property with about 8 hectares.

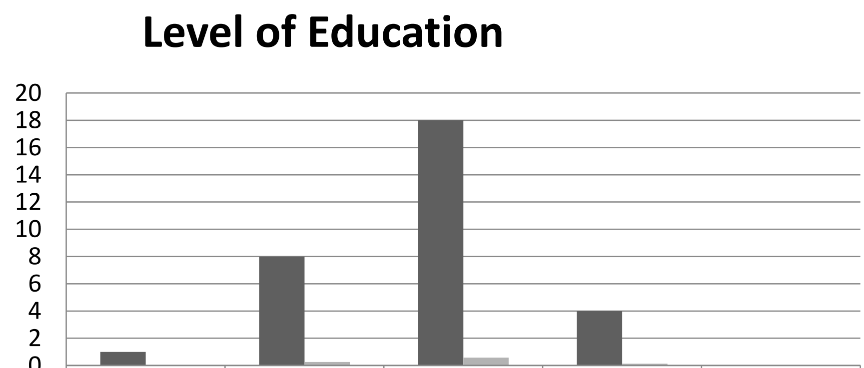
It can be observed that the educational level can only be considered "good", since although the activity does not require producers with a high level of education, they are favored if they have a higher level of education, as it brings a greater easiness for the absorption of new technologies for increasing the productivity. More than half of the producers show minimal knowledge at reading, writing, calculations and routine note taking, among other tasks (Chart 1), similar data were found in a study titled Characterization of Dairy Cattle in the Municipality of Diamantina-MG). In this study, it was observed that 42% of the interviewees have elementary education (8 years of formal study); 17.1% went to high school (11 years of formal study); 15.5% do not have schooling; 14.8% have incomplete primary education; 7.9% have university degree (15 years of formal studies) and 2.6% have not finished their university course yet (Almeida, 2013).

The income results showed that 52% of the households earn less than the minimum wage with the activity (minimum wage in Brazil 2011 ~ R$ 545.00 during the research, where in September/2011, US$1 = R$ 1.75 and US$1 = R$ 1.77, in October/2011). According to the data, 45% earn more than the minimum wage at the time and 3% earned the equivalent of a minimum wage (Chart 2). These indices show that the income uniformity is due to the fact that, the families take their livelihood only from the milk activity. This means the absence of pluriactivity (Schneider, 2003). This perception is perhaps liked to the low level of education of the participants. This is then a barrier in terms of low degree of human capital and local cultural vision, the accommodation to an existing situation, not looking for other sources of income. A priori, in the vision of the producer, the daily milk activity does not cause the perception of such need. Moreover, the low degree of centrality, within Christaller's vision, favors the open options with the plurarity, in this adverse situation. Another factor that can correlate these indices is the activity time, since 94% of the producers have already been engaged in the activity for more than 10 years and are more stabilized, despite the low financial gains (Chart 3).

This information gives a relative view, but when the GDP per capita is analyzed, the reality becomes different. For this, some comparative data are observed. The largest Brazilian municipality in terms of population, São Paulo, would have GDP per capita of R$ 37,105.08. Florianópolis, in Santa Catarina, would have GDP per capita of R$ 31,998.89. Chapecó, in Santa Cantarina, presents R$ 26,121.03 for this indicator, and Maceió, in Alagoas, R$ 14,836.26. Finally, Jacaré dos Homens presents GDP per capita of R$ 7,286.06 (IBGE, 2017), considering the value of the currency for the year 2012. This is considered as the Real currency with current price for the year 2012. The cities in Alagoas have a very low indicator, being worse for Jacaré dos Homens. The milk cattle activity, thus, has not yet been able to bring to the city a greater income vitality or better distribution of the income generated, despite presenting a better performance than Maceió in terms of income distribution, according to the Gini index. This may reflect the need to further increase the milk and dairy production chain in the region, so as to bring greater aggregation of local value and improvement in per capita income.

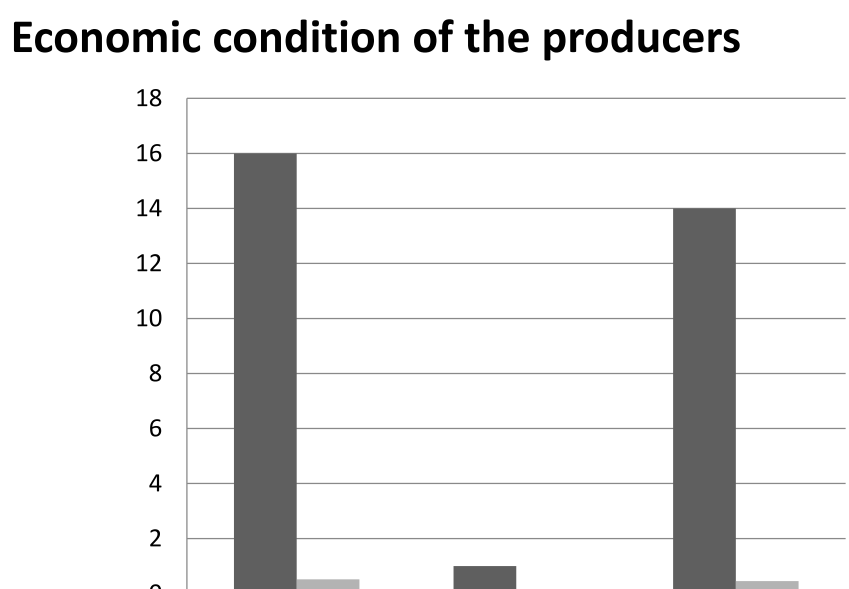
Considering the analyzed properties, from the total cattle herd destined to milk production, the predominant breed was Girolando, a result of crossbreeding between the GIR and Holstein breeds. As shown in Chart 4, 35% of the cows are lactating, 12% are dry cows, about 25% are calves and 13% are heifers. Through Chart 5, it can be analyzed that the milk production of the Baixas community in Jacaré dos Homens is characterized by small producers, who have an average daily production under 40 L. Out of the total of cows in the lactation period, the average daily production is 31.4 L day and the average production per cow reaches 10.6 L/day, which is equivalent to 3872 liters/cow/year.

According to IBGE (2014), the average productivity of milk production in Brazil was 1,525 liters/cow/year in 2014, corresponding to a growth of 2.2% in relation to



	Literate	Illiterate	Elementary School	High School	University
Absolute frequency	1	8	18	4	0
Relative frequency %	3.2%	25.8%	58.1%	12.90%	0.00%

Chart 1. Level of education, Source: Based on the survey data.



	< 1 minimum wage	1 minimum wage	> 1 minimum wage
Absolute frequency	16	1	14
Relative frequency %	52%	3%	45%

Chart 2. Economic situation of producers, Source: Based on the survey data.

2013 (1,492 L/cow/year). The South Region showed the highest national productivity, 2 789 liters/cow/year, an increase of 4.3% in 2014, compared to the previous year. The highest productivities occurred in the South of the country, in terms of aggregated data by State; The State of Rio Grande do Sul has the highest national productivity (3,034 L/cow/year), followed by the States of Santa Catarina (2,694 L/cow/year) and Paraná (2,629 L/cow/year). The lowest productivity was found in the State of Roraima (345 L/cow/year), in the northern region of Brazil. In terms of cities, despite the leadership of Araras (11,364 L/cow/year), in the State of São Paulo (SP), southeast region, more than 50 cities are among the largest producers, and all of them are in the southern

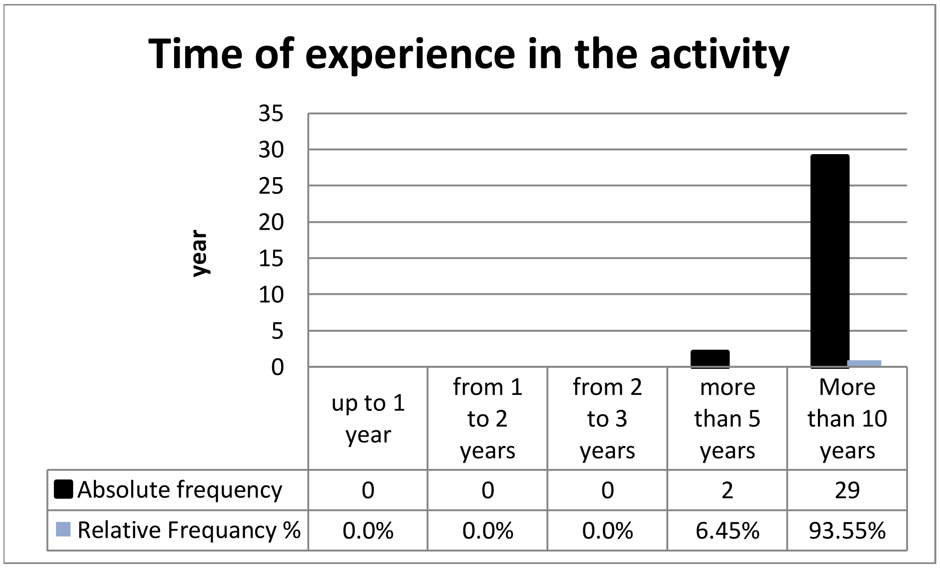


Chart 3. Time of experience in the activity, Source: Based on the survey data.

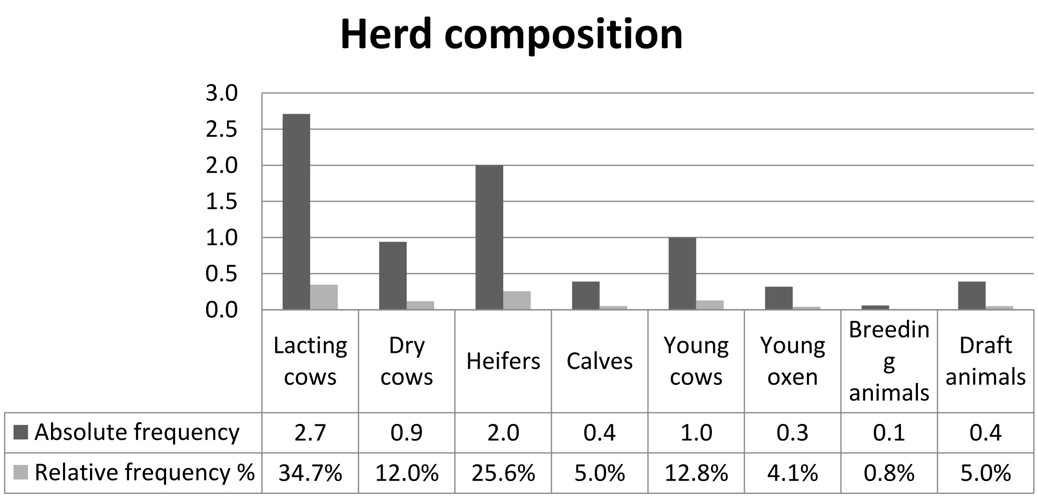


Chart 4. Herd composition, Source: Based on the survey data.

region of Brazil. Castro, in the State of Rio Grande do Sul, Castro (7469 L/cow/year) and Carlos Barbosa (6827L/cow/year), in the State of Paraná, are the second and third place in this productivity ranking, respectively. Therefore, the average productivity of the producers surveyed is twice the national average. The result comes from a sample (not probabilistic), for convenience, composed by who is the part of the program in that city. For comparative purposes, the IBGE data estimated for 2014 showed a production of 2336 L/cow/year. Of course, slightly lower than the mean of the selected sample, even with 2014 data.

Regarding the management of agricultural practices, in addition to seeking to maximize the dairy productivity of the herds, both the feeding, and the economic and zootechnical data also have repercussions on the quality of the milk. However, in order to obtain a better yield, it is necessary to make use of a set of sanitary, herd management and pasture practices. However, none of the producers do soil analysis and only 3% use mechanized traction to work the soil of the property.

Zootechnical control is a management technique that has been widely used in dairy farms. With this technique, the producer has the possibility to make notes on the productive life (milk control), reproductive (reproductive control) and sanitary (sanitation control) of each animal of the property. These indicators of zootechnical performance are fundamental for the decision making of the milk producer, aiming at the efficiency and productivity of the milk activity. In the region studied,

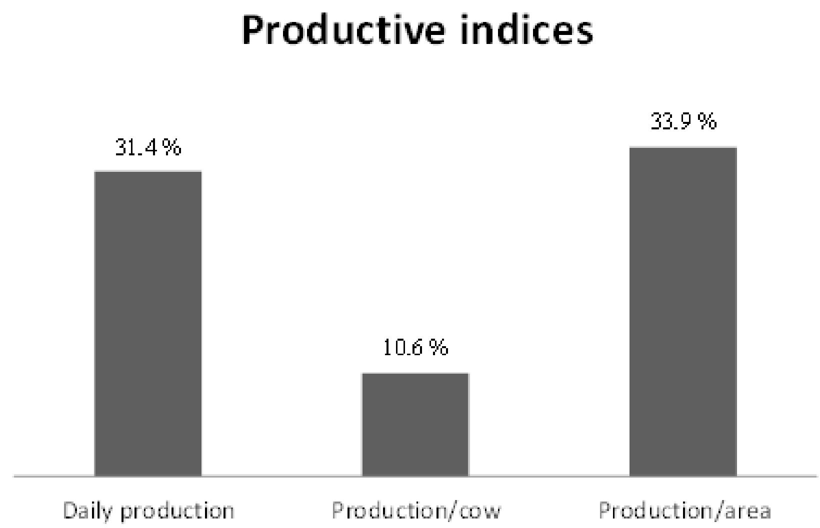


Chart 5. Production indices, Source: Based on the survey data.

amounts of 45% of producers claim not to make any kind of control within their property. On the other hand, 42% of them do zootechnical and economic control. This percentage corresponds to almost half of the interviewees and is considered as a source of production growth within the municipality. It is estimated that this number will increase in the coming years (Chart 6).

An example of the advantage of adoption of zootechnical control is the knowledge of the production profile of the animals in the farm, allowing them to be separated by batches, so the balance of the diet can be specific for each group. It is also possible to observe the period of droughts and rainfall of the region in function of the feeding management of the animals, since during the rainy season the animals feed mainly on native pasture, and during the dry season the food supplementation is based on the use of silage and palm, according to Charts 7 and 8. The importance of the combination of pasture, batch separation, zootechnical control and food supplementation is evidenced when evaluating its contribution to the productivity of the herd. Therefore, planning is essential to ensure the balance between forage production and demand, in order to ensure high efficiency of pasture utilization and maintenance of conditions favorable to productivity and animal performance. In the dry period, the main food is spineless cactus (*Nopalea cochenillifera*), corn silage (*Zea mays* L) and pasture grasses, mainly Buffel (*Cenchrus ciliaris*). In the rainy season, pastures of native plants abound, with herbs and shrubs favoring the feeding of animals. In addition to green Buffel, there are other grasses such as Milhã (*Digitaria horizontalis* Willd) and Quince (*Cydonia oblongata*).

Regarding reproductive management, 55% of the interviewees opt for uncontrolled mating and 45% use the artificial insemination method (Chart 9). The first type of management is advantageous due to the low cost of specific labor. However, the second excels because insemination ensures a greater chance of fertilization and calving as well as providing the improvement of the herd and allowing the choice of features that will remain in the calves. In a study in the southern region of the country, higher percentages were found. It was found that 81% of interviewees use artificial insemination as the main method of reproduction, which shows the use of technology performing on the activity. The remainder, approximately 19%, uses mating by natural mating in the breeding system (Caixeta, 2009).

Through a good health management - conducting clinical examinations and vaccinations - the farmer is able to prevent, control and even eradicate some diseases. It is important to note that, in addition to the foot-and-mouth disease, other diseases such as brucellosis, clostridiosis, carbuncle, mastitis and parasitic diseases should be monitored and treated. It was observed that almost all producers carry out vaccination against foot-and-mouth disease and parasite control, and have a 100% non-vaccinated herd against anthrax, clostridiosis and brucellosis (Chart 10). In the same study mentioned above, it was observed that in vaccination against foot-and-mouth disease, 100% of the respondents said that it was done during the established periods. As for mastitis and other diseases caused by the lack of adequate health management, it was verified that all the interviewees consider low the index that affects the herd, therefore they do not see the necessity of vaccination of the animals (Caixeta, 2009). The control agencies of the State Government (Agency of Defense and Agricultural Inspection of Alagoas - ADEAL) and Federal control (Ministry of Livestock and Supply) monitor the control of vaccinations to maintain the control of zoonosis and infectious diseases in the State of Alagoas and Brazil.

In 97% of the properties, two daily milks were performed, considering the 12 h milking interval (Zoccal, 2004). During the interview, all producers stated that the milking is done manually and do not perform the sanitary practices of pre and post dipping. This information is a negative indicator for both the prevention of health of the herd, and for the quality of milk, as these tools are essential for reducing contamination by the skin of the teats before milking and eliminating most bacteria that are on their skin after milking, reducing the colonization of the skin of the teats, which is the main way of transmission of contagious mastitis without leaving residues in milk (Simões, 2012).

Conclusions

After the research, it is concluded that despite the low level of education of the producers, most of them are more than 10 years in the activity and more than half of them have income less than a minimum wage. Despite having a good average production (10 L/cow/day), the number of animals is low, justifying the income less than 1 minimum wage. About 45% of the producers do not have any type of economic or zootechnical control.

According to data from the Brazilian Institute of Geography and Statistics (IBGE, 2014), considering the municipal productivity (liters/cow/year) according to the traditional calculation method, Jacaré dos Homens has an HDI well below the cities of Araranguá (SC) and Anahy (PR). In spite of this, these mentioned municipalities present the same productivity of milk.

In this case, we can conclude four distinct and complementary situations. The first is that there is no pluriactivity, that is, farmers do not have alternative sources of income. Second, there is a lack of chain densification also with the purpose of aggregating value and indirectly to provide a better distribution of income along the chain. Third, Balde Cheio program is fundamental to increase the diffusion of technologies that allow greater gains through greater productivity, and even the expansion of the herd. There is room for this, clearly.

Finally, this article aimed to characterize a production system based on an exploratory research, which makes it very important to reduce the asymmetry of existing information. In addition, to this, the research agenda is allow to expand, as it can encourage interesting international comparisons which is a specific biome with edaphoclimatic conditions that impose restrictions for the activity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEGMENTS

The authors appreciate the State Government through the State Agriculture Secretariat - SEAGRI and SEBRAE-AL, the Pecuária Intensiva Company (Faazenda Eficiente), EMBRAPA Pecuária Sudeste (Balde Cheio), and the technical extension workers.

REFERENCES

Almeida MAF (2013). Caracterização da pecuária leiteira no município de diamantina – mg. Post-graduation in Zootechnics. Federal University of Vales dos Jequitinhonha e Mucuri.

Alves RRN, Mendonça LET, Confessor MVA, Vieira WLS, Lopez LCS (2009). Hunting strategies used in the semi-arid region of northeastern Brazil. J. Ethnobiol. Ethnomed. 5(1):10.

Caixeta WR (2009). Análise socioeconômica da pecuária leiteira e o desenvolvimento da atividade: um estudo dos produtores filiados ao sindicato rural do Arizona/GO. 48º Congresso SOBER (Sociedade Brasileira de Economia Administração e Sociologia Rural) Campo Grande–GO. Available at: http://www.sober.org.br/palestra/15/595.pdf.

DB-CITY (2016). Cidades e Vilas do Mundo. Available at: http://pt.db-city.com/Brasil--Alagoas--Jacar%C3%A9-dos-Homens.

Eurich J, Weirich NPH, Rocha CH (2016). Pecuária leiteira em uma colônia de agricultores familiares no município de Palmeira, Paraná. Rev. Ceres, Viçosa 63(40):454-460 .

Guimarães Filho C, Soares JGG (1999). Sistema CBL para produção de bovinos no semi-árido. Petrolina: Embrapa – CPSAT., 4p. (Comunicação Técnica, 2).

Instituto Brasileiro de Geografia e Estatística (IBGE) (2014). Aquisição de leite pela indústria cresce 8,4% no 2º trimestre de 2014 em relação ao mesmo período de 2013. Instituto Brasileiro de Geografia e Estatística. Available at: http://www.ibge.gov.br. Accessed 1 June 2016.

Instituto Brasileiro de Geografia e Estatística (IBGE) (2015). Rebanho bovino brasileiro cresce e chega a 212,3 milhões de cabeças de gado. Available at: http://www.brasil.gov.br/economia-e-emprego/2015/10/rebanho-bovino-brasileiro-cresce-e-chega-a-212-3-milhoes-de-cabecas-de-gado . Accessed 28 June 2016.

Instituto Brasileiro de Geografia e Estatística (IBGE) (2017). Pesquisa trimestral de leite. Instituto Brasileiro de Geografia e Estatística. Available at: http://www.ibge.gov.br. Accessed 6 February 2017.

Lima PO, de Lima RN, Duarte, LS, Souza AZB, Costa LBA, de Miranda MVFG (2011). Avaliação de propriedades rurais após implantação de programa de assistência técnica. Rev. Acta Vet. Bras. Mossoró 5(2):192-196.

Programa de las Naciones Unidas para el Desarrollo (PNUD) (2010). Ranking IDHM Municípios 2010. Available at < http://www.br.undp.org. Accessed> Accessed 6 February 2016.

Portal Brasil (2015). Portal Brasil com informações do IBGE. Rebanho bovino brasileiro cresce e chega a 212,3 milhões de cabeças de gado. Available at: http://www.brasil.gov.br/economia-e-emprego/2015/10/rebanho-bovino-brasileiro-cresce-e-chega-a-212-3-milhoes-de-cabecas-de-gado.

Schneider S (2013). Teoria Social, Agricultura e Pluriatividade. Rev. Bras. Ciênc. Soc. 18:51.

Simões TM (2012). Mastite bovina: Considerações e impactos econômicos. Aracajú: Embrapa Tabuleiros Costeiros,. 25p. (Documentos/ Embrapa Tabuleiros Costeiros, ISSN 1678-1953; 170). Available at: http://www.cpatc.embrapa.br/publicacoes_2012/doc_170.pdf.

U.S. Department of Agriculture's (USDA) (2014). Departamento de Agricultura dos Estados Unidos. Análise da Conjuntura Agropecuária. Available at: http://www.agricultura.pr.gov.br/arquivos/File/deral/Prognosticos/bovinocultura_leite_14_15.pdf.

Zoccal R (2004). Cem recomendações para o bom desempenho da atividade leiteira. Juiz de Fora: Emprapa Gado de Leite. (Empraba Gado de Leite. Comunicado técnico, 39). Available at: https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/594910/1/COT39Cemrecomendacoesparao.pdf.

academicJournals

Vol. 13(6), pp. 288-293, 8 February, 2018
DOI: 10.5897/AJAR2017.12938
Article Number: 987877E55897
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Phytosociology of weed community in two vegetable growing systems

Rubens Pessoa De Barros*, Ligia Sampaio Reis, Isabelle Cristina Santos Magalhães, Wanderson Ferreira Da Silva, João Gomes Da Costa and Aldenir Feitosa Dos Santos

Faculdade de Medicina, Estadual University of Alagoas, Brazil.

Received 17 December, 2017; Accepted 18 January, 2018

The aim of this study was to perform a phytosociological survey of the weed community present in organic and conventional vegetable growing systems conducted in Alagoas state, in Brazil. The survey was carried out from February 2014 to January 2016, within which 30 samplings were made. The evaluated parameters were given by the calculation of frequency, density, abundance, relative frequency, relative density, similarity index (SI) and importance value index (IVI) for each species. In total, 299 weed species were identified, which were grouped into 11 botanical families: Amaranthaceae, Asteraceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Malvaceae, Molluginaceae, Phyllantaceae, Poaceae, Rubiaceae and Solanaceae. The Euphorbiaceae family in conventional farming, stood out, since it showed an importance value index (IVI) more than, the Amaranthaceae family in the organic farming. In the conventional cultivation, IVI was of 91.53% for Asteraceae and 46.95% for Poaceae. Moreover, a major diversity of weed species was observed in organic cultivation, being superior to conventional one in all phytosociological parameters.

Key words: Diversity, olericulture, weed community.

INTRODUCTION

Vegetable growing in Brazil is diverse with more than 70 species of vegetables being produced and consumed. This production has increased in 33% during the last decade. Even though there has been a decrease of 5% in grown area, yields have been increased in 38% due to adoption of certain cultural practices (EMBRAPA Hortaliças, 2012).

The South and Southeast regions of Brazil are responsible for most part of the domestic production, wherein 60% of the farms are located near the great consumer centers. These greenbelts, as are so-called, are family farms of around 10 hectares, which are intensively exploited (Silva et al., 2015). Information released by the Brazilian Yearbook of Vegetable Growing indicate a production of around 18 thousand tons of vegetables within a planted area of 800,000 hectares, with an average yield of 23 tons per hectare, being equivalent to 94 kg per inhabitant year^{-1} (Anuário brasileiro de hortaliças, 2014).

Growing together with weeds is a factor that compromises yield and quality of agricultural crops, mainly with regard to vegetables. Weed species generally

*Corresponding author. E-mail: pessoa.rubens@gmail.com.

interfere with crops by competing for light and nutrients within the soil-plant system (Soares et al., 2010). The degree of interference of weeds in the crops depends on the distribution, frequency and abundance of the species, especially those that are in greater density and diversity (Kuva et al., 2000). Ricci et al. (2006) and Gama (2009) reported increasing frequency of weed species in organic cultivations, where agro-ecological practices are adopted instead of the use of herbicides, in which, even so, there is an increase of undesirable grass species are unwelcome for a selective management.

According to Gomes and Christoffoleti (2008), phytosociological surveys are necessary to bring knowledge of the distribution of a certain species over the others, allowing quantitative interpretation of a studied community, as well as viewing of their biological interrelations, assisting in weed management through the adoption of efficient of controls strategies. When dealing with agro-ecosystems of low yield, special attention should be given mainly with regard to ecological problems arising from the increase in irrigated areas, which enhance germination of weed seeds and soil salinization (Srivastava and Singh, 2014).

The production of safe food in a bountiful way is of great importance to solve the problems of world hunger. However, crop phytosanitary problems with pest insects and weeds hinder the achievement of such production targets. Improvements in pathogen control or coexistence between plants could significantly increase food production. The three major cereals - wheat, rice and maize - grown worldwide provide about 60% of human food. These crops are derived from weeds that have become the three plants abundantly scattered on planet Earth (Tilaman et al., 2002).

This study assumes that phytosociological parameters of a weed community (PPWC) within a farming system show the interaction between adopted management practices (MP) and weed species adaptation within the soil-plant system (WASP), that is, PPWC = MP + WASP. Thus, the aim of this research was to make a phytosociological survey of the weed community in two types of vegetable growing systems, organic (management with natural products) and conventional systems (management with synthetic products).

MATERIALS AND METHODS

The phytosociological survey of the weed community was carried out between the months of February 2014 to January 2016, in a 5.0-ha organic and conventional growing areas located within an environmentally harsh region of the State of Alagoas, Brazil. The survey was conducted in the field at 45 days after transplanting the seedlings, dividing each growing system into 30 plots. The plants in each plot were collected and properly identified following the Angiosperm Phylogeny Group - APG system.

Samplings were conducted by throwing a wooden square of 0.5 m² randomly on the net plot. All weeds within the square were considered as one sample and were identified by botanical family, using method similar to that used by Cunha (2014) and Kuva et al. (2000). Samples of plant material taken from the field were collected along with root system, being spread flat on sheets of newsprint duly identified and separated by botanical species and family; and then dried under Full sunlight at room temperature.

The weed species were quantified according to frequency, which expresses occurrence intensity at different areas, in percentage; to density, which is the number of plants per unit area, expressed in plants per square meter; and to abundance, which shows the concentration of certain species within a certain area. In addition to these calculations, the values of relative frequency, density and abundance were also quantified, with which it was possible to estimate the importance value index (IVI) for each species. This index establishes an integration parameter for the partial variables, joining them into one simple expression, showing the relative importance of each species in a better way when compared to other phytosociological parameters. For the calculations of such parameters, the equations below were used (Cunha et al., 2014):

$$\text{Frequency (Fr)} = \frac{\text{Total number of plots with the species} \times 100}{\text{number total of plots used}} \quad (1)$$

$$\text{Density (D)} = \frac{\text{Total number of individuals per species}}{\text{Total sample area}} \quad (2)$$

$$\text{Abundance (Ab)} = \frac{\text{Total number of individuals per species}}{\text{Total number of plots containing species}} \quad (3)$$

$$\text{Relative frequency (FrR)} = \frac{\text{Frequency species} \times 100}{\text{Overall frequency}} \quad (4)$$

$$\text{Relative density (DeR)} = \frac{\text{Density species} \times 100}{\text{Total density}} \quad (5)$$

$$\text{Relative abundance (AbR)} = \frac{\text{Abundance} \times 100}{\text{Overall abundance}} \quad (6)$$

$$Importance\ Value\ Index = DeR + FrR + AbR \quad (7)$$

Since the number of individuals per species was obtained, a descriptive analysis was made through phytosociological parameters represented by the relative importance (R.I%) (Pitelli and Pitelli, 2008). The IVI was estimated by equation too. The relative importance index was chosen to describe changes on weed community and on each weed species, because such index best expresses relationships among the populations composing the community. Such effectiveness come from the fact that this index considers for each plant population the frequency of occurrence, the number of individuals and the accumulated dry matter (Carvalho et al., 2008).

RESULTS AND DISCUSSION

The botanical diversity was significant, in which the weed community was represented by 299 species grouped into 11 families, being common to both growing systems. The

Table 1. Phytosociology data of weed communities in organic farming.

Species	Freq. (%)	Den. (%)	Abu. (%)	FrR. (%)	DeR. (%)	AbR. (%)	IVI (%)
Amaranthus deflexus L.	83.33	0.22	6.8	11.62	26.92	8.28	46.82
Amaranthus Lividus L.	16.66	0.01	2.00	2.32	1.32	2.43	6.07
Amaranthus spinosus L.	16.66	0.04	6.00	2.32	5.31	7.31	14.94
Amaranthus spp	50.0	0.086	4.66	6.97	10.45	5.67	23.09
Phyllanthus spp	16.66	0.01	4.00	2.32	1.32	4.87	8.51
Phyllanthus niruri L.	50.0	0.016	1.00	6.97	1.99	1.21	10.17
Chamaesyce hirta (L.) Milisp.	50.0	0.06	3.00	6.97	7.54	3.65	18.16
Chamaesyce prostrata (Aiton) Small	33.33	0.07	5.5	4.65	9.30	6.70	20.65
Acalypha communis Mull. Arg.	83.33	0.71	21.6	11.62	83.42	26.32	121.36
Cammelina benghalensis L.	66.66	0.19	7.5	9.30	23.35	9.13	41.78
Sida spp	66.66	0.04	1.5	9.30	4.88	1.82	16
Pennisetum clandestinum Hochst. ex Chiov	33.33	0.046	3.5	4.65	5.98	4.26	14.89
Brachiaria plantaginea (Link.) Hitchc.	16.66	0.006	1.00	2.32	0.67	1.21	4.2
Cynodon dactylon (L.) Pers.	16.66	0.02	3.00	2.32	2.23	3.65	8.2
Ricinus communis L.	16.66	0.02	4.00	2.32	2.65	4.87	9.84
Luziola peruviana juss. ex. J.F.Gmel	16.66	0.006	1.00	2.32	0.79	1.21	4.32
Eleusine indica (L.) Gaertn.	16.66	0.02	3.00	2.32	2.65	3.65	8.62
Pyhysalis pubescens L.	66.66	0.066	3.00	9.30	9.02	3.65	21.97

FrR =relative frequency; DeR= relative density; AbR= relative abundance; Freq = frequency; Abu= abundance; Den.=density; IVI= importance value index.

observed families were Amaranthaceae, Asteraceae, Commelinaceae, Cyperaceae, Euphorbiaceae, Malvaceae, Molluginaceae, Phyllantaceae, Solanaceae, Poaceae and Rubiaceae. Cunha et al. (2016) presented similar families in a phytosociological survey with forage tifton.

In organic farming, the highlighting species from Euphorbiaceae family were *Acalypha communis* Mull. Arg. (121.36%), *Chamaesyce prostrata* (20.65%) and *Chamaesyce hirta* (L.) Milisp. (18.16%). Data revealed that under conventional cultivation, Asteraceae family was predominant, which is considered one of the largest families of weed in number of species. The representative species were *Ageratum conyzoides* L. and *Conyza bonariensis* (L.). Surveying in sweet pepper cultivations, Cunha et al. (2014) found weed species similar to this research.

In the same way, Erasmo et al. (2004) reported similar results when assessing weed communities in wetlands of Viçosa in Minas Gerais state (Brazil); the authors highlighted the Euphorbiaceae family for showing the largest number of species in the studied areas. The high number of weed species in organic systems observed in this study may be due to the high potential viability of a seed bank to germinate where there is no herbicides applied.

Silva et al. (2007) stated that all agricultural land is a potential weed seed bank, holding about 2,000 and 50,000 seeds per square meter within the upper 10 cm of the soil profile. In vegetable crops, rhizosphere is quite shallow, which increases germination chances, even though in a given period, only 2 to 5% seed would germinate whereas the rest remain dormant.

The species of major importance in organic farming was *Acalypha communis* Mull. Arg., with an IVI of 121.36, found in plots at a frequency of 83.33% and density of 0.71 plant m^2 (Table 1). Vaz de Melo et al. (2007) noticed that Bidens pilosa was the species of greatest relative importance in crop of sweetcorn. Another genus that stands out is Amaranthus, commonly known as pigweed. Kissmann and Groth (2000) stated that there are about 60 plant species belonging to this genus (pigweed or caruru), among which 10 are important weed in crops (Table 1).

The genera Acalypha and Amaranthus showed major similarity indexes respectively, in the organic cultivation. In this environment, mulch is widely used, which hampers germination of soil seed bank. Nevertheless, this system presents a greater diversity of weeds compared to the conventional farming system growing the same vegetables (Braga et al., 2012).

The similarity index (SI) was used to verify the similarity among the weed species found in the plots in areas of organic cultivation. Through that, it was possible to detect similar genera existing among all evaluated plots; for instance, the species *A. communis* Mull. Arg. and *A. deflexus* L. showing SI of 83.72 and 26.35% (Table 2). For values above 25%, it is said that the species are adapting themselves to the current growing system, remaining their genotypes through seed bank (Table 2).

Table 2. Similarity index (SI) among all plot in the research area – organic farming.

Species	SI (%)
Amaranthus deflexus L.	26.35
Amaranthus Lividus L.	1.55
Amaranthus spinosus L.	4.65
Amaranthus spp	10.85
Acalypha communis Mull. Arg.	83.72
Brachiaria plantaginea (Link.) Hitch	0.77
Chamaesyce hirta (L.) Milisp.	6.97
Chamaesyce prostrata (Aiton) Small	8.52
Commelina benghalensis L.	23.25
Cynodon dactylon (L.) Pers.	2.32
Eleusine indica (L.) Gaertn.	2.32
Luziola peruviana Juss. ex J.F.Gmel	0.77
Pennisetum clandestium Hochst. ex Chiov.	5.42
Phyllanthus spp	3.10
Phyllanthus niruri L.	2.32
Sida spp	4.65
Ricinus communis L.	3.10
Pyhysalis pubescens L.	9.30

These values were higher than those found by Braga et al. (2012), who estimated this index for species found in no-till and conventional tillage, with or without limestone applications and at different times of evaluation. These authors found a value of 81.1%, which is considered high. Similar results were encountered by Duarte Jr. et al. (2009), who reported an index of 85.71% for infesting plants in different planting systems.

Among 41 individuals found in conventional farming, seven botanical families were identified, among which Asteraceae and Poaceae were the mostly present groups. These botanical families represent the main groups of existing weeds in Brazil. Furthermore, these families do not only occur in conventional crops, but also have great importance in other distinct production systems, such as sunflower, farming in wetlands and even in areas of lawns (Maciel et al., 2008; Brighenti et al., 2003; Tuffi Santos et al., 2004).

The species *A. conyzoides* (L.) and *Pennisetum clandestinum* Hochst. ex Chiov. were of great highlight in the conventional farming system. *A. conyzoides (*L.) is an annual herbaceous species that grows across the country, especially in areas cropped with garlic, onions, carrots and tomatoes. Yet, *P. clandestinum* Hochst. ex Chiov is an annual grass, less clumped and grown throughout the country for biomass production and incorporation to the soil.

Partelli et al. (2010) found similar genera in conilon coffee plantations. Maciel et al. (2010) discussed the importance of these studies to decide the best method of control. As observed in the phytosociological data in the system, *A. conyzoides* and *P. clandestinum* stood out due to their IVI values, which were of 91.53 and 46.95% respectively (Table 3). Although under a conventional system, the low use of herbicides allow the emergence of such species with increasing frequency, since seeds remained in the soil for more than one cultivation cycle. These data represented by the sum of relative density, relative frequency and relative dominance which indicate major influence within the weed community (Oliveira and Freitas, 2008) (Table 3).

The results revealed similarity among species, among which the genus Ageratum should be highlighted by its significant index (87.80%), followed by the genus Pennisetum. The species *A. conyzoides* (L.) and *P. clandestinum* (Hochst. ex Chiov.) stood out in this survey, as shown in Table 4. Adegas et al. (2010) stressed the importance of knowing the weed species throughout the crop cycle to enable decision making regarding the best method of control (Table 4).

The absence of routine application of herbicides in both crop systems enabled germination of weed seeds at a higher frequency than the normal. Phytosociological surveys compare different weed populations within a particular location at a particular time. Therefore, when repeatedly performing this study, variations on the level of importance of one or more populations could be observed. Such variations are derived from the adopted agricultural practices and managements. In structural analysis of a particular crop, the phytosociological parameters become reliable measures of weed floristic composition at this niche (Oliveira and Freitas, 2008),

Table 3. Weed phytosociology – conventional farming.

Species	Freq. (%)	Den. (%)	Abu. (%)	FrR. (%)	DeR. (%)	AbR. (%)	IVI (%)
Ageratum conyzoides L.	100	0.12	6.00	20.00	46.87	24.66	91.53
Conyza bonariensis (L.) Cronquist	33.33	0.006	0.33	6.67	2.34	1.35	10.36
Pennisetum clandestinum Hochst. ex Chiov	33.33	0.04	6.00	6.67	15.62	24.66	46.95
Brachiaria plantaginea (Link.) Hitchc.	33.33	0.006	1	6.67	2.34	4.11	13.12
Mollugo verticillata L.	66.66	0.02	2.00	13.34	7.81	8.22	29.37
Bulbostylis capillaris (L.) C. B. Clarke	33.33	0.006	1.00	6.67	2.34	4.11	13.12
Cyperus difformis L.	33.33	0.01	2.00	6.67	3.90	8.22	18.79
Chamaesyce hirta (L.) Milisp.	33.33	0.01	2.00	6.67	3.90	8.22	18.79
Chamaesyce prostrata (Aiton) Small	33.33	0.006	1.00	6.67	2.34	4.11	13.12
Richardia grandiflora (Cham and Schltdl.) Steud.	33.33	0.006	1.00	6.67	2.34	4.11	13.12
Solanum americanum Mill	66.66	0.02	2.00	13.34	7.81	8.22	29.37

FrR =relative frequency; DeR= relative density; AbR= relative abundance; Freq.= frequency; Abu= abundance; Den.=density; I.V.I= importance value index.

Table 4. Similarity index (SI) among the plots of the survey – in conventional farming.

Species	SI (%)
Ageratum conyzoides L.	87.80
Conyza bonariensis (L.) Cronquist	4.87
Pennisetum clandestinum Hochst. ex Chiov	29.26
Brachiaria plantaginea (Link.) Hitchc.	4.87
Mollugo verticillata L.	19.51
Bulbostylis capillaris (L.) C. B. Clarke	4.87
Cyperus difformis L.	9.75
Chamaesyce hirta (L.) Milisp.	9.75
Chamaesyce prostrata (Aiton) Small	4.87
Richardia grandiflora (Cham & Schltdl.) Steud	4.87
Solanum americanum Mill	19.51

and may assist in choosing a control method for them, since they have influence on management efficiency (Maciel et al., 2010).

Conclusions

The phytosociological survey revealed that Euphorbiaceae and Asteraceae families had the highest numbers of individuals in organic and conventional farming systems, respectively. The soil seed bank in the assessed vegetable growing areas showed a wide range of plant genera. Regarding similarity index, all species seems to be well distributed in the dry region of Alagoas; Brazil, showing good adaptability to the local biological, climatic and soil conditions. Further surveys are needed to confirm the adaptation of the weed families to the cultivation regions, complementing the results found in this research.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors want to thank the University of Alagoas State – UNEAL, through the Undergraduate Program of Scientific Research Initiation – PIBIC, the Federal University of Alagoas / School of Agricultural Sciences - CECA, through the Graduate Program on Plant Protection, the Company Brazilian Agricultural Research Corporation (EMBRAPA) in Alagoas and the Foundation of Support to the Research of the State of Alagoas – FAPEAL, for supporting research projects of Scientific Research Initiation through grants of PIBIC scholarships.

REFERENCES

Adegas FS, Oliveira MF, Vieira OV, Prete CEC, Gazziero DLP, Voll E (2010). Levantamento Fitossociológico de Plantas Daninhas na Cultura do Girassol. Planta Daninha, Viçosa-MG. 28(4):705-716.

Anuário Brasileiro de Hortaliças (2014). Brazilian Vegetable Yearbook. Santa Cruz do Sul: Editora Gazeta Santa Cruz 88p.

Braga RR, Sury JP, Santos JB, Byrro ECM, Silva DV, Carvalho FP, Ribeiro KG (2012). Ocorrência de plantas daninhas no sistema lavoura-pecuária em função de sistemas de cultivo e corretivo de acidez. Rev. Ceres Viçosa 59(5):646-653.

Brighenti AM, Castro C, Gazziero DLP, Adegas FS, Voll E (2003). Cadastramento fitossociológico de plantas daninhas na cultura do girassol no Município de Chapadão do Céu, GO. Bol. Inform. Soc. Bras. Ciênc. Plant. Daninhas 9(1):5-8.

Carvalho LB, Pitelli, RA, Cecílio Filho AB, Bianco S, Guzzo CD (2008). interferência e estudo fitossociológico da comunidade infestante em beterraba de semeadura direta. Plant. Daninha 26(2):291-299.

Cunha JLXL, Carvalho IDEC, Coelho MEH, Silva Júnior AB, Oliveira FS (2016). Levantamento fitossociológico em pastagens de tifton vaqueiro em Rio Largo-AL. Tecnol. Ciênc Agropecu. João Pessoa 10(4):49-54.

Cunha JLXL, Freitas FCL, Coelho MEH, Silva MGOS, Silva KSS, Nascimento PGML (2014). Phytosociology of weeds in sweet pepper cultivation in no-tillage and conventional planting systems. Revi. Agro@mbiente On-line 8(1):119-126.

Duarte Jr JB, Coelho FC, Freitas SP (2009). Dynamics of populations of weed in the sugarcane in system no-tillage and conventional one. Semina: Ciênc. Agrár. Londrina 30(3):595-612.

EMBRAPA HORTALIÇAS (2012). Cores e sabores - Importância Nutricional das Hortaliças. Hortaliças em revista. Gama-DF, Publicação da Embrapa Hortaliças16p.

Erasmo EAL, Pinheiro LLA, Costa NV (2004). Levantamento fitossociológico das comunidades de plantas infestantes em áreas de produção de arroz irrigado cultivado sob diferentes sistemas de manejo. Planta Daninha, Viçosa-MG. 22(2):195-201.

Gama JCM (2009). Florística e Fitossociologia de Plantas Espontâneas em Comunidades Antropizadas do Cerrado em Minas Gerais.106f. Dissertação (Mestrado), Universidade Federal de Minas Gerais – UFMG.

Gomes Jr FG, Christoffoleti PJ (2008). Biologia e manejo de plantas daninhas em áreas de plantio direto. Plant. Daninha 26(4):789-798.

Kissmann KG, Groth D (2000). Plantas infestantes e nocivas. Tomo III, 2.ed. São Paulo: BASF. 726p.

Kuva MA, Pitelli RA, Christoffoleti PI, Alves PLCA (2000). Períodos de interferência das plantas daninhas na cultura da cana-de-açúcar. I – Tiririca. Plant. DaninhaViçosa 18(2):241-251.

Maciel CDG, Poletine JP, Aquino CJR, Ferreira DM, Maio RMD (2008). Floristic Composition of the Weed Community in *Paspalum notatum* Flügge Turfgrasses in Assis, SP. Planta Daninha, Viçosa-MG. 26(1):57-64.

Maciel CDG, Poletine JP, Oliveira Neto AM, Guerra N, Justiniano W (2010). Levantamento fitossociológico de plantas daninhas em cafezal orgânico. Bragantia 69(3):631-636.

Oliveira AR, Freitas SP (2008). Levantamento fitossociológico de plantas daninhas em áreas de produção de cana-de-açúcar. Plant. Daninha 26(1):33-46.

Partelli FL, Vieira HD, Freitas SP, Espindola JAA (2010). Aspectos fitossociológicos e manejo de plantas espontâneas utilizando espécies de cobertura em cafeeiro Conilon orgânico. Semina: Ciênc. Agrár. Londrina 31(3):605-618.

Pitelli RA, Pitelli RLCM (2008). Biologia das plantas daninhas. In: Vargas L, Roman ES (Ed.). Manual de manejo e controle de plantas daninhas. Bento Gonçalves: Embrapa Uva e Vinho 1:11-38.

Ricci MSF, Neves MCP, Nanneti AN, Moreira CF, Aguiar-Menezes EL, Silva E, Caixeta IF, Araújo JBS, Leal MAA, Fernandes MC, Almeida PS, Pedini S (2006). Cultivo do café orgânico. Sistemas de produção. 2 ed., Dez.

Silva AA, Ferreira FA, Ferreira LR, Santos JB (2007). Biologia de plantas daninhas. In: Silva AA, Silva JF. Tópicos em manejo de plantas daninhas. Viçosa-MG: Universidade Federal de Viçosa pp. 17-61.

Silva WF, Marques DJ, Silva EC, Bianchini HC, Ishimoto FA, Pereira Jr MJF (2015). Diagnóstico da produção de hortaliças na região metropolitana de Belo Horizonte. Hortic. Bras. 33:368-372.

Soares IAA, Freita FCL, Negreiros MZ, Freire GM, Aroucha EMM, Grangeiro LC, Lopes WAR, Dombroski JLD (2010). Interferência das plantas daninhas sobre a produtividade e qualidade de cenoura, Plant. Daninha 28(2):247-254.

Srivastava R, Singh KP (2014). Diversity in weed seed production and the soil seed bank: Contrasting responses between two agroecosystems. Weed Biol. Manage. 14:21-30.

Tilaman D, Cassmon KG, Matson PA, Naylor R, Polaskey S (2002). Agricultural sustainability and intensive production practices. Nature 418:671-677.

Tuffi Santos LD, Santos IC, Oliveira CH, Santos MV, Ferreira FA, Queiroz DS (2004). Levantamento fitossociológico em pastagens degradadas sob condições de várzeas. Planta Daninha 22(3):343-349.

Vaz de Melo A, Galvão JCC, Ferreira LR, Miranda GV, Tuffi Santos LD, Santos IC, Souza LV (2007). Dinâmica populacional de plantas daninhas em cultivo de milho-verde nos sistemas orgânico e tradicional. Plant. Daninha 25(3):521-527.

academicJournals

Vol. 13(6), pp. 294-301, 8 February, 2018
DOI: 10.5897/AJAR2017.12939
Article Number: 344A5A555900
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Role of climate change awareness in sustainable soil nutrient management by smallholder farms in Burkina Faso

Boundia Alexandre Thiombiano[1*], Dénis Ouédraogo[1], Quang Bao Le[2] and Samuel Nii Odai[3]

[1]Institut du développement rural (IDR), Université Polytechnique de Bobo-Dioulasso (UPB), 01 BP 1091 Bobo-Dioulasso 01, Burkina Faso.
[2]International Center for Agricultural Research in Dry Areas (ICARDA), Yousef El Sukkar Street, Bld no. 8, Amman 11195, Jordan.
[3]Kwame Nkrumah University of Science and Technology (KNUST), University Post office, Kumasi, Ghana.

Received 17 December, 2017; Accepted 16 January, 2018

Climate change effects are threats to the livelihood of Sub-Saharan smallholder farms. Farmers' response and readiness to take adaptive measures depend on how they perceive (perception) and moreover understand and recognize the causes (awareness) of climate change. Most studies used interchangeably perception and awareness to climate change. Taking the example of soil nutrient management, this study demonstrated the importance of distinguishing awareness from perception in climate change adaptation studies and for policy design. The study was conducted in South-western Burkina Faso. Using a semi-structured questionnaire, 360 households were surveyed. Rainfall variation and onset of the cropping season were used as climate change evidences to assess climate change perception and awareness. Descriptive statistics and Z-test were run. Results showed that beyond climate change perception, farmers largely took adaptive measures when they understand and can explain causes of climate change. Therefore, climate change adaptation studies and policy interventions should distinguish awareness from perception, and policy design should stress on raising climate change awareness of smallholder farmers.

Key words: Climate change perception, climate change awareness, sustainable soil nutrient management, smallholder farms, Burkina Faso.

INTRODUCTION

Climate change negatively impacts farming activities, aggravates crop production deficiencies, and threatens livelihoods (Jarvis et al., 2010; Lobell and Burke, 2010; Olsson et al., 2014; Porter et al., 2014). Studies (Blanc, 2012; Sultan et al., 2013) estimated that yield of main staple crops in Sub-Saharan Africa (maize, millet and

*Corresponding author. E-mail: boundia@gmail.com.

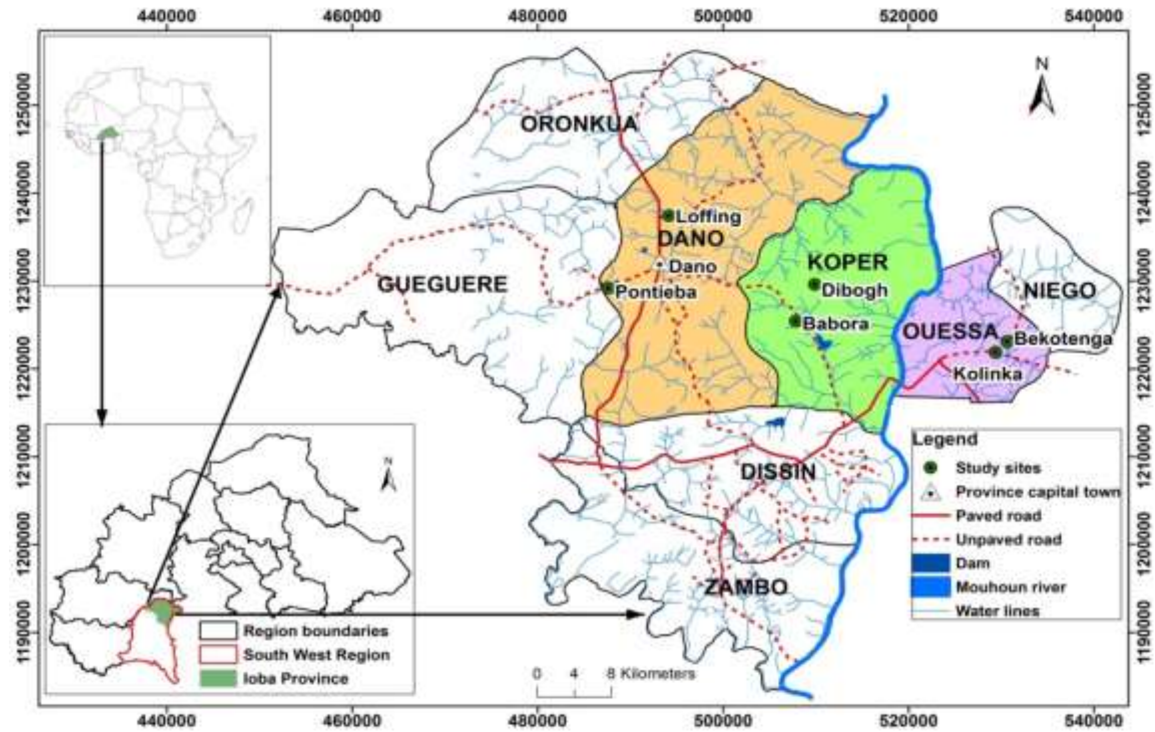


Figure 1. Study zone.

sorghum) will decrease by up to 25.5-27% under climate change during 21st century. Adapting to climate change through adoption of supplemental irrigation for instance (Sanfo et al., 2017) and building farm resilience is paramount to improving food security and livelihood of smallholder farms.

To improve and sustain food production, smallholders farms need to change current agricultural practices (International Food Policy Research Institute (IFPRI), 2007; Andrieu et al., 2015) mostly inadequate in the context of climate change. In Burkina Faso, spots of changes were noted for the use of water harvesting techniques (Kabore-Sawadogo et al., 2013) as well as for soil conservation practices (Pouya et al., 2013). However, adoption of these specific techniques and practices (Bunclark et al., 2015) and of other sustainable nutrient management practices (Place et al., 2003; Bationo et al., 2006; Anley et al., 2007; Chianu et al., 2012, 2012a) is still limited in Burkina Faso in particular and in Sub-Saharan Africa in general. Besides financial constraints (Koutou et al., 2016) and in some extent insufficient technical know-how, lack of understanding of ongoing climate variability and its implications contributes to explaining the poor soil fertility management performances in Sub-Saharan African smallholder farms for food crops.

There is need to increase knowledge on farmers' awareness to climate change for guiding decision making on smallholder farms adaptation and resilience to climate change. The extent of climate change impact largely depends on farmers' awareness (Fosu-Mensah et al., 2012). Awareness is a key determinant of adaptation to climate change (IFPRI, 2007; Ishaya and Abaje, 2008). For being proactive and taking efficient adaptation actions, smallholder farms need to understand climate change, its causes and implications. Climate change awareness enhances adaptive capacities (Marshall et al., 2013).

However, most studies (Gbetibouo, 2009; Fosu-Mensah et al., 2012; Nzeadibe et al., 2012) did not clearly distinguish climate change perception from climate change awareness. Moreover, more studies analyzing climate change awareness in relation to sustainable nutrient management practices are still needed.

Therefore, the objective of this study is to analyze climate change perception and awareness, and the implication for sustainable soil nutrient management in smallholder farms. The specific objectives are: (i) to assess climate change perception and awareness of smallholder farmers and (ii) to analyze the effect of climate change awareness on soil nutrient management.

MATERIALS AND METHODS

Study zone

The study was conducted in Ioba province located in South-western Burkina Faso (Figure 1). Ioba province belongs to the South-Sudanian climatic zone. This climatic zone used to have average

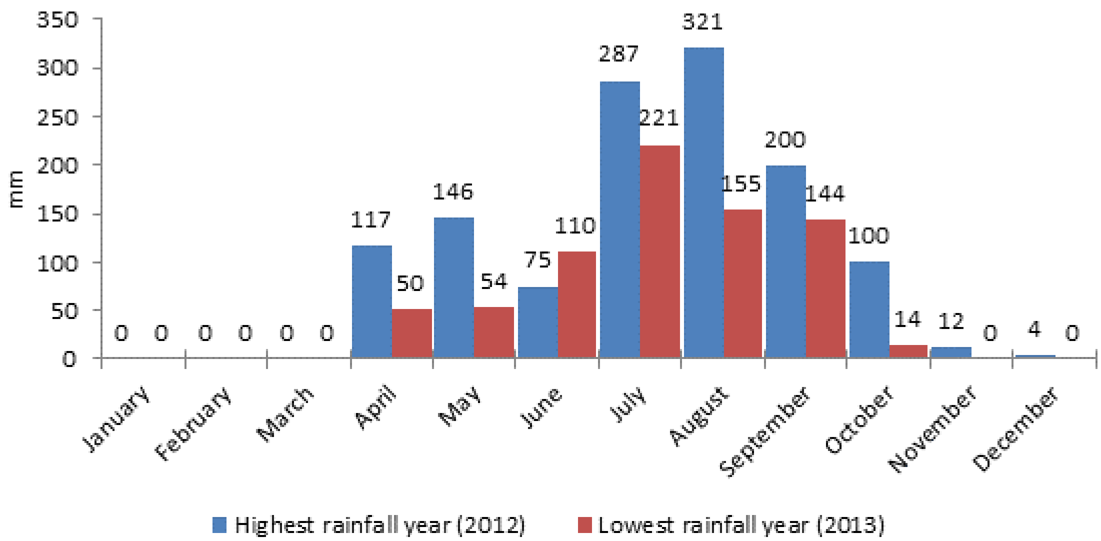


Figure 2. Monthly rainfall (mm) in Ioba province for extreme years of the decade 2004-2013.
Source: Calculated from data provided by *Direction provinciale de l'agriculture du Ioba* for the rain gauge stations of Dano, Koper and Ouessa villages.

annual rainfall greater than 1000 mm in the 1960s (Robert, 2010). However, under climate change, average annual rainfall is nowadays evaluated to 900-960 mm (MAHRH and GTZ, 2004; Schmengler, 2011; DPA Ioba, 2013). The province experiences rainfall variability in time and space (MAHRH and GTZ, 2004). Based on the data provided by the Ioba Provincial Directorate of Agriculture, the years 2012 and 2013 recorded the highest and lowest rainfall of the last decade 2004-2014, respectively (Figure 2). The livelihood in the study zone is essentially farm-based. Agricultural activities rely mainly on rainfed productions. The endemic crops in the study zone are sorghum, maize, cotton, millet, rice, groundnuts and beans; whereas the main animal species are cattle, small ruminant, porcine and poultry.

The main non-farm activities consist of petty trade and traditional gold mining. As for the rest of the country, education level is low. The study sites consisted of six villages selected in three sub-districts on the basis of demographic data, soil erosion information, soil and land use maps, and normalized difference vegetation index (NDVI) data of the province.

According to *Bureau national des sols* (BUNASOL) inventory, dominants soils types encountered in the Ioba province are:

i) Leached ferruginous tropical soils: they are dominant soils in Burkina Faso and represent 85% of the country lands (Pallo and Thiombiano, 1989).Two groups of this soil type are found in Ioba province.

a) leached and hardened ferruginous tropical soils which are generally shallow and form the main soil type of the province. They cover nearly 52% of Ioba lands. Most of cultivated lands fall into this type;

b) leached ferruginous tropical soils with spots and concretions, encountered for only 2% of the lands in Ioba. These soils are poor in organic matter, macro nutrient (NPK) and have low Cationic Exchange Capacity (CEC) (Pallo and Thiombiano, 1989);

ii) Hydromorphic soils: Also characterized by low organic matter content and very low phosphorus content, they constitute the third main soil type in Burkina Faso and cover 13% of its lands (Kissou et al*.,* 2000) and around 37% of the Ioba province lands;

v) Lithosols: cover 3% of Burkina Faso territory (Kissou et al*.,* 2000) and represents 5% of lands in Ioba province;

vi) Brown eutrophic tropical soils: they form 6% of soils in Burkina and 4% of Ioba province lands. Brown eutrophic tropical soils are constrained in NPK (Kissou et al*.,* 2000).

Conceptual framework

Warming, rainfall and its unusual variability in a location are some of the most patent evidences of climate change for farmers. They can realize, feel and observe these changes without classic scientific measurements. We define this as perception of climate change. In perceiving climate change evidences, farmers can give trend over a period (e.g. increase and decrease of the amplitude of climate parameters). Beside the perception, farmers can understand changes, explain causes and implications for their activities. This allows them to take more and strong action (Figure 3), build strategies in order to cope, adapt to or mitigate these changes. We define the fact of understanding the causes of the changes as well as their implication for livelihood activities as awareness. Awareness can be raised by education capital, learning (e.g. from extension services and other developmental stakeholders), and through information (e.g. exposure to media). Because of their differences in assets endowment (education, financial resources, equipment, exposure to outside world) farmers of different socio ecological settings are expected to have different levels of climate change awareness. It appeared from literature that most of previous studies used interchangeably climate change perception and awareness (Mertz et al*.,* 2008; Gbetibouo, 2009; Fosu-Mensah et al*.,* 2012; Nzeadibe et al*.,* 2012).

Sampling strategy and data collection

After selecting the six villages, 60 households were randomly selected per village using a list of households in the village. These lists were obtained from village leaders and updated before sampling. We obtained a sample of 360 households. The sample accounted for 29% of the total households in the six villages. The

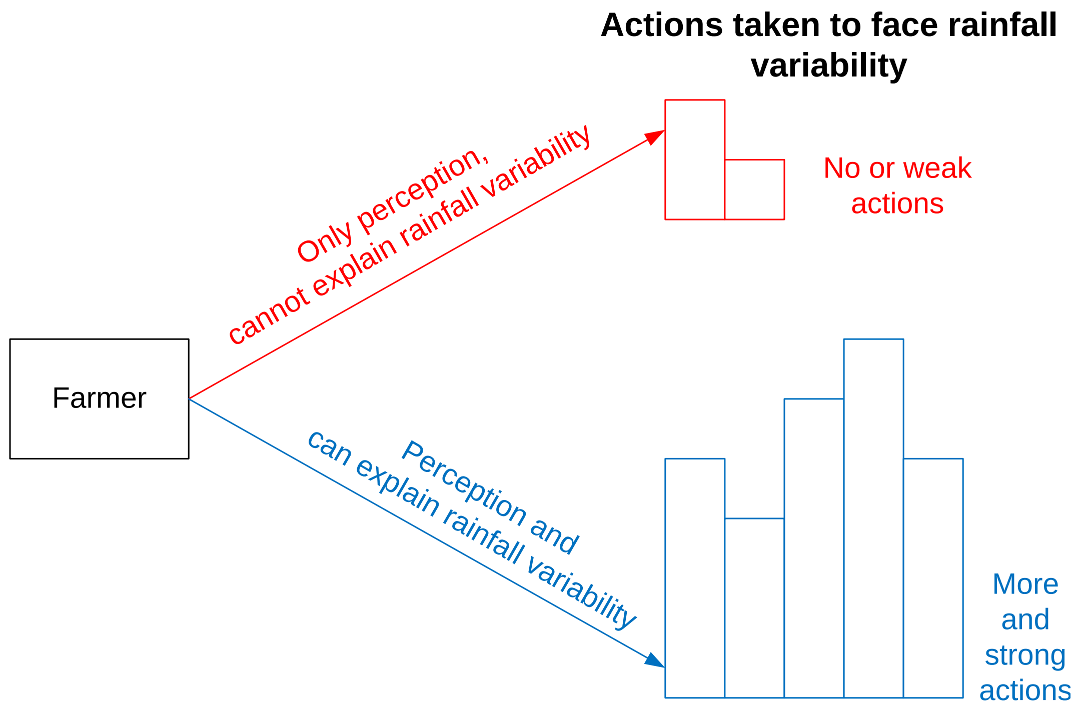


Figure 3. Conceptual framework of the study.

field surveys took place during dry season from January to March 2013. Community entry meetings were held before surveys. We were assisted during these meetings by local agricultural service personnel and local leaders. Surveys were performed through face-to-face interviews. Semi-structured questionnaires were designed and collected demographic, socio economic and geographical data as well as information on rainfall pattern. Famers were asked to give an appreciation of the rainfall pattern for the last five and to explain the causes of the pattern they observed. Ten years rainfall data was acquired from the provincial directorate of agriculture of Ioba.

Data analysis

The rainfall data was analyzed for trend detection in XLSTAT 2014 using Mann-Kendall trend test. Comparative analysis of the socio economic data was done in SPSS.20 using Z-test to test the difference between groups for the actions taken to face rainfall variability. Two groups of famers were considered: a group perceiving only rainfall variability but unable to explain, and a group perceiving rainfall variability and able to explain the reasons of this variability.

RESULTS

Farmers' perception of climate variability and change

To facilitate appreciation by farmers, they were questioned on a period of 5 years. Results showed that about 99% of the study sample perceived variability of rainfall during the last five years (2009-2013). As shown in Figure 4, almost 60% of farmers responded that the rainfall has decreased while for about 4% of farmers it has increased. A percentage of 36.33% of farmers however noted a fluctuation of the rainfall (e.g. no trend).

The perceived trends by farmers were compared to the trend of measured rainfall data using Mann-Kendall trend test (Table 1). This test revealed no trend in the rainfall for the considered period, implying fluctuating rainfall as observed by 36% of farmers. The perception of the remaining 64% of farmers did not fit the rainfall data trend. In addition to rainfall variability perception, 72.40% of farms noted a change in the onset of the cropping season. They estimated that onset of cropping season intervened late compared to the past. This calls for a change in the management of farming activities.

Farmers' awareness of climate variability and change

Figure 5 shows responses given by farmers on the question regarding causes of the observed rainfall pattern. As much as 50% of farmers were unable to explain the causes of the rainfall variation (Don't know). A percentage of about 26% of farmers explain rainfall variation by beliefs. For these farmers, rainfall variation is due to people's misbehaviors, abandonment of customs (e.g. sacrifices to ancestors) or punishment of humans by God. Only 4.10% referred to causes we interpreted as climate change and 19.20% cited deforestation as a cause of rainfall variation. We considered these two groups (Farmers who responded climate change and

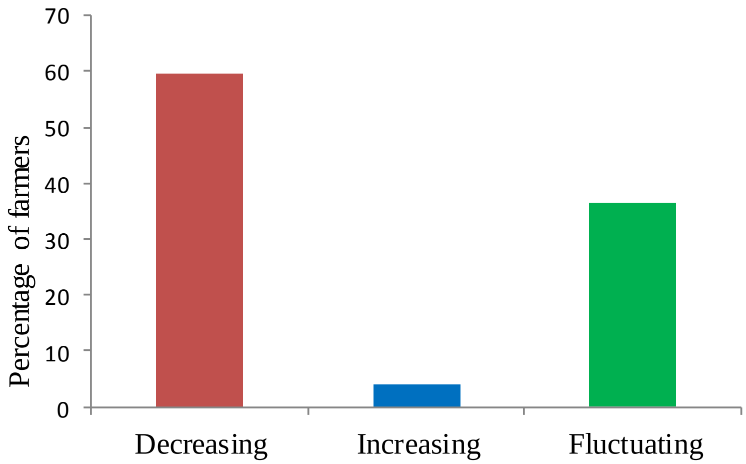


Figure 4. Perception of rainfall trend over last five years by farmers.

Table 1. Mann-Kendall trend test.

Kendall's tau	0.156
S	7.000
Var(S)	0.000
p-value (Two-tailed)	0.601
Alpha (α)	0.05

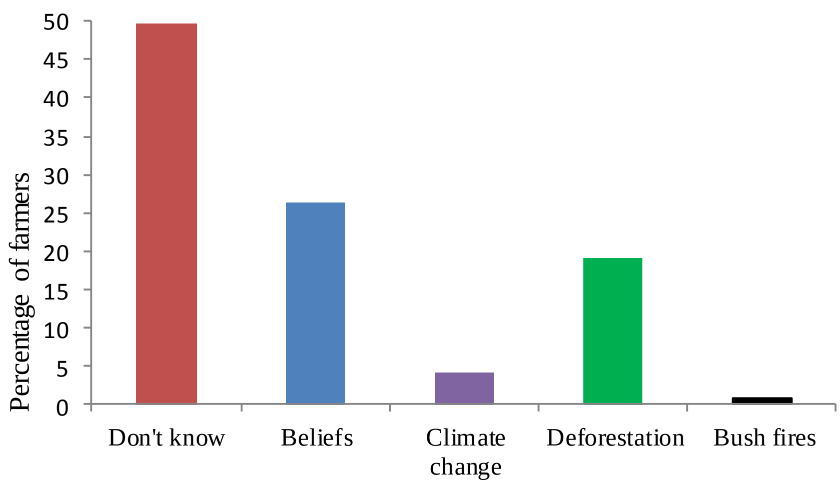


Figure 5. The causes of rainfall variation according to farmers.

deforestation) as farmers that have climate change awareness.

Farmers' responsiveness to climate change and variability in terms of soil nutrient management

We analyzed measures undertaken by farmers in response to rainfall variation. The main identified measures are presented in Figure 6. Farmers' responses in terms of sustainable soil nutrient management consisted mainly in the use of fertilizer alone (mineral or organic), the use of soil conservation measures alone (e.g. stone bunds), and the combination of fertilizer and soil conservation measures. As expected, a large proportion of farmers who have no climate change

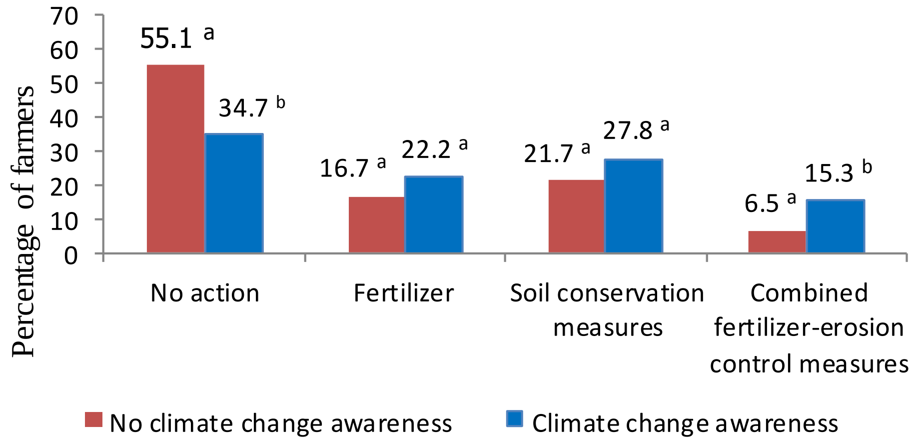


Figure 6. Actions taken by farmers in response to rainfall variability. Bars chart with same letter per action are not significantly different at 5% ($p<0.05$).

awareness (55.13%) took no action in response to rainfall variability. A proportion of 34.72% of farmers who have climate change awareness took no action. These two percentages were significantly different at 5%.

No significant difference was however found between the two groups (with and without climate change awareness) for fertilizer use alone and soil conservation measures alone. But significant difference at 5% was found between farmers group with no climate change awareness and farmers group with climate change awareness for combined use of fertilizer and erosion control measures (integrated response).

DISCUSION

Awareness generating stronger responsiveness of famers to climate variability and change than perception

The findings of this study demonstrates that farmers largely perceive ongoing climate variability and change in the region as previously found by a nationwide study (Ouédraogo et al., 2010). However the perception by up to 64% of farmers did not fit the rainfall data trend. This illustrates the difficulties for farmers to keep an accurate track of inter-annual rainfall variations. This fact may negatively effect on their response capacity to climate variability and change. The issue could be address by building farmers' capacities in agro meteorology through extension services and media. Indeed, a network of raingages set by agricultural extension office exists in the study area that could contribute to a better management of farming activities and efficient response to climate change. The approach however requires a better collaboration between famers and extension agents who can provide farmers with accurate time series rainfall information and help better address rainfall variability effects on farm activities.

The findings of this study further highlight that farmers' capability of understanding and explaining the underlying causes of rainfall variability is key for taking sound adaptive measures. Comprehension based on sole beliefs (lack of awareness) more likely leads to weak or not strong response in terms of soil nutrient management, in response to rainfall variability. The percentage of farmers with climate change awareness who combined the use of fertilizer and soil conservation measures was significantly higher than the percentage of farmers with no climate change awareness who took the same action. This combination is a stronger response and can have better effect compared to individual use of fertilizer or soil conservation measure alone. Farmers are more likely to take action against rainfall variability when they have climate change awareness. All farmers with climate change awareness may not take action as other factors (e.g. labor, financial resources and education) may affect sustainable soil nutrient management (Anley et al., 2007; Kassie et al., 2013; Lambrecht et al., 2014; Martey et al., 2014). Likewise without awareness, farmers will still adopt efficient measures based only on their perception of climate change. Farmers may adopt soil fertility management measures because of growing land scarcity and new market opportunities rather than the perceived climate change (Barbier et al., 2008).

Implications for policy intervention and research

Climate change is a growing issue worldwide in general and in particular for sub-Saharan African countries which are agricultural based economies. They will likely be more vulnerable due to the poverty of the populations, the rainfed agriculture and its current low performance. Building adaptive capacities and resilience to climate change effects in agriculture sector will depend on available resources and a sound understanding of farmers' behaviour in the face of the phenomenon. Perception and awareness to climate change are often used interchangeably. However our study demonstrates the needs for distinguishing the two as with awareness farmers are more likely to undertake strong adaptive measures. Therefore, policy intervention should aim at building and improving awareness among farmers. Research should as well distinguish between the two for providing suitable information and for better guiding decision making.

Conclusion

This study investigates the role of climate change awareness in sustainable soil nutrient management by smallholder farms. Farmers overwhelmingly perceived climate change. It was shown that perceiving climate change only is not enough for farmers to take adaptive measures. It is crucial for them to understand what is causing this change. On methodological level, the study showed the need for clearly distinguishing climate change perception from climate change awareness in sustainable land management studies. At policy level, policy intervention should focus on raising farmers' climate awareness through education and training. The findings of the present study should guide further research in the study zone and in similar settings to support building smallholder farms' adaptiveness and resilience to climate change.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGMENTS

Authors are grateful to German Federal Ministry of Education and Research (BMBF) which fully funded this research through West African Science Service Center on Climate Change and Adapted Land use (WASCAL).

REFERENCES

Andrieu N, Vayssières J, Corbeels M, Blanchard M, Vall E, Tittonell P (2015). From farm scale synergies to village scale trade-offs: Cereal crop residues use in an agro-pastoral system of the Sudanian zone of Burkina Faso. Agric. Syst. 134:84-96.

Anley Y, Bogale A, Haile-Gabriel A (2007). Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo District, Western Ethiopia. Land Degradation Dev. 18(3):289-302.

Barbier B, Yacouba H, Karambiri H, Zoromé M, Somé B (2008). Human Vulnerability to Climate Variability in the Sahel: Farmers' Adaptation Strategies in Northern Burkina Faso. Environ. Manage. 43(5):790-803.

Bationo A, Hartemink A, Lungu O, Naimi M, Okoth P, Smaling E, Thiombiano L (2006). African Soils: Their Productivity and Profitability of Fertilizer Use. African Ferilizer Summit. A. Bationo, H. A., L. O.et al. 9-13 June 2006, Abuja, Nigeria P 25.

Blanc E (2012). The Impact of Climate Change on Crop Yields in Sub-Saharan Africa American J. Clim. Change 1:1-13

Bunclark L, Gowing J, Oughton E (2015). Dealing with messy problems: lessons from water harvesting systems for crop production in Burkina Faso. 38th WEDC International Conference: Water, Sanitation and Hygiene Services Beyond 2015: Improving Access and Sustainability. Loughborough University, UK. P 6.

Chianu JN, Chianu JN, Mairura F (2012). Mineral fertilizers in the farming systems of sub-Saharan Africa. A Rev. Agron. Sustain. Dev. 32(2):545-566.

Chianu JN, Chianu JN, Mairura F (2012a). Organic Fertilizers in Sub-Saharan Farming Systems. Organic Fertilisation, Soil Quality and Human Health. E. Lichtfouse, Springer Netherlands 9:31-65.

DPA Ioba (2013). Relevé pluviometriques des stations agrométerologiques de la province du Ioba. Dano, Direction provincial de l'agriculture du Ioba.

Fosu-Mensah BY, Vlek PLG, MacCarthy DS (2012). Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. Environ. Dev. Sustain. 14(4):495-505.

Gbetibouo GA (2009). Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability.The Case of the Limpopo Basin, South Africa IFPRI Discussion Paper 00849 International Food Policy Research Institute (IFPRI) P. 36.

International Food Policy Research Institute (IFPRI) (2007). Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa. *Discussion Paper 00714* Washington DC, USA, IFPRI P. 30.

Ishaya S, Abaje IB (2008). Indigenous people's perception on climate change and adaptation strategies in Jema'a local government area of Kaduna State, Nigeria. J. Geogr. Reg. Plan. 1(8):138-143.

Jarvis A, Ramirez J, Anderson B, Leibing C, Aggarwal P (2010). Scenarios of Climate Change Within the Context of Agriculture. Climate Change and Crop Production. M. P. Reynolds. Oxfordshire, UK and Cambridge, USA, CAB Int. pp. 9-37.

Kabore-Sawadogo S, Ouattara K, Balima M, Ouédraogo I, Traoré S, Savadogo M, Gowing J (2013). Burkina faso: A cradle of Farm-Scale technologies. Water Harvesting in Sub-Saharan Africa. W. Critchley and J. Gowing. London (UK) and New York (USA), Routledge pp. 51-69.

Kassie M, Jaleta M, Shiferaw B, Mmbando F, Mekuria M (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. Technol. Forecast. Soc. Change 80(3):525-540.

Kissou R, Thiombiano L, Nébié AK, Semde A, Yago KJ (2000). La Base mondiale de données sur les sols: avantages et faiblesses pour la connaissance et l'utilisation des milieux édaphiques au Burkina Faso. Quatorzième Réunion du Sous-Comité ouest et centre africain de corrélation des sols pour la mise en valeur des terres, 9 au 13 octobre 2000, Abomey, République du Bénin, FAO, Rome.

Koutou M, Sangaré M, Havard M, Toillier A, Sanogo L, Thombiano T, Vodouhe DS (2016). Sources de revenus et besoins d'accompagnement des exploitations agricoles familiales en zone cotonnière ouest du Burkina Faso. *Biotechnol.* Agron. Soc. Environ. 20(1):42-56.

Lambrecht I, Vanlauwe B, Merckx R, Maertens M (2014). Understanding the Process of Agricultural Technology Adoption: Mineral Fertilizer in Eastern DR Congo. World Dev. 59:132-146.

Lobell D, Burke M (2010). Economic Impacts of Climate Change on Agriculture to 2030 Climate Change and Crop Production. M. P. Reynolds. Oxfordshire, UK and Cambridge, USA, CAB Int. pp. 38-49.

MAHRH, GTZ (2004). Mission d'appui à l'identification des interventions du Programme de Developement de l'Agriculture de la coopération germano-burkinabè dans la région administrative du Sud-Ouest. Ouagadougougou P 35.

Marshall NA, Park S, Howden SM, Dowd AB, Jakku ES (2013). Climate change awareness is associated with enhanced adaptive capacity. Agric. Syst. 117(0):30-34.

Martey E, Wiredu AN, Etwire PM, Fosu M, Buah SSJ, Bidzakin J, Ahiabor BDK, Kusi F (2014). Fertilizer Adoption and Use Intensity Among Smallholder Farmers in Northern Ghana: A Case Study of the

AGRA Soil Health Project. Sustainable Agric. Res. 3(1):36.
Mertz O, Mbow C, Reenberg A, Diouf A (2008). Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel. Environ. Manage. 43(5):804-816.
Nzeadibe T, Egbule C, Chukwuone N, Agwu A, Agu V (2012). Indigenous innovations for climate change adaptation in the Niger Delta region of Nigeria. Environ. Dev. Sustain. 14(6):901-914.
Olsson L, Opondo M, Tschakert P, Agrawal A, SH. Eriksen, S. Ma, L. N. Perch and S. A. Zakieldeen (2014). Livelihoods and poverty. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. C. B. Field, V. R. Barros, D. J. Dokkenet al. Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press: 793-832.
Ouédraogo M, Dembélé Y, Somé L (2010). Perceptions et stratégies d'adaptation aux changements des preécipitations : cas des paysans du Burkina Faso. Sécheresse 21(2):87-96.
Pallo FJP, Thiombiano L (1989). Les sols ferrugineux tropicaux lessivés à concrétions du Burkina Faso : Caractéristiques et contraintes pour l'utilisation agricole. Soltrop 89:307-327.
Place F, Barrett CB, Freeman HA J, Ramisch J, Vanlauwe B (2003). Prospects for integrated soil fertility management using organic and inorganic inputs: evidence from smallholder African agricultural systems. Food Policy 28(4):365-378.
Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB, Travasso MI (2014). Food security and food production systems. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change C. B. Field, V. R. Barros, D. J. Dokkenet al, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. pp. 485-533.
Pouya MB, Bonzi M, Gnankambary Z, Traoré K, Ouédraogo JS, Somé AN, Sédogo MP (2013). Pratiques actuelles de gestion de la fertilité des sols et leurs effets sur la production du cotonnier et sur le sol dans les exploitations cotonnières du centre et de l'ouest du burkina faso. Cahiers Agric. 22(4):282-292.
Robert É (2010). Les zones pastorales comme solution aux conflits agriculteurs / pasteurs au Burkina Faso : l'exemple de la zone pastorale de la Doubégué. Les Cahiers d'Outre-Mer 249:47-71.
Sanfo S, Barbier B, Dabiré IWP, Vlek PLG, Fonta WM, Ibrahim B, Barry B (2017). Rainfall variability adaptation strategies: An ex-ante assessment of supplemental irrigation from farm ponds in southern Burkina Faso. Agric. Syst. 152:80-89.
Schmengler AC (2011). Modeling soil erosion and reservoir sedimentation at hillslope and catchment scale in semi-arid Burkina Faso
Sultan B, Roudier P, Quirion P, Alhassane A, Muller B, Dingkuhn M, Ciais P, Guimberteau M, Traore S, Baron C (2013). Assessing climate change impacts on sorghum and millet yields in the Sudanian and Sahelian savannas of West Africa. Environ. Res. Lett. 8:9.

academicJournals

Vol. 13(6), pp. 302-310, 8 February, 2018
DOI: 10.5897/AJAR2017.12839
Article Number: D3B66E855902
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of *Pseudomonas putida* on chrysanthemum growth under greenhouse and field conditions

Matheus A. P. Cipriano* and Sueli S. Freitas

Soils and Environmental Resources Centre, Agronomic Institute of Campinas (IAC), São Paulo, Brazil.

Received 27 October, 2017; Accepted 21 December, 2017

Chrysanthemum production stands out in ornamental plants market and several techniques can improve the production of this plant. Among them, is the use of beneficial microorganisms such as plant growth promoting rhizobacteria (PGPR); however, the use of PGPR has not been explored enough so far in chrysanthemum production, especially in field conditions. With regards to rhizobacteria, the group, *Pseudomonas*, can be explored as a good alternative to improve plant development. Hence, the objective of the present study was to evaluate the effect of PGPR on seedlings and, on the field experiments, plants development and the impact on rhizosphere soil. The strains of *Pseudomonas putida* IAC-RBcr5 and IAC-RBcr2 were able to improve chrysanthemum shoot biomass up to 40%. In addition, the plants treated with these strains had increased number of flowers, which is a desirable feature for the flower market. This is the first study to demonstrate the effect of *P. putida* strains on chrysanthemum seedlings and cut flowers grown in tropical field conditions.

Key words: *Chrysanthemum morifolium* L., rhizobacteria, inoculant, soil quality indicators.

INTRODUCTION

The flower market in Brazil is growing, between 10 and 15%, and generates nearly $ 800 million per year (CNA, 2017). The chrysanthemum plants (*Chrysanthemum morifolium* L.) have a wide variety of inflorescences types, with great durability, different formats, and can be commercialized in vessels or as cut flower (Lopes et al., 2004). Research to generate knowledge and technologies to improve chrysanthemum cultivation are conducted including the management of organic and mineral fertilization (Ji et al., 2017), alternative substrates as pathogen suppressive (Pinto et al., 2013), and the improvement of irrigation contributing to the development of plants (Kirnak 2016). Furthermore, application of beneficial microorganisms may generate positive impact on chrysanthemum production.

Among the beneficial microorganisms, there is a group of bacteria living in the soil under the roots that increases the growth of plants, called plant growth promoting rhizobacteria (PGPR) (Kloepper and Schroth, 1978). Represented by a wide variety of rhizosphere bacteria, the use of those microorganisms is a viable alternative and meets the new expectations of the consumer market, by adding quality to the products and decreasing the use of pesticides (Gosal et al., 2017). Plant growth improvement can be triggered by PGPR through different mechanisms or by a combination of different factors,

*Corresponding author. E-mail: mhcipriano@gmail.com.

such as auxin indole-3-acetic acid (IAA) production, hydrogen cyanide production (HCN), phosphate solubilization and biological nitrogen fixation (Kielak et al., 2016; D'Agostino et al. 2017). A specific group of rhizobacteria widely studied is the *Pseudomonas* group that can promote the growth of several plants and decrease the damage caused by pathogens (Khabbaz et al., 2015; Rodríguez-Blanco et al., 2015). However, little is known about the effect of those growth promoters on ornamental plants, such as chrysanthemum, especially in field conditions.

There are several microorganisms recommended as inoculants with plant growth improvement and antagonistic properties (Meena et al., 2017). Regarding chrysanthemum culture, few studies indicate potential use of rhizobacteria as inoculant. For example, chrysanthemum treated with *Pseudomonas fluorescens* resulted in higher plant weight and number of flowers (Göre and Altin, 2006). Recently, researches showed the same effect in chrysanthemum plants treated with *Pseudomonas* spp. or *Bacillus* spp. or a mixture of both microorganisms that resulted in maximum of fresh and dry weight and flower yield (Kumari et al., 2016; Hanudin et al., 2017). The rhizobacteria-chrysanthemum interaction can have effect on the plant growth and also in the biological control of some pathogens. A mixture of rhizobacteria such as *Pseudomonas*, *Bacillus*, *Azotobacter*, inoculated on chrysanthemum reduce the white rust incidence (Hanudin et al., 2017) and the combined inoculation of fungi *Glomus mosseae* and the rhizobacteria *Pseudomonas putida* can mitigate phytoplasma damage (D'Amelio et al., 2011). Although, these researches present promissory use of rhizobacteria *Pseudomonas* as inoculant, there are no studies on the effect of *Pseudomonas* strains on chrysanthemum seedlings and on plants cultivated in the field conditions, as well as soil quality indicators such as microbial biomass and basal respiration, especially in tropical soil in Brazil. Based on this, this study aimed to evaluate the effect of *P. putida* strains on chrysanthemum growth in the field conditions and on soil biological properties. The hypothesis was that *P. putida* strains would have positive impact on the soil quality indicators, improving the plant biomass and increasing the number of chrysanthemum flowers.

MATERIALS AND METHODS

Traits of *P. putida* strains and inocula preparation

The nine strains tested (belonging to Agronomic Institute of Campinas IAC, Brazil, culture collection) were isolated from healthy lettuce, chrysanthemum, rucola and maize rhizosphere. All *P. putida* strains were producers of growth promoting metabolites and have already been reported as plant growth promoting rhizobacteria in lettuce, in previous study by Cipriano et al. (2016). The characteristics of the strains are shown in Table 1.

Bacterial strains were grown on King's B (KB) (King et al., 1954) liquid medium and incubated at 28°C for 24 h. At the end of the interval, the suspensions were centrifuged (13.000 xg for 10 min), suspended in $MgSO_4.7H_2O$ (0.01 mol.L^{-1}) and final concentration adjusted to 10^8 CFU mL^{-1}.

Greenhouse and field experiments

Location and experimental design

The experiments were conducted in two parts. Part 1: experiments (seedling production) was conducted in the MudaFlor company specialized in chrysanthemum seedlings production (company A), located in Arthur Nogueira (22°34' S, 47°10'W), state of São Paulo Brazil. Part 2: the experimental field was conducted at Sítio Picollini company specialized in the production and marketing of chrysanthemum cut flowers, located in Cordeirópolis (22°28' S, 47°27' W). The experiments were developed in different locations because the company Mudaflor (Location 1) works just with the seedlings production and the company Sítio Picollini (Location 2) is specialized in the cut flowers. This is the typical way chrysanthemum companies work in Brazil.

The nine strains tested in this work were evaluated in three different experiments. In Experiment 1 (September to December, 2012), three strains were tested with and without root hormone (indolic-3-butyric acid – IBA), in a completely randomized design in the factorial scheme 2 x 3 (with or without IBA x three strains - IAC-RBal3, IAC-RBcr2 and IAC-RBcr5). In Experiment 2 (October 2012 to January 2013), four strains were evaluated in the factorial scheme 2 x 4 (with or without IBA x four strains - IAC-RBcr1, IAC-RBal2, IAC-RBal1 and IAC-RBcr3). In Experiment 3 (February to May 2013), three treatments were evaluated in the factorial scheme 2 x 3 (with or without IBA x two strains - IAC-RBmi1, IAC-RBcr4 and the third treatment composed by the mixture of the others two strains, named Mix).

Part 1

The seedlings were prepared with plants cutting (5 cm of lenth), obtained from pattern plants (Zembla variety). After plants were treated with IBA (IBA talc – 2000 mg.mL^{-1}) they were placed in trays (63 cells seedlings trays) with substrate (mixture of rice straw and pine bark, disinfected in a boiler machine). Rhizobacterial suspension (4 mL/each plant) was used to inoculate seedlings lap and seedlings of control were drenched with 0.01 mol L^{-1} $MgSO_4.7H_2O$ instead of bacterial suspension. The same procedure was also applied to treatments without IAB. After three days, Chlorothalonil and Triazole fungicides were applied, according to the manufacturer's recommendations. The seedlings remained for 14 days in a greenhouse under artificial illumination (artificial illumination for 15 min every 3 h at night). After that, half of the plants were harvested and the remaining ones were treated once again with the strains and transferred to the field of São Pedro company for part 2 of the experiments.

Part 2

The soil of the field was previously fertilized before transplanting the seedlings, wherein the organic fertilizer BioBokashi was incorporated into the soil, according to the manufacturer's instructions. This organic fertilizer (composed of bone meal, fish and rock carbonized cereals, and molasses) is routinely used for chrysanthemum production in Brazil. After the seedlings transplantation to the field, the fertilization with organic fertilizer was performed 15, 30 and 45 days later, by aspersing Sulfammo 11® (18-0-18), at the same intervals as already described. Plants were also treated with fungicides Cercobim 700WP (thiophanate-methyl),

Table 1. *Pseudomonas putida* strains able (+) or not able (-) to produce indole-3-acetic acid (IAA), hydrogen cyanide (HCN) and phosphate solubilization (PS), and 16S RNA accession numbers deposited in GenBank, according to Cipriano et al. (2016).

Strain	Host plant origin	PGP traits			Accession number
		IAA	HCN	PS	
IAC-RBal1	Lettuce	+	+	+	KJ590502
IAC-RBal2	Lettuce	-	-	-	KJ590503
IAC-RBal3	Lettuce	-	+	-	KJ590504
IAC-RBcr1	Chrysanthemum	-	-	-	KJ590496
IAC-RBcr2	Chrysanthemum	-	-	-	KJ590497
IAC-RBcr3	Chrysanthemum	-	-	-	KJ590498
IAC-RBcr4	Chrysanthemum	+	+	+	KJ590499
IAC-RBcr5	Chrysanthemum	+	-	+	KJ590500
IAC-RBmi1	Maize	+	+	+	KJ590507

NT Dithane (mancozeb), acaricide/fungicide Score (difenoconazole) and biological fungicide *Trichoderma harzianum* Ecotrich®, following the manufacturers' recommendations. The plants remained in the field for 75 days, and at the end of this period, they were harvested and samples of soil were collected. The plant parameters evaluated were shoot and roots dry masses, and number of flowers. Soil quality indicators analyses were also evaluated: microbial biomass carbon (MBC) was determined by the fumigation-extraction (Vance et al. 1987), and basal respiration (BR), determined by quantification of CO_2 released during soil incubation according to Alef (1995) methodology. The metabolic quotient (qCO_2) was obtained by the ratio of BR and MBC. Throughout all the experiments, each treatment consisted of five replicates completely randomized, each replicate contained five plants. The data were submitted to analysis of variance by the Scott-Knott test at 5% probability using the statistical software Sisvar (Ferreira, 2008). It is worth noting that, except the inoculation of rhizobacteria, all management adopted in the experiments was the same as chrysanthemum farmers' in Brazil.

RESULTS

Greenhouse and field experiments- plant growth promotion

In Experiment 1, the strains inoculated had valuable effect on growth promotion on seedlings and cut plants (Table 2). The strains IAC-RBcr 2 and IAC-RBcr5 improved the shoot dry mass (16 and 18%, respectively) of the seedlings without IBA; regarding the roots, the strains IAC-RBal3 and again the strain IAC-RBcr5 improved the growth independent of the treatment with hormone (up to 23 and 30% respectively). According to the cut plants data, the plants with IBA treated with the rhizobacteria IAC-RBcr2 and IAC-RBcr5 yielded the highest values for shoot dry mass (40 and 29%, respectively). The strain IAC-RBcr2 also improved the root dry mass of roots without IBA (38%).

In Experiment 2, the strains had no effect on the shoot dry mass of the seedlings. Regarding the roots, with IBA, the plants treated with IAC-RBal1, IAC-RBal2 and IAC-RBcr3 obtained lower dry matter of roots. With regards to the shoots of the cut plants, the strains IAC-RBal2, IAC-RBal1 and IAC-RBcr3 without IBA and IAC-RBcr1 and IAC-RBal2 with IBA showed lower dry mass. The strains IAC-RBal1 improved the root growth of the plants without IBA (48%) and IAC-RBcr1 improved the root growth of the plants without and with IBA (38 and 31%).

In Experiment 3, the shoots of the seedlings treated with IAC-RBcr4 and Mix (composed by strains IAC-RBcr4 and IAC-RBmi1) without IBA and IAC-RBmi1 with IBA resulted in lower dry mass. Moreover, cut plants with IBA and treated with the strains IAC-RBmi1 and IAC-RBcr4 obtained the highest values for shoot dry biomass (20 and 28%).

Soil microbial activity- rhizospheric soil

The results of rhizosphere soil showed that inoculation of the strains interfered in the soil microbial activity (Table 3). In experiment 1, according the MBC values, there was a significant difference between control treatments with and without IBA, and MBC values of the treatments without IBA were higher than those with IBA. The BR values indicated that the treatment without hormone IAC-RBcr5 and with hormone, IAC-RBal3 and IAC-RBcr2, were lower than the control. The results obtained by the MBC and BR analysis generated the qCO_2 data revealing no changes in this variable due the strains inoculation, in comparison with the control treatment.

In Experiment 2, there were significant differences in the MBC values due the inoculation of the strain IAC-RBal2 resulting in lower values in treatments with and without IBA. The BR values were higher in the treatments without IBA in plants treated with the strains IAC-RBal2, IAC-RBal1 and IAC-RBcr3. The BR values were higher in the treatments with IBA, in plants treated with strains IAC-RBcr1, IAC-RBal1 and IAC-RBcr3. According to the qCO_2 results, only the control treatment without IBA had lower

Table 2. *Pseudomonas putida* strains and their effect on chrysanthemum plants (seedlings and cutting plants). Data shows shoot and root dry mass (g/plant). The data with bold letters represent the best result obtained.

		Treatments	Shoot		Root	
			Without IBA	With IBA	Without IBA	With IBA
Experiment 1	Seedlings	Control	1.08^{Ba}	1.10^{Aa}	0.11^{Ba}	0.13^{Ba}
		IAC-RBal3	1.16^{Ba}	1.24^{Aa}	**0.13^{Ab}**	**0.16^{Aa}**
		IAC-RBcr2	**1.26^{Ab}**	1.08^{Aa}	0.10^{Bb}	0.15^{Ba}
		IAC-RBcr5	**1.28^{Aa}**	1.15^{Aa}	**0.14^{Aa}**	**0.17^{Aa}**
	Cutting plants	Control	10.03^{Aa}	7.36^{Bb}	0.63^{Bb}	0.82^{Aa}
		IAC-RBal3	11.40^{Aa}	7.86^{Bb}	0.70^{Bb}	0.89^{Aa}
		IAC-RBcr2	9.16^{Aa}	**10.33^{Aa}**	**0.87^{Aa}**	0.74^{Aa}
		IAC-RBcr5	11.03^{Aa}	**9.56^{Ab}**	0.68^{Ba}	0.78^{Aa}
Experiment 2	Seedlings	Control	1.77^{Aa}	1.75^{Aa}	0.19^{Ab}	0.36^{Aa}
		IAC-RBal1	1.72^{Aa}	1.72^{Aa}	0.21^{Ab}	0.27^{Ba}
		IAC-RBal2	1.62^{Aa}	1.55^{Aa}	0.19^{Ab}	0.28^{Ba}
		IAC-RBcr1	1.77^{Aa}	1.65^{Aa}	0.18^{Ab}	0.31^{Aa}
		IAC-RBcr3	1.70^{Aa}	1.66^{Aa}	0.18^{Aa}	0.23^{Ba}
	Cutting plants	Control	15.34^{Aa}	15.41^{Aa}	0.68^{Ba}	0.88^{Ba}
		IAC-RBal1	12.30^{Bb}	17.20^{Aa}	**1.01^{Aa}**	0.92^{Ba}
		IAC-RBal2	12.40^{Ba}	13.36^{Ba}	0.78^{Ba}	0.71^{Ca}
		IAC-RBcr1	15.10^{Aa}	13.24^{Bb}	**0.94^{Ab}**	**1.16^{Aa}**
		IAC-RBcr3	10.16^{Bb}	15.43^{Aa}	0.67^{Bb}	0.86^{Ba}
Experiment 3	Seedlings	Control	1.59^{Aa}	1.66^{Aa}	0.15^{Ab}	0.19^{Aa}
		IAC-RBmi1	1.63^{Aa}	1.35^{Bb}	0.16^{Aa}	0.17^{Aa}
		IAC-RBcr4	1.37^{Ba}	1.47^{Aa}	0.14^{Ab}	0.18^{Aa}
		Mix	1.43^{Ba}	1.52^{Aa}	0.14^{Ab}	$0.19.^{Aa}$
	Cutting plants	Control	12.12^{Aa}	11.31^{Ba}	0.93^{Aa}	0.80^{Aa}
		IAC-RBmi1	11.56^{Aa}	**13.58^{Aa}**	0.81^{Aa}	0.97^{Aa}
		IAC-RBcr4	12.34^{Aa}	**14.49^{Aa}**	0.96^{Aa}	0.96^{Aa}
		Mix	12.11^{Aa}	12.00^{Ba}	0.89^{Aa}	0.94^{Aa}

*Mean values followed by the same small or large letters within a line or column represent values that are not significantly different according to Scott-Knott test (P≤0.05).

value.

In Experiment 3, the two strains tested, IAC-RBmi1 and IAC-RBcr4, and Mix improved the CBM in the treatment with IBA. The BR was higher in the rhizosphere treated with strains IAC-RBmi1 independent of the hormone treatment. The strains had no impact on the qCO_2 data.

Flower evaluation– cut plants

In Experiment 1 (Figure 1a), the plants without IBA treated with strains IAC-RBcr2 and IAC-RBcr5 obtained more flowers than the other treatments, including the control treatment. The plants with IBA and treated with the strains IAC-RB al3 and IAC-RBcr5 also had more flowers than the other treatments.

The plants without IBA, in Experiment 2, treated with IAC-RBal2 and IAC-RBcr3 produced more flower than the other treatments (Figure 1b). In plants with IBA, the plants treated with IAC-RBal1 and IAC-RBcr3 produced more flowers. In Experiment 3, the rhizobacteria inoculation did not improve the flowers numbers (Figure 1c).

DISCUSSION

Effect of rhizobacterial strains on plant biomass

The strains evaluated in the present study had already been tested in a previous work on lettuce seedlings and field conditions (Cipriano et al., 2016) and plant growth promoting characteristics are listed in Table 1. The principal results of the present research are summarized in Table 4, indicating the promising use of *Pseudomonas* trains in chrysanthemum production in seedlings and cutting plants phases. Interestingly, the Mix treatment (Experiment 3) was the only one that had no effect on the

Table 3. Microbial biomass carbon (MBC), basal respiration (BR) and metabolic quotient (qCO_2) from soils of chrysanthemum plants treated with *P. putida* strains. The data with bold letters represent the best result obtained.

	Treatments	MBC#		BR		qCO_2	
		Without IBA	With IBA	Without IBA	With IBA	Without IBA	With IBA
Experiment 1	Control	420^{Aa}	256^{Ab}	194^{Aa}	207^{Aa}	0.48^{Aa}	0.84^{Aa}
	IAC-RBal3	292^{Aa}	224^{Aa}	207^{Aa}	140^{Bb}	0.71^{Aa}	0.66^{Aa}
	IAC-RBcr2	314^{Aa}	226^{Aa}	169^{Aa}	122^{Bb}	0.54^{Aa}	0.55^{Aa}
	IAC-RBcr5	299^{Aa}	222^{Aa}	94^{Bb}	200^{Aa}	0.31^{Ab}	0.89^{Aa}
Experiment 2	Control	553^{Aa}	489^{Aa}	130^{Ba}	133^{Ba}	**0.24^{Ba}**	0.27^{Aa}
	IAC-RBcr1	399^{Aa}	492^{Aa}	135^{Bb}	**179^{Aa}**	0.34^{Aa}	0.36^{Aa}
	IAC-RBal2	359^{Ba}	385^{Ba}	**152^{Aa}**	120^{Bb}	0.42^{Aa}	0.31^{Ab}
	IAC-RBal1	442^{Ab}	618^{Aa}	**143^{Aa}**	**155^{Aa}**	0.32^{Aa}	0.25^{Aa}
	IAC-RBcr3	480^{Aa}	523^{Aa}	**158^{Aa}**	**166^{Aa}**	0.33^{Aa}	0.32^{Aa}
Experiment 3	Control	353^{Aa}	355^{Ba}	116^{Bb}	135^{Ba}	0.33^{Aa}	0.38^{Aa}
	IAC-RBmi1	444^{Aa}	**538^{Aa}**	**154^{Aa}**	**171^{Aa}**	0.35^{Aa}	0.32^{Aa}
	IAC-RBcr4	485^{Aa}	**480^{Aa}**	130^{Ba}	147^{Ba}	0.27^{Aa}	0.31^{Aa}
	Mix	436^{Aa}	**531^{Aa}**	144^{Ba}	128^{Ba}	0.33^{Aa}	0.24^{Aa}

#Values for MBC expressed in $\mu g.g^{-1}$; BR expressed in $\mu g.g^{-1}day^{-1}$ and $C\text{-}CO_2$ and qCO_2 expressed in μg CO_2 μg $CBM^{-1}day^{-1}$. *Mean values followed by the same small or large letters within a line or column represent values that are not significantly different according to Scott-Knott test ($P \leq 0.05$).

plant growth and flower number. The rhizobacteria strains used in this mixture had already been tested in combination with others *Pseudomonas* strains on lettuce seedlings and adult plants revealing the strain IAC-RBcr4 as a promising inoculant for that culture when applied alone, but not when applied in combination with other strains (Cipriano et al., 2016). The data of the present study is in agreement with that of Cipriano et al. (2016) indicating that our strain (IAC-RBcr4 *P. putida*) can improve plant growth when applied alone, but not in combination with others *Pseudomonas* strains. Several studies have reported that the mixture of different rhizobacteria strains, from different genera, can improve the plant growth, but rhizobacteria from the same genera, do not have the same benefit. For example, the mixture of *Pseudomonas fluorescens*, *Azotobacter chroococcum*, *Bacillus subtilis*, *Trichoderma* sp. and *Paecilomyces* sp. promoted chrysanthemum plant growth (Hanidum et al., 2017). The mixture of *Pseudomonas* strains is not commonly evaluated on chrysanthemum growth. Otherwise, pseudomonad combinations increase the yield of wheat plants (Pierson and Weller, 1994). The strains, IAC-RBcr1 and IAC-RBmi1 evaluated in the present study were tested previously in combination with other strains and improved the shoot growth of lettuce cultivated in field conditions (Cipriano et al., 2016). Based on these observation, it is concluded that certain combinations of strains can benefit the plant growth or not, as observed by Pierson and Weller (1994). As known, this is the first study on the effect of the interaction of *P. putida* strains mixture with chrysanthemum on seedlings and under field cultivation (cut plants). The strains IAC-RBal1and IAC-RBcr1 (Table 2, Experiment 2) were capable of improving the root development of plants cultivated on field untreated with IAB, and the strains IAC-RBcr1 also improved the root growth of plants treated with IBA. It can be hypothesized that benefit triggered by IAC-RBal1 (Table 1) can be related to the strain characteristics; this strain is IAA producer and able to solubilize P, which can improve the root growth and provide soluble phosphate to the plant (Ibañez et al., 2014; Oteino et al., 2015). The strain IAC-RBcr1 also improved the root growth, even though this strain do not produce any of the compounds related to plant growth promotion investigated (Table 1). The strains inoculation resulted in higher values of microbial biomass carbon (MBC), basal respiration (BR) in some treatments (Table 3). Based on this, it can be assumed that the strains may have improved the abundance and activity of microorganisms according to the MBC and RB data, respectively. These results can be related specially to the strains IAC-RBcr1 and IAC-RBal1 inoculated, which consequently increased the MBC and BR resulting in root growth improvement. Here, it is hypothesized that these strains were able to improve the quality indicator, such as MBC and RB, and improve the beneficial microorganisms resulting in root plant growth. Otherwise, this result did not alter the metabolic quotient (qCO_2). The current findings are in agreement with other studies which observed no impact on microbial community activity according to the same analyses (Fließbach et al., 2009; Cipriano et al., 2016). Moreover, in some cases, the inoculation of rhizobacteria does not result in greater plant growth; however, it may increase the MBC,

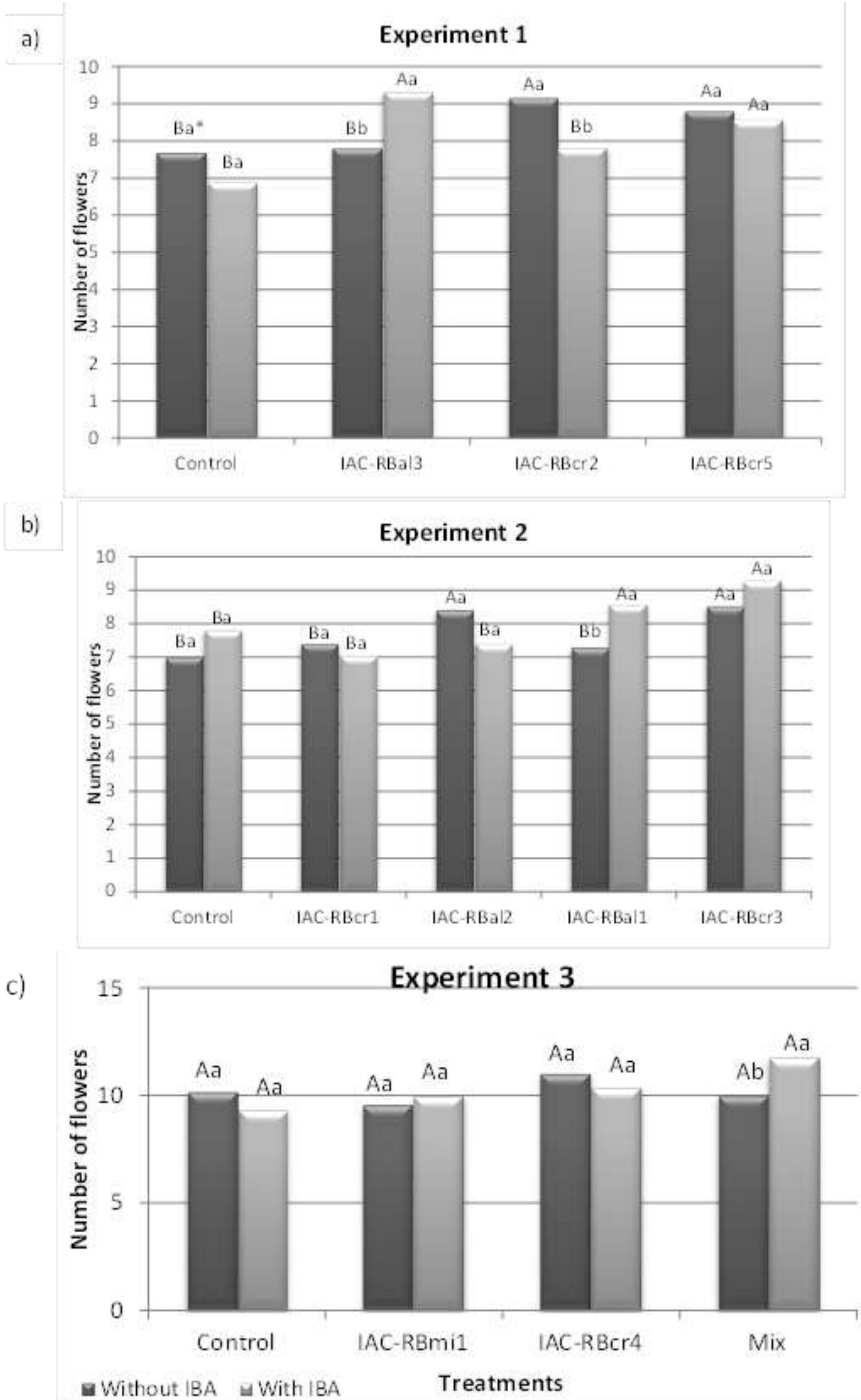


Figure 1. Effect of *Pseudomonas putida* strains on number of chrysanthemum flowers. *Bars for each treatment, with the same small or large letters represent values that are not significantly different according to Scott-Knott test (P≤0.05).

Table 4. *Pseudomonas putida* strains and their effect on chrysanthemum plants at different growth stages (seedlings and adult plants). Dry mass increase (+) or no dry mass increase (-) and higher number of flowers (+) or not (-).

Experiment	Strain	Seedling		Cutting plants		
		Shoot	Root	Shoot	Root	Flowers
I	IAC-RBal3	-	+	-	-	+
	IAC-RBcr2	+	-	+	+	+
	IAC-RBcr5	+	+	+	-	+
II	IAC-RBcr1	-	-	-	+	-
	IAC-RBal2	-	-	-	-	+
	IAC-RBal1	-	-	-	+	+
	IAC-RBcr3	-	-	-	-	+
III	IAC-RBmi1	-	-	+	-	-
	IAC-RBcr4	-	-	+	-	-
	Mix	-	-	-	-	-

nutrients in the plant and reduce the effects of disturbances in plants under adverse conditions (Lau and Lennon, 2012). The inoculation of beneficial microorganisms may increase the CBM values of soil under roots influence and benefit the host plant, improving the soil quality, root improvement and phosphorus availability (Prasanna et al., 2013).

The most promising result regarding plant growth promotion was obtained with the strains evaluated in the first experiment (Table 2), and all them had a good impact on plants cultivated with seedlings and/or cutting plants on field. At seedlings phase, the strain IAC-RBcral3 improved the root growth, independent of the hormone treatment, and IACRB-cr2 improved the shoot growth of plants without IBA. The plants gained more biomass when treated with IAC-RBcr5 strain, resulting in improvement of total plant growth (shoot and root), without IBA and also the root of plants with IBA. At cutting plants phase, the strains IAC-RBcr2 and IAC-RBcr5 again affected plant growth, especially, the shoot. The highest shoot growth suggests plants with better visual architecture for marketing (Neto et al., 2015), a major factor in the flower market. According to the microbial soil quality indicators, the lower BR in soil that received the strains indicated lower microbial activity in those treatments.

The effect of rhizobacteria inoculation on plant growth and soil quality can vary according the soil microbiota and plant development. The plants were harvested and the soil samples were collected 75 days after strains inoculation. So, in this period (75 days), probably the endogenous microbiota was restored in the soil and did not let the strains interferer anymore with plant development. The findings are in agreement with some studies which also observed this behavior pattern for rhizobacteria strains inoculated in field conditions (Schreiter et al., 2014; Cipriano et al., 2016).

Flowers improvement due to *Pseudomonas* inoculation

Six different strains (IAC-RBal3, IAC-RBcr2, IAC-RBcr5, IAC-RBal2, IAC-RBal1 and IAC- RBcr3) improved the chrysanthemum number flowers per plant (Table 4). Previous study also showed an increase of chrysanthemum flower, due the *Pseudomonas* strains inoculation (Kumari et al., 2016). The findings are in the same line with that of Kumari et al. (2016), although these authors did not characterize their strains regarding plant growth promoting traits. In the present study, the strains IAC-RBcr5 and IAC-RBal1, which improved the flowers number, are known as IAA producers (Table 1). IAA is one of the most auxin produced and released by rhizobacteria which can interfere with plants growth process and regulate root growth and flower development (Patel and Saraf, 2017). There is scarce information on the effect of *Pseudomonas* strains on chrysanthemum flower development, but other study revealed that the inoculation of *Pseudomonas* strains with arbuscular mycorrhizal fungi (AMF) induced the earlier flower production, probably due the hormone production and photosynthate which have an indirect influence on flowering time (Bona et al., 2015). The current data suggest that these rhizobacteria can improve the numbers of flowers of chrysanthemum cutting plants, at least in tropical soils, according the management done by chrysanthemum producers.

Conclusion

In the present work, knowledge on chrysanthemum-*Pseudomonas* interaction regarding seedling and cut plants cultivated in field conditions were broadened. Moreover, the findings led to accepting the initial hypothesis that *Pseudomonas* strains are able to improve the chrysanthemum plant growth and increase the number of flowers, without negative impact on soil quality.

The experiments were conducted with the same management used by local chrysanthemum producers, in order to approach as much as possible, the use of rhizobacteria inoculants for their production. Improvement of seedling production is necessary because of the importance of this stage for producers working with seedlings production, such as the producers of chrysanthemum seedlings in Brazil. It is known that poorly formed seedlings will give rise to plants with production below their genetic potential (Bezerra Neto et al., 2005). In addition, a plant obtained in the seedling phase must have high vigor, showy leaves, with sufficient amounts of roots to adapt to field conditions.

The strains, IAC-RBcr5 and IAC-RBcr2 evaluated in the present work improved the chrysanthemum production up to 40% (shoot dry mass) under field conditions and improved the number of flowers per plant. Here, it is reported for the first time, important findings regarding chrysanthemum market by using *Pseudomonas* on seedlings phase and field conditions in tropical soils, to increase the plant growth and number of flowers.

ACKNOWLEDGEMENTS

The authors are grateful to the Mudaflor and Sítio Picollini companies for help in conducting the field experiments. The first author thanks the Brazilian Council of Higher Education (CAPES) for the received scholarship.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

REFERENCES

Alef K (1995). Soil respiration. In: Methods in applied soil microbiology and biochemistry (Alef K, Nannipieri P. Eds.). New York, USA. London: Academic Press 576p.

Bezerra Neto F, Rocha RHC, Rocha RCC, Negreiros MZ, Leitão MM, Nunes GHS, Sobrinho JE, Queiroga RCF (2005). Sombreamento para produção de mudas de alface em alta temperatura e ampla luminosidade. Hortic. Bras. 23(1):133-137.

Bona E, Lingua G, Manassero P, Cantamessa S, Marsano F, Todeschini V, Copetta A, D'Agostino G, Massa N, Avidano A, Gamalero E, Berta G (2015). AM fungi and PGP pseudomonads increase flowering, fruit production, and vitamin content in strawberry grown at low nitrogen and phosphorus levels. Mycorrhiza 25:181-193.

Confederação da Agricultura e Pecuária do Brasil (CNA) (2017). Brasil pretende ampliar as exportações de flores no Mercosul. http://www.cnabrasil.org.br/noticias/brasil-pretende-ampliar-exportacoes-de-flores-no-mercosul

Cipriano MAP, Lupatini M, Lopes-Santos L Silva MJ, Roesch LF, Destéfano SAL, Freitas, SS, Kuramae EE (2016). Lettuce and rhizosphere microbiome responses to growth promoting *Pseudomonas* species under field conditions. FEMS Microbiol. Ecol. 92:12.

D'Agostino N, Sorrentino R, Scotti R, Salzano M, Aurilia V, Zaccardelli M. (2017). Draft genome sequence of the plant growth-promoting rhizobacterium *Pseudomonas fluorescens* strain CREA-C16 isolated from pea (*Pisum sativum* L.) rhizosphere. Genome Announc. 5:e01456-16.

D'Amelio R, Berta G, Gamalero E, Massa N, Avidano I, Cantamessa S, D'Agostino G, Bosco D, Marzachi C (2011). Increased plant tolerance against chrysanthemum yellows phytoplasma (*Candidatus phytoplasmaasteris*) following double inoculation with *Glomus mosseae* BEG12 and *Pseudomonas putida* S1Pf1Rif. Plant Pathol. 60:1014-1022.

Ferreira DF (2008). Sisvar: um programa para análises e ensino de estatística. Rev. Cient. Symp. 6:36-41.

Fließbach A, Winkler M, Lutz MP, Oberholzer HR, Mäder P (2009). Soil amendment with *Pseudomonas fluorescens* CHA0: lasting effects on soil biological properties in soils low in microbial biomass and activity. Microb. Ecol. 57:611-23.

Göre ME, Altin N (2006). Growth promoting of some ornamental plants by root treatment with specific fluorescent *Pseudomonads*. J. Biol. Sci. 6(3):610-615.

Gosal SK, Kaur J, Kaur J (2017). Plant growth-promoting rhizobacteria: a probiotic for plant health and productivity. A probiotic for plant health and productivity. In: Kumar V, Kumar M, Sharma S, Prasad R (eds). Probiot. Plant Health pp. 589-600.

Hanudin KB, Marwoto Budi (2017). Application of PGPR and antagonistic fungi-based biofungicide for write rust disease control and its economycs analysis in chrysanthemum production. J. Agric. Sci. 39(3):266-278.

Ibanñez F, Arroyo ME, Angelini J, Tonelli ML, Muñoz V, Ludueña L, Valetti L, Fabra A (2014). Non-rhizobial peanut nodule bacteria promotemaize (*Zea mays* L.) and peanut (*Arachis hypogaea* L.) growth in a simulated crop rotation system. Appl. Soil Ecol. 84:208-12.

Ji R, Dong G, Shi W, Min J (2017). Effects of liquid organic fertilizers on plant growth and rhizosphere soil characteristics of chrysanthemum. Sustainability 9(5):841.

Khabbaz SE, Zhang L, Cáceres LA, Sumarah M, Abbasi P (2015). Characterization of antagonistic *Bacillus* and *Pseudomonas* strains for biocontrol potencial and suppression of dumping-off and root diseases. Ann. Appl. Biol. 166:456-471.

Kielak AM, Cipriano MAP, Kuramae EE (2016). *Acidobacteria* strains from subdivision 1 act as plant growth‐promoting bacteria. Arch. Microbiol. 198(10):987-993.

King EO, Ward MKE, Raney DE (1954). Two simple media for the demonstration of pyocyanin and fluorescini. J. Lab. Clin. Med. 44:301-307.

Kirnak H (2016). A computer controlled irrigation of potted chrysanthemum grown at outdoor conditions. Curr. Trend Nat. Sci. 9:139-144

Kloepper JW, Schroth MN (1978). Plant growth-promoting rhizobacteria on radishes. In: Proceedings of the 4th International Conference on Plant Pathogenic Bacteria, Tours: Gilbert-Clarey 2:879-882.

Kumari, A. Gyal, RK, Choudhary M, Sindhu SS (2016). Effects of some plant growth promoting rhizobacteria (PGPR) strains on growth and flowering of chrysanthemum. J. Crop Weed. 12(1):7-15.

Lau JA and Lennon JT (2012). Rapid responses of soil microorganisms improve plant fitness in novel environments. PNAS. 109:14058-14062.

Lopes FL, Costa ACS, D'Oliveira, P.S., Gil, LG (2004). Agricultural use of industrial sludge as a source of Zn for chrysanthemum cultivation. Hortic. Bras. 22:620-623.

Meena VS, Meena SK, Verma JP, Kumar A, Aeron A, Mishra PK, Bisht JK, Pattanayak A, Naveed M, Dotaniya ML (2017). Plant beneficial rhizospheric microorganism (PBRM) strategies to improve nutrients use efficiency: A review. Ecol. Eng. 107:8-32.

Neto AEF, Boldrin KVF, Mattson NS (2015). Nutrition and quality in ornamental plants. Ornam. Hortic. 21:139-150.

Oteino N, Lally RD, Kiwanuka S, Lloyd A, Ryan D, Germaine KJ, Dwoling DN (2015). Plant growth promotion induced by phosphate solubilizing endophytic *Pseudomonas* isolates. Front. Microbiol.

6:745.
Patel T, Saraf M (2017). Biosynthesis of phytohormones from novel rhziobacterial isolates and their *in vitro* plant growth-promoting efficacy. J. Plant Interact. 12.
Pierson E, Weller D (1994). Use of mixtures of fluorescent pseudomonad to supress take-all and improve the growth of wheat. Infect. Ecol. Epidemiol. 84:940-7.
Pinto ZV, Morandi MAB, Bettiol W (2013). Induction of suppressiveness to *Fusarium* wilt of chrysanthemum with composted sewage sludge. Trop. Plant Pathol. 38:414-422.
Prasanna R, Sharma E, Sharma P, Kumar A, Kumar R, Gupta V, Pal KP, Shivay YS, Nain L (2013). Soil fertility and establishment potential of inoculated cyanobacteria in rice crop grown under non-flooded conditions. Pad. Water Environ. 11:175-183.
Rodríguez-Blanco A, Sicardi M, Frioni L (2015). Plant genotype and nitrogen fertilization effects on abundance and diversity of diazotrophic bacteria associated with maize (*Zea mays* L.). Biol. Fertil. Soils 51:391-402.
Schreiter S, Ding G, Grosch R, Kropf S, Smalla K (2014). Soil type-dependent effects of a potential biocontrol inoculant on indigenous bacterial communities in the rhizosphere of field-grown lettuce. FEMS Microbiol. Ecol. 90:718-30.
Vance ED, Brookes PC, Jenkinson DS (1987). An extraction method for measuring soil microbial biomass C. Soil Biol. Biochem. 19:703-707.

African Journal of Agricultural Research