OPEN ACCESS

8 March 2018
ISSN 1991-637X
DOI: 10.5897/AJAR
www.academicjournals.org

AcademicJournals

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 10, 8 March, 2018

ARTICLES

academicJournals

Vol. 13(10), pp. 440-451, 8 March, 2018
DOI: 10.5897/AJAR2017.12851
Article Number: 2E61D5C56238
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Perceptions and clustering of Greek farmers on the new CAP: Opportunity or threat?

George Theodossiou[1*], Christos Karelakis[2] and Apostolos Goulas[3]

[1]Department of Business Administration, Tei of Thessaly School of Business and Economics, TK 41110 Larissa, Greece.
[2]Department of Agricultural Development, School of Geotechnical and Forestry Sciences, Democritus University of Thrace, Orestiada, Greece.
[3]Department of Planning and Regional Development, University of Thessaly, Larissa, Greece.

Received 2 November, 2017; Accepted 18 January, 2018

This study aims to highlight the problems of the Greek agriculture and to identify the level of information that the farmers have regarding the Common Agricultural Policy (CAP). Here, primary data were collected from in-depth interviews (structured questionnaire) with 241 farmers in the region of Thessaly-Greece. The study was conducted in November 2016, within the geographical boundaries of the Region of Thessaly. The data were analyzed via descriptive statistics, the non-parametric Friedman test, Factor Analysis and Cluster Analysis. The results indicate that Greek farmers are not adequately informed about the CAP. The research findings showed that Greece requires an agricultural sector that will also be eco-friendly, producing high added value products. These factors are important and could become the country's comparative advantage. The innovation of the study lies in the fact that the survey was conducted in a highly representative Greek rural prefecture, investigating the farmer's information level as it concerns the CAP policy schemes.

Key words: Common agricultural policy, agricultural sector, agricultural production, Thessaly, Greece.

INTRODUCTION

The Common Agricultural Policy (CAP) is the agricultural policy implemented by the European Union (EU) and comprises a set of laws and regulations that designate the operation of the farm sector (crop and livestock) (Andrei and Darvasi, 2012). Its primary objectives are to provide consumers with stable, safe and affordable prices, while ensuring a decent standard of living for farmers (European Commission, 2016). The CAP is one of the oldest policies of the EU covering both the managerial, productive, environmental and social activities of the agricultural sector and, on the other hand, all its links with other sectors of the economy (Jurkenaite and Volkov, 2011).

In European agriculture, the role of the family business

*Corresponding author. E-mail: geortheo@teilar.gr. Tel: +302410684465, +306974584457.

JEL Classification Codes: Q1, Q13, Q14, Q18.

in the agricultural sector is decisive concerning both employment and its significant contribution to the protection of society (De Castro et al., 2014). In the international literature, several studies have explored the relationship between CAP subsidies and employment in the rural area despite the diversification of results in each EU country (Galluzzo, 2017). The CAP can hardly cope with the challenges it faces because of the contradictions between the pre-defined problems and the measures proposed to deal with them. This is because it offers limited changes to the previous CAP (Popp and Jámbor, 2015). The vague and different directions of the Treaty of Rome which are being pursued in the Treaty of Lisbon create difficulties in the implementation of the agricultural policy. This is a typical component of the structure Tinbergen (Hill, 2012).

The policy context regulates how the farm sector operates at all stages of production and marketing. It also describes the movement of goods, the use of soil, the determination of subsidies, the product quality and the environment, ensuring price stability and employment in the agricultural sector, and offering the European quality products and continuous economic and social development. The main disadvantage of the CAP is that to implement all laws and regulations, it involves extensive paperwork and bureaucracy. For these reasons, the CAP was the subject of significant disagreements between the EU Member States that have led and will lead in a continuous evolution, necessary for the adjustment and the agricultural sector as other sectors of the economy.

Still, the absence of coordination between sectors and between member states resulted in merely pathogenic implemented policies. Over the last fifty years, the various policy schemes within the CAP created a food system of increased productivity per surface of the land, supply of large volumes of food, ultimately ensuring food provision to all. Apparently, farmers were supported to provide cheap raw materials for the food processing industry, whereas the consumer was satisfied by the plethora of food products in the supermarkets. A policy that was efficient, proving economies of scale and low-cost food at large quantity was acceptable at that time. Nowadays, the CAP moves to new directions, and the current discussions on its reform may offer the platform for a sustainable and rational food production system.

The EU financial perspectives for the period 2015 - 2020 are: a) the reduction in the agriculture market share in the EU budget b) make the CAP greener at a price of 30% for environmental reasons, and c) the progressive convergence of the funds of the EU Member States up to90% of the average European Instrument. The primary question for the present research is if the Greek farmers are well informed regarding the new CAP for the period 2015 – 2020.

It is a fact that the reform of the agricultural policy aimed to maintain the income of farm households.

According to El Benni and Finger (2013), these goals could be achieved through different policy measures that include the market support and direct farm payments. Moreover, they claimed that the inequality between individuals is of highest societal and political importance. Alexiadis et al. (2013) underlined the importance of agriculture as one of the most crucial for regional convergence and development. Furthermore, Zasada and Piorr (2015) argued that during the funding periods of 2000 – 2006 and 2007 - 2013, within the EU, there was an effort of improving the competitiveness of the primary sector and protecting the environment and the countryside. That was the case where the third axis of Pillar II of the CAP was introduced and had as a principal aim to sustain and enhance the quality of life in the rural areas.

Still, according to Kotakou and Katranidis (2008), 'the decoupling of CAP payments leads production decisions and allocation of resources to be dependent on the market prices. Also, many agricultural economists have addressed the effect of the CAP on the various changes in the use of productive factors. Even Bartolini and Viaggi (2011) argued that scholars have underlined the effect of the agricultural policy components such as the decoupled payments. The same opinion was shared by Schmid et al. (2007) who mentioned that 'prices have been further reduced, and farmers will receive decoupled income support payments instead of production premiums from 2005 onwards'. Despite the changes in the CAP and the significance of the funds spent, the degree of tackling the problem of "farm income" remains unclear (Ackrill, 2008). The new CAP budget is significantly reduced as a percentage of the EU budget but remains the most critical funding policy. In the 2014 - 2020 period the CAP received 37.6% of the EU budget, compared with 43.5% for the 2007 -2013 period. This was a significant reduction compared to previous decades when the CAP accounted for 60% of the budget in the 1990s and 70% in the 1970s (Papadopoulos, 2015).

Based on those mentioned above, the objective of the present study is to investigate and access the perceptions and views of farmers, from a Greek rural region, towards the different aspects of the new CAP. Accordingly, it will be feasible to highlight the problems of the Greek agriculture and to identify the level of information that the farmers have regarding the Common Agricultural Policy (CAP). The remainder of the paper includes a general overview of the new CAP and its implementation to the Greek agriculture, followed by a description of the materials and methods employed in the study. Results are thereafter presented, discussed and the study concluded.

Is the new CAP an opportunity for Greece?

According to a neoliberal opinion, the modern economy should unify and deliberate on the markets and this may result in the effectiveness of the agricultural product markets and the creation of added value for these commodities. Like in the business world, those agricultural units that will not adapt to the modern international market will be automatically excluded. Moreover, in the last years a sharp decline in the living standards can be observed, with increased poverty, hunger, displacement – migration of population to various countries that ensure safety and a low minimum standard of living. The increase in production costs and the launch of taxes during the crisis led to a severe fall in agricultural income in our country. Over the period 2009 - 2013, the rise in the cost of inputs to agricultural production has increased by more than 10.5%. Characteristic was the change in energy costs, which grew by 44.2% in the 2009 - 2013 period of five years. In the same five years, taxes on production went up from EUR 141.7 million to EUR 441.9 million, an increase of around 211%; a change corresponding to a cost of some EUR 300 million. On the other hand, the financial sector gets stronger, often through state protection policies (too-big-to-fail[1]), increasing speculation on raw materials, metals, food, rural depopulation in the name of productivity, technology, markets, production costs, and reforms.

Agricultural policy and rural development should be designed concerning the protection of the environment, that is to say, nature and the place where man is active. This broadens the orientations and actions of agricultural policy from the agricultural sector to a holistic rural management policy (Vlahos and Louloudis, 2011). The central area of environmental investment for investment projects in agriculture was irrigation, but this was just 2% of all investment plans for the country as a whole (Vorloou and Castritsi-Catharios, 2012). In all European countries, there was a steady migration from the countryside to the urban area, which aggravated the general living conditions of the population in rural areas (Kasimis et al., 2010). During the economic crisis, there was a significant return from urban areas to rural areas. "Rural return" is defined as the internal migration process of the urban population that decides to move to the countryside - since no formal element exists to facilitate research or research on the actual return to the place of origin (Anastasiou and Duquenne, 2015).

Such rural policies aim to drive farmers to private insurance (further strengthening of the financial sector), and on minimal support from national, international institutions (such as EU). The following diagram of the OECD shows the evolution of the assistance of the agricultural sector in EU-28 and the OECD countries (Figure 1). In the last years, the agricultural sector has faced changes and challenges of the public policies (CAP) in both the traditional role and new role. Traditional role concerns food production, raw materials, and job creation, and new role regarding environmental protection, production of quality products, development of rural areas, social cohesion and entrepreneurial form of organization (Karanikolas and Martinos, 2012).

The needs and claims in the modern agricultural production and marketing of agricultural products (input costs, intensification of production, etc.), from an economic and organizational point of view (use of new technologies, global market of agricultural products, etc.), with the constant changes in community policies and with reduction of the production protection for the period 2010 – 2014 (Figure 2) create an enormous uncertainty amongst the farmers.

Adding the climate change, the mentality of the farmers, the global economic crisis that has a significant influence in the agricultural sector and the speculation of the large multinational companies in the food sector (e.g. rice, corn, etc.), we may have a complete picture of the agricultural sector without the economic incentives, especially for small-scale farmers. Agricultural products market instead of becoming self-regulate, deregulated, and the control of markets operating mechanisms also turned off, so we were led to speculation (Dumenil and Levy, 2005). This is the agricultural sector operating environment and is part of the neoliberal view which considers the farmer as the entrepreneur who must adapt to the market conditions. Since 1980 there has been a shift in the agricultural sector to the neoliberal model of markets.

The Greek agricultural sector has contributed to the development of the country's economy as one of the significant factors of development, but also, influenced other sectors as well, such as rural areas development, agro-food security, and regulation, etc. The active population of the country engaged in the agricultural sector accounts for 12% of the total population (Table 1). However, Greece contributes only 3.0% of gross value added of the agricultural sector of the EU (Average 2012 - 2014) and is significantly lower than major competitors. The gross value added has continuously decreased between 1995 and 2014. From 2011 to 2014 has been a slight improvement (Figures 3 and 4).

The generated added value to agricultural production in Greece is far behind from its main competitors. Moreover, in the last decade, the farm income in Greece decreased by an average annual rate of 0.4%, against an increase of 1.6% in the rest of the Eurozone countries.

With Greece's entry into the EU in 1981, the country's economic policy was based on the Keynesian theory, which means the extensive redistribution of income to increase the rate of demand and investment. Furthermore, due to the increase of the EU's imported

[1]During the economic crisis of 2008, the US government intervened in the fate of companies such as AIG because such a company was too big to fail and if it did the outcome would be unprecedented and cataclysmic. (http://www.businessdictionary.com).
The too-big-to-fail doctrine, sometimes called T.B.T.F., goes back at least as far as Brandeis' time, when, in 1914, the Treasury stepped in to provide financial aid to New York City. (Eeic DASH JUNE 20, 2009 If It's Too Big to Fail, Is It Too Big to Exist? http://www.nytimes.com/2009/06/21/weekinreview/21dash.html?_r=0)

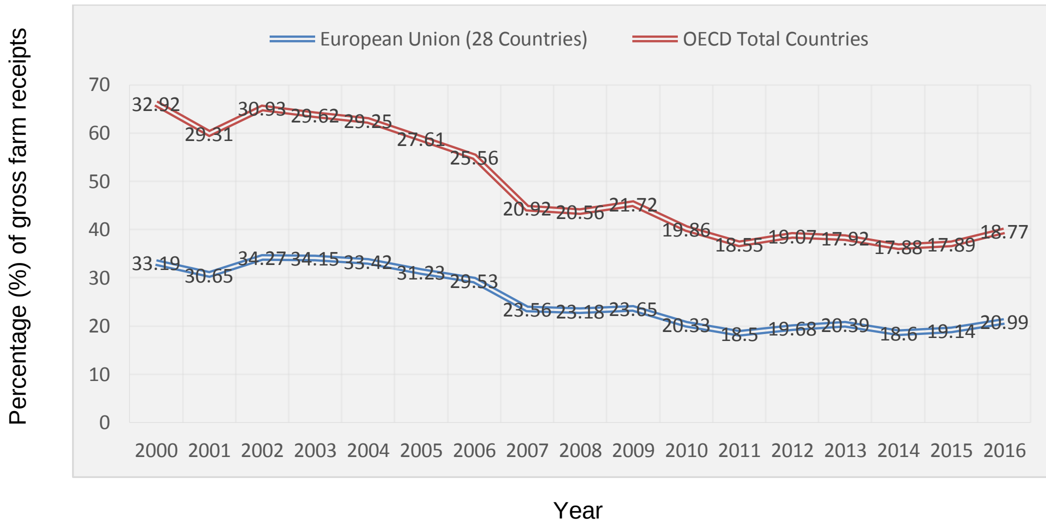
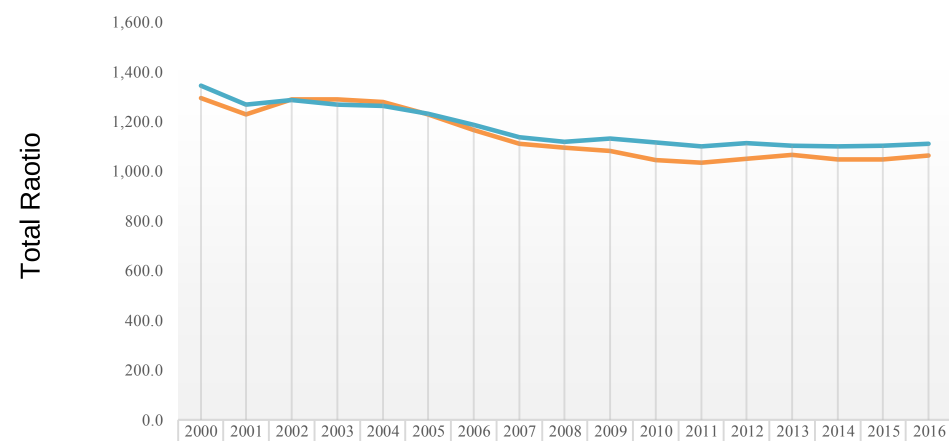


Figure 1. Agricultural support
Source: OECD (2016a).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
European Union (28 Countries)	1,293	1,227	1,288	1,289	1,277	1,229	1,165	1,109	1,093	1,080	1,045	1,033	1,050	1,066	1,046	1,048	1,063
OECD - Total Countries	1,343	1,267	1,287	1,267	1,263	1,230	1,186	1,136	1,119	1,130	1,116	1,099	1,113	1,101	1,099	1,101	1,109

Year

Figure 2. Total Producer protection
Source: OECD (2016b).

products, the agricultural sector external balance became negative. With the CAP of the 80s began the degradation of the agricultural sector. Table 2 illustrates a SWOT analysis for the Greek agriculture:

As reported by Dautopoulos and Pyrovetsi (2002), the Greek agriculture is confused. There is a vision that determines who we are and who we want to reach. Agriculture is drawn from the CAP developments and globalization that neither controls nor defines. Otherwise, the country will make food imports from other countries at better prices and the farmer will be out of the market. In theory, this is correct, but in social terms should we see another agriculture leading to sustainable agriculture as reported by Dautopoulos and Pyrovetsi (2002). The Sustainable Agriculture has the following features:

1. An integrated rural policy.
2. Regional planning.
3. Mediterranean recipes.
4. Local agricultural research.
5. Local control and planning of agricultural education.
6. Tin development of the cooperative movement of the

Table 1. Main characteristics of the agricultural sector in Greece.

Characteristic	2007	2008	2009	2010	2011	2012
Employment in the Primary Sector **(%)**	11.1	10.9	11.2	11.7	12.3	13
Crop Production value (mil.**€)**	7385.21	7008.93	6495.85	6738.69	7081.75	7012.86
Animal Production Value (mil.**€)**	2675.77	2776.78	2800.17	2781.88	2833.79	2767.16
Total production of the Agricultural Sector (million**. €)**	10896.37	10728.77	10251.77	10519.7	10926.31	10781.52

Source: Eurostat, Hellenic Statistical Authority (2015).

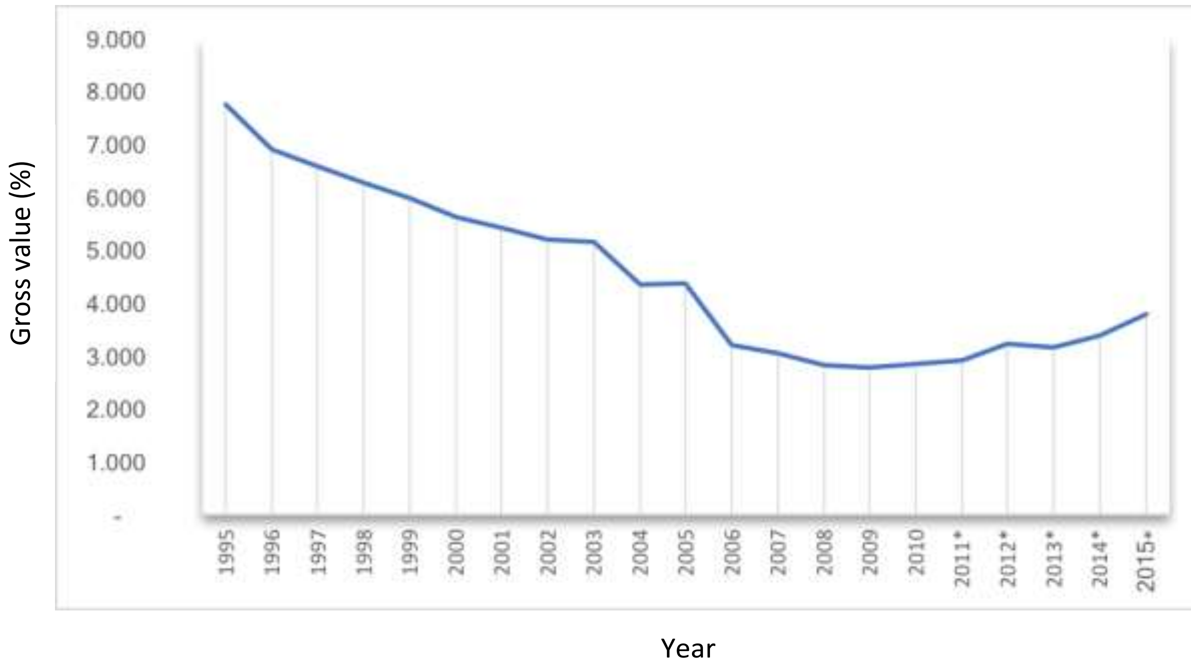


Figure 3. Gross value in agricultural and livestock production and other activities.
Source: Hellenic Statistical Authority (2015).

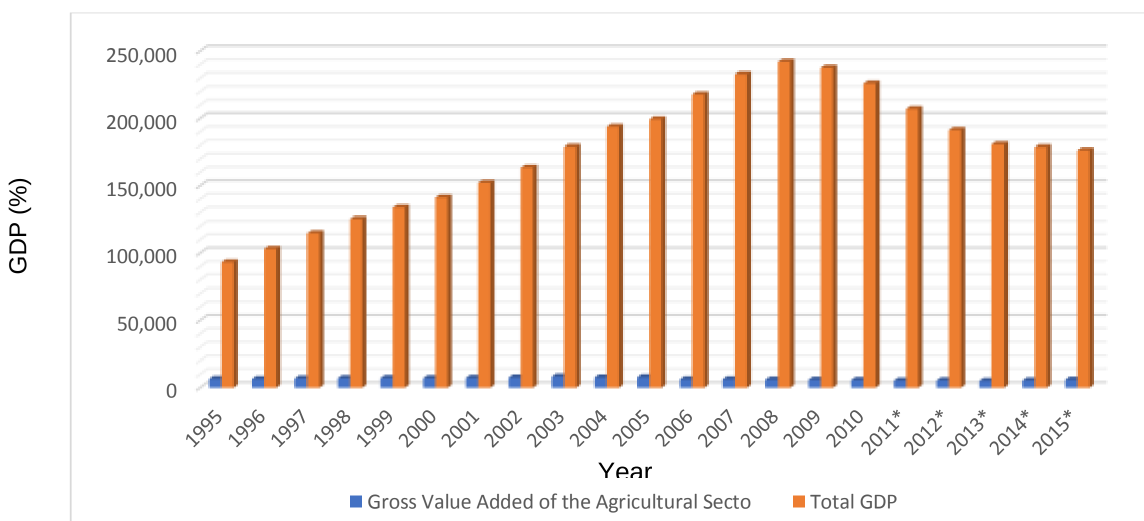


Figure 4. Partition of agricultural sector on GDP (%) Gross Value Added (million Euros).
Source: Eurostat, Hellenic Statistical Authority (2015).

Table 2. SWOT analysis for the Greek Agriculture.

Strength	Weakness
Excellent climatic and soil conditions, low pollution, high quality, ease and low cost of conversion of large areas or livestock to organic, etc.	Serious structural problems (small size and multiplicity of farms, aging, low educational level, lack of entrepreneurship and innovative spirit).
Great international recognition of products and regions in the country. Very high production differentiation and global uniqueness for some products.	High cost of production, high dependence on subsidies. Objective difficulties in creating comparative price advantages.
An important position of the agri-food sector in the country's economy and the existence of significant production capacity in processing. Powerful Brand Names of Big Companies	Insufficiencies of the structures, processing, promotion and distribution of agricultural products abroad. Lack of cooperative consciousness.
The negative structural features of Greek production (mountainous or semi-mountainous lands, island regions, small farms, etc.) can be turned into comparative advantages.	Problems of interconnection between agriculture, processing and marketing. Insufficient agricultural research. Lack of domestic production of inputs required. Low production size at local level that prevents the vertical integration or transportation of products in large urban centers.

Opportunity	Threat
High global demand for quality agricultural products. Favorable conditions in mature but also emerging markets for increased exports of Greek products.	Deterioration of the financial crisis. Reduced per capita consumption and shift to cheap imported due to reduced disposable income.
Creating favorable conditions for the modernization, development and resolution of structural problems following the revision of the CAP. Emphasis on the EU's agricultural policy sustainable development and raising awareness of the environment and food safety	Increase competition in the long term, from low-cost third countries.
Sufficiency of agricultural resources and the existence of unused land. Significant margins to increase productivity and improve quality. Variety of natural and cultural environments and excellent environmental conditions favoring the development of agrotourism.	Market liberalization and the failure of certain branches of Greek agriculture to respond to the challenges. Low productivity and lack of international competitiveness of basic export products, following the revision of the CAP
Possibilities of exploiting agriculture (in times of severe economic crisis), to combat unemployment.	State mechanism inefficiency, service malfunctions and infrastructure problems.
Existence of intense interest in serious business activity in the industry. Ability to exploit new technologies to create effective marketing networks.	Difficulties in expanding and modernizing many viable farms and failing to achieve economies of scale.

Source: Dagalidis (2014).

base.

7. Farmers equity-creative.

Nowadays, the farmer operates on a business basis as the work has three dimensions: economic, social and environmental. Therefore, today's farmer should have the ability to understand the evolution of the economy. The agricultural production of the country will be turned into products that meet the international market. This means that agricultural products are competing independently of the producing country and the country of destination. A competitive economy means having the capacity to produce goods and services at lower cost and in excellent quality. In this case, the economy is attractive for investment, thus increasing productivity. So, the competitiveness and investments are directly linked (Jayasuriya, 2011; Milner and Pentecost, 1996; Walsh and Yu, 2010). So, the economy will show increased growth because competitive considered that the economy is showing increased growth by continuously improving productivity.

Defining competitiveness as "the ability of a country or a company to proportionally generate more wealth than its competitors in world markets," the question for policymakers is whether such studies are relevant in comparing economic performance across countries (Kliesen, 1995). The actual competitiveness is measured by productivity (Porter et al., 2005). The main questions are: How can the competitiveness of the monetarist-liberal view be increased when the average farmer in Greece has a low income and high production costs; when the farmer - entrepreneur relationship is not competitive because the majority of farms are family-related? What is the bargaining power of farmers in the formation of prices following the benefit-cost view when the trend of prices of agricultural products varies widely from year to year and for most products is determined by international food exchanges and speculators (Kourmousis, 2010). The abundant quantities and slow economic growth have pushed food prices to significant fluctuations. The variation of the quotation has often a dramatic impact on the economy.

Unfortunately, the variables that determine the competition is not only the price and quality of products but also other variables such as the size of production units, the cost of production, bargaining power, tax, and insurance system, infrastructure, justice, public administration, etc. Therefore, the market conditions are determined exogenously by large multinational manufacturing agricultural industries and retail food chains rather than farmers. A Greek farmer is limited to the production of products, receiving little of the goodwill of the final products, but not regarded as a producer of food necessary for the survival and good health of people but as a business based on competitiveness. This view may have a negative impact on consumer both from the health and economic perspectives.

MATERIALS AND METHODS

The survey was based on primary data gathered using a questionnaire filled in by telephone interviews. The study was conducted in November 2016, within the geographical boundaries of the Region of Thessaly. The telephone survey using a structured questionnaire was conducted on a sample of 241 farmers in the region aged over 18 years. The sample was selected using the multistage sampling method (Oppenheim, 1992; Stathopoulos, 1997), whereas the total population of the research area along with the social and economic data were provided from the 2011 National Statistical Office of Greece (NSSG, 2011). The sample design involved, firstly, the proportional representation of the people (family leaders) working as agricultural producers in the four provinces of Thessaly (Magnesia, Larissa, Karditsa and Trikala) and secondly, the proportional representation of rural regions per county so that the results of the survey can be as general as possible for the entire population of the research area.

The study sample comprised farmers who responded to the phone calls randomly assigned to telephone devices in the research area and were considered suitable persons to participate in the survey. Thus, there was the possibility that some of them did not live permanently in the region but have been found at random or for some limited time. However, this possibility was not high and do not alter the results of the survey, nor does it represent an obstacle to generalizing conclusions for the whole population.

Accordingly, based on the sampling organization, it can be assumed that the total sample of the 241 farmers in the region corresponded to a population with similar characteristics, where its size varied within the range required by the application of multistage sampling (Stathopoulos, 1997).

The questionnaire was tested on a sample of fifty people to identify possible weaknesses and to investigate the necessary improvements in its structure. The questions included in the survey instrument were based on extensive literature review, after the significant changes were made to respond to the specific purposes of the study (Babbie, 2011; Oppenheim, 1992; Dautopoulos, 2000; Javeau, 1996). The questionnaire included a total of 46 closed-type questions divided into three categories: the socio-demographic characteristics of farmers, the structural features, and problems of farms and the farmer's views on the new CAP (views, components). The data were analysed using SPSS 17.0 and employing a series of statistical analyses, namely the descriptive statistics, statistical hypothesis tests (X^2), non-parametric statistical analysis of the Friedman, Factor Analysis and Cluster Analysis.

Factor analysis was performed using the principal component analysis (PCA) method with the axes rotating by the Varimax method. Accordingly, the technique was employed to the questions that referred to the farmer’s responses regarding the most significant factor of the new CAP and the most significant changes that the new CAP brought about. The former questions were measured with four items on a 5-point Likert scale (1-not at all important to 5-very important), whereas the latter was gauged with four items measured with the same scale. Subsequently, the factors revealed from the analysis were used to perform a cluster analysis.

Cluster analysis is a method designed to classify existing observations using the information that exists in some variables. It can be argued that by looking at how similar some observations about a number of variables are, the method tends to create groups of similarity-like observations. A successful analysis should result in groups for which the observations within each group are as homogeneous as possible, but observations of different groups differ as much as possible (Hair et al., 2010). Cluster analysis can be conducted through a) by hierarchical clustering, and b) by the K-Mean cluster analysis.

In the present study, a combination of the two methods was employed. Initially, a hierarchical cluster analysis was used to identify the number of clusters. Subsequently, the non-hierarchical cluster analysis was applied to determine these in detail, utilizing the findings of the hierarchical analysis. The hierarchical clustering method was performed using the Ward method to minimize cluster differences. Applied distance measure was the square of the Euclidean distance. Regarding the choice of the number of clusters to be created, the number of farmers in the sample was the basis for selecting a range of two to five clusters. The number of clusters resulted from the assessment of the agglomeration coefficients as well as from the fact that the number of farmers in each cluster was theoretically valid and practical. The researcher is looking for significant increases in agglomeration coefficients to determine the number of clusters to be created. Finally, based on the specific data, size of the sample and its theoretical interpretation, analysis of the three clusters in the second stage of the analysis (non-hierarchical) was examined to analyse the results. Consequently, the non-hierarchical analysis was applied to K averages to determine in detail the final number of clusters derived from the hierarchical analysis. The center of each cluster is merely the average of all variables and for those observations that fit into that cluster (Hair et al., 2010).

RESULTS AND DISCUSSION

The investigation of the probability of a statistical difference between farmers' views on the most important changes brought about by the 2003 CAP was gauged through application of the Friedman's statistical test (Table 3). According to the results, it was found that the decoupling of subsidies was the main change of the CAP according to the farmers' views, with a 2.95 average ranking; also, the next most significant change is in the relationship with the ginning plants, with a rating of 2.79.

The Friedman's statistical test was also applied to investigate the possibility of a statistical difference between farmers' views for the most important CAP factors of 2003 (Table 4). The results indicate that increase in competition is the most important factor, with a rating of 3.09, followed by the agro-environmental measures, with an average value of 2.84.

Besides, the Friedman's statistical test has employed the existence of a statistical difference between farmers' views on which farming method or tactic would change in the years to come. According to the results (Table 5), farmers are more likely to make changes in farm buildings and other infrastructures, with an average of 5.67, with other changes including the irrigated area (5.55) and the private area (5.51).

Respondents were also asked how they perceive the changes of the new CAP for the future of farmers, through a question where they had to choose between the answers 1 = Threat, 2 = Opportunity, 3 = Neutral, 4 = I do not know. Accordingly, the results showed that most farmers do not know (33%) or consider neutral (31%) the changes in the 2003 CAP for the future of farmers, followed by 25% of the sample that discusses the changes as an opportunity, and 11% considers them as a threat. Farmers were also asked to indicate the perceived changes in the 2003 CAP for the employment in the agricultural sector, choosing between the answers: 1 = Threat, 2 = Opportunity, 3 = Neutral, 4 = I do not know.

The results indicated that the farmers do not know (29%) or consider the changes in the 2003 CAP for the employment in the agricultural sector as neutral (30%) or opportunity (28%), while only 11% considered the changes as actual threats. Finally, the sampling farmers were asked their views regarding the situation for the farmer and agriculture after 2015, choosing between 1 = Better, 2 = Worst, 3 = Do not Know. The majority of respondents do not know what the state of agriculture and farmers will be after 2015, while 25% perceived that it would be an opportunity and 21% of the sample are of the opinion that it will be a threat.

Table 3. Most important changes brought about by the 2003 CAP, Friedman test results.

Changes in the CAP reform	Mean rank
Decoupling of subsidies	2.95
Comply with environmental restrictions	2.34
Changes in the role of cooperatives	1.92
Relations with ginning plants	2.79

Table 4. Most important factors of the 2003 CAP reform, Friedman test results.

Factors of the CAP reform	Mean rank
Reduction in subsidies	1.30
Agri-environmental measures	2.84
Increase in competition	3.09
Decoupling of payments	2.77

The next step of the methodology involved the factor analysis. Table 6 illustrates the results of the analysis, where two factors were revealed explaining 63.3% of the total variance.

The first factor can be named “Organizational changes” as it includes the changes in the role of cooperatives and the compliance with environmental constraints. The second factor can be named “Decoupling” since it comprised the decoupling scheme of the CAP and the changes in the relations with the ginning plants. As regards the most significant components of the new CAP, the factor analysis revealed two factors that explained 69.59% of the total variance. The first factor (Table 6) can be named “Farm competition” since it contained the items of and the increase in competition and the agri-environmental measures. The second factor comprised the items of ‘decoupling’ and ‘decrease in subsidies’ and can be named “Subsidies.” The revealed factors were further used for cluster analysis to identify possible groups of farmers. Variables that were also included in this grouping procedure involved the farmer’s perceptions regarding the changes in the new CAP, their attitudes regarding how agriculture and farmers will be after 2015, their satisfaction from sale prices, the problems they confront regarding sales and the level of information concerning the new CAP. The 3-cluster solution was interpreted easier and displayed the highest number of significant factor differences among the clusters (Table 7). The three formed clusters (cluster 1, n= 80; cluster 2, n=61; cluster 3, n=100) are evidently separate regarding the perceptions of farmers regarding the new CAP.

Table 5. Changes in farming methods or tactics, Friedman test results.

Farming method	Mean rank
Investment in machinery	4.56
Machine use contract and machine sharing	4.73
Investing in agricultural buildings and other infrastructure (roads, water, electricity, drainage, watering, fences, etc.)	5.67
Irrigated area	5.55
Owned land	5.51
Rented area	5.41
Use of fertilizers	4.34
Use of agrochemicals	4.16
Use of quality seeds	5.09

Table 6. Factor analysis results.

Component	Factors	
Significant changes of the new CAP	**1**	**2**
Organizational changes		
Changes in the role of cooperatives	0.834	
Compliance with environmental constraints	0.779	
Decoupling		
Relations with the ginning plants		0.683
Decoupling		0.776
Most significant components of the new CAP	**Factors**	
Farm Competition		
Increase in competition	0.896	
Agri-environmental measures	0.862	
Subsidies		
Decoupling		0.833
Decrease in subsidies		0.669

Table 7. K-Means cluster analysis results (three-cluster solution) (mean values).

Component	Cluster			F ratio	Sig.
	1 (N=80)	2 (N=61)	3 (N=100)		
Organizational Changes	1.0734	1.9397	1.5100	40.187	0.000
Decoupling	2.9543	2.4678	2.1380	34.506	0.000
Farm competition	2.0781	2.8303	2.3389	4.761	0.009
Subsidies	2.8734	2.3876	2.0980	37.414	0.000
Perceptions regarding the changes in the new CAP	2.1758	1.4456	1.9734	47.012	0.000
Perceptions regarding how agriculture and the farmers will be after 2015.	1.7210	2.8620	2.2105	1.612	0.202
Satisfaction from sale prices	1.1750	2.4727	1.4145	27.547	0.000
Problems regarding sales of products	2.1875	2.9962	1.4812	15.262	0.000
Information regarding the new CAP	2.8461	2.0896	1.4989	21.001	0.000

Next is a description of the cluster profiles of the farmers.

Cluster 1

The first cluster includes 80 farmers that represent 33.1% of the total sample. The farmers in this cluster do not perceive that the new CAP had any organizational changes but believe that the decoupling of payments was the most significant amendment. As regards the most vital elements of the new CAP, the farmers in this cluster

Table 8. SWOT analysis of the farmers' answers.

Strengths	Weaknesses
i) Investing in agricultural buildings and other infrastructure, with other changes including the irrigate area. ii) 25% of the sample that discusses the changes of the new CAP as an opportunity iii) The new CAP moved to significant organizational changes	i) The farmers are medium informed regarding the measures included in the new CAP. Most farmers do not know (33%) or consider neutral (31%) the changes of the new CAP. ii) The majority of respondents do not know what the state of agriculture and farmers will be after 2015. iii) The farmers do not face particular problems as concerns product sales, and they are satisfied with prices
Opportunities	**Threats**
i) Comply with environmental restrictions ii) The view of farmers regarding the subsidies and decoupling as components of the new CAP is mediocre, iii) The farmers do not see farm competition as an essential element stemming from the policy measures.	i) Increase in competition ii) Changes in farming methods iii) The farmers do confront significant problems in selling their products, besides the fact that they are moderately satisfied with product prices..

think that the issues referring to subsidies are the most significant and the farm competition stemmed from the applied policy schemes. Besides, they have a favourable view concerning the changes in the new CAP and are well informed for the implemented measures. Still, they are not at all satisfied with their product's prices and confront mediocre problems in selling their products. Based on the above characteristics, the farmers in this cluster may be named as "active-informed farmers."

Cluster 2

This cluster involves 61 farmers that represent 25.3% of the total sample. Farmers in this cluster perceive that the new CAP moved to significant organizational changes, but overall, they do not think that many changes occurred with the new policy scheme. Moreover, their view regarding the subsidies and decoupling as components of the new CAP is mediocre, and they do not see farm competition as an essential element stemming from the policy measures. They do not face particular problems as it concerns product sales, and are satisfied with prices. Still, they are medium informed regarding the measures included in the new CAP. Accordingly, the farmers in this second cluster may be named "impartial farmers."

Cluster 3

One hundred farmers belong to this cluster capturing the majority (41.6%) of the sample. Farmers in this group do not believe that significant changes occurred regarding either organizational ones or financial (decoupling-subsidies). Their perception concerning the changes that the new CAP brought about is mediocre considering that they are not at all well informed about the policy schemes implemented. Finally, they do confront significant problems in selling their products, besides the fact that they are moderately satisfied with product prices. Consequently, the farmers that belong to this third cluster can be named "passive-misinformed farmers."

Bearing in mind the above-mentioned results of the study, a SWOT analysis was employed based on the answers provided by the farmers in the sample (Table 8). The major threats for farmers are the existence of competition, their dissatisfaction with the prices of products and the difficulties they have in selling the products. These are considered as competition threats. We think that competition comes mainly from countries with low labor costs.

Although Solomou et al. (2008) argued that informing Greek farmers about the CAP and its reforms is inadequate concerning good practice, mainly due to the lack of information and the low educational level, the present study found that farmers are well informed about the long-term growth potential of the CAP.

Conclusion

The objective of the present study was to investigate farmers' perceptions and view regarding different aspects of the new CAP. The results of the study focus mainly on the socio-demographic characteristics of the respondents and their views regarding the issues that emerged after the 2013 CAP reform. Also, farmers are more likely to make changes in farm buildings and others about the decoupling of payments and the relations with the ginning plants, whereas the respondents perceived as most important factors the increase in competition and the agri-environmental infrastructures, the irrigated land, and the owned land. Finally, they were not aware of the changes to the new CAP for the future of farmers, employment in the agricultural sector, and the situation for agriculture and the farmer after 2015. To increase farm incomes, it is recommended that farmers be continuously informed on product prices and the financial requirements of each crop.

The Greek agricultural sector should turn to sustainable agriculture. Moreover, according to Goulas (2017), in the last years European Union rural policies are focused on a balanced rural development and especially those policies are focused on less favoured agricultural areas. It should focus on the quality of agricultural products and not just on quantity. Farmers should make use of new technologies, invest in the production process to reduce production costs, reduce their dependence on water, eliminate the use of chemicals in greenhouses, and reduce antibiotics in livestock farming. While they will have to redefine their role in the Greek economy and society and work cooperatively, possibly in the form of cooperatives, it is believed that the country will be competitive in international markets with direct consequences on investment in the agricultural, agro-industrial, education and employment sectors. There are three issues that will contribute overall to the country's economic growth.

One of the disadvantages that characterize the Greek agriculture is the distorted structure of ages, with the highest percentage of farmers being over 55 years old. They do not have the reflexes demanded by the new competitive environment; hence they cannot make significant upheavals, but only improvements in the quality direction, as long as they are rewarded accordingly. A necessary prerequisite for their viability is therefore, the consolidation of the market by concerted practices and the reduction of production costs, which, at least regarding agricultural supplies, is a multiple of the European average. Nonetheless, the aging rural population - despite the concerns it creates - could hide at the same time the potential for improving the structure of the Greek agriculture in the medium term if it was combined with an entry program for young farmers in the profession. However, the rate of exit is much higher than the rate of entry, and this is due to the fact that despite the high youth unemployment, the farmer's profession is not attractive but mostly discouraged. There are, of course, new farmers with an essential requirement for a secure business environment. Parameters that define it includes: the use of financial instruments with a development dimension, information, education, training, research, innovation. Mostly, however, they demand quality of life in the countryside, education, health and culture.

Within the new CAP context, farm support has been tailored to the priorities and concerns of consumers. Having left behind when subsidies were linked to the quantity of production, support for the CAP has now turned to the achievement of objectives on quality, the natural environment, and food safety, in line with the priorities of European citizens. Greek farmers have once again the freedom to produce according to market demand. By removing the incentives for overproduction, the reforms have made the CAP less distortive in international trade and consider the needs of developing countries. Most importantly, farmers must be aware of the business dimension of their profession. The continuous and stable quality must be a necessary thing to do, along with improving products and services. Local quality standards, combined with networks of similar businesses, can act as excellent means of displaying attractive products and services, tempting investors and managing visitors.

Future research will try to investigate the impact on the new CAP and its application on local products and farmers willing to invest on that form of agriculture.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Ackrill R (2008). The CAP and its Reform – Half a Century of Change? EuroChoices 7(2):13-21.

Alexiadis S, Ladias C, Hasanagas N (2013). A regional perspective of the Common Agricultural Policy. Land Use Policy 30(1):665-669.

Anastasiou E, Duquenne MN (2015). Return to the Rural in Greece during the last decade: a methodological approach of the potential spatial patterns. International Conference on the Population of the Balkans at the Dawn of the 21st Century, Ohrid, 21-24 October 2015.

Andrei JV, Darvasi D (2012). Perspectives and challenges in financing the new common agricultural policy, a new paradigm. Food Agric. Environ. 10(1):904-907.

Babbie E (2011). Introduction to Social Research-5th Edition. Wadsworth, Cengage. Learning. ISBN 978-960-218-750-0.

Bartolini F, Viaggi D (2013). The common agricultural policy and the determinants of changes in EU farm size. Land Use Policy 31:126-135.

Benni NEl, Finger R (2013). Gross revenue risk in Swiss dairy farming. J. Dairy Sci. 96(2):936-948.

Dagalidis A (2014). Specialization and Competitiveness of Greek Agriculture 1961-2011, Sector Study, Piraeus Bank. Greece.

Dash E (2009). If It's Too Big to Fail, Is It Too Big to Exist? http://www.nytimes.com/2009/06/21/weekinreview/21dash.html

Dautopoulos G (2000). Methodology of Social Research. Zygos Publishing, 3rd Edition, Thessaloniki. (in Greek)

Dautopoulos G, Pyrovetsi M (2002). Sustainable Agriculture: The vision of the Greek Agriculture. Georgia – Ktinotrofia 1:52-60.

De Castro P, Adinolfi F, Capitanio F (2014). Family farming issues and challenges in the reformed common agricultural policy. Econ. Agrar.

Recur. Nat. 14(1):169-176.
Dumenil G, Levy D (2005). Costs and Benefits of Neoliberalism. In Epstein, Gerald (ed.), Financialization and the World Economy. Cheltenham and Northampton: Edward Elgar. 2004. Capital Resurgent: Roots of the Neoliberal Revolution. Cambridge and London: Harvard University Press.
European Commission (2016). Agriculture and rural development. The CAP in your country https://ec.europa.eu/agriculture/sites/agriculture/files/cap-in-your-country/pdf/el_en.pdf
Eurostat (2012). Statistics Explained Archive - European Commission - Europa EU — General and economic statistics December 2012. Luxembourg: Publications Office of the European Union, 2013, ISSN 1977-3951 Cat. No KS-FM-13-002-EN-N.
Galluzzo N (2017). The Common Agricultural Policy and employment opportunities in Romanian rural areas: The role of Agritourism. Bulg. J. Agric. Sci. 23(1):14-21.
Goulas A (2017). Local products as a tool of development for the local economies, Actahortic 2017.1175.1, October 2017. DOI: 10.17660/Acta Hortic.2017.1175.1
Hair JF, Black WC, Babin BJ, Anderson RE (2010). Multivariate data analysis: A global perspective (7th ed). New Jersey, Pearson Prentice Hall.
Hellenic Statistical Authority (2015). Hellenic Statistical system. http://www.statistics.gr/en/home
Hill B (2012). Understanding the Common Agricultural Policy. Earthscan, London and New York 335p.
Javeau C (1996). The Questionnaire Survey: The Good Researcher's Manual. Editor-in-English: Tzannone-Tzortzis, Publisher: Typothito - G. Dardanos, Athens.
Jayasuriya D (2011). Improvements in the World Bank's Ease of Doing Business Rankings: Do they translate into Greater Foreign Direct Investment inflows? The World Bank, Policy Research Working Paper No 5787.
Jurkenaite N, Volkov A (2011). Challenges of Common Agricultural Policy development [Bendrosios žemės ūkio politikos plėtros problematika]. Business: Theory Practice 12(2):120-130.
Karanikolas P, Martinos N (2012) The Greek Agriculture in the crisis: Problems and Perspectives. Logios Ermis (in Greek). P 2.
Kasimis C, Papadopoulos AG, Pappas C (2010). Gaining from Rural Migrants: Migrant Employment Strategies and Socioeconomic Implications for Rural Labour Markets. Sociol. Ruralis 50(3):258-276
Kliesen KL (1995). The Fixation on International Competitiveness. Federal Reserve Bank of St Louis. The Regional Economist January 1995 https://www.stlouisfed.org/Publications/Regional-Economist/January-1995/The-Fixation-on-International-Competitiveness.
Kotakou C, Katranidis S (2008). Evaluating the Effects of Decoupled Payments under Output and Price Uncertainty The 84th Annual Conference of the Agricultural Economics Society Edinburgh 29th to 31st March 2010, http://ageconsearch.umn.edu/record/91753/files/51Kotakou_katranidis.pdf
Kourmousi M (2015). The war on food stock has began. http://www.aua.gr/gr/synd/eedip/Nea/2008/Trofi_eleyth_08-04-12_Kourmousis_Litsis.pdf (Accessed on 01 February 2016) (Edition 2015)
Milner C, Pentecost E (1996). Locational advantage and US foreign direct investment in UK manufacturing. Appl. Econ. 28(5):605-615.
Organization For Economic Co-operation and Development (OECD) (2016a), Agricultural support (indicator). (Accessed on 01 February 2016) (Edition 2015). doi: 10.1787/6ea85c58.
Organization For Economic Co-operation and Development (OECD) (2016b), Producer protection (indicator). doi: 10.1787/f99067c0-en (Accessed on 02 February 2016).
Oppenheim A (1992). Questionnaire Design, Interviewing and Attitude Measurement. Printer, London and Washington.
Papadopoulos AG (2015). The Impact of the CAP on Agriculture and Rural Areas of EU Member States' Agrarian South: J. Polit. Econ. 4(1):22-53.
Popp J, Jámbor A (2015). How consistent is the new common agricultural policy with the challenges it faces? Soc. Econ. 37(2):225-243.
Porter ME, Schwab K, Lopez-Claros A (2005). The Global Competitiveness Report 2005–06: Policies Underpinning Rising Prosperity, Palgrave Macmillan: New York.
Schmid E, Sinabell F, Hofreither MF (2007). Phasing out of environmentally harmful subsidies: Consequences of the 2003 CAP reform. Ecol. Econ. 60:596-604.
Solomou A, Tsogia S, Mousxoudi K, Fragia T, Sfougaris A, Tzortzios S (2009). Farmers' views and attitudes towards the reformed common agricultural policy in Greece. Int. J. Sustain. Dev. Plan. 4(3):265-276.
Stathopoulos B (1997). Market Research Methods. A. Stamoulis, Athens. Bohrnstedt, G. W. (1977). Reliability and Validity Assessment in Attitude Measurement" in Gene F. Summers (eds.), Attitude Measurement. Kershaw Publishing Company Ltd, London.
Vlahos G, Louloudis L (2011). Landscape and agriculture under the reformed Common Agricultural Policy in Greece: Constructing a typology of interventions. Geografisk Tidsskrift 111(2):131-147.
Vorloou AA, Castritsi-Catharios J (2012). The common agricultural policy's effects on the agricultural sector in Greece and its environmental impacts. Greece: Econ. Polit. Soc. Iss. pp. 163-174. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84895305017&partnerID=40&md5=92d44fdde8dc6054a945d380321b5a62
Walsh JP, Yu J (2010). Determinants of Foreign Direct Investment: A Sectoral and Institutional Approach. IMF working paper. WP/10/187.
Zasada I, Piorr A (2015). The role of local framework conditions for the adoption of rural development policy: An example of diversification, tourism development and village renewal in Brandenburg German. Ecol. Indic. 59:82-93.

academicJournals

Vol. 13(10), pp. 452-459, 8 March, 2018
DOI: 10.5897/AJAR2016.11969
Article Number: CEBDD0056241
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Cotton growth in response to water supply in red Latosol cerrado

Vitor Marques Vidal, Frederico Antonio Loureiro Soares*, Marconi Batista Teixeira, Fernando Nobre Cunha, Leonardo Nazário Silva dos Santos, Cicero Teixeira Silva Costa, Giovani Santos Moraes, Washington Bezerra, Gustavo da Silva Vieira, Wilker Alves Morais, Aurélio Ferreira Melo, Ana Carolina Oliveira Horschutz, Jenifer Kelly Ferreira dos Santos, Igor Olacir Fernandes Silva and Leandro Spíndola Pereira

Federal Institute of Goiás (Instituto Federal Goiano – IF Goiano), Campus Rio Verde, Goiás GO Brazil.

Received 18 November, 2016; Accepted 24 January, 2017

There are few studies that demonstrate the influence of water stress in biometric variables and cotton growth. Thus, the objective of this study was to evaluate different levels of water supply in the BRS 2 cotton growth, in the field of Campus Rio Verde - GO, in 2015. Experimental design used was randomized blocks, with three replications in a split-plot scheme of 5 x 4 with five water replacements (WR) (25, 50, 75, 100 and 125%) of evapotranspiration, and four times of evaluation (ET) during the growth cycle (40-60, 61-80, 81-100 and 1-20 days after emergence). The variables analyzed were plant height (PH), leaf area (LA), dry phytomass stem (DPS), dry phytomass of leaves (DPL), dry phytomass of reproductive organ (DPRO), dry phytomass of aerial part (DPAP), absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR). The behavior of PH and LA under the influence of water levels revealed that for a better performance of studied variables, it is important to consider the irrigation management, besides the crop coefficient. Water replacement influenced the cotton growth. Low cotton growth rate was caused by the reduction of water supply until the end of growth cycle.

Key words: *Gossypium hirsutum* L., dry phytomass, drip irrigation, crop evapotranspiration.

INTRODUCTION

Cotton crop (*Gossypium hirsutum* L.) has great socio-economic importance, being one of the main Brazilian agricultural products to be used in the textile industry, animal feed and the production of vegetable oil, as well as, its derivatives for human consumption, among other purposes.

Its cultivation is mainly in the Midwest region of Brazil, with about 627 thousand hectares planted in 2014/15 (Conab, 2015), due to the favorable edaphoclimatic conditions. However, most cases are in a situation of water deficit. During cotton life cycle, cultivation requires between 650 and 900 mm of water (Aquino et al., 2012), with a daily rate of water consumption relatively low (about 6.5 mm day^{-1} during the phase of higher transpiracy

*Corresponding author. E-mail: fernandonobrecunha@hotmail.com.

Table 1. Some physical and chemical characteristics of a 0 - 20 cm soil layer of a dystrophic Red Latosol at Campus Rio Verde.

Depth	Density	Total porosity	Sand	Silt	Clay	Sorption Complex[1]									
						Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	H+Al	OM	BS	CEC	V	pH
cm	$g\ cm^{-3}$	%	$g\ kg^{-1}$			$cmol_c\ dm^{-3}$					%	$cmol_c\ dm^{-3}$		%	-
0 - 20	1.19	53.03	463	174	322	2.71	1.16	0.13	0.52	0.3	4.02	5.41	7.83	69.1	5.50

[1]Ca^{2+} and Mg^{2+} extracted with HCl 1 mol L^{-1} at pH 7.0; Na^{+} and K^{+} extracted using NH_4OAC 1 mol L^{-1} at pH 7.0; pH determined in $CaCl_2$ solution.

of higher transpiratory demand), even in hot climates and with adequate supply of water in the soil (Oliveira et al., 2004).However, according to Bezerra et al. (2010) cotton has a low water demand up to flowering stage which occurs around 50 DAE.

Water availability is a very important factor affecting cotton morphology and physiology, which influence crop productivity. As Oliveira et al. (2012) noted, the best cotton yield was obtained with a certain amony of water corresponding to approximately 20% of soil water content, which exceeds the ETo.

Although cotton shows a good tolerance to water stress, water deficit may cause significant losses in productivity (Batista et al., 2010) due to a reduction in plant growth and vegetative development.According to Baldo et al. (2009), water deficit may cause drops of flowers and fruits, as well as, the production of low fiber content. Oliveira et al. (2008) affirming that biometric variables, like the stem diameter and plant height are affected, in addition to the leaf area and biomass, resulting in lower productivity and worse quality of fiber (Cordão Sobrinho et al., 2007).

There are few studies that demonstrate the influence of water stress in these biometric variables, and the growth of the cotton crop. Thus, the objective of present study was to evaluate different levels of water replacements in the cotton growth.

MATERIALS AND METHODS

The experimental study was conducted in an experimental area of the Federal Institute Goiano, Campus Rio Verde (17°48'S, 50°54'W; 744 m asl.). Sowing was held on July 05, 2015.

The climate is classified according to Köppen and Geiger (1928) as Aw, tropical, with an average annual temperature of 21ºC, annual precipitation between 1,500 to 1,800 mm and a relative humidity of 30 to 85%.

Soil of experimental area is classified as dystrophic Red Latosol (Oxisol), with a medium texture in the cerrado phase (Santos et al. 2013). Soil preparation was performed with a harrow and leveler. In Table 1, the main physical and chemical characteristics of the soil are presented.

Experimental design used was under randomized blocks, with three replications in a split plot scheme of 5 x 4 with five water replacements (WR) (25, 50, 75, 100 and 125%) of evapo-transpiration and four times of evaluation (ET) of culture (40-60, 61-80, 81-100 and 1-20 days after plant emergence, DAE). Each plot consisted of 5 lines and 4.0 m long and 0.90 m spacing between lines. The area of the plot consisted of 3 central lines of 2.0 m/each.

A drip irrigation system, managed by the method of simplified water balance based on Tank "Class A" (AGR) (Allen et al., 1998), in which, first determined the irrigation efficiency (Ie) system according to Keller and Karmeli (1975), measured daily evaporation (mm) using a micrometer and evapotranspiration of reference (ET_0) was determined by multiplying the evaporation and the tank coefficient (Kp) equal to 0.65. Crop evapotranspiration (ETc) was determined by multiplying the ET_0 the crop coefficient (Kc) determined by Oliveira et al. (2013). The 100% water depth was determined based on ETc and Ei, and then extrapolated to other blades used to compose the treatments.

In each evaluation time (ET), measurements of plant height (PH) were taken, considering the distance from ground level to the plant apex. Afterwards, two plants were collected at ground level in each replicate, and were separated in plant organs: leaves, stems+branches and reproduction organ.The leaf area was determined using the equation proposed by Grimes and Carter (1969): $y = 0.4322\ x^{2,3002}$, where y is 1-leaf, x is the length of the main rib cotton leaf; and then the leaf area per plant was determined by the sum of leaf areas.

Plant material was placed in forced-air circulation greenhouse, at 65°C for 72 h and subsequently weighed to determine dry phytomass stem (DPS), dry phytomass leaf (DPL), dry phytomass of the reproductive organ (DPRO) anddry phytomass of aerial part (DPAP).

AGR (absolute growth rate) per day, was calculated by the equation AGR = (Pn - Pn-1)/(Tn - Tn-1), in which Pn is the dry phytomass accumulated until evaluation to n; Pn-1 is the accumulated dry phytomass to evaluation n-1; Tn is the number of days after treatment when evaluation n; and Tn-1 is the number of days after treatment at the time of evalution n-1.

The RGR (relative growth rate) growth in a certain time interval in relation to the phytomass accumulated at the beginning of this interval, the RGR was calculated by the equation RGR = (ln P2 - P1 ln) / T1 T2-g^{-1} g per day.

The NAR (net assimilation rate) is dry phytomass produced per unit leaf area and time and was calculated using the following equation: NAR = [(Pn - Pn-1) / (Tn - Tn-1)] [(1nAn - 1nAn-1) / (An - An-1)], where An is the leaf area; and An-1 is area leaf of the plant during evaluation n-1.

LAR (leaf area ratio) was calculated by the equation An = LAR/Pn, and the relationship between leaf area responsible for the photosynthesis and total dry phytomass produced.

Results were submitted to analysis of variance and significant variances were compared at 5% probability level. Choice of the models was based on the significance of the regression coefficients using the t-test at 5% probability and the coefficient of determination.

RESULTS AND DISCUSSION

There was a significant effect for the interaction of evaluation time (ET) and water replacement (WR) for the

Table 2. Summary of analysis of variance for the variables plant height (PH), leaf area (LA), dry phytomass stem (DPS), dry phytomass of leaves (DPL), dry phytomass of reproductive organ (DPRO), dry phytomass of aerial part (DPAP), absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) under different water replacement (WR) at different evaluation times (ET) during the crop cycle, in Campus Rio Verde - GO, 2015.

Source of variation	df	Means square[1]					
		PH	LA	DPS	DPL	DPRO	DPAP
WR	4	795.52**	3716703.00**	92.79**	137.66**	31.07**	839.22**
Block	2	3.37^{ns}	52898.61^{ns}	2.82^{ns}	14.48^{ns}	1.63^{ns}	3.97^{ns}
Residue (a)	8	4.08	168623.50	14.28	9.76	0.77	4.08
ET	3	6380.42**	21948699.94**	2127.90**	516.53**	8926.94**	27019.27**
WR x ET	12	58.71**	351302.33**	3.55^{ns}	4.13^{ns}	8.48**	57.89**
Residue (b)	30	4.82	115777.71	9.02	11.09	0.80	4.07
CV (a) (%)		2.58	10.28	10.31	10.15	3.07	2.09
CV (b) (%)		2.80	8.52	8.20	10.82	3.12	2.09

		AGR	RGR	NAR	LAR
WR	4	0.05**	3.00x10$^{-5\ ns}$	1.46x10-8 **	98.77**
Block	2	0.01^{ns}	7.90x10$^{-7\ ns}$	2.56x10$^{-9\ ns}$	4.29 ^{ns}
Residue (a)	8	0.003	1.67x10^{-7}	2.11x10^{-9}	25.46
ET	3	3.22**	1.86x10-3 **	2.40x10-7 **	1088.13**
WR x ET	12	0.44**	1.28 x10-4 **	9.37x10$^{-9\ ns}$	60.25 ^{ns}
Residue (b)	30	0.016	3.00x10^{-6}	1.84x10^{-9}	13.60
CV (a) (%)		3.71	1.80	11.40	11.40
CV (b) (%)		8.60	7.68	10.65	8.33

[1] ^{ns} – F - value non-significant at p $\geq$ 0.05. ** - F - value significant at 1% of probability.

following variables: plant height (PH), leaf area (LF),dry phytomass of the reproductive parts (DPRP), dry phytomass of aerial part (DPAP), absolute growth rate (AGR) and relative growth rate (RGR). The variables, dry stem phytomass (DPS), dry leaf phytomass (DPL), net assimilation rate (NAR) and leaf area ratio (LAR) showed significant variability for isolated factors. The coefficients of variation were low (2.09 - 10.82%), which shows relatively good experimental precision (Table 2).

Several researchers have noted the importance of study related to irrigation levels on the growth, development and production of different cultures, because of this, allow the identification of the level that provides the best conditions to culture, as an example of Smith et al. (2015) found that variability in biomass and production of sunflower under the influence of irrigation levels, as Morais, et al. (2016) on growth and development of the bean crop and Zonta et al. (2015) in the production of cotton.

Changes in the performance of plants related to irrigation is explained to the stress caused by excess water in the soil, causing the death of root tissues due to lactic fermentation and acidosis in the cells, the moment that the soil is in lack of oxygen , which leads to lack of energy, and causes the plant to reduce the potential for absorption of nutrients.On the other hand, the soil water deficiency can lead to plant water stress and thus cause a reduction in cell growth, leaf area, ratio of the biomass of roots and shoots, lower nutrient absorption, stomatal closure and reduction in photosynthesis (Taiz and Zeiger, 2010).

Figure 1 shows the positive linear adjustment of variables DPS and DPL due of WR and ET. DPS and DPL increased with WR (Figure 1A), with estimated increase of 0.22 and 0.35%, respectively, with a unit increase in WR. Still, for DPS and DPL (Figure 1B), there was an increase in the estimated daily from 15.69 and 1.92%, respectively, in a 20-days period.Thus, it is clear that even for ET of 101-120 days, the cotton plants is still able to assimilate production by stems and leaves.

Increased water stress resulted in the formation of small leaves with reduced leaf area, and consequently reduction in light absorption by plant and lower production of assimilates (Souza, 2014).

Figure 2 shows the WR split within each level of ET. It was found that for 60, 80, 100 and 120 DAE a larger PH was estimated (62.4; 94.6; 106.1 and 108.6 cm for 109.2; 119.7; 125 and 125% WR, respectively) (Figure 2A). This fact shows that plants did not enter the senescence before 120 DAE. In unfolding the ET in each level WR, noted that 25% RH the 7.31% PH increased daily 50% WR greater PH was estimated at 120 DAE, while WR 75, 100 and 125 found to be larger PH (99.48; 107.30 and 104.63 cm) at 120, 114 and 114 days, respectively

DPS = 31.38 + 0.070**WR $R^2 = 0.99$
DPL = 24.36 + 0.085**WR $R^2 = 0.99$

DPS = - 2.7923 + 0.4382**ET $R^2 = 0.902$
DPL = 11.266 + 0.2167**ET $R^2 = 0.909$

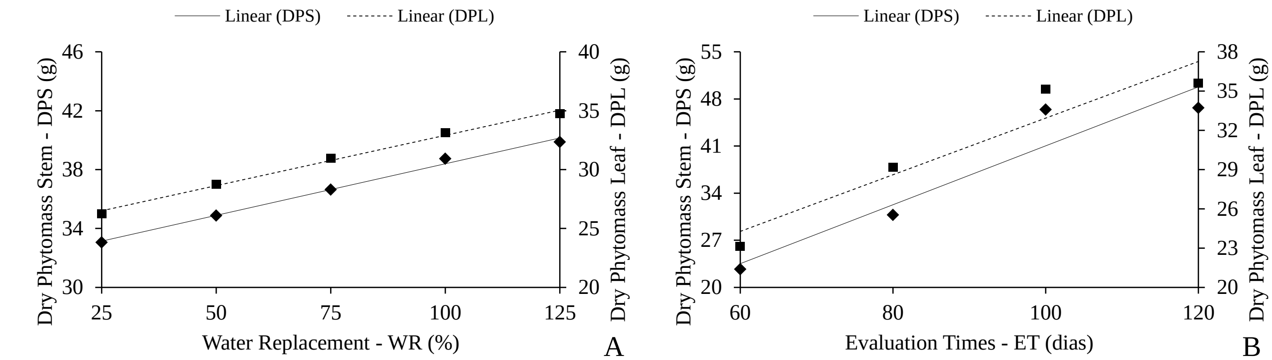
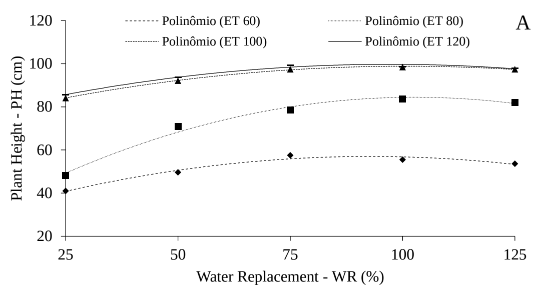
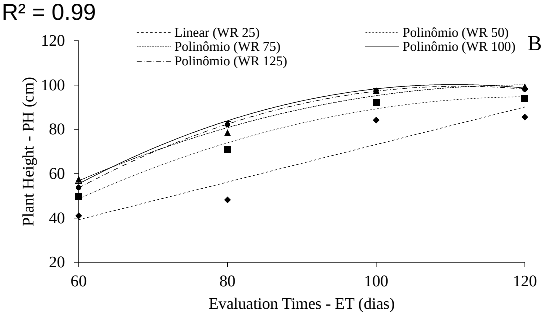


Figure 1. Regression analysis for following variables: dry phytomass leaf and stem (A) depending water replacement and dry phytomass leaf and stem (B) due cotton in evaluation time, Campus Rio Verde, March 2016. ** - F - value significant at 1% of probability.

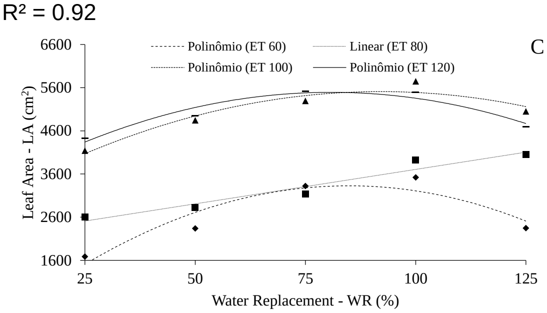
ET (40-60) = 26.66 + 0.655**WR - 0.003**WR^2
$R^2 = 0.97$
ET (61-80) = 23 + 1.197**WR - 0.005**WR^2
$R^2 = 0.99$
ET (81-100) = 72.85 + 0.516**WR - 0.002**WR^2
$R^2 = 0.99$
ET (101-120) = 74.23 + 0.525**WR - 0.002**WR^2
$R^2 = 0.98$



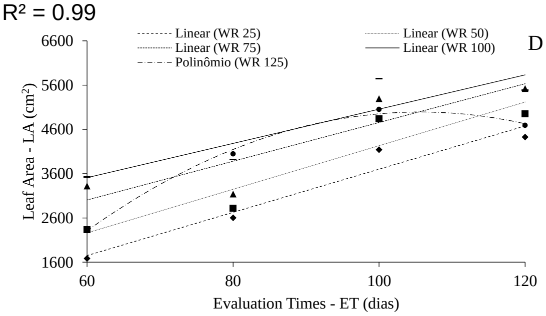
WR (25) = - 11.59 + 0.847**ET
$R^2 = 0.87$
WR (50) = - 86.38+ 2.99*ET -0.012**ET^2
$R^2 = 0.98$
WR (75) = - 72.6+ 2.874**ET -0.012**ET^2
$R^2 = 0.99$
WR (100) = - 114.2+ 3.881**ET -0.017**ET^2
$R^2 = 0.99$
WR (125) = - 116.3+ 3.876**ET -0.017**ET^2
$R^2 = 0.99$



ET (40-60) = - 329.1 + 86.15**WR -0.507**WR^2
$R^2 = 0.87$
ET (61-80) = 2110 + 15.95**WR
$R^2 = 0.94$
ET (81-100) = 3074 + 59.85**WR - 0.370**WH^2
$R^2 = 0.92$
ET (101-120) = 3074 + 59.85WR - 0.370**WR^2
$R^2 = 0.92$



WR (25) = - 1181 + 48.83**ET
$R^2 = 0.945$
WR(50) = - 693.1 + 49.24**ET
$R^2 = 0.88$
WR(75) = 378 + 43.79**ET
$R^2 = 0.80$
WR(100) = 1189 + 38.68**ET
$R^2 = 0.80$
WR(125) = – 9372+ 271.9**ET -1.287**ET^2
$R^2 = 0.99$



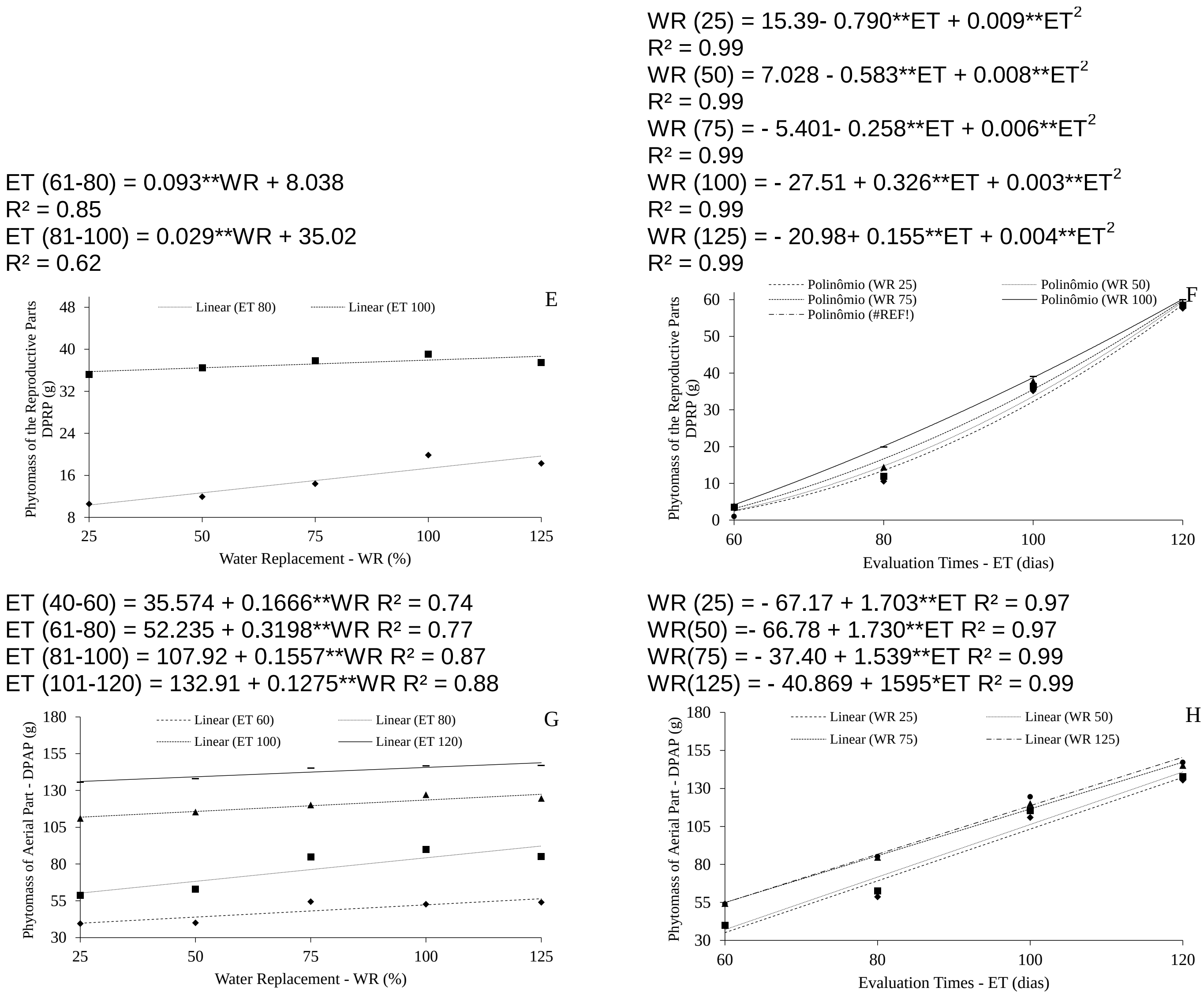


Figure 2. Plant height (A), leaf area (C), dry phytomass of reproductive part (E) dry phytomass of aerial part (G) each evaluation period due to the water replacement levels and plant height (B), leaf area (D), dry phytomass of the reproductive part (F) dry phytomass of aerial part (H) due cotton in evaluation times, Rio Verde, March 2016.

(Figure 2B). These results indicate that when cotton does not suffer water stress has its continued growth to 120 DAE.

Its noted that LA to 60, 100 and 120 days showed the highest increases (3326.03, 5508.98, and 5491.78 cm^2), the WR 84.85; 92.04; and 80.78%, respectively, on day 80 there was an increase of 0.38% per unit WR (Figure 2C). In the WR 25, 50, 75 and 100% LA presented respectively increments of 3.13; 2.83; 2.33; and 1.99% at an interval 20 days, as 125% WR and AF showed the largest increase (4992.03 cm^2) at approximately 106 days of development (Figure 2D).

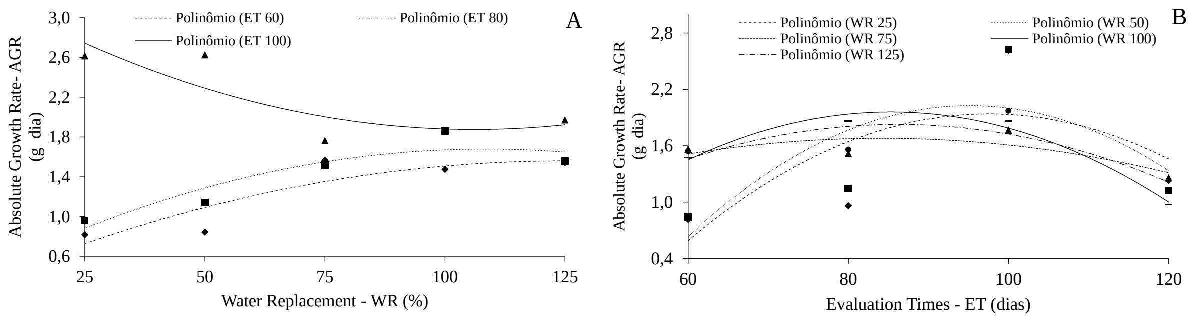
The behavior of plant height and leaf area under the influence of water replacement levels, reveal that for a higher performance variables, it is important to consider in the design of the irrigation management, besides the crop coefficient (Kc) Results research as demonstrated by study.

Its noted that DPRP was difference betwem WR only after 80 and 100 days and the regression equation as presented increments of 1.16 and 0.08% per unit increase in WR, respectively (Figure 2E). According to the equations EA scrolling regressions within each WR level, the largest accumulations of DPRP (58.8; 59.4; 60.1; 60.6; and 59.6 g) were scanned at 120 days in respective WR 25, 50, 75,100 and 125% (Figure 2F).

There is difference between WR in all the DPAP and ET and at 60, 80, 100 and 120 days showed increases DPAP 0.47; 0.61; 0.14 and 0.10% per unit increase of WR, respectively (Figure 2G). At 100% WR, there was no

WR (25) = - 7.1664 + 0.1866**ET - 0.001**ET^2 $R^2 = 0.49$
WR(50) = - 8.1696 + 0.2142**ET - 0.0011**ET^2 $R^2 = 0.55$
WR(75) = - 0.3498 + 0.0482**ET - 0.0003**ET^2 $R^2 = 0.57$
WR(100) = - 3.8409 + 0.136**ET -0.0008**ET^2 $R^2 = 0.98$
WR(125) = - 2.1636 + 0.0926**ET - 0.0005**ET^2 $R^2 = 0.61$

ET (40-60) = 0.258 + 0.020**WR – 0.00008**WR^2 $R^2 = 0.80$
ET (61-80) = 0.334 + 0.024**WR - 0.0001**WR^2 $R^2 = 0.86$
ET (81-100) = 3.361 - 0.028**WR + 0.0001**WR^2 $R^2 = 0.73$



WR (25) = - 0.0321 + 0.0015**ET – 0.000009**ET^2 $R^2 = 0.48$
WR(50) = - 0.0357 + 0.0016**ET– 0.00001**ET^2 $R^2 = 0.67$
WR(75) = 0.1305 - 0.002**ET + 0.000008**ET^2 $R^2 = 0.97$
WR(100) = 0.0924 - 0.001**ET + 0.000003**ET^2 $R^2 = 0.99$
WR(125) = 0.1128 - 0.0015**ET + 0.000006**ET^2 $R^2 = 0.96$

ET (40-60) = 0.014+0.0005**WR– 0.000002**WR^2 $R^2 = 0.81$
ET (61-80) = 0.015+0.0002**WR - 0.000001**WR^2 $R^2 = 0.61$
ET (81-100) =0.044-0.0005**WR+0.000002**WR^2 $R^2 = 0.83$

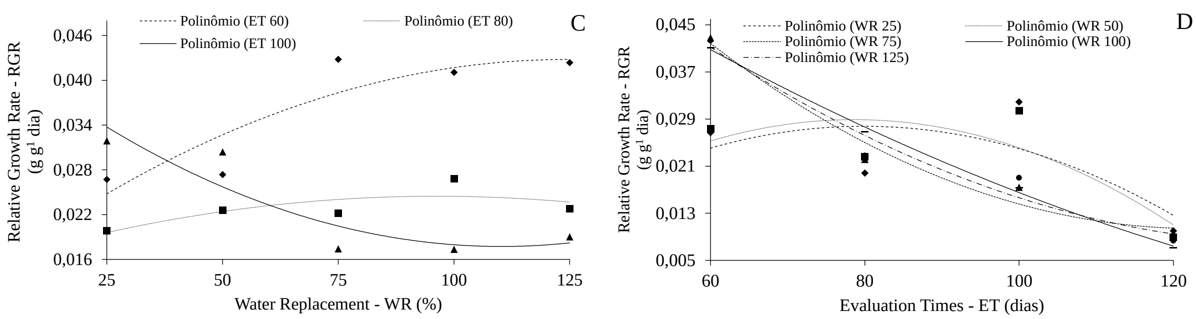


Figure 3. Absolute growth rate - AGR (A) and relative growth rate - RGR (C) for each evaluation time interval depending on the water replacement levels and absolute growth rate (B) and relative growth rate (D) due cotton in evaluation times, Rio Verde, March 2016. ** - F - value significant at 1% of probability.

significant difference between ET, but WR 25, 50, 75 and 125%, the DPAP accumulation in a 20 day interval was increased by 50.71; 51.81; 82.30 and 78.05%, respectively (Figure 2H).

The result of the largest responses for plants growth in height and leaf area between 100 and 120 days, the culture also showed greater assimilates productions shoot and thus the reproductive part linked to a water replacement of 100% of evapotranspiration.

Studying the behavior of cotton cultivar Delta Opal under water stress in controlled environment, Baldo et al. (2009) found that smaller plant height, stem diameter, number of leaves and also the commitment of the formation of reproductive structures were water deficit of the consequences of 25% of the total pores, and even the best results for production of dry phytomass of aerial part and root were provided by replacement of 100%.

Figure 3 showed the settings variables evaluated for WR unfolding in each level of ET. In time slots 40 to 60 and 61 to 80 days, it was found according to the regression equation, the highest absolute growth rates with 1.51 and 1.87 g per day, the WR 125 and 124%,

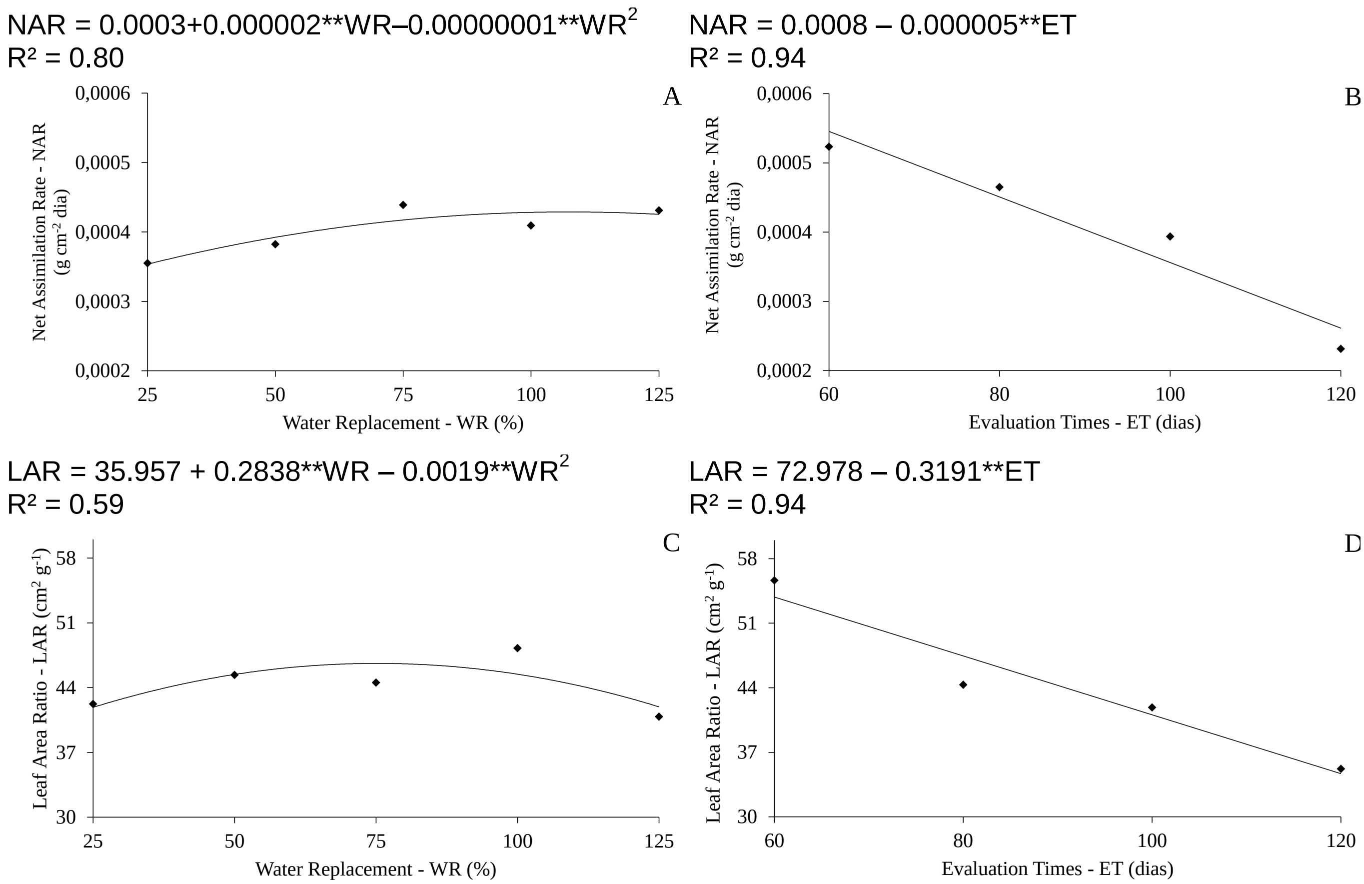


Figure 4. Net assimilation rate - NAR (A) and leaf area ratio - LAR (C) due of levels and net assimilation rate - NAR (B) and leaf area ratio - LAR (D) due cotton in evaluation times, Rio Verde, March 2016. ** - F - value significant at 1% of probability.

respectively, since the period of 81 to 100 days greater AGR (2.72 g daily) was afforded by 25% WR (Figure 3A). The highest AGR (1.54, 2.26, 1.59, 1.94 and 2.12 g per day) in the WR 25, 50, 75, 100 and 125% were observed at 93.3, 97.4, 80.3, 85.0, 92.6 days, respectively (Figure 3B).

In the intervals 40 to 60 and 61 to 80 days, the WR 100 to 125%, showed highest RGR (0.045 and 0.025 g g^{-1} per day), respectively, and length of 81 to 100 days found reduction RGR due levels of RH. 25% WR estimated a RGR 0.033 g g^{-1} per day, exceeding 125% WR growth of 61.07% (Figure 3C). In the WR 25 and 50%, there was the highest estimated RGR (0.030 to 0.028 g per day) after 83 and 80 days, respectively, and the WR 75, 100 and 125% decreased the RGR from 60 days; however, the RGR at 75% WR was higher than in the 100 and 125% in the range 61-80 days of development of cotton (Figure 3D).

In cotton, the reduction absolute growth rates and on the period between 81 and 100 days is expected, since any increase in phytomass, plant height and leaf area at the end of the cycle culture is smallest; , this increase is directly relating to value obtained in the previous period, as the growth rate of a plant varies throughout the plant cycle, it depends on two other growth factors: the useful leaf area for photosynthesis and leaf area ratio (LAR), and net assimilation rate (NAR), which is gross photosynthetic rate, discounting breathing and how this period there were decreases in the LAR and NAR (Figure 4A and B) the AGR and RGR were influenced directly.

The reduction of absolute and relative growth rates in the period of 81 to 100 DAE of cotton is explained by the fact that this period coincides with the flowering period and training of apples, which are effective plant drains (Freitas et al., 2006). At this stage, it is important to irrigate for HR 75% of evapotranspiration to soften these reductions.

The larger NAR was estimated for 100% WR (Figure 4A), showing that WR is ideal for keeping a good phytomass production and consequently the plant achieve higher net photosynthesis. A linear reduction of 12.5% NAR was observed for each increase of 20 DAE (Figure 4B). This reduction in NAR due to the increase plant leaf area influenced in greater or lesser net photosynthesis produced by plants.

The behavior NAR (Figure 4B) was similar to RGR

(Figure 3D). Thus, a more efficient dry phytomass by leaves occurred. To alleviate the problems by reducing the NAR, it is recommended to adopt a 100% WR, regardless of the ET.

The higher LAR (46.55 cm^2 g^{-1}) was verified in the 74.7% WR (Figure 4C) and in relation to ET, observed a reduction of 6.38 cm^2 g^{-1} in the LAR 20 for each intervals days of development of culture (Figure 4D). The LAR high in the initial stage indicates there was investment in the development of the leaves to the light energy capture and then, due to the aging of the leaves was the direction of assimilates to other plant parts.

The reduction LAR in the course of crop development is explained according Benincasa (2003), by the fact upper leaf to cause self-shadowing of lower leaves, and to the extent that the crop will develop during their cycle, this problem it is increased. Urchei et al. (2000) found that reduction of LAR in the course of crop development is due to the emergence of reproductive structures (and apple bud) are designed as highly competitive drains.

The study of water replacement levels showed great importance with regard to the growth and development of cotton, by the fact that it was identified levels that can be used in a specific developmental stage, in order to ease the reduction of the problems of growth rate and provide better agronomic performance and productivity to cotton.

Conclusions

Water replacement influenced the cotton growth. Low growth rate was conditioned by the reduction of water supply, until the end of cotton cycle. Water supply of 100% provided higher phytomass production of reproductive organ.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors would like to thank the Ministry of Science and Technology (MCT), the Foundation for Research Support of the State of Goiás (FAPEG), the Coordination for Upgrading Higher Institution Personnel (CAPES), the Brazilian Council for Scientific and Technological Development (CNPq) for funding the current scientific project.

REFERENCES

Allen RG, Pereira LS, Raes D, Smith M (1998). Pan evaporation method. In: Crop evapotranspiration. Roma: FAO, (Irrigation and Drainage) 56:78-85.

Aquino LA, Aquino FBA, Silva TC, Santos DF, Berger PG (2012). Aplicação do fósforo e da irrigação na absorção e exportação de nutrientes pelo algodoeiro. Rev. Bras. de Engenharia Agríc. Ambient 16(4):355-361.

Baldo R, Scalon SPQ, Rosa YBC, Mussury RM, Betoni R, Barreto WS (2009). Comportamento do algodoeiro cultivar delta opal sob estresse hídrico com e sem aplicação de bioestimulante. Ciênc. e Agrotecnologia, Edição Especial 33:1804-1812.

Batista CH, Aquino LA, Silva TR, Silva HRF (2010). Crescimento e produtividade da cultura do algodão em resposta a aplicação de fósforo e métodos de irrigação. Revista Brasileira de Agricultura Irrigada. Fortaleza - CE 4(4):197-206.

Benincasa MP (2003). Análise de crescimento de plantas (noções básicas). Jaboticabal: FUNEP 1-41.

Bezerra JRC, Azevedo PV, Silva BB, Dias JM (2010). Evapotranspiração e coeficiente de cultivo do algodoeiro BRS-200 Marron, irrigado. Rev. Bras. de Engenharia Agríc. e Ambient. 14:625-632.

CONAB (2015). Acompanhamento de safra brasileira: grãos, nono levantamento.Companhia nacional de abastecimento. Brasília, DF 2:1-37.

Cordão Sobrinho FP, Fernandes PD, Beltrão NEM, Soares FAL, Terceiro Neto CPC (2007). Crescimento e rendimento do algodoeiro BRS-200 com aplicações de cloreto de mepiquat e lâminas de irrigação. Revista Brasileira de Engenharia Agrícola e Ambiental. Campina Grande- PB 11(3):284-292.

Freitas RS, Tomaz MA, Ferreira LR, Berger PG, Pereira CJ, Cecon PR (2006). Crescimento do algodoeiro submetido ao herbicida trifloxysulfuron-sodium. Planta Daninha 24(1):123-129.

Grimes DW, Carter LM (1969). A linear rule for direct nondestrutive leaf area measurements. Agron. J. Madison 3(61):477-479.

Keller J, Karmeli D (1975). Trickle irrigation design. Rain Bird Sprinkler Manufacturing Corporation pp. 1-133.

Köppen W, Geiger R (1928). Klimate der Erde. Gotha: Verlag Justus Perthes.

Morais WAM, Soares FAL, Cunha FN, Vidal VM, Silva NF, Teixeira MB (2016). Reposição hídrica e adubação com NPK no crescimento e produção do feijoeiro. Rev. Bras. de Agric. Irrigada 10(2):496-506.

Oliveira FA, Silva MNB, Oliveira AP, Santos D, Pereira WE, Oliveira RC, Gondim SC (2008). Rev. Bras. ol. fibros. Campina Grande 12(1):49-57.

Oliveira RH, Rosolem CA, Trigueiro RM (2004). Importância do fluxo de massa e difusão no suprimento de potássio ao algodoeiro como variável de água e potássio no solo. R. Bras. Ci. Solo 28:439-445.

Oliveira SEM, Andrade Júnior AS, Ribeiro VQ, Morais ELC (2012). Desempenho produtivo do algodão em monocultivo e consorciado com feijão-caupi em resposta à disponibilidade hídrica do solo. Comun. Sci. 3(4):282-291.

Oliveira SRM, Andrade Júnior AS, Ribeiro JL, Barros MA (2013). Coeficientes de cultura do algodão herbáceo e do feijão-caupi em sistemas monocultivo e consorciado. Rev. Bras. Agric. Irrig. 7(3):191-200.

Souza AMS (2014). Estresse hídrico e expressão de genes no início do crescimento de algodoeiros naturalmente coloridos. Dissertação – Universidade Estadual da Paraíba pp. 20-73.

Taiz L, Zeiger E (2010). Pant Physiology, 5.ed. Sunderland: Sinauer Associates Inc. Publishers pp. 1-782.

Urchei MA, Rodrigues JD, Stone LF (2000). Análise de crescimento de duas cultivares de feijoeiro sob irrigação, em plantio direto e preparo convencional. Pesqui. Agropecu. Bras. 35(3):497-506.

Zonta JH, Bezerra JRC, Sofiatti V, Farias FJC, Carvalho LP (2015). Efeito da irrigação no rendimento e qualidade de fibras em cultivares de algodoeiro herbáceo. Rev. Caatin. 28(4):43-52.

academicJournals

Vol. 13(10), pp. 460-469, 8 March, 2018
DOI: 10.5897/AJAR2018.13009
Article Number: DB0E0CD56249
ISSN 1991-637X
Copyright ©2018
Author(s) retain the copyright of this article
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Diversity of insects in conventional and organic tomato crops (*Solanum lycopersicum* L., solanaceae)

Rubens Pessoa de Barros[1*], Ligia Sampaio Reis[2], Isabelle Cristina Santos Magalhães[1], Miriany de Oliveira Pereira[1], Ana Cleia Barbosa de Lira[1], Claudio Galdino da Silva[1], Jaciara Maria Pereira e Silva[1], João Gomes da Costa[3] and Elio Cesar Guzzo[3]

[1]Department of Biological Sciences, State University of Alagoas, Brazil.
[2]Center for Agricultural Sciences, Federal University of Alagoas, Brazil.
[3]Rio Largo Research Unit Technical-Scientific Area, EMBRAPA - Rio Largo-AL, Brazil.

Received 20 January, 2018; Accepted 12 February, 2018

This study aims to compare the diversity and relative abundance of insect families collected in organic and conventional tomato production systems located in Alagoas, Northeast Brazil (09°81'76"S and 36°59'42"W). In this region, the visible spectrum is quite broad with sunlight throughout the year. Between rows of tomato plants, we set up a system of colored traps colored blue, yellow, white, green, red, and transparent. The experiment was between September 2015 and January 2017. The experimental design was completely randomized with six experiments and with five replicates. The data collected were analyzed using the Scott-Knott test at 5% probability. Analysis of the various diversity indices was made using DivEs software. A total of 56,955 insects from 25 families were collected from the organic system, and 10,660 from 22 families in the conventional system. We observed that, in the conventional system, insect diversity and relative abundance (AR) were significantly greater than those of the organic system. The averages of the indices were as follows: For the organic system: Shannon-Wiener, 2.97; Simpson, 0.79; Simpson Dominance, 0.19; Margalef, 5.13; and Pielou, 2.27, respectively. For the conventional system, the indices were 3.49; 0.86; 0.12; 6.93; and 2.56; respectively. Several families of insect orders collected in the colored traps showed significant mean values for families of pollinator insects, predators, parasitoids, and pests. This may aid in decision making for the protection of plants and other agroecosystems. The collected insects did not differ significantly in terms of diversity of families. Colored traps may be exploited for pest control and for conservation of insect.

Key words: Vegetables, agricultural management, agroecology, plant protection.

INTRODUCTION

Tomato is very important in Brazil, being the second most important vegetable crop. However, disease and pest infestation in crop have caused significant damage to tomato production. These insects' damages generate morphological and physiological derangements in the tomato, causing them to ripen irregularly (Santos et al.,

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

2008b).

Environmental variation contributes diversity of species in natural ecosystems and in agroecosystems, where farm managers follow procedures aimed at causing the least impact to the environment. This applies regardless of whether the system is conventional or organic (Alencar et al., 2013). When the agroecosystem is managed with chemicals and the control of insects is done by insecticides, the diversity is damaged. Unlike the organic system, the diversity is represented by several families of insects (Letourneau and Goldstein, 2001).

Plants protect themselves through the visible portion of the electromagnetic spectrum because colors motivate insects to search for food, locate mating sites, lay eggs, and pollinate (Skorupski and Chittka, 2010; Wanga et al*.,* 2013). Paula et al. (2015) point out that colored traps may provide a potential alternative for insect control and integrated pest management. It may be possible to use such a system to monitor fluctuations in insect species and richness.

Vrdoljak and Samways (2012) argue that yellow color, compared with other colors, leads to a higher number of insects captured, with yellow traps catching insects from various groups in several growing areas and natural systems. Campos (2008) showed that various trap colors attract insects in agricultural settings and forests.

Predator insects are important in the agricultural context because they feed on other insects and control their populations. Predators are abundant in agricultural environments that have adequate management for pest control (Harterreiten- Souza et al., 2011).

Therefore, it is necessary to know which groups of insects associated with the tomato crop are attracted by what colors, in order to define a strategy for the use of colored adhesive traps for the attraction and capture of insect pests, or only attraction of beneficial insects without catching them and eliminating them from the environment.

We hypothesized that colored traps would reveal similar indices of insect diversity in conventional and organic production systems. The objective was to compare the diversity and richness indices of insect families collected in conventional and organic production systems for the tomato (*Solanum lycopersicum* L.), for the management of insects pests in crops.

MATERIALS AND METHODS

Research area

The study was carried out in two commercial tomato growing farms, both in Alagoas, (09°81'76"S and 36°59'42''W) in Northeast Brazil, with an altitude of 264 m. One farm was conventional and another was organic. The two agricultural areas cultivated several vegetables, in addition to tomato. The experiment was created 45 days after emergence (DAE) of the seedlings between September 2015 and January 2017. The conventional and organic systems had the same distribution of tomatoes, with single rows spaced 1.5 and 25 m long. Each plot occupied an area of 1.5 ha, with approximately 6,000 ft of tomato. Organic farming has natural product management and conventional management uses synthetic products. The planted varieties were TY-2006 and Santa Clara. In both areas, the soil was predominantly eutrophic yellow Red Latosol (Embrapa, 2009). The climate is Köppen type As', that is, tropical and warm, with minimum average temperatures of 23°C and maximum average temperature 32°C. Rainfall in autumn/winter is between 500 mm and 1,000 mm (Alagoas, 2017).

Figure 1. Colored traps made with PET bottles placed on tomato crops.
Source: The author (2015).

Trap set-up and monitoring

The traps were made from plastic bottles, type Polyethylene Terephthalate (PET) with capacity of 2.5 L. Eighteen bottles were painted blue, yellow, white, green, red, and unpainted (transparent), three bottles for each color. To monitor insects in each experimental area, the colored PET bottles were installed randomly, mounted with the mouth fitted onto a 1.2 m bamboo stalk, close to the height of tomato plants. We applied entomological glue over a 75.00 cm^2 area of the bottle body (Fig. 1A, B, C, D, and F.). The traps were initially placed in the field as pre-test and positive results were obtained regarding the use and adaptation for experimental design (Figure 1).

Experimental design and statistical analysis

The experimental design was a randomized block with six treatments: PET0 - colorless, PET1 - yellow, PET2 - green, PET3 - red, PET4 - white, PET5 – blue. The experiment was carried out over four crop cycles. The traps were randomly arranged. For comparison purposes, insect data collected and identified at the family level were analyzed using analysis of variance - ANOVA and the Scott-Knott test at 5% probability using Assistat Software Version 7.7 (Silva and Azevedo, 2016).

Methodological procedures

The insects caught in the traps were counted and removed in the field with the aid of a clamp and organic solvent, every five days.

Table 1. Average number of insects per families in the conventional system collected by the colored traps by the Skott-Nott test at 5% probability (collection period February 2015 to January / 2017) - Arapiraca-AL.

Famílies	Average number of insects per family					
	PET yellow	PET blue	PET white	PET green	PET red	PET colorless
Agromyzidae	85.00^{B}	300.00^{A}	308.00^{A}	68.00^{B}	62.66^{B}	64.00^{B}
Aphididae	30.66^{B}	1.00^{D}	20.00^{C}	1.00^{D}	45.33^{A}	1.00^{D}
Apidae	46.66^{A}	10.66^{C}	22.66^{B}	1.00^{D}	22.66^{B}	1.00^{D}
Asilidae	4.00^{C}	21.33^{A}	10.66^{B}	2.66^{C}	5.33^{C}	2.66^{C}
Blattidae	1.33^{C}	1.00^{D}	1.00^{D}	2.66^{B}	4.00^{A}	1.00^{D}
Calliphoridae	10.66^{C}	36.00^{B}	60.00^{A}	1.33^{D}	1.33^{D}	1.33^{D}
Cicadelidae	16.00^{A}	2.66^{B}	1.33^{B}	1.00^{B}	1.00^{B}	5.33^{B}
Carabidae	4.00^{A}	1.33^{B}	1.33^{B}	1.00^{B}	1.33^{B}	1.33^{B}
Coccinellidae	1.00^{B}	2.66^{A}	1.00^{B}	4.00^{A}	1.33^{B}	1.00^{B}
Curculionidae	1.33^{A}	1.66^{A}	1.33^{B}	1.00^{B}	1.33^{A}	1.33^{A}
Elateridae	32.00^{B}	41.33^{A}	18.66^{C}	8.00^{C}	14.00^{C}	12.00^{C}
Formicidae	42.66^{B}	36.00^{B}	34.66^{B}	42.66^{B}	58.66^{A}	68.00^{A}
Muscidae	32.00^{C}	100.0^{A}	66.66^{B}	4.00^{D}	10.66^{D}	16.00^{D}
Nymphalidae	1.00^{B}	6.66^{A}	1.00^{B}	1.00^{B}	2.66^{B}	4.00^{B}
Passalidae	5.33^{A}	1.00^{B}	1.00^{B}	10.66^{A}	2.66^{A}	5.33^{A}
Pompilidae	1.00^{B}	9.33^{A}	8.00^{A}	12.00^{A}	1.00^{B}	1.00^{B}
Reduviidae	1.00^{B}	1.00^{B}	4.00^{B}	2.66^{B}	14.66^{A}	6.66^{B}
Scarabaeidae	20.00^{C}	37.33^{B}	6.66^{C}	54.66^{A}	50.66^{A}	3.00^{B}
Scoliidae	2.66^{C}	8.00^{A}	4.00^{B}	5.33^{B}	1.00^{D}	1.00^{D}
Tabanidae	45.33^{C}	208.00^{B}	289.33^{A}	13.33^{D}	10.66^{D}	6.66^{D}
Thripidae	10.66^{E}	93.33^{B}	129.33^{A}	14.66^{E}	56.00^{C}	30.66^{D}
Vespidae	25.33^{A}	12.00^{B}	20.00^{A}	8.00^{B}	1.33^{B}	17.33^{A}

Mean values not followed by the same letter differ significantly in the row by the Scott-Knott test at 5% probability.
Source: Research data.

Insects were placed in jars containing 70% alcohol and that were deposited in the Laboratory of Ecology and Biodiversity of the State University of Alagoas/Campus I, for screening and identification. Insect identification was carried out by stereoscopic binocular microscopy (Opton®) at 80x. Identifications were made with the aid of arthropod pictorial identification keys and with images from entomological taxonomies (Seltmann, 2004; Carrano-Moreira, 2015; Rafael et al., 2012).

Analysis of insect family diversity indices

For the analysis of diversity, the following indices were considered: diversity (Shannon-Wiener, Simpson), richness (Margalef), dominance (Simpson), and evenness (Pielou). These parameters were analyzed using DivEs software (Rodrigues, 2016). Relative abundance (AR) for insect families was described by the formula AR (%) = n / N x 100, where AR = abundance percentage, n = number of specimens of the order and family, and N = total number of specimens captured in each system (Soares et al., 2016).

RESULTS AND DISCUSSION

During the period of the research (2015 to 2017), we collected 56,955 insects in the organic system and 10,660 in the conventional system. We considered for analysis only insects that are ≥ 1 were captured. The traps attracted 22 families to the conventional system and 25 in the organic system.

Amaral et al. (2010) describe densely wooded areas with well-adapted insect diversity, some attracted by colors more than the others. The control of insects in agricultural systems with agroecological management, diversity is sustainable (Letourneau and Bothwell, 2008).

Table 1 displays comparison data for the conventional system using the Scott-Knott test at 5% probability, for 22 families collected in the colored traps. The order Diptera was most prominent, with the Agromizidae and Tabanidae families being most collected in the blue and white traps. Santos et al. (2008a) reported that yellow most attracted the Agromizidae family. This order is second highest in terms of number of species, accounting for a very varied niche, including hematophagous insects, phytophagous insects, miners, predators, parasitoids, and pollinators (Azevedo et al., 2015). The Tabanidae family are dipterans of veterinary and medical interest. Those that are ectoparasites of horses, prefer dark brown and reddish brown animals (Bassi et al., 2000; Mikuška et al., 2016).

Santos et al. (2008b) points out that insects can be

Table 2. Average number of insects per families in the organic system collected by the colored traps by the Skott-Nott test at 5% probability (collection period February 2015 to January / 2017) - Arapiraca-AL.

Famílies	**Average number of insects per family**					
	PET yellow	**PET blue**	**PET white**	**PET green**	**PET red**	**PET colorless**
Agromyzidae	128.00^{B}	173.33^{A}	93.33^{B}	76.00^{B}	232.00^{A}	40.00^{B}
Apidae	20.00^{A}	13.33^{A}	8.00^{B}	6.66^{B}	4.00^{B}	1.33^{B}
Asilidae	85.33^{B}	49.33^{C}	140.00^{A}	8.00^{C}	12.00^{C}	46.66^{C}
Blattidae	1.00^{C}	1.00^{C}	1.00^{C}	1.33^{B}	2.66^{A}	1.33^{B}
Calliphoridae	73.33^{A}	166.66^{A}	80.00^{A}	20.00^{B}	100.00^{A}	46.66^{B}
Carabidae	66.66^{C}	82.66^{B}	200.00^{B}	93.33^{B}	966.66^{A}	213.33^{B}
Cicadelidae	786.0^{A}	498.0^{A}	151.0^{B}	126.0^{B}	66.6 ^{C}	248.0^{B}
Coccinelidae	20.00^{A}	1.00^{B}	2.66^{B}	0.00^{B}	24.00^{A}	6.66^{B}
Chrysomelidae	1573.33^{A}	800.00^{B}	300.00^{D}	253.33^{D}	133.33^{D}	500.00^{C}
Curculionidae	1.33^{B}	28.00^{A}	1.33^{B}	5.33^{B}	1.33^{B}	1.00^{B}
Formicidae	6.66^{B}	48.00^{A}	38.66^{A}	10.66^{B}	13.33^{B}	4.00^{B}
Miridae	20.00^{B}	1.00^{D}	4.00^{C}	6.66^{C}	40.00^{A}	1.00^{D}
Muscidae	27.00^{C}	267.66^{B}	120.33^{C}	187.00^{B}	469.33^{A}	173.33^{B}
Nitidulidae	46.66^{C}	200.33^{B}	1.00^{C}	1.00^{C}	286.6^{A}	1.00^{C}
Notodontidae	28.66^{B}	16.00^{C}	6.66^{C}	9.33^{C}	66.66^{A}	13.33^{C}
Pompilidae	5.33^{C}	13.33^{B}	1.00^{B}	1.00^{B}	80.00^{A}	1.00^{B}
Reduviidae	4.00^{B}	24.33^{A}	1.00^{B}	1.00^{B}	1.33^{B}	1.00^{B}
Scarabaeidae	767.00^{C}	1634.33^{B}	267.00^{D}	273.33^{D}	3003.33^{A}	142.66^{D}
Sphecidae	12.00^{A}	1.00^{B}	1.00^{B}	1.00^{B}	14.66^{A}	5.33^{B}
Sthaphylinidae	52.00^{B}	97.33^{B}	120.00^{B}	21.33^{B}	6.66^{B}	346.66^{A}
Stratiomyidae	53.33^{C}	560.00^{A}	270.66^{B}	126.66^{C}	453.33^{A}	212.66^{C}
Syrphidae	1.33^{B}	1.00^{B}	1.33^{B}	1.00^{B}	6.66^{A}	1.00^{B}
Tabanidae	29.33^{B}	40.00^{B}	1.00^{C}	1.00^{C}	262.66^{A}	6.66^{C}
Thripidae	24.00^{D}	500.00^{A}	82.66^{B}	44.00^{C}	34.66^{C}	40.00^{C}
Vespidae	4.00^{B}	2.66^{B}	16.00^{A}	1.00^{B}	1.00^{B}	1.00^{B}

Mean values not followed by the same letter differ significantly in the row by the Scott-Knott test at 5% probability.
Source: Research data.

attracted by different colors. For example, *Lyriomiza trifolii* (Burgess, 1880) (Diptera: Agromyzidae) is attracted by yellow, and *Thrips tabaci* (Lindeman, 1889) *(*Thysanoptera: Thripidae) by blue. However, Vrdoljak and Samways (2012) highlight that yellow and black may be repellent to some families and attractive to others.

The Apidae family, who is important for tomato pollination in the conventional system, comprised 46.66% of insects collected in the yellow traps. Barbosa et al. (2016) reported the presence of *Apis mellifera* (Linnaeus, 1758) and *Trigona spinipes* (Fabricius, 1793), of the Apidae family. Freitas et al. (2006) commented that bees of the genus *Exomalopsis*, *Epicharis* and *Centris* were good tomato pollinators. *Nanotrigona pirilampoides* (Cresson, 1878) (Hymenoptera: Apidae), use a mechanism involving wing vibration that results in cross-pollination of heavier fruits with more seeds (Cauich et al., 2004; Castro et al., 2006) (Table 1).

Table 2 displays 25 insect families in the organic system by the Scott-Nott average comparison test, at 5% probability. The number of insects was higher in the organic system than in the conventional system. As for the diversity of insect families, the organic system was slightly larger than the conventional system. Santos et al. (2008a) suggested that yellow attracted adults of *Diabrotica speciosa* (Germar, 1824), (Coleoptera: Chrysomelidae), *Bemisia tabaci* (Gennadius, 1889) (Hemiptera: Aleyrodidae), *Liriomyza trifolii* (Burgess, 1880) (Diptera: Agromyzidae), *Myzus persicae* (Sulzer, 1776)*,* and *Macrosiphum euphobiae* (Thomas, 1878) (Hemiptera: Aphididae).

The diversity of families and the number of insects can serve as bioindicators of diversified management, indicating polyculture areas where shrub and tree plants such as the neem (*Azadirachta indica* A. Juss.; Meliaceae) function as wind barriers. In addition, the growing area includes cashew (*Anacardium occidentale* L.; Anacardiaceae), guava (*Psidium guajava* L.*;* Myrtaceae), mango (*Mangifera indica* L.; Anacardiaceae), coconut (*Cocos nucifera* L.; Arecaceae), jocote (*Spondias purpúrea* L.; Anacardiaceae), mulberry (*Morus nigra* L.; Moraceae), acerola (*Malpighia emarginata* DC;

Table 3. Diversity indexes of insect families collected under the influence of color of the colored traps.

Index of diversity	Index of diversity of insect families in PET traps						
	Crops	Yellow	Blue	White	Green	Red	Colorless
Shannon-Wiener	Organic	2.38	3.08	3.51	3.14	2.63	3.10
	Convencional	3.93	3.17	3.08	3.43	3.64	3.71
Simpson	Organic	0.66	0.82	0.89	0.85	0.71	0.84
	Conventional	0.91	0.82	0.82	0.86	0.90	0.88
Margalef	Organic	5.55	5.05	4.54	4.78	6.34	4.53
	Conventional	7.95	6.64	5.41	7.21	6.37	8.03
Simpson's Dominance	Orgânic	0.33	0.17	0.10	0.14	0.28	0.15
	Conventional	0.08	0.17	0.17	0.13	0.09	0.11
Equity of Pielou	Organic	1.75	2.29	2.80	2.50	1.82	2.47
	Conventional	2.77	2.29	2.36	2.56	2.75	2.65

Source: Research data.

Malpighiaceae), orange (*Citrus sinensis* L.; Rutaceae), lime (*Citrus limon* L.; Rutaceae), and various weeds. Cardozo (2007) reports that these trees, when maintained in the agroecosystem, serve to protect plants, both from pesticide drift from neighboring areas, and from the spores and/or invasive propagules.

The presence of pollinators, predators, and parasitoids in the area guarantees stability of the families of insects collected in the various colored traps. Campos (2008), in an open field study, listed 22 species of tomato pollinators distributed among the families Apidae, Halictidae and Andrenidae. Insects can be attracted to colors, by means of their long photoreceptor fibers (Skorupski and Chittka, 2010; Wanga et al., 2013).

Albuquerque et al. (2006) highlight melitophilia as a common pollination among the various solanaceous species, it is particularly attracted by floral structure, as is the case of the tomato in this study (Del Sarto, 2005). To pollinate the tomato, the bee's anthers need to vibrate in order to the release pollen. This fact reduces the number of effective pollinators, since such species as *Trigona spinipes* (Fabricius, 1793) (Hymenoptera: Apidae) cannot vibrate (Vianna et al., 2007). Santos and Nascimento (2011), in a study of diversity indices in organic crops, reported that the most abundant family was Apidae, representing 48.76% of the total sample (Table 2).

Table 3 displays various ecological indices (Shannon-Wiener and Simpson for diversity, Simpson for dominance, Margalef for richness, and Pielou for evenness) with respect to the colors of the PET traps. The data show differences in terms of diversity and richness of the insect families, highlighting the indices for the conventional system. The collected insects were attracted by the colors in each visited habitat, and foraging occurred on the basis of this attraction. We found that yellow, blue, and white attracted more insects than did green, red, and colorless.

The diversity indices of the insects collected in the colored traps revealed a tendency of attraction for the colors. This study highlighted the α (alpha) diversity that is constituted in the number of species (richness) in homogeneous fragments of a particular habitat type (Whittaker et al., 2001; Tuomisto, 2010; Chi et al., 2014). For both systems, the Jaccard similarity index was 0.88. The Jaccard index varies between 0 for different communities regarding the composition of species and 1 in similar communities regarding species composition (Zanzini, 2005).

In both systems, the Margalef indices were greater than 5.0, suggesting considerable families richness. Higher values of the Margalef index suggest proportional value for rare species. The Shannon-Wiener and Simpson indices were significantly different in each system. The Pielou index revealed a balance between the number of families in the two systems. According to Pielou (1966, 1975), values of the index vary between 0 for minimum uniformity, and 1 for maximum uniformity. In this study, the values were higher than 1.5.

Virginio et al. (2016) argue that the greater the knowledge regarding the fauna of an area, the more effective are the strategies for its conservation. This is especially true for northeastern ecosystems, where there is a shortage of studies.

Wilsey et al. (2005) suggest that species richness is dependent on sample size. In the conventional system, there was greater dominance index compared with the organic system. However, the samples collected during the study showed a balance in terms of evenness index.

Table 4. Relative abundance - AR (%) of orders and families of insects of agricultural importance for protection of plants in conventional and organic tomato crops.

Order	Famíly	Presence in crop AR (%)		Agricultural importance	References
		Conv.	Org.		
Coleoptera	Chrysomelidae	0.22	1.17	Pollinators	Santos (2009), Triplehorn and Johnson (2005) and Silva and Carvalho (2015)
	Carabidae	0.41	8.53	Predators	Parra et al. (2002) and Cárcamo et al. (2009)
	Coccinellidae	0.22	0.28	Predators pollinators	Parra et al. (2002)
	Elateridae	3.54	0.03	Predators pollinators	Susek and Ivancic (2006)
	Nitidulidae	2.81	0.00	Predators pollinators	Fernandes et al. (2012) and Lima (2002)
	Scarabaidae	5.66	3.05	Pollinators	Triplehorn and Johnson (2005)
	Curculionidae	0.89	0.18	Predators	Bustillo et al. (2002)
	Staphylinidae	0.20	3.39	Predators	Cunha et al. (2014)
Diptera	Agromyzidae	24.92	3.91	Predators pollinators	Cunha et al. (2014)
	Asilidae	1.79	1.39	Predators	Parra et al. (2002)
	Calliphoridae	3.11	2.56	Pollinators	Gullan and Cranston (2008) and Azevedo et al. (2015)
	Muscidae	6.45	6.55	Pollinators	Triplehorn and Johnson (2005, 2011)
	Stratiomyidae	0.17	8.82	Pollinators	Malerbo-Souza and Halak (2009)
	Syrphidae	0.23	0.83	Pollinators predators	Malerbo-Souza and Halak (2009) and Parra et al. (2002).
	Tabanidae	1.78	16.13	Parasites or predators	Cunha et al. (2014)
Hemiptera	Cicadelidae	18.74	0.71	Phytophagous	Cunha et al. (2014) and Silva and Carvalho (2015)
	Miridae	0.26	0.37	Predators	Cunha et al. (2014)
	Reduviidae	0.78	0.15	Predators	Parra et al. (2002)
Lepidoptera	Nymphalidae	0.33	0.00	Pollinators	Noubissié et al. (2012)
	Notodontidae	0.00	0.73	Pollinators	Gullan and Cranston (2008).
Hymenoptera	Apidae	3.29	0.28	Pollinators	Santos (2009), Silva and Carvalho (2015) and Ramalho (2004)
	Formicidae	7.95	0.63	Predators Decomposers	Parra et al. (2002), Bustillo et al. (2002) and Silva and Carvalho (2015)
	Pompilidae	0.82	0.07	Predators	Cunha et al. (2014)
	Scoliidae	0.56	0.00	Predators or Parasites	Cunha et al. (2014)
	Vespidae	2.36	0.11	Predators Pollinators	Parra et al. (2002).

Source: Research data.

We observed that the more homogeneous the number of individuals per species, the greater the evenness and uniformity.

Following this reasoning, a given diversity index may indicate that community A is more diverse than B, while another index indicates the opposite (Mendes et al., 2008). Diversity is defined as a set of multivariate statistical procedures that inform various characteristics of the structure of biological communities (Ricotta, 2005).

According to Medeiros et al. (2011), it is essential to understand the interactions between insects and plants in order to understand biodiversity, since the resources provided by the plants are fundamental for the adaptive spread of the animals (Gaertner and Borba, 2014). Similarly, Ribeiro (2005) and Ferraz et al. (2009) emphasize that higher values of these indices suggest greater dominance and the lower diversity (Table 3).

Table 4 displays relative abundance - AR (%) of insect families and orders in both systems. The highest relative abundance of individuals collected in the traps were from the order diptera, 40.19% for the organic system and 37.45% for the conventional system. The Agromizydae family (AR = 24.92% organic) featured prominently, obtaining greater significance for yellow, blue, white, and

Table 5. Mean orders of insects in the two cropping systems collected in the colored PET traps by the Skott-Nott test at 5% probability.

Order	Crops	Yellow	Blue	White	Green	Red	Colorless
Blattodea	Orgnic	1.00^{C}	1.00^{C}	1.00^{C}	1.33^{B}	2.67^{A}	1.33^{B}
	Conventional	1.33^{B}	1.00^{C}	1.00^{C}	2.66^{B}	4.00^{A}	1.00^{C}
Coleoptera	Organic	963.00^{C}	2085.3^{B}	689.66^{C}	430.66^{D}	4346.00^{A}	762.66^{C}
	Conventional	68.00^{B}	96.00^{A}	48.00^{C}	85.33^{A}	72.66^{B}	64.00^{B}
Diptera	Organic	396.33^{D}	1265.00^{B}	704.33^{C}	41.66^{D}	1536.00^{A}	525.33^{D}
	Conventional	186.66^{C}	668.00^{B}	780.66^{A}	96.66^{D}	90.66^{D}	97.33^{D}
Hemiptera	Organic	159.33^{A}	824.00^{B}	304.00^{D}	260.00^{D}	174.66^{D}	500.00^{C}
	Conventional	57.33^{B}	12.00^{D}	29.33^{C}	4.00^{D}	98.66^{A}	22.66^{C}
Hymenoptera	Organic	42.66^{C}	77.33^{A}	62.66^{B}	17.33^{D}	33.33^{C}	10.66^{D}
	Conventional	129.33^{A}	78.66^{B}	89.33^{B}	68.00^{B}	88.00^{B}	89.33^{B}
Lepidoptera	Organic	30.66^{B}	16.00^{C}	6.66^{C}	9.33^{C}	66.66^{A}	13.33^{C}
	Conventional	9.33^{B}	6.66^{B}	1.00^{C}	1.00^{C}	46.66^{A}	1.00^{C}
Thysanoptera	Organic	1.00^{B}	1.33^{B}	1.00^{B}	1.00^{B}	80.00^{A}	1.00^{B}
	Conventional	10.66^{D}	93.33^{B}	129.33^{A}	14.66^{D}	56.00^{C}	14.66^{D}

Mean values not followed by the same letter differ significantly in the row by the Scott-Knott test at 5% probability.
Source: Research data.

red. Lima and Serra (2008) affirm that this order has a wide range of niches and diversity of families.

Some families in Table 4 represent predatory insects, phytophagous, natural enemies, and pollinators in the agroecosystem. Even with the systematic application of insecticides three times a week, these insects acquire resistance and remain active. Moura et al. (2014) point out that the most common predators found are wasps, ants, the neuropteran *Chrysoperla externa* (Hagen, 1861) (Neuroptera: Chrysopidae), spiders and bedbugs of the Reduviidae, Pentatomidae and Nabidae families. According to Togni et al. (2010), this abundance and diversity of families is mainly due to the greater availability of spaces protected from intra-species predation and access to alternative food resources.

The presence of the leafminer *Liriomyza trifolii* (Burgess, 1880) (Diptera: Agromizydae) in tomato crops suggests that integrated pest management requires greater attention, since this insect causes direct damage to the tomato leaf, reducing its productivity. Gusmão (2004) found abundant leafminer larvae in tomato leaves. In this study, we performed a random survey of ten plants and found two leafminer nests larvae on leaves of each tomato plant examined.

The order Coleoptera had an AR of 45.63% in the organic system and 13.95% in the conventional system. The Scarabaidae family had an AR of 32.05% in the organic system and 5.66% in the conventional system. Lima et al. (2013) studied diversified environments and found a significant number of this family. Matta et al. (2017) report predatory activity of the Carabidae family on weeds in cotton fields.

The Carabidae family had and AR of 8.53% in the organic system and 0.41% in the conventional system. Al-Attal et al. (2003) found 36% of the total number of insects identified as specimens of this family, with diversified functions in the agroecosystem. According to Cividanes et al. (2003), specimens of the Carabidae family spread by walking or flying. In this niche, they contribute to the pollination and decomposition of particulate matter.

The order Hymenoptera, generally abundant in vegetable environments, in the collections had an AR of 14.98% in the conventional system and 1.09% in the organic system. Alencar et al. (2007) and Kaminski et al. (2009) observed that this order has a diverse behavior in the agroecosystem. They are associated with specific ecological interactions as detritivores, predators, granivores, and herbivores. The Apidae family achieved an AR of 3.29% in the conventional system and 0.28% in the organic system. This is notable because these insects are important pollinators (Vianna et al., 2007).

The order Hemiptera had an AR of 19.78% in the organic system and 1.23% in the conventional system. The Cicadelidae family had a higher presence with an AR of 18.74% in the conventional system and 0.71% in the organic system. These are phytophagous insects, vectors of *Xylella fastidiosa* (Wells et al., 1987) (Table 4).

Table 5 shows the significant results of the orders of insects collected in the colored traps. Seven orders of insects were attracted, including many of agricultural interest. The red traps attracted the orders Coleoptera and Lepidoptera, which are useful for plant pollination in both tomato growing systems.

Paz and Pigozzo (2012) investigated mangrove, Atlantic Forest and Restinga, using traps with colored water. They report the most attractive colors to the insects were green, white, and blue. They show that Atlantic Forest was the environment with the greatest abundance of individuals and orders of insects, being a biome with a greater diversity of plants than other areas. The colors of the flowers and or plants serve as an attraction to insects, who visit in order to feed and lay eggs. In so doing, they pollinate as well. In this niche, there are also predators and parasitoids (Skorupski and Chittka, 2010; Wanga et al., 2013).

According to Vasconcellos et al. (2010), the seasonality in the Caatinga region favors the presence of the insect orders found. They found 20 orders belonging to the Insecta class, of which seven are found in the table collected in this study: Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, and Thysanoptera. The order Hymenoptera, with a mean of between 10.0 and 129.0 individuals in both systems, represents a good part of the collections as social insects, a result corroborated in Dutra and Machado (2001), Santos and Nascimento (2011), Souza (2011), and Rocha et al., 2010).

In this study, the red trap was significantly superior to the others, attracting a greater number of insects of the order Coleoptera. We hypothesize that these insects are attracted to red, since electromagnetic waves have wavelength ≥ 700 nm (Table 5).

Conclusions

The use of colored traps is an efficient strategy to know the diversity of insects of the agricultural environments, allowing an integrated pest management planning. The insect family diversity indexes collected were different in the colored traps for the two cropping systems.

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.

REFERENCES

Al-Attal YZ, Kasrawi MA, Nazer IK (2003). Influence of Pollination Technique on Greenhouse Tomato Production. Agric. Marine Sci. 8(1):21-26.

Alagoas (2017). Secretaria de Estado do Meio Ambiente e dos Recursos Hídricos – AL.Diretoria de Meteorologia. Boletim anual de dados climatológicos. 2017. Disponível em:< http://meteorologia.semarh.al.gov.br/relatoriospdf/>. Acesso em 23 abr. 2017.

Albuquerque LB, Velázquez A, Vasconcellos-Neto J (2006). Composição florística de solanaceae e suas síndromes de polinização e dispersão de sementes em florestas mesófilas neotropicais. Interciencia 31(011):807-816.

Alencar GV, Mendonça ES, Oliveira TS, Jucksch I, Cecon PR (2013). Percepção ambiental e uso do solo por agricultores de sistemas orgânicos e convencionais na Chapada da Ibiapaba, Ceará. Rev. de Econ. e Sociologia Rural *51*(2):217-236.

Alencar IDCC, Fraga FB, Tavares MT, Azevedo CO (2007). Perfil da fauna de vespas parasitóides (Insecta, Hymenoptera) em uma área de Mata Atlântica do Parque Estadual de Pedra Azul, Domingos Martins, Espírito Santo, Brasil. Arquivos do Instituto Biológico, São Paulo 74(2):111-114.

Amaral DS, Venzon M, Pallini A, Lima PC, Desouza O (2010). A diversificação da vegetação reduz o ataque do bicho-mineiro-do-cafeeiro Leucoptera coffeella (Guérin-Mèneville) (Lepidoptera: Lyonetiidae)? Neotrop. Entomol. 39(4):543-548.

Azevedo FR, Azevedo RA, Santos CAM, Moura ES, Nere DR (2015). Análise Faunística e Flutuação Populacional da Dipterofauna de Ecossistemas da Área de Proteção Ambiental do Araripe, Barbalha, CE. EntomoBrasilis 8(2):117-124.

Barbosa BC, Paschoalini M, Maciel TT, Prezoto F (2016). Visitantes florais e seus padrões temporais de atividade em flores de *Dombeya wallichii* (Lindl.) *K. Schum* (Malvaceae). Entomotropica 31(16):131-136.

Bassi RMA, Cunha MCI, Coscaron AS (2000). Study of behavior of tabanids (Diptera, Tabanidae) from Brazil. Acta Biol. Par., Curitiba 29 (1, 2, 3, 4):101-115.

Bustillo AE, Cárdenas R, POSADA FJ (2002). Natural Enemies and Competitors of *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae) in Colombia. Neotrop. Entomol. 31(4):635-639.

Campos MJ (2008). Landscape management and pollinator richness in tomato (*Lycopersicon esculentum* Mill., Solanaceae) crops in Southeastern Brazil. In: Pollinators Management in Brazil. MMA: Brasília 41p.

Carrano-Moreira AF (2015). Insetos: manual de coleta e identificação. 2ª ed. Rio de Janeiro: Technical Books 369p.

Cardozo AII (2007). Produção de pimentão com vibração das plantas. Ciênc. agrotec. Lavras 31(4):1061-1066.

Cárcamo MC, Brandão RK, Costa VA, Ribeiro PB (2009). Ocorrência de *Aprostocetus hagenowii* (Hymenoptera, Eulophidae), parasitoide de ootecas da barata americana, no Rio Grande do Sul. Ciência Rural *39*(9):2649-2651.

Castro MS, Koedam D, Contrera FAL, Venturieri GC, Nates-Parra G, Malagodi-Braga KS, Campos LO, Viana M, Cortopassi-Laurino M, Nogueira-Neto P, Peruquetti RC, Imperatriz-Fonseca VL (2006). Stingless bees. In: Imperatriz-Fonseca, V.L., Saraiva, A.M. & De Jong, D. Bees as pollinators in Brazil: assessing the status and suggesting best practices. Ribeirão Preto: Holos pp. 75-88.

Cauich O, Quezada-Euán JJG, Macias-Macias JO, Reyes-Oregel V, Medina-Peralta S, Parra-Tabla V (2004). Behavior and pollination efficiency of Nannotrigona perilampoides (Hymenoptera: Meliponini) on greenhouse tomatoes (*Lycopersicon esculentum*) in Subtropical Mexico. Hortic. Entomol. 97(2):475-481.

Cividanes FJ, Souza VP, Sakemi LK (2003). Composição faunística de insetos predadores em fragmento florestal e em área de hortaliças na região de Jaboticabal, Estado de São Paulo. Acta Scientiarum. Biological Sciences. Maringá 25(2):315-321.

Chi Chun-Huo, Lou JOST, Chao ANNE (2014). Phylogenetic beta diversity, similarity, and differentiation measures based on Hill numbers. Ecol. Monogr. 84(1):21-44.

Cunha ASD, Nóbrega MAS, Antonialli Junior WF (2014). Insetos Polinizadores em Sistemas Agrícolas. Ensaios e Ciência: Ciênc. Biol. Agrár. Saúde 18(4):185-194.

Del Sarto MCL (2005). Avaliação de Melipona quadrifasciata Lepeletier (Hymenoptera: Apidae) como Polinizador da Cultura do Tomateiro em Cultivo Protegido. Viçosa, MG: Tese Doutorado. 61 fls. Programa de Pós-Graduação em Entomologia, Universidade Federal de Viçosa (UFV).

Dutra J, Machado VL (2001). Flowering entomofauna in *Stenolobium stans* (Juss.) Seem (Bignoniaceae). Neotrop. Entomol. 30(1):43-53.

Embrapa (2009). Mapa exploratório do reconhecimento do solo em Arapiraca-AL. Disponível em: < http://www.uep.cnps.embrapa.br/solos/index.php?link=al> Acesso em 17 mar. 2017.

Fernandes DRR, Bená DC, Lara RIR, IDE S, Perioto NW (2012). Nitidulidae (Coleoptera) associados a frutos do café. Coffee Sci. Lavras 7(2):135-138.

Ferraz ACP, Gadelha BQ, Aguiarcoelho VM (2009). Análise faunística de Calliphoridae (Diptera) da Reserva Biológica do Tinguá, Nova Iguaçu, Rio de Janeiro. Rev. Bras. de Entomologia, São Paulo 53(4):620-628.

Freitas BM, Martins CF, Schlindwein CP, Wittman D, Santos IA, Cane JH, Ribeiro MF, Gaglianone MC (2006). Bumble bees and Solitary bees. In: Imperatriz- Fonseca, V.L., Saraiva, A.M. & De Jong, D. Bees as pollinators in Brazil: assessing the status and suggesting best practices. Ribeirão Preto: Holos pp. 55-62.

Gaertner C, Borba RS (2014). Diferentes cores de armadilhas adesivas no monitoramento de pragas em alface hidropônica. Rev. Thema 11(01).

Gullan PJ, Cranston OS (2008). Os insetos: um resumo de entomologia. São Paulo: Rocca, 2008.

Gusmão MR (2004). Amostragem de Liriomyza trifolii (Burguess) (Diptera: Agromizydae) no Tomateiro. 2004. 83 f. (Tese de Doutorado). Tese de Doutorado apresentado à Universidade Federal de Viçosa – Programa de Pós-Graduação em Entomologia. Viçosa-MG.

Harterreiten-Souza ES, Pires CSS, Carneiro RGC, Sujii ER (2011). Predadores e Parasitoides: aliados do produtor rural no processo de transição agroecológica. Brasília, DF: Emater, Embrapa Recursos Genéticos e Biotecnologia, CNPq. 92p.

Kaminski LA, Sendoya SF, Freitas AVL, Oliveira P (2009). Ecologia comportamental na interface formiga-planta-herbívoro: interações entre formigas e lepidópteros. Oecologia Brasiliensis, 13(1):27-44.

Letourneau DK, Goldstein B (2001). Pest damage and arthropod community structure in organic vs. conventional tomato production in California. J. Appl. Ecol. 38:557-570.

Letourneau DK, Bothwell SG (2008). Comparison of organic and conventional farms: challenging ecologists to make biodiversity functional. Front Ecol. Environ. 6(8):430-438.

Lima VP, Serra AL (2008). Análise morfológica comparada da venação de asas da ordem Diptera (Linnaeus, 1758- Arthropoda, Insecta). Conscientia e Saúde, São Paulo 7(4):525-533.

Lima IMM (2002). Registro da ocorrência de *Cybocephalus* sp. (Coleoptera: Nitidulidae) predando espécies-praga de Diaspididae (Hemiptera), no estado de Alagoas. Neotrop. Entomol. 31(1):157-159.

Lima MGA, Silva RPA, Sousa MDF, Costa EM (2013). Diversidade de Scarabaeinae (Coleoptera: Scarabaeidae) no Parque Botânico do Ceará, Caucaia - CE, Brasil. Revista Agro@mbiente On-line 7(1):89-94.

Matta DH, Cividanes FJ, Silva RJ, Batista MN, Otuka AK, Correia ET, Matos STS (2017). Feeding habits of Carabidae (Coleoptera) associated with herbaceous plants and the phenology of coloured cotton. Acta Scientiarum. Agron. Maringá 39(2):135-142.

Medeiros MA, Harterreiten-Souza ES, Togni PHB, Milane PVGN, Pires CSS, Carneiro RG, Sujii ER (2011). Princípios e práticas ecológicas para o manejo de insetos praga na agricultura (livreto). Brasília: Emater-DF / Embrapa. 1:44.

Mendes RS, Evangelista LR, Thomaz SM, Agostinho AA, Gomes C (2008). A unified index to measure ecological diversity and species rarity. Ecography 31(4):450-456.

Mikuška A, Mlinarić S, Begović L, Curran E (2016). Comparative efficiency of traps for horse fly (Diptera: Tabanidae) survey in riparian oak-ash forests in Danube floodplain. Eur. J. Entomol. 113:531–536.

Moura AP, Michereff Filho M, Guimarães JA, Liz RS (2014). Manejo integrado de pragas do tomateiro para processamento industrial. EMBRAPA – Circular Técnica –nº 129, Fevereiro.

Noubissié JBT, Yadji HT, Baldena I (2012). Screening Sorghum Populations for Resistance to *Striga hermonthica* (Del.) Benth in Northern Cameroon. Ann. Biol. Res. 3(5):2357-2364.

Parra JRP, Botelho PSM, Correa-Ferreira BS, Bento JMS (2002). Controle biológico no Brasil: parasitóides e predadores. São Paulo: Editora Manole 609p.

Paula DP, Andow DA, Pires SCS, Sujii ER (2015). Impacto da Introdução de Pragas sobre a Biodiversidade. Cap. 3. In: Sugayama, R. L.; Lopes-Da-Silva, M.; Silva, S. X. B.; Ribeiro, L. C.; Rangel, P. L.E. Defesa vegetal: fundamentos, ferramentas, políticas e perspectivas. 1ª ed. Belo Horizonte; SBDA-Sociedade Brasileira de Defesa Agropecuária 544p.

Paz JRL, Pigozzo CM (2012). Comparação da Entomofauna Coletada por Armadilhas Coloridas de Água em um Fragmento de Mata Atlântica e Dois Ecossistemas Associados, Bahia. Candombá – Revista Virtual 8(1):63-72.

Pielou EC (1975). Ecological Diversity. Wiley Interscience, New York.

Pielou EC (1966). The measurement of diversity in different types of biological collections. J. Theor. Biol.13:131-144.

Rafael JA, Melo GAR, Carvalho CJB, Casari AS (2012). Insetos do Brasil: Diversidade e Taxonomia. Ribeirão Preto: Holos, Editora 810p.

Ramalho M (2004). Stingless bees and mass flowering trees in the canopy of Atlantic Forest: a tight relationship. Acta Bot. Bras., 18(1):37-47.

Ribeiro FV (2005). Biodiversidade e distribuição geográfica de *Anastrepha* spp. (Diptera: Tephritidae) no Alto e Médio Rio Solimões, Amazonas. 2005. 106f. Dissertação (Mestrado em Agricultura e Sustentabilidade na Amazônia) - Faculdade de Ciências Agrárias, Universidade Federal do Amazonas, Manaus.

Ricotta C (2005). Through the jungle of biological diversity. Acta Biotheor. 53(1):29-38.

Rocha JF, Pimentel RR, Rosa MMT, Machado SR (2010). Anatomia e histoquímica dos nectários florais de *Dombeya wallichii* (Lindl.) K. Schum. e *Dombeya natalensis* Sond. (Malvaceae). Rev. Biol. Neotrop. 7(1):27-36.

Rodrigues WC (2017). DivEs - Diversidade de Espécies v4.0. Software e guia do usuário. Disponível em:< http://dives.ebras.bio.br>. Acesso em 15 de jan. 2017.

Santos JP, Wamser AF, Becker WF, Mueller S, Suzuki A (2008). Captura de insetos sugadores e fitófagos com uso de armadilhas adesivas de diferentes cores nos sistemas de produção convencional e integrada de tomate em Caçador, SC. Hortic. Bras. 26: S157-S163.

Santos JPS, Wamser AF, Mueller WFBS, Romano F (2008). Atraidos pela cor. Tomate-Cultivar HF, Fevereiro / Março. pp. 18-19.

Santos AB, Nascimento FS (2011). Diversidade de visitantes florais e potenciais polinizadores de *Solanum lycopersicum* (Linnaeus) (Solanales: Solanaceae) em cultivos orgânicos e convencionais. Neotrop. Biol. Conserv. 6(3):162-169.

Seltmann K (2004). Building web-based interactive keys to the Hymenopteran families and superfamilies. Lexington, Kentucky, 2004. 73 p. Dissertação (Master of Science in Entomology in the College of Agriculture) - University of Kentucky.

Silva FF, Carvalho GA (2015). Espécies, número e frequência de visitantes florais em culturas agrícolas submetidas à aplicação de produtos fitossanitários. Arq. Inst. Biol., São Paulo 82:1-7.

Silva FAS, Azevedo CAV (2009). The Assistat Software Version 7.7 and its use in the analysis of experimental data. Afr. J. Agric. Res. 11(39):3733-3740.

Skorupski P, Chittka L (2010). Photoreceptor Spectral Sensitivity in the Bumblebee, *Bombus im*patiens (Hymenoptera: Apidae). PLoS ONE 5(8): e12049.

Soares JBC, Costa EM, Silva FEL, Araujo EL (2016). Insect diversity in an experimental vineyard in the State of Rio Grande do Norte, Brazil. Revista Caatinga, Mossoró, 29(1):239-245.

Souza DTM (2011). Comportamento forrageiro de insetos visitantes florais da romãzeira (L.). Magistra 23(3):122-128.

Susek A, Ivancic A (2006). Pollinators of *Helleborus niger* in Slovenian naturally occurring populations. Acta Agric. Slovenica pp. 205-211.

Togni PHB, Cavalcante KR, Langer LF, Gravina CS, Medeiros M, Pires CSS. Fontes EMG, Sujii ER (2010). Conservação de inimigo naturais (Insecta) em tomateiro orgânico. Instituto Biologico, 77(4):669-676.

Triplehorn CA, Johnson NF (2005). Borror and delong's introduction to the study of insects. Belmont: Thomson Brooks.

Vasconcellos A, Andreazze R, Almeida AM, Araujo HFP, Oliveira ES, Oliveira U (2010). Seasonality of insects in the semi-arid Caatinga of northeastern Brazil. Revista Brasileira de Entomologia, Curitiba, 54(3):471-476.

Vianna MA, Marco-Junior P, Campos LA (2007). O. Manejo de polinizadores e o incremento da produtividade agrícola: uma abordagem sustentável dos serviços do ecossistema. Resumo do II Congresso Brasileiro de Agroecologia. Rev. Bras. Agroecologia. 2(1):144-147.

Virginio F, Maciel TT, Barbosa BC (2016). Novas contribuições para o conhecimento de vespas sociais (Hymenoptera: Vespidae) para Estado do Rio Grande do Norte, Brasil. Entomotropica 31(26):221-22.

Vrdoljak SM, Samways MJ (2012). Optimising coloured pan traps to survey flower visiting insects. J. Insect Conserv. 16:345-354.

Wanga H, Conchou L, Bessière J, Cazals G, Schatz B, Imbert E (2013). Flower color polymorphism in Iris lutescens (Iridaceae): Biochemical analyses in light of plant–insect interactions. Phytochemistry 94:123-134.

Wells JM BC, Raju H, Hung WG, Weinsberg L, Mandelco-Paul DJB (1987). *Xylella fastidiosa* gen. nov. sp.nov.: Gram-negative, sylem-limited fastidiosa bacteria related to *Xanthomonas* spp. Int. J. Syst. Bacteriol. 37:136-143.

Wilsey BJ, Chalcraft DR, Bowles CM, Willig MR (2005). Relationships among indices suggest that richness is an incomplete surrogate for grassland biodiversity. Ecology 86(5):1178-1184.

Zanzini ACS (2005). Descritores Quantitativos de Riqueza e Diversidade de Espécies Lavras: UFLA/FAEPE. 43p.

academicJournals

Vol. 13(10), pp. 470-476, 8 March, 2018
DOI: 10.5897/AJAR2018.13012
Article Number: 44D402256251
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Efficacy of *Xylopia aethiopica* ethanolic and aqueous extracts on the control of *Sitophilus oryzae* in stored rice grain

Ekeh F. N., Odo G. E.*, Nzei J., Ngozi E., Ohanu C. and Onuoha O.

Department of Zoology and Environmental Biology, University of Nigeria, Nsukka, Enugu State, Nigeria.

Received 21 January, 2018; Accepted 7 February, 2018

Stored product insects reduced the quantity, quality, nutritive value and viability of stored crops such as maize, sorghum, wheat and rice. These pests and many others threaten food security. The study investigated the efficacy of *Xylopia aethiopica* in the control of *Sitophilus oryzae* on stored rice. The extracts of this plant were made using ethanol and aqueous as solvent and prepared at the concentrations of 3, 6, 8 and 0 g. Zero gram is the untreated grain that served as the control. Five pairs of male and female each of a day old adult of *S. oryzae* were introduced into jars containing 20 g of rice each and were observed daily for 6 weeks for mortality, oviposition, developmental stages and natality. The phytochemical analysis of the extracts revealed that alkaloids, glycosides, flavonoid and polyphenol which was moderately high and which exposes the active ingredient of the extracts. The phytochemical analysis of the extracts revealed that alkaloids, glycosides, saponins, flavonoids, reducing compounds and polyphenols were present in the extracts in moderate quantities. The proximate analysis of the grain revealed that the carbohydrate content (83.45±0.1) of *Oryza sativa* followed by moisture (7.33±0.1), the least nutrient of proximate analysis was seen in ash (1.00±0.00). Out of the two extraction methods employed, the ethanol extract was a more effective method and thus recommended.

Key words: *Xylopia aethiopica,* ethanolic and aqueous, *Sitophilus oryzae,* rice grain.

INTRODUCTION

Insect pest damaged stored grains result in major economic losses and in Africa where subsistence grain production supports the livelihood of majority of the population, grain loss caused by storage pest such as the rice weevils *Sitophilus oryzae* (Ulebor et al., 2011) is a serious issue. Stored product insects reduce the quantity, quality, nutritive value and viability of stored crops like maize, sorghum, wheat and rice (Okonkwo, 1998). These pests and many others, threaten food security (Ulebor et al., 2011). Control of pests in stored grains is a serious problem in developing countries in the tropics due to favorable climatic conditions and poor storage structures

*Corresponding author. E-mail: gregory.odo@unn.edu.ng.

(Bekele and Hasanali, 1997). *Sitophilus* is a genus of weevils. Some species are familiar as pests of stored food products.

Notable species include the rice weevil (*S. oryzae*), wheat weevil (*Sitophilus granarius*) and maize weevil (*Sitophilus zeamais*) (Shadia, 2011).

The rice and maize weevils have a nearly cosmopolitan distribution, occurring throughout the warmer parts of the world. In Europe they are replaced by the temperature palaearctic wheat weevil (Plarre, 2010).

The adult female weevil bores in a grain, nut, or seed, and deposits an egg per individual grain. She seals the hole with a secretion. The larva develops while feeding on the interior of the grain, and then pupates. It usually leaves the grain completely hollow when it exists as adult (Plarre, 2010). The wheat weevil can live on acorns, and may have used them as a host before agriculture made grain plentiful. The rice weevil can live on beans, nuts, grains and some types of fruits such as grapes (Ebeling, 2011). Several other *Sitophilus* use the acorns of oaks such as bluejack oak (*Quercusincana*) and moru oak (*Quercus floribunda*). Some use the seeds of trees in dipterocarpaceae and the legume family, Fabaceae. The tamarind weevil *(Sitophilus linearis*) is only known from the seeds of tamarind (Plarre, 2010).

Several *Sitophilus* species are hosts to an intracellular y-protobacterium weevils and bacterium have a symbiotic relationship in which the bacterium produces nutrients such as amino acids and vitamins for the host supplementing its cereal diet (Vallier et al., 2009).. As of 1993, there are about 14 species of *Sitophilus* (Ebeling, 2011). They include *Sitophilus conicollis, Sitophilus cribosus, Sitophilus erosa, Sitophilus glandium, S. granarius, S. linearis, S. oryzae, Sitophilus quadrinotatus, Sitophilus rugicollis, Sitophilus rugosus, Sitophilus sculpturatus, Sitophilus vateriaea, S. zeamais* (maize weevil) (Schoenherr, 1938).

Oryza sativa, commonly known as Asian rice, is the plant species most commonly referred to in English as rice. *O. sativa* is a grass with genome consisting of 430mb across 12 chromosomes. It is renowned for being easy to genetically modify, and is a model organism for cereal biology (Vallier et al., 2009).

Rice is a seed of the grass species *O. sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the agricultural commodity with the third highest worldwide production, after sugar cane and maize. Since a large portion of maize crops are grown for purposes other than human consumption, rice is the most important grain with regards to human's nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by humans (Ivbijaro, 1983).

Rice is a monocot that is normally grown as an annual plant, although in tropical areas it can survive as a perennial and can produce Raton crop for up to 30 years. Rice cultivation is well-suited to countries and regions with low labor costs and high rainfall, as it is labor intensive to cultivate and requires ample water. However, rice can be grown practically anywhere, even on a sleep hill or mountain area with the use of water –controlling terrace systems. Although its parent species are native of Asia and certain parts of Africa, centuries of trade and exportation have made it common place in many cultures worldwide (FAO, 2014).

Cereal crops especially rice is widely attacked by the grain weevil *Sitophilus* species causing 25 to 100% post-harvest losses in storage (Okonkwo, 1998). *S. zeamais* and *S. oryzae* are the two main species known to attack maize and rice in Nigeria. Owing to the insidious feeding habits, they are often undetected until damage has occurred (Okonkwo, 1998). Owing to the losses resulting from the feeding activities and damages of the rice grain pests, it is essential that necessary control measures are put in place to ensure adequate rice production and storage (Bekele and Hasanali, 1997). Insect pest in stored food products has relied heavily on the use of gaseous fumigants and residual contact insecticides. The implication of these are serious problems of toxic residues, health and environmental hazards, development of insect strain resistance to insecticides, increasing cost of application and erratic supply in developing countries due to foreign exchange constraints (Okonkwo and Ewete, 1999).

Similarly, Tetees and Gilstrap,(1998) were of the view that the use of chemical insecticides which hitherto was the control measure adopted in storage, has of recent been criticized because of the difficulties associated with its procurement, hazards with its use, development of pest resistance and pest resurgence problems. Thus, these problems have created the need to find materials that will effectively protect stored grains or produce, that are readily available, affordable, relatively less poisonous and less detrimental to the environment (Abd-el-Azc and Ismail, 2000).

Different spice and herbal plant products in the form of essential oil (EO), powders, pellets, extracts or distillates could be harnessed as potential toxicants, deterrents, antifeedants, repellents, and fumigants for exclusion of stored product pests from grain, have been used. *Xylopia aethiopica* is an evergreen, aromatic tree, of the Annonaceae family that can grow up to 20 mm high. It is native to the lowland rainforest and moist fringe forests in the savanna zones of Africa. The dried fruits of *X. aethiopica* (Grains of selim) are used as a spice and as herbal medicine (Moller and Maier, 2010).

Xylopia is a compression from Greek xylonpikron meaning "bitter wood". The second part of the plant's binomial name, *aethiopica*, refers to the origin of the tree, in Ethiopia, though currently it grows most prominently as a crop in Ghana (Harris et al., 2011). *X. aethiopica* grows in tropical Africa; It is present in the rain forests, especially near the coast. It also grows in the riverine and fringing forests, and as a pioneer species in the savanna region. The wood is known to be resistant to termite attack and is used in hut construction; posts, scantlings, roof-ridges and joints. An infusion of the plant's bark or fruit has been useful in the treatment of bronchitis and dysenteric conditions, or as a mouthwash to treat toothaches. It has also been used as a medicine for biliousness ad fibril pains. In Senegal, the fruit is used to flavor café Touba, a coffee drink that is the country's spiritual beverages and the traditional drink of the Mouride brotherhood (Harris et al., 2011). In the middle ages, the fruit was exported to Europe as a 'pepper'. It remains an important item of local trade throughout Africa as a spice, and flavoring for food and medicine. The fruit is sometimes put into jars of water for purification purposes (Burkil and Humphrey, 1985).

The African pepper or spice tree, *X. aethiopica* is an important, evergreen, medicinal plant widely distributed in West Africa, and concoctions prepared from its morphological parts are used in traditional medicine for the treatment of skin infections, candidiasis, cough, fever, dysentery and stomach ache (Okigbo et al., 2005). Extracts from *X. aethiopica* have been reported to exhibit antibacterial and antifungal (Okigbo et al., 2005) mosquito repellent (Adewoyin et al., 2006), and termite anti-feedant activities (Lajide et al., 1995). *X. aethiopica* can be harnessed in the form of oil extracts and powders for use in storage and entomology (Bekele and Hasanali, 1997). The achievement in this direction will help to increase the scope of rice production and utilization, to meet up with the ever increasing demand for rice and rice products (Okonkwo and Ewete, 1999).

Chemical pesticides has made way to controlling and management of pests both in field and in store, but the menace they cause is one that gives serious concern to man, his animals and the environment. As a result, scientists have been looking for a way to produce a more friendly pesticide that will not cause serious harm and so manageable; it is with this in mind that the zeal for the study was conceived.

Though works has been carried out by some authors with botanicals/biopesticides, the aqueous extract of the stem bark of *P. santalinoides* has been established to have effects on *Pseudomonas aeruginosa* (Eze et al., 2012). According to Anowi et al. (2012), the methanolic extract of leaves of some botanicals possesses analgesic activity. Okpo et al. (2011) reported the anti-diarrhea property of aqueous extract of some plant leaves. Other workers on biopesticides includes Adeleke et al. (2009) who reported the larvicidal properties of some plant extract; and Otitoju et al. (2014) who reported the welcoming effect of the plant in food. There is still paucity of information on the efficacy, effectiveness and potency of *X. aethiopica* as grain protectant against *S. oryzae* (Kunz et al., 2001).

This study investigated the efficacy, effectiveness and potency of *X. aethiopica* extracts (ethanolic and aqueous), and evaluated the mortality, oviposition, developmental and natality rates of *X. aethiopica* in the control of *S. oryzae* on stored rice.

MATERIALS AND METHODS

Cereal grains

One kilogram of dry African rice *O. glaberrima* was collected from Ogige market, Nsukka, Enugu State and identified. The rice was fumigated for 48 h with carbon tetra chloride and aerated for 7 days in order to kill the resident insect pest as suggested by Ivbijaro (1983). The seeds were sieved with a 2-mm sieve to remove dead insects, and the processed grains were packaged in polythene bags and kept pending use (Becky, 2004).

Sitophilus oryzae

A weevil culture of *S. oryzae* that developed on rice was established on March 2015. The mass production of *S. oryzae* took place in the Applied Entomology Laboratory, Department of Zoology and Environmental Biology, University of Nigeria, Nsukka, Enugu State, Nigeria with relative humidity and temperature of 66.6% and 28±5°C, respectively. Hundred adults of mixed sex (male and female) of *S. oryzae* were obtained from the weevil culture and reared in glass jar covered with muslin cloth. The food media were the rice. After two weeks, when oviposition has been noticed, the parent stocks of *S. oryzae* were removed by sieving the grain with a 2.00 mm sieve. The grains with the oviposited ova were left under laboratory conditions till emergence of F1 progeny. The F1 progenies from the cultures were used for the experiment (Ekeh et al., 2013).

Plant materials

The fruits of *X. aethiopica* were collected from Cemetery Market, Aba, Abia State and were dried to constant weight under room temperature. The dry material was ground to very fine powder and used for the experiment. The experiment was to find out the comparative efficacy of the seed extracts (Keay et al., 1964).

Aqueous extract of *Xylopia aethiopica*

Five hundred grams of the powdered fruits of *X. aethiopica* was ground and weighed into 1000-ml conical flask. 800 ml of distilled water was added to the sample in the flask. The solution was then stirred with a glass rod and allowed to soak for 24 h. The aqueous extract was filtered thrice through a plug of adsorbent cotton wool embedded in a glass funnel. The filtrate was then filtered through 11 cm round filter paper. The solution was concentrated by gentle evaporation on a heating mantle and poured into 500 ml beaker (AOAC, 2000).

Ethanolic extract of *Xylopia aethiopica*

Five hundred grams of the fruit was ground into fine powder and weighed using the electrical weighing balance. Five hundred milliliters of absolute ethanol was added to the sample in the flask. The solution was stirred with a glass rod, allowed to soak for 24 h, filtered using the filter paper and the filtrate allowed to evaporate under room temperature.

Table 1. Phytochemical screening of *Xylopia aethiopica*.

Parameter	Ethanolic extract	Aqueous extract
Alkaloids	+	++
Glycosides	++	+
Saponins	+	++
Tannins	-	-
Flavonoids	++	+
Reducing compounds	++	+
Polyphenols	++	+
Phlobatannins	-	-
Anthraquinones	-	-
Triterpenes	+	-
Steroids	+	-

-Not present; + present in small concentration; ++ present in moderately high concentration.

Table 2. Quantitative estimation of some phytochemicals of *Xylopia aethiopica.*

Parameter	Concentration (%)
Alkaloids	2.401±0.1
Flavonoids	8.10±0.1
Saponins	1.36±0.01
Polyphenol	2.75±0.03

Table 3. Percentage proximate analysis of *Oryza sativa.*

Nutrients	% Proximate analysis
Moisture	7.33 ± 0.1
Fat	0.50 ± 0.01
Crude protein	6.22 ± 0.01
Crude fibre	1.50 ± 0.10
Ash	1.00 ± 0.00
Carbohydrate	83.45 ± 0.1

Phytochemistry of plant materials

Phytochemical analysis was carried out for the presence of alkaloids, saponins, flavonoids, plobatannins, cardiac glycosides, tannins and anthraquinones (Table 1). These were screened using the method described by Trease and Evans (1996).

Quantitative estimation of some phytochemicals

Quantitative estimation of alkaloids, flavonoids, saponins, polyphenols and reducing compounds were determined using the method described by AOAC (1990) (Table 2).

Proximate study of rice (*Oryza sativa*)

The proximate study was carried was carried out to ascertain the constituent nutrient (Carbohydrate, crude protein, ash, crude fibre, fat, moisture) and the level of their presence in rice grain following the methods of Okoh and Ugwu (2011) (Table 3).

Experimental design

Split plot design of four concentrations replicated three times was used. Ethanolic and aqueous extracts of *X. aethiopica* was used for the experiment. Five pairs (five males and five females) of zero day old *S. oryzae* were introduced into each of the jars already with 20 g of rice and 8 g/6 g/3 g/0 g of *X. aethiopica* each. The ethanolic and aqueous extract was applied at the 8, 6 and 3 per 20 g of rice. Another control group was set up with the grain and *S. oryzae* but no botanical (experimental control). Each jar was covered with a muslin cloth to allow air movement and prevent insects from leaving the jar. The set up was allowed for 15 days with daily monitoring. Dead insects in each jar was collected and counted and the percentage insect mortality was calculated. When the eggs were noticed in the set-up, the pest *S. oryzae* was removed and eggs counted and recorded for each jar, the oviposition was monitored for 10 days for the inception of larva and pupa where developmental study was done. When the larva and pupa was noticed, the set up was monitored till natality of pests occurred and newly emerged adults of *S. oryzae* counted. The whole experiment lasted for a period of seven weeks (50 days) (Ekeh et al., 2013).

LD_{50} of *Xylopia aethiopica*

Fifty percent lethal dose (LD_{50}) of *X. aethiopica* was done using the methods described by Don-Pedro (1989). The concentration of ethanolic and aqueous extract that killed 50% of the 20 *S. oryzae* exposed to it for a period of 24 h was recorded (Ousman et al., 2007).

Data analysis

One way analysis of variance (ANOVA) was carried out to compare differences in treatment means. Significant treatment means were separated using Duncan multiple range test. The efficacies of the ethanolic and aqueous extracts were also compared with Duncan multiple range tests.

RESULTS

Mortality

Table 4 presents univariate analysis of mortality rate on ethanol extract using analysis of variance (ANOVA). From the results shown, it was observed that the mortality of *S. oryzae* increased with increase in the dosage application. The highest mortality of weevil was recorded in 8 g (20.00 ± 0.58) of ethanolic extracts which was followed by 6 g (9.33 ± 0.67) and 3 g (3.33 ± 0.88). The least mortality was seen in 0 g (1.33 ± 0.33) due to the absence of the extract and it is the control group. There was no significant difference between 0 g and 3 g but there was significant difference between 6 g and 8 g.

Oviposition

Table 4 presented univariate analysis of oviposition rate

Table 4. Activities of *Xylopia aethiopica* against *Sitophilus oryzae*.

Concentration (g/20 g grain)	Ethanolic	Aqueous
	Mortality	
Control (0.0)	1.33 ± 0.33[c]	1.33 ± 0.33[c]
3.0	3.33 ± 0.88[c]	1.00 ± 0.00[c]
6.0	9.33 ± 0.67[b]	4.00 ± 1.55[b]
8.0	20.00 ± 0.58[a]	11.67 ± 0.88[a]
	Oviposition	
Control (0.0)	22.33 ± 1.45[a]	22.33 ± 1.45[a]
3.0	14.67 ± 0.88[b]	17.67 ± 1.33[b]
6.0	10.33 ± 0.88[c]	17.67 ± 0.67[b]
8.0	4.67 ± 0.33[d]	8.33 ± 0.33[c]
	Emergence (Larva)	
Control (0.0)	21.67 ± 0.88[a]	21.67 ± 0.88[a]
3.0	13.00 ± 0.58[b]	16.67 ± 0.88[b]
6.0	8.33 ± 0.33[c]	15.67 ± 0.67[b]
8.0	3.67 ± 0.33[d]	8.00 ± 0.00[c]
	Emergence (pupa)	
Control (0.0)	18.00 ± 1.15[a]	20.67 ± 0.67[a]
3.0	11.67 ± 0.67[b]	15.33 ± 0.88[b]
6.0	6.33 ± 0.67[c]	12.33 ± 0.33[c]
8.0	2.33 ± 0.67[d]	6.33 ± 0.33[d]
	Natality	
Control (0.0)	16.33 ± 0.88[a]	19.67 ± 0.88[a]
3.0	11.00 ± 1.00[b]	14.00 ± 0.58[b]
6.0	4.67 ± 0.88[c]	11.33 ± 0.33[c]
8.0	1.33 ± 0.67[d]	4.67 ± 0.33[d]

Values with different alphabet superscript for a parameter in a column are significantly different ($p < 0.05$).

on the ethanolic and aqueous extracts of *X. aethiopica* using analysis of variance (ANOVA). From the study, it was observed that *S. oryzae* were able to lay eggs at all treatment dosages. However, the oviposition rate of the insects decreased with increase in the dosage application. The highest oviposition was observed in 0 g (22.33 ± 1.45) for both extracts, which was followed by 3 g (14.67± 0.88) and 6 g (10.33 ± 0.88). The least oviposition was observed in 8 g (4.66 ± 0.33), (8.33 ± 0.33) for both extracts which has the highest concentration of the extract. There was significant difference in all the concentrations going by the superscript of performance of ethanolic and aqueous extraction methods of *Xylopia aethiopica.*

Figure 1 compares the performance of ethanolic and aqueous extraction methods of *Xylopia aethiopica*. From all indications, ethanolic extraction was more efficacious than aqueous.

Developmental rate (larva)

Table 4 presents univariate analysis of developmental rate (larva) on the ethanolic extract using analysis of variance (ANOVA). The result of the bioactivities of *X. aethiopica* ethanolic extract on the larval stage of *S. orzae* as presented in Table 4 shows that more larva were observed in the control, followed by 3 g, 6 g and the lowest number of larva was observed on the 8 g for both ethanolic and aqueous extraction due to the concentrations. There was significant difference in all the concentrations going by the superscript.

Developmental rate (Pupa)

Table 4 presents univariate analysis of developmental rate (pupa) on the ethanolic and aqueous extract using analysis of variance (ANOVA). The result of the bioactivities of *X. aethiopica* extracts on the larval stage of *S. orzea* as presented in Table 4 shows that more pupa were observed in the control, followed by 3 g, 6 g and the lowest number of pupa was observed on the 8 g due to the effect of the extracts and concentration. Going by the superscript, there were significant differences in all the concentrations.

Natality

In Table 4, the result showed that the natality of *S. oryzae* decreased with increased dosage application. The untreated grain 0 g (16.33 ± 0.88) has the highest rate of natality for both ethanolic and aqueous extractions which was followed by 3 g and 6 g. The least birth was observed in 8 g (1.33 ± 0.67), (4.67 ± 0.33) which shows the lowest number of natality. There was significant difference in all concentration going by the superscript.

DISCUSSION

In the present study, the ethanol and aqueous extracts prepared from *X. aethiopica* have shown very high insecticidal properties against *S. oryzae*. The ethanolic and aqueous extracts of *X. aethiopica* at the dosage rates of 3, 6 and 8 g in rice gave promising levels of control of *S. oryzae* in terms of increase in mortality and reduction in oviposition, natality and developmental rates with the ethanolic extracts having high insecticidal properties than the aqueous. The present work agreed with the findings of Yankachi and Gadachi (2010) where the insecticidal actions of different plant products were compared against *S. oryzae*. Onolemhemhen and Oigiangbe (1991) have also reported the superiority of *X. aethiopica* and *Piper guinensis* seed in increasing mortality against *S. oryzae.* Onolemhemhen et al. (2011)

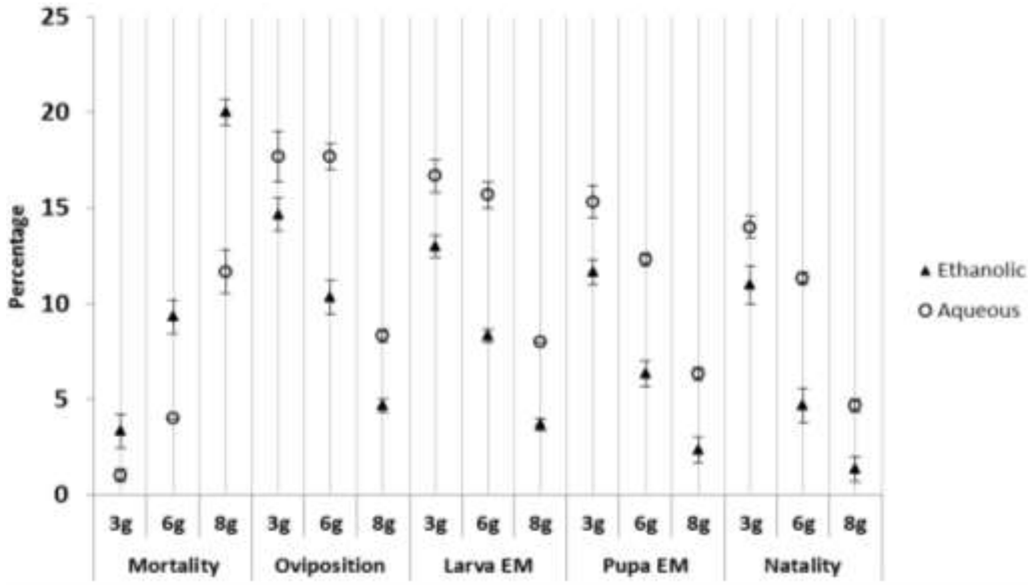


Figure 1. Comparison of activities of the two extraction solvents. Activity of ethanolic extract significantly better than aqueous extract at inhibition of oviposition, larva and pupa emergence and natality ($p < 0.05$). Ethanolic extract is also significantly more effective at causing mortality ($p < 0.05$).

reported that *X. aethiopica* has a pungent smell which functioned more as an insect repellent and perhaps caused suffocation and death of the weevils. The insecticidal features of the plant's extract may be due to their constituent components, pungent smell and mode of actions. These may have accounted for their effective control of *S. oryzae* and other insects. Extracts of *X. aethiopica* might have exhibited some insecticidal actions resulting in low natality and oviposition of *S. oryzae* even though the natality and oviposition of *Sitophilus oryzae* were not completely halted at any of the treatment dosage rates (8 g, 6 g, 3 g), they were lower than the control treatment (0 g). This agreed with the findings of Edelduok et al. (2015) that cotyledon powder of melon halted the ovipositon of *S. zeamais* which might have been due to the presence of essential oil. The mode of action of oil has been suggested by Credland (1992) to include physical barrier to respiration of insect's eggs and young larvae. Moreover, Rajapaske (2006) suggested that the mechanical effects of the large quantities of powders could have effects on oviposition. Lubijar (1983), who embarked on another botanical study of the neem seed *Azadirachta indica* found out that the neem seed severely reduced egg laying in female *S. oryzae* while increasing the mortality (Ekeh et al., 2013).

Treatment with *X. aethiopica* increased larval and pupal period and reduced the total oviposition period, adult longevity and fecundity suggesting that the phytochemicals in the *X. aethiopica* interfere with the neuroendocrine system in insects, which controls the synthesis of ecdysone and juvenile hormone. In the present investigation, it was found that *X. aethiopica* affords better protection against *S. oryzae*. It was observed that the ethanolic extract was more effective in checking mortality, natality, developmental rate and oviposition than the aqueous extracts. *X. aethiopica* has many other activities against insects disrupting or inhibiting development of eggs, larvae, pupae, delaying the molting of larvae, disrupting mating and sexual communication, repelling larvae and adults, poisoning larvae and adults, feeding deterrent and preventing adult to maturation. This is in agreement with the work of Radha and Susheela (2014) who reported that the use of different botanicals severely reduced the oviposition, developmental rates and natality of *Callosobruchus maculatus*. The findings of this work indicated that the ethanol extract of *X. aethiopica* could be used in controlling rice weevil in stored rice. This will reduce chemical pesticide usage, remove the risk of toxic residues in food and ensure the continued availability of insect free rice for food, planting, trading and storage (Ngamo et al., 2007).

Conclusion

The present work has revealed the efficacy of *X. aethiopica* on rice weevil (*S. oryzae),* established the concentration that controls the weevils on rice grain at different quantities and has also looked at different extraction methods of the *X. aethiopica*. The effects of *X. aethiopica* in protecting the grain against *S. oryzae* were comparable to using standard pesticides. It has been confirmed that ethanolic extraction stands out as the best extraction methods because it exposes the active ingredients of the extract making it more efficacious as having the potentials in the control of insect pests and thus recommended as a biopesticide.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

Immense gratitude goes to the Head, Department of Zoology and Environmental Biology, Prof. P. O. Ubachukwu for approving the laboratory space and all the technical staff of Department for this work.

REFERENCES

Abd-El-Azc AI (2000). Ismail as protestant of broad bean against the infestation by Bruchidius incarnates (schm) during storage. Ann. Agric Sci. Ainshams Univ. Cairo 45:717-725.

Adewoyin FB, Odaibo AB, Adewunmi CO (2006). Mosquito repellent activity of *Piper guinensis* and *Xylopia aethiopica* fruits oils on *Aedesaegypti.* Afr. J. Trad. Complement. Altern. Med. 3:79-83.

Adeleke MA, Popoola SA, Agbaje WB, Adewals B, Adeoye MD, Jimoh WA (2009). Larvicidal efficacy of seed oil of *P. santoleinoides* and tropical manihot sp against Aedes eagypti and effect of aquatic fauna. Tanz. J. Health Pres. 11:250-252.

Anowi CF, Okonkwo C, Aghata CA, Ezeoka E (2012). Preliminary phyto chemical screening, evaluation of acute toxicity and Antipyretic activity of methanolic extrat of P santolienoides .Int. J. Pharm. Phytopharmacol. Res. 1(6):343-346.

Association of Official Agricultural Chemists (AOAC) (2000). Official methods of analysis. 17th edition, Washington, D.C. USA.

Association of Official Agricultural Chemists (AOAC) (1990). Official method of Analysis, vitamins and other nutrients, Washinton D.C.

Becky H (2004). The acacia tree: A sustainable resource for Africa. FRP/DFID. Oxford pp. 9-24.

Bekele A, Hassanali A (1997). Evaluation of Ocinumkenyense as source of repellents, toxicants and protectants in storage against the major stored products and insects pest. J. Appl. Entomol. 121:169-173.

Burkil J, Umphrey M (1985). Entry for *Xylopia aethiopica*. The useful plants of west tropical. Afr. J. Med. Plants 34:2-8.

Credland PF (1992). The structure of bruccid eggs may explain the ovicidal effects of oil. J. Stored Prod. Res. 28:1-9.

Don-Pedro KN (1989).Mechanisms of action of some vegetable oils against *Sitophiluszeamais* on wheat. J. Stored Prod. Res. 25:217-223.

Ebeling N (2011). Pests of stored food products. J. Urban Entomol. 23:32-40.

Edelduok EG, Akpabio EE, Eyo JE, Ekpe EN (2015). Evaluation of the insecticidal activities of cotyledon powders of melon (*Citrullus vulgaris*) against the maize weevil, *Sitophilus zeamais*. J. Biopestic. Environ. 1:50-57.

Ekeh FN, Oleru KI, Ivoke N, Nwani CD, Eyo JE (2013). Effects of Citrus sinensis peel oil on the oviposition and development of cowpea beetle *Callosobruchus maculatus* (Coleoptera: Chrysomelidae) in some legume grains. Pakistan J. Zool. 45(4):967-974.

Eze SO, Cornelius C, Okereke HC (2012). Phytochemical and antimicrobial activities of stem bark of *P. Santolienoides*. Asia J. Nat. Appl. Sci. 1(3):1-7.

Harris DJ, Florence J, Bridgewater K (2011). An introduction to the tree from the North of the republic of Congo. J. Ecol. Res. 14:371-382.

Ivbijaro MF (1983).Prevention of *Sitophilus oryzae* with the neem seed, *Azadiracta indica.* Prot. Ecol. 5:177-182.

Keay RWJ, Onochie CFA, Stanfield DP (1964). Nigeria trees. Ibadan Nig. Department of Forest Research P 1.

Kunz R, Vist G, Oxman A (2007). Randomization to protect against selection bias in healthcare trials. Cochrane database. Syst. Rev. MR000012.

Lajide L, Escoubas P, Mizutani J (1995).Termitesanti feedant activity in *Xylopia aethiopica..* J. Phytochem. 40:1105-1112.

Moller HJ, Maier W (2010). Evidence based medicine in psycho pharmacotherapy: Possibilities, problems and limitations. iEur. Arch. Psych. Clinc. Neurons 260:25-39.

Ngamo TSL, Ngatonko I, Ngassoum MB, Mapon, Amestsem PM, Hance T (2007). Persistence essential activities of crude essential oil of 3 aromatic plants towards 4 major stored product insect pests. Afr. J. Agric. Res. 2:172-177.

Okigbo RN, Mbajiuka CS, Njoku, CO (2005). Antimicrobial and potentials of *Xylopia aethiopica* and *Ocimumgratis simum* on some pathogens of man. Int. J. Mol. Med. Adv. Sci. 1:392-397.

Okoh AO, Ugwu SI (2011). The proximate and mineral compositions of five major rice varieties in Abakaliki, South –Eastern Nigeria. Int. J. Plant Physiol. Biochem. 3:25-27.

Okonkwo EU (1998). A bibliography of plant materials use for controlling insect pest of stored products in Nigeria. Rev. Agric. Entomol. 30:75-82.

Okonkwo EU, Ewete MA (1999).Insecticidal effect of some spices on *Sitophilus oryzae* in rice. Int. J. Pest Manage. 41:143-145.

Onolemhemhen OP, Oigiangbe CN (1991). Biology of *Callosobruchus maculates* on cowpea and pigeon pea treated with vegetable oil. J. Agric. Res. 8:57-63.

Okpo SO, Ching FP, Ekeleme IC (2011). Evaluation of the anti- diarrhea activity of the aqueous extract from leaves of *P. santolienoides*. Res. J. Pharm. Chem. Sci. 2(3):590-597.

Otitoju O, Onwurah INE, Otitoju GTO, Ndem JI, Uwah AF (2014). Effect of Bonny light crude oil contaminated diet on serum cholesterol and testosterone concentrations in wister Albino rat. Afr. J. Biotechnol. 10(53):10986-10990.

Ousman A, Ngassoum MB, Essia NJ, Ngamo LS, Ndjouenke R (2007). Insecticidal activity of spicy plant oils against *Sitophilus zeamais* in stored maize in Cameroon. Agric. J. 2:192-196.

Plarre R (2010). An attempt to reconstruct the natural and cultural history of the granaryweevils. Eur. J. Entomol. 107:1-11.

protectants in storage against the major stored products and insects pest. J. Appl. Entomol. 121:169-173.

Radha R, Sunshield P (2014). Efficacy of plant extracts on the toxicity, ovipositional deterrence and damage assessment of the cowpea weevil (*Callosobruchus maculatus*). J. Entomol. Zool. Stud. 2:16-20.

Radha R, Sunshield P (2014). Efficacy of plant extracts on the toxicity, ovipositional deterrence and damage assessment of the cowpea weevil (*Callosobruchus maculatus*). J. Entomol. Zool. Stud. 2:16-20.

Rajapaske HS (2006). The potential of plants and plants products in stored insect's pest management. J. Agric. Sci. 2:11-20.

Schoenherr B (1838). Natural crop protection. Gen. sp. Curc 4(2):967.

Shadia E, Abd El-Aziz (2011). Control strategies of storev product pest. J. Trop. Plants 8(2):101-122.

Tetees GL, Gilstrap FE (1998). Development and evaluation of systems for controlling insect pests on sorghum and millet by integration of resistant varieties, cultural manipulation and biological control. Entomology 56:214-223.

Trease GE, Evans WC (1996). *Textbook of pharmacognosy*: 14th Edition W. B Sanders, London. pp. 46-47, 832.

Ulebor J, Umeri C, Onolemhemhen P 2011. The efficacy of Xylopia aethiopica and Piper guinensis seeds powder on *Sitophilus oryzae* mortality. J. Agric. Soc. Res. 12:56-60.

Vallier A (2009). RNA in the cereal weevil Sitophilus Sp. Systemic gene knockdown in the base teriome tissue BMC Biotechnology 9(1):44.

Vallier A (2009).Dietary reference intake for antioxidant nutrients. J. Agric. Res. 10:56-63.

Yankachi SR, Gadache AH (2010). Grain protectant efficacy of certain plant extracts against rice weevil (*Sitophilus oryzae*). J. Pestic. 3:511-513.

academicJournals

Vol. 13(10), pp. 477-489, 8 March, 2018
DOI: 10.5897/AJAR2017.12949
Article Number: BBCA0CD56253
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effects of lime, vermicompost and chemical P fertilizer on yield of maize in Ebantu District, Western highlands of Ethiopia

Abdissa Bekele[1*], Kibebew Kibret[1], Bobe Bedadi[1], Tesfaye Balemi[2] and Markku Yli-Halla[3]

[1]School of Natural Resources Management and Environmental Sciences, Haramaya University, Ethiopia.
[2]ILRI/CIMMYT, Gurd Shola, P. O. Box 5689, Addis Ababa, Ethiopia.
[3]Department of Food and Environmental Sciences, Faculty of Agriculture and Forestry, University of Helsinki, Finland.

Received 23 December, 2017; Accepted 12 February, 2018

Integrated use of lime with organic and chemical fertilizers is considered as a good approach for sustainable crop production under acidic soils. Vermicompost (VC) and chemical phosphorus (P) fertilizer when used with lime play a vital role in enhancing productivity of acidic soils. Field experiments were conducted for two consecutive cropping seasons of 2015 and 2016 to evaluate the effects of lime, VC and chemical P fertilizer on yield and yield components of maize in Ebantu District, Western highlands of Ethiopia. The experiments were laid out in a randomized complete block design as a factorial combination of two lime rates (0, and 4 t $CaCO_3$ ha^{-1}), three VC rates (0, 2.5 and 5 t VC ha^{-1}) and three chemical P rates (0, 20 and 40 kg P ha^{-1}) which were replicated three times. Relevant crop parameters were measured following standard procedures. Tasseling days (102), silking days (109), highest leaf area index (5.91), plant height (3.48 m), cob length (47.83 cm), number of grain per cob (644) and above ground dry biomass yield (22 t ha^{-1}) were exhibited by 5 t ha^{-1} VC and 40 kg ha^{-1} chemical P fertilizer with lime of 0 and 4 t ha^{-1} while the highest 1000-seed weight (508 g), grain yield (4.87 t ha^{-1}) and harvest index (24%) were obtained at 2.5 t ha^{-1} VC and 40 kg P ha^{-1} with lime. Integrated application of organic and chemical fertilizers with lime amended the acidic soils and improved its fertility which in turn increased crop yields. Combined use of VC at 2.5 t ha^{-1} and chemical P fertilizer at 20 kg ha^{-1} with lime at 4 t ha^{-1} is economically optimum and could be recommended for reclaiming soil acidity and improve nutrients for maize as it enhanced grain yield and yield components of maize plant in strongly acidic soils for the two consecutive years pooled together.

Key words: Maize yield, lime, Vermicompost (VC), phosphorus (P), integrated application.

INTRODUCTION

Maize (*Zea mays* L.) is the most widely grown staple food crop in sub-Saharan Africa (SSA) occupying more than 33 million ha each year (FAO, 2015). Ethiopia is Africa's fourth biggest maize producer next to South Africa, Nigeria and Egypt but the yield of the crop was low in the country (ECEA, 2009).

In Ethiopia, maize had been growing from moisture stress areas to high rainfall areas and from lowlands to highlands of the country. Among cereals, maize is the first and second crop in terms of volume of production and area coverage followed by and next to *teff* (*Eragrostis tef*) (CSA, 2017).

Although maize is an important crop, the major constraint limiting its production in medium to high agricultural potential areas in tropical Africa is soil acidity (Kanyanjua et al., 2002; Opala et al., 2015). Low soil fertility and nutrient availability due to acidity and low level of input use are also among the major crop production constraints in Ethiopia including maize crop (Alemayehu et al., 2011; Abreha et al., 2013). Maize does well with pH of 5.5-5.7, while strongly acidic soil (pH ≤ 5.0) is unsuitable for good yield (Mbah and Nkpaji, 2010). The productivity of acid soils is limited by the presence of toxic levels of aluminium (Al) and manganese (Mn) and deficiency of nutrients such as phosphorus (P), calcium (Ca), magnesium (Mg) and molybdenum (Mo) (Brady and Weil, 2014).

Aluminium toxicity due to high exchangeable Al reduces P uptake by fixing P which in turn affects maize growth and yield on acid soils (Gaume et al., 2001). In sub-humid agro-ecosystem of Western Ethiopia, the highest maize grain yield recorded under farmers' field has been11 t ha^{-1} (Wakene et al., 2007). Surprisingly, CSA (2017) reported that the potential maize productivity on farmers' field in East Wollega is only 4.5 t ha^{-1} due to constraints related to soil acidity and nutrient deficiency problems.

Achieving high maize yield requires adequate and balanced supply of plant nutrients as declining soil fertility is a prominent constraint for maize production (Barbieri et al., 2008; Okoko and Makworo, 2012). There are different materials of conventional and non conventional sources to amend soil acidity and fertility. The general practice for ameliorating soil acidity is the application of lime. However, the key to sustainable food production in low input agricultural system is the use of locally available nonconventional liming materials to reduce soil acidity and increase soil fertility simultaneously.

Vermicompost (VC) and wood ash were reported to increase the pH of acid soils and improve soil fertility by supplying essential plant nutrients (Chaoui, 2003; Materechera, 2012). Along with this, Zeinab et al. (2014) reported that VC has large particulate surface area that provides sites for the microbial activity and retention of nutrients. Similarly, Wael et al. (2011) declared that VC can be used to increase the pH in acidic soils and reduce Al and Mn toxicity because of its alkalinity. It has been reported that application of VC increases the supply of easily assimilated as well as micronutrients to plants besides mobilizing unavailable nutrients into available form (Zeinab et al., 2014). Its application had a positive effect on yield parameters of maize (Gutiérrez-micely et al., 2008). VC contains high levels of total and available N, P, potassium (K) and micronutrients (Tesfaye, 2017), microbial activities and growth regulators (Chaoui, 2003). It significantly stimulates the growth of sweet corn (Lazcano et al., 2011).

Generally, VC can improve seed germination, growth and yield of crops (Nagavallemma et al., 2004). There is an increasing interest in the potential use of VC as soil amendment, where the addition of VC improves the soil physical and chemical properties (Angin et al., 2013; Lordan et al., 2013). Continuous and adequate use of VC with proper management can increase soil organic carbon (OC), soil water retention and permeability (Mahdavi, 2007).

Phosphorus is a critical element in natural and agricultural ecosystems throughout the world (Onweremadu, 2007) as its limited availability is often the main constraint for plant growth in highly weathered soils of the tropics (Bunemann et al., 2004). The application of mineral P fertilizers and the introduction of sustainable land management practices have amended P deficiency in some soils used for crop production. However, P deficiency remains a major constraint in rainfed upland farming systems throughout the tropics (Fairhurst et al., 1999). The high available P contents associated with the mineral P treated soils were attributed to the fact that mineral P applied in the form of TSP is a source of soluble P (Asmare et al., 2015).

Nowadays agronomists are concentrating on reducing the use of inorganic fertilizers by using biofertilizers such as VC (Darzi et al., 2011). The management practices with organic materials influence agricultural sustainability by improving physicochemical and biological properties of soils (Haj Seyed Hadi et al., 2011). Inappropriate use of chemical fertilizers is also becoming a chronic problem due to its high cost (Johannes, 2013) and effect in deteriorating soil biological properties as well as environmental impacts (Zarina et al., 2010). On the other hand, integrated and judicious use of organic sources of nutrients not only supplies nutrients but also has some positive interaction with chemical fertilizers to increase their efficiency and thereby to improve soil structure (Elfstrand et al., 2007).

Similarly, integrated use of organic matter (OM) and chemical fertilizers is beneficial in sustainably improving crop production, soil pH, OC and available N, P, and K in soils (Rautaray et al., 2003). Tilahun et al. *(*2013) also stated that neither inorganic nor organic fertilizers alone can result in sustainable productivity. This situation made the use of integrated nutrient management in maize production necessary since combined use of organic and inorganic fertilizers builds ecologically sound and economically viable farming systems (Rajeshwari, 2005; Wakene et al., 2007). In maize, significantly higher seed

*Corresponding author. E-mail: abdissabekele1@gmail.com.

yield (7.48 t ha^{-1}) was obtained with the application of VC at 5 t ha^{-1} along with the recommended dose of fertilizer when compared with VC alone (Pawar et al., 1995).

Although Ebantu district is humid and sub-humid in its agro-ecology, maize yield is low due to very high soil acidity and low fertility caused by high rainfall, continuous cropping using acidity accelerating mineral fertilizers and crop residue removal from fields. Hence, increasing yield in maize production could be taken as an important step and actual fertilizer recommendations should be made on the basis of experimental results for different nutrients. Farmers in the district do not practice proper application of lime and organic materials integrated with inorganic fertilizers.

However, research on an integrated nutrient management for maize production has not been conducted in the study area. Due to this gap of scientific studies, logical recommendations for combined application of VC and mineral P fertilizer with recommended lime rates were not employed for maize production in the study district. Thus, it is pertinent to study the effect of an integrated use of VC and mineral P fertilizers with lime to improve nutrient availability and hence, crop yield. Therefore, the objective of this study was to evaluate the effects of lime, VC and mineral P fertilizer on maize yield and yield components at the study site.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Ebantu district, East Wollega Zone of Oromia National Regional State (ONRS), Western Ethiopia (Figure 1). It is located at approximately 483 km from Addis Ababa and around 153 km from Nekemte, the capital city of East Wollega zone. The district lies between 9°58'30" to 10°14'0" N and 36°3'0" to 36° 89'40" E and covers an estimated area of 929 km^2 with an altitude that ranges from 1994 to 2176 meters above sea level (masl).

Geologically, the study area is covered by the metamorphic basement rocks in which tertiary volcanic rocks buildup and that is characterized by fine granular rock, small crystal which is invisible by naked eye. This rock is characterized by large vesicles from where gas escaped out and used for percolation of precipitation (Amenti, 1990). The predominant soil type in southwest and western Ethiopia in general and the study area in particular, is Dystric Nitisols according to (FAO, 2001) soil classification system. On average, the soil is deep and relatively highly weathered, well drained and very strongly to strongly acidic in reaction. Nitisols are highly weathered soils in the warm and humid areas of the west and southwest Ethiopia (Mesfin, 1998). Its vernacular name is "*Biyyee Diimaa*" meaning red soil.

The district receives an annual average rainfall of 1778 mm and has monthly mean minimum, maximum and mean air temperatures of 16.6, 20 and 18.3 °C, respectively (NMA, 2015) (Figure 2). The rainfall pattern is unimodal, stretching from April to October.

In terms of topography, 30% of the total area is gentle slope, while flat and steep slope lands account for 52 and 18%, respectively. Out of the total area of the district 35% is covered by cultivated land, 19% is grazing land, 20% is natural forest land, 16% is fallow land, 8% is shrubs and about 2% is estimated to be area covered by settlement (Ebantu district Agricultural development Bureau, 2014 unpublished).

According to the local and the Ethiopian agro-climatic zonation, the study area belongs to the humid (*Baddaa)* and sub-humid *(Badda Daree)* climatic zones (FAO, 1990). The economic activity of the local society of the study area is primarily mixed farming system that involves animal husbandry and crop production. Continuous cultivation without any fallow periods coupled with removal of crop residues is a common practice on cultivated fields. All farmers in the study area use diammonium phosphate (DAP) ($(NH_4)_2HPO_4$), urea ($CO(NH_2)_2$), and cow dung as sources of fertilizers. The major crops are maize (*Zea mays* L.), teff *(Eragrostis tef),* coffee (*Coffee arabica* L*.)*, barley *(Hordeum vulgare* L*)*, potato *(Solanum tubersoum* L.) and noug (*Guizotia abyssinica*)*.* These major crops are produced usually once per year (Ebantu district Agricultural development Bureau, 2014 unpublished).

Treatments, experimental design, and procedures

The experiment consisted of factorially combined three factors namely: two rates of lime (0 and 4 t $CaCO_3$ ha^{-1}), three rates of VC (0, 2.5, and 5 t ha^{-1}) and three rates of mineral P fertilizer (0, 20, and 40 kg P ha^{-1}) as triple superphosphate (TSP) or [$Ca(H_2PO_4)_2$], while N fertilizer was applied in the form of urea (46% N) to all treatments at rate of 69 kg N ha^{-1}. The rates of lime were calculated from the lime requirement using the acid saturation method and confirmed by incubation experiment. Treatments were laid out in randomized complete block design (RCBD) with three replications. Thus, there were 2*3*3 =18 treatment combinations, which contained 54 experimental plots each season.

The field experiment was conducted for two consecutive main cropping seasons of 2015 and 2016. A land with average pH of 4.81 was selected for the study and land preparation took place well in advance before sowing maize, as lime and VC need certain incubation period to bring change in physicochemical properties of the soil. Plot size was 5.1 m by 4.5 m with an area of 22.95 m^2. Total area used for this experiment was 52.5 m by 40.6 m (2131.5 m^2) including border areas. The experimental field was prepared following the conventional farmers' practices. The field was oxen ploughed three times before sowing. The seed bed was prepared by ploughing and harrowing using oxen and then leveled manually. All agronomic practices such as hoeing and weeding, were undertaken uniformly to all plots by hand.

The treatments of lime and VC were applied to the plots as per treatment in band according to the randomization set before sowing of maize; and left for two months of incubation period for lime and three weeks for VC. A hybrid maize variety (BH-660) was used as a test crop. An inter- and intra-row spacing of 75 cm and 30 cm was used, respectively. At the time of sowing one third of N fertilizer (69 kg N ha^{-1}) and the whole mineral P rates (0, 20, and 40 kg ha^{-1}) were applied as side dressing 2 cm apart from the maize seed and 5 cm deep into the soil. The remaining two third rate of N was applied at knee height stage of the crop.

Soil sampling and analysis

Soil samples from 0 to 20 cm depth were collected prior to maize planting in 2014 to analyze selected soil physicochemical properties. A Total of three composite samples were collected from the three blocks. Soil samples were collected by auger from eighteen sub-samples in each block and thoroughly mixed to make soil bulk density (ρ_b) of the area were collected at random by taking one sample per block using core method. All the laboratory activities were undertaken at Haramaya University and Nekemte

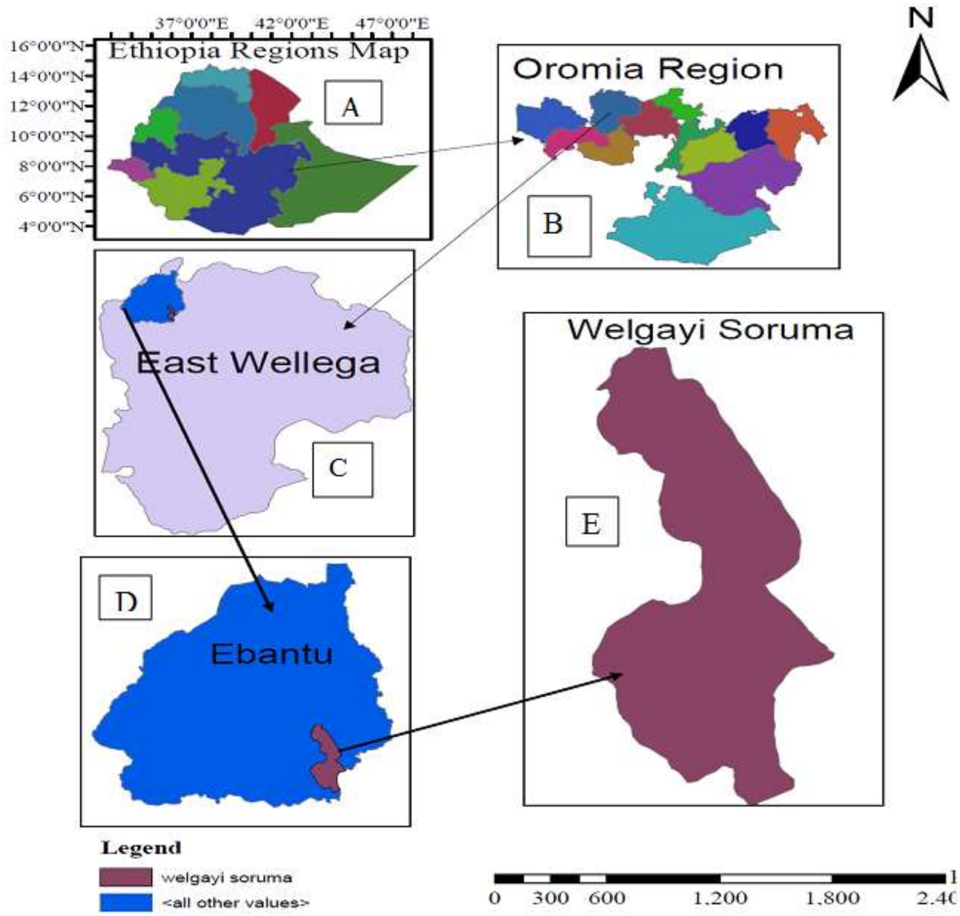


Figure 1. Location map of Ethiopian regions (A), Oromia National Regional State (ONRS) (B), East Wellega Zone (C), Ebantu district (D) and study site (E)

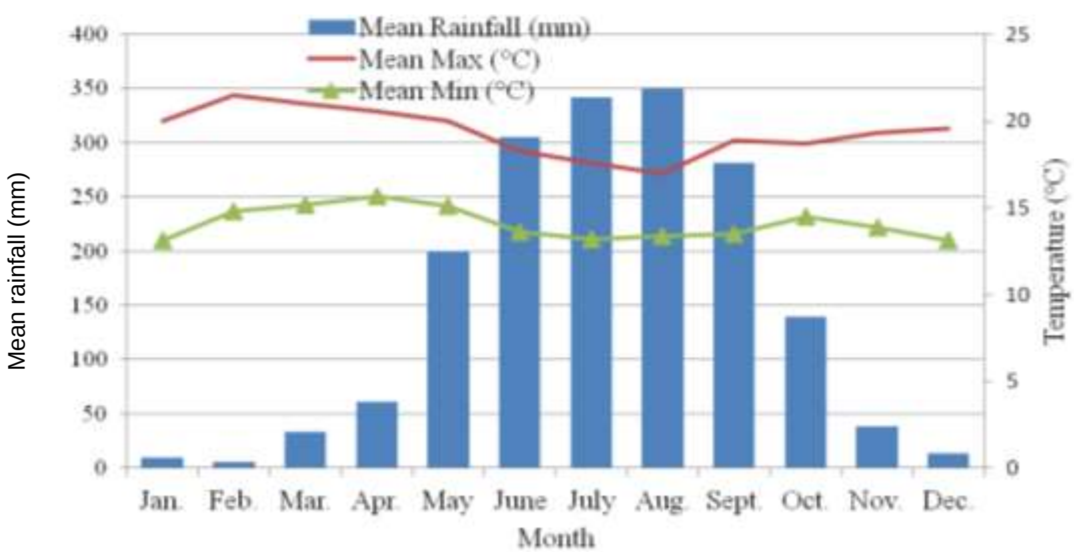


Figure 2. Mean monthly rainfall (mm), minimum and maximum temperatures (°C) of the study area recorded for the year from 2006-2015. Source: National Meteorological Agency; Gida Ayana Meteorological Station.

Soil Research Center according to standard laboratory procedures.

Soil particle size distribution was analyzed by the Bouyoucus hydrometer method (Bouyoucos, 1951). Soil ρ_b was measured from three undisturbed soil samples collected using a core sampler as per the procedure described by Jamison et al. (1950), while particle density (ρ_s) was measured using pycnometer (Barauah and Barthakulh, 1997) at the Nekemte Soil Research Center. Total porosity (ϕ) was calculated from the values of ρ_b and ρ_s (Brady and Weil, 1996) as:

$$\phi = \left(1 - \frac{\rho_b}{\rho_s}\right) * 100$$

Soil pH was measured potentiometrically in 1:2.5 soils: H_2O solution using a combined glass electrode pH meter (Chopra and Kanwar, 1976). Total exchangeable acidity was determined by saturating the soil samples with 1 M KCl solution as described by Rowell (1994). From the same extract, exchangeable Al in the soil samples was determined by application of 1 M NaF. Acid saturation (AS) was calculated from exchangeable acidity and CEC Rowell (1994).

$$\text{AS}(\%) = \frac{\text{Excchangeable acidity (cmol}_\text{c}\text{ kg}^{-1})}{\text{CEC (cmol}_\text{c}\text{ kg}^{-1})} \text{x} 100$$

Where:

AS = Acid saturation, CEC = Cation exchange capacity

Organic carbon (OC) content of the soil was determined by the wet combustion procedure of Walkley and Black (1934) and OM% was obtained by multiplying OC% by 1.724. The total nitrogen (N) content of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Available P was extracted by the Bray II method (Bray and Kurtz, 1945). Exchangeable basic cations (Ca, Mg, K, and Na) were determined by saturating the soil samples with 1M NH_4OAc solution at pH 7.0. Then Ca and Mg were determined by using atomic absorption spectrophotometry (AAS), while exchangeable Na and K were measured by flame photometer from the same extract. The cation exchange capacity (CEC) of the soil was determined from the NH_4^+ saturated samples that were subsequently replaced by K from a percolated KCl solution (Chapman, 1965). The extractable micronutrients (Fe, Mn, Zn, and Cu) were extracted by diethylene triamine pentaacetic acid (DTPA) as described by Sahlemedhin and Taye (2000) and all these micronutrients were measured by atomic absorption spectroscopy (AAS).

Analysis of vermicompost

Vermicompost was prepared from the raw materials like cow dung, sheep and goat faeces, dried chopped maize residues and chopped grasses by using red worm (*Eisenia fetida*). Selected parameters of VC were determined using dried samples which were ground to pass through a 2 mm sieve as described by Pisa and Wuta (2013). Electrical conductivity (EC) and pH were determined from a suspension of 1:10 VC: H_2O as described by Ndegwa and Thompson (2001). The total OC was estimated by wet combustion procedure of Walkey and Black (1934). Total OM% was obtained by multiplying total OC% by 1.8 (Emeterio and Victor, 1992). The total N content of the VC was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Total Ca, Mg, K, and Na were extracted by wet digestion using concentrated sulphuric acid (H_2SO_4), selenium (Se) powder, lithium sulphate (Li_2SO_4), and hydrogen peroxide (H_2O_2) mixture (Okalebo *et al*., 2002). Total Ca and Mg were determined from the wet digested samples by AAS while K and Na were estimated by flame photometer. Total P was extracted using concentrated H_2SO_4, Se powder, salicylic acid ($C_7H_6O_3$), and H_2O_2 mixture (Okalebo *et al*. 2002). Micronutrients (Fe, Mn, Zn, and Cu) were extracted using concentrated H_2SO_4, Se powder, $C_7H_6O_3$ and H_2O_2 mixture and their concentrations were determined from the wet digested samples by AAS (Okalebo *et al*. 2002).

Data collections and measurements

Agronomic data were collected during both growing seasons. The data collected were crop phenology, growth parameters, yield and yield components.

Crop phenology

Days to 50% tasseling (the number of days from planting to the start of shedding of pollen by 50% of maize plants in the plots) and days to 50% silking (number of days from planting to silking by 50% of the maize plants in the plots) were recorded at their respective stages. Days to physiological maturity (DPM) was recorded as the number of days after sowing to the formation of a black layer at the point of attachment of the kernel with the cob.

Growth parameters, yield and yield components

Plant height (PH) was measured in cm from the soil surface to the base of the tassel of ten randomly taken plants from the net plot area at physiological maturity. Data on leaf area (LA, cm^2) was taken to calculate leaf area index (LAI) for maize at 50% tasseling. The LA was determined using methods of McKee (1964). The width (W) and length (L) of leaves from 10 randomly taken plants in each plot was measured and LA was calculated (Uzun and Celik, 1999).

LA = W × L × 0.733

Where:

LA = Leaf area (cm^2)
W = Maximum leaf width (cm)
L = Maximum leaf length (cm)
0.73 = Correction factor for maize

Leaf area index (LAI) was then calculated by dividing leaf area per sampled ground area (Radford, 1967). Cob length (CL, cm) was measured during harvesting while number of grains per cob (NGPC) was recorded simply by counting for the ten plants picked randomly in the four central rows of the net area. Grain yield (GY) per plot was weighed in kg/plot and adjusted to12.5% moisture content and then converted to t ha^{-1} and above ground dry biomass yield (AGDBY, t ha^{-1}) for each plot were recorded after harvesting and air drying the samples to constant weight. Thousand seed weight (TSW) was weighed (g) and grain harvest index (HI) was calculated as the ratio of dried grain yield to the AGDBY.

Economic analysis

The economic analysis comprising partial budget with dominance and marginal rate of return was carried out. To estimate economic parameters, the marketable maize yield was valued based on average market price collected from the local markets during the two consecutive years of production immediately after harvest where average maize price was 8 Birr kg^{-1}. The average cost of P and VC were 15.96 and 1.00 Birr kg^{-1}, respectively. A wage rate of 40 Birr per man day^{-1} was used. In the partial budget analysis, total variable cost, gross field benefit, net benefit and marginal rate of return were employed. Total variable cost refers to the sum of all costs of variable inputs (fertilizers) and management practices. The gross field benefit ha^{-1} was obtained as the products of real price and the mean maize yield for each treatment adjusted to 10% whereas the net benefit ha^{-1} is the difference between the gross field benefit and total variable cost (CIMMYT, 1988). The dominance analysis procedure, which was used to select potentially profitable treatments, comprised ranking of treatments in an ascending order of total variable cost from the lowest to the highest cost to eliminate treatments costing more but producing a lower net benefit than the next lowest costing treatment was undertaken. For each pair of ranked non-dominated treatments, marginal rate of return was also calculated in percent. The percent marginal rate of return between any pair of undominated treatments denoting the return per unit of investment for crop production was analyzed. The marginal rate of return (%) was calculated (CIMMYT, 1988).

$$\text{MRR } (\%) = \frac{\Delta \text{NB}}{\Delta \text{TVC}} \text{ x } 100$$

According to CIMMYT (1988) for a treatment to be considered a worthwhile option to farmers, the marginal rate of return needed to be between 50 and 100% by taking the minimum acceptable rate of return to be 50%. The values of other materials used uniformly for each treatment were not considered in the budget for the partial economic analysis.

Statistical analysis

In all cases, the variations in the two consecutive years of the study were not significantly different and the error variances were homogeneous using the F-test as illustrated by Gomez and Gomez (1984). Thus, combined analysis of variance (ANOVA) for the two years data was performed using SAS 9.2 (SAS, 2004). Duncan's Multiple Range Test was employed to test the significant difference between means of treatments. Moreover, simple Pearson's correlation analysis was done to determine the association of various agronomic characters of maize with each other.

Table 1. Selected soil physical and chemical properties of the experimental soils.

Soil parameters	Value
Sand (%)	50
Silt (%)	38
Clay (%)	12
Textural class	Loam soil
ρ_b (g cm^{-3})	1.3
ρ_s (g cm^{-3})	2.28
ϕ (%)	43
pH (H_2O) (1:2.5)	4.81
Exchangeable acidity ($cmol_c$ kg^{-1})	2.44
Exchangeable Al ($cmol_c$ kg^{-1})	2.03
AS (%)	12
OM (%)	2.15
Total N (%)	0.18
Available P (mg kg^{-1})	4.6
Exchangeable Ca ($cmol_c$ kg^{-1})	3.51
Exchangeable Mg ($cmol_c$ kg^{-1})	1.61
Exchangeable K ($cmol_c$ kg^{-1})	0.27
Exchangeable Na ($cmol_c$ kg^{-1})	0.11
CEC ($cmol_c$ kg^{-1})	21
Fe (mg kg^{-1})	35.1
Mn (mg kg^{-1})	36.7
Zn (mg kg^{-1})	2.96
Cu (mg kg^{-1})	2.73

ρ_b =Bulk density; ρ_s = Particle density; ϕ =Total porosity; AS = Acid saturation; OM = Organic matter; Total N = Total nitrogen; CEC = Cation exchange capacity.

RESULTS AND DISCUSSION

Soil physicochemical properties before planting and vermicompost

The experimental soil is loamy in texture (Table 1). Soil pH of 4.81 was in the very strongly acidic soil range (Jones, 2003). The contents of exchangeable acidity and Al were relatively high. The OM content (2.15%) was low and total N (0.18%) was moderate according to Tekalign (1991). Available P was in the low range (0 – 10 $mgkg^{-1}$) (Clements and McGowen, 1994). The mean soil exchangeable Ca and K were in the low range, while exchangeable Mg was in medium range (FAO, 2006). The CEC of the soil was categorized as medium according to Roy et al. (2006). The soil DTPA-extractable Fe, Mn, and Zn were high whereas Cu was medium (Jones, 2003). Generally, the result of pre-soil analysis showed that the soils of the study site had acidity problem and were poor in chemical fertility. Selected nutrient contents and the pH of VC are presented in Table 2. These sources of the nutrients could be decomposition of VC by the activities of microorganisms. Through its contents, the VC can decrease soil acidity and increase soil fertility status in general.

Crop phenology

Tasseling, silking, and physical maturity

The ANOVA showed that the combined application of VC, mineral P and lime significantly (P ≤ 0.01) speeded up tasseling of maize (Table 3). Early days to tasseling were recorded with the application of lime, VC, and

Table 2. Chemical characterization of vermicompost.

Vermicompost	Value
pH (H_2O) (1:10)	7.5
EC (dSm^{-1}) (1:10)	5.2
Total OM (%)	25.74
Total N (%)	1.95
Total P ($g\ kg^{-1}$)	5.3
Ca ($cmol_c\ kg^{-1}$)	36.3
Mg ($cmol_c\ kg^{-1}$)	19.8
K ($cmol_c\ kg^{-1}$)	27.7
Na ($cmol_c\ kg^{-1}$)	14.2
Fe ($mg\ kg^{-1}$)	219
Mn ($mg\ kg^{-1}$)	397
Zn ($mg\ kg^{-1}$)	152
Cu ($mg\ kg^{-1}$)	95

EC = Electrical conductivity; Total OM = Total organic matter; Total N = Total nitrogen; Total P = Total phosphorus.

mineral P fertilizer at the rate of 4 t ha^{-1}, 5 t ha^{-1}, and 40 kg ha^{-1}, respectively. The latest days to 50% tasseling was obtained for the control. The application of each factor at maximum rates decreased days to tasseling by as much as 19 days (16%) as compared to the control. This may be due to rapid physiological activities observed with high plant nutrients availability via VC and mineral P fertilizer application with lime. In line with this result, Arancon *et al*. (2008) and Ramasamy and Suresh (2011) reported that VC stimulates plant flowering, increases the number and biomass of the flowers. Silking days were also hastened with the application of 5 t VC ha^{-1} and 20 kg P ha^{-1} with lime. Contrary to tasseling and silking, time to reach physiological maturity was highly significantly ($P \leq 0.001$) prolonged by the applications of lime, VC, and chemical P fertilizer (Table 3). The application of the highest rates of all the three factors prolonged the maturity of the maize plants by as much as 17 days compared to the control. An interesting observation is that in the control it took only 33 days to reach maturity after silking, but at the application of the highest rates of all the three factors, this period was extended to 75 days. There was thus much more time for growth and development in the plots well supplied with nutrients. Late maturity in response to increasing rate of lime, VC, and mineral P fertilizer may be ascribed to the availability of optimum nutrients contained in VC and increment of available P that may have led to prolonged maturity through enhanced leaf growth and photosynthetic activities thereby increasing partition of assimilate to the storage organ. This is supported by Jolien (2014) who reported that the maturity of maize was prolonged when treated by high dose of diammonium phosphate (DAP) and compost.

Plant height and leaf area index

The highest leaf area index was recorded at the plots treated by 5 t VC ha^{-1} and 40 kg P ha^{-1} with lime which was increased by 43% over the control (Table 4). The maximized leaf area index of maize at higher rates of treatments is attributed to enhanced vegetative growth. Zeinab *et al.* (2014) and Atarzadeh et al. (2013) also stated that the highest leaf area index was observed when plants were grown under integrated VC and inorganic fertilizers management. There was highly significant ($P \leq 0.001$) interaction effect of lime, VC, and mineral P fertilizer on plant height (Table 4). The tallest mean plant height was recorded in plots treated with high doses of VC and mineral P fertilizer integrated with lime while the shortest plant was recorded for the control. Maize plants grown in plots treated with nil fertilizer rates were stunted while plant height was increased with increasing VC, mineral P fertilizer, and lime rates. Hence, there was a clear synergistic effect between the treatments. In the unlimed plots VC and chemical P fertilizer increased plant height only slightly. Vermicompost had little effect also in limed plots that did not receive P fertilization. But plant height was increased by about 1 m in plots receiving lime, VC, and chemical P fertilizer. This is in harmony with the findings of Kannan et al. (2013) who reported that integrated nutrient management has positive effect on maize height. Manish et al. (2017) also reported that the tallest plant height was observed on the plots treated by VC and cattle manure, whereas the shortest was in the control. Similarly, Atarzadeh et al. (2013) also described that VC contains many humic acids which improve morphological traits of the crop and, thus, increase plant height.

Maize yield parameters and grain yield

Cob and seed characteristics

Application of lime, VC, and mineral P fertilizer had a significant ($P \leq 0.01$) effect on cob length (Table 5). Accordingly, the highest mean cob length was recorded in plots that received the highest rates of P and VC in the limed plots, where the cob length was 2.5 times higher than that of the control. The increase in the cob length might be attributed to the reduction in acidity and increase in nutrient availability, whereas the reduction in cob length of the control might be due to unavailability of nutrients as a result of lower pH and P sorption. This is supported by Oluwatoyinbo (2005) who indicated the possibility of increasing cob length by reducing soil acidity through the application of soil acidity amendments. A perusal of data presented in Table 5 also showed highly significant ($P \leq 0.001$) interaction effects of lime, VC, and mineral P fertilizer on grain number per cob. The highest grain number per cob (644) was recorded in plots treated with the highest doses of VC and mineral P with lime,

Table 3. Days to tasseling, silking and maturity of maize receiving different rates of lime, mineral P fertilizer and vermicompost (VC).

Lime and VC (t ha^{-1})		Crop phenology								
		Mineral P fertilizer (kg ha^{-1})								
Lime	VC	Tasseling (days)			Silking (days)			Maturity (days)		
-	-	0	20	40	0	20	40	0	20	40
-	0	121^{a}	116^{e}	111.3^{i}	131.3^{a}	123.3^{c}	120.8^{d}	164.8^{h}	172.0^{efg}	173.3^{def}
0	2.5	120^{b}	113^{fg}	111.7^{ghi}	128.7^{b}	124.0^{c}	120d^{e}	170.5^{g}	174.2^{de}	174.2^{de}
-	5	117^{cd}	114^{f}	112.3^{f-i}	123.5^{c}	123.3^{c}	120.5^{de}	172.5^{d-g}	172.8^{d-g}	174.8^{cd}
-	0	118^{c}	111.5^{hi}	106.3^{j}	118.8^{ef}	118.0^{f}	110.3^{h}	171.5^{fg}	170.8^{g}	173.5^{def}
4	2.5	116de	111.2^{i}	104.2^{k}	118.0^{f}	114.3^{g}	108.5^{i}	172.2^{efg}	174.2^{de}	178.2^{b}
-	5	113^{f-h}	106.3^{j}	102.3^{l}	119.0^{ef}	113.8^{g}	109.0^{hi}	172.8^{d-g}	177.2^{bc}	181.7^{a}
CV (%)	-	-	1.28	-	-	1.29	-	-	1.17	-
F-test	-	-	**	-	-	***	-	-	***	-
SE (±)	-	-	0.52	-	-	0.63	-	-	0.83	-

Means sharing the same letter(s) are not significantly different according to DMRT at 5% level of significance. **and *** indicate significance at P ≤ 1% and 0.1%, respectively. VC = Vermicompost; CV = Coefficient of variation; SE = standard error.

Table 4. Plant height and leaf area index of maize as affected by liming, and different rates of VC and chemical P fertilizer.

Lime and VC (t ha^{-1})		Growth parameters					
		Mineral P fertilizer					
		LAI			PH (m)		
Lime	VC	0	20	40	0	20	40
-	0	3.40^{k}	3.77^{j}	3.84^{hij}	2.07^{f}	2.26^{def}	2.30^{def}
0	2.5	3.79^{ij}	4.09^{fgh}	4.11^{fg}	2.17^{ef}	2.31^{def}	2.36^{de}
-	5	4.10^{fg}	5.08^{cd}	5.05^{cd}	2.23^{def}	2.45^{d}	2.41^{de}
-	0	4.04^{ghi}	4.34^{f}	5.02^{de}	2.39^{de}	2.46^{cd}	2.44^{d}
4	2.5	4.23^{fg}	4.77^{e}	5.30^{c}	2.43^{d}	2.81^{b}	2.71^{bc}
-	5	5.11^{cd}	5.56^{b}	5.91^{a}	2.45^{d}	3.40^{a}	3.48^{a}
CV (%)	-	-	4.94	-	-	8.74	-
F-test	-	-	**	-	-	***	-
SE (±)	-	-	0.09	-	-	0.09	-

Means sharing the same letter (s) are not significantly different according to DMRT at 5% level of significance. **and *** indicate significance at P ≤ 0.01 and 0.001, respectively. VC = Vermicompost; LAI = Leaf area index; PH = Plant height; CV = Coefficient of variation; SE = Standard error.

whereas the lowest (343) was recorded in the control (Table 5), which indicated an increase of about 112%. In addition to the higher number of grains, the grains were also significantly (P ≤ 0.001) heavier in maize receiving lime, VC, and /or chemical P fertilizer (Table 5). This might in turn have improved the normal development of maize with increasing grain number per cob. This is in line with the reports of Mihiretu (2014), who stated that maize seed setting is highly dependent and responsive to the amount and availability of P fertilizer during critical growth stages mainly the reproductive phase.

Thousand seed weight

The interaction effect of lime, VC and mineral P fertilizer had highly significant (P ≤ 0.001) effect on 1000-seed weight (Table 5). The highest mean 1000-seed weight (508 g) was recorded in plots treated with 2.5 t VC ha^{-1} and 40 kg P ha^{-1} with lime, while the lowest (255 g) was in the control indicating an increase of about 99% due to the treatments. Such high increase in 1000-seed weight might be due to the synergistic effects of the combined factors for better growth and grain filling of maize as well as effects of VC and lime in improving the physicochemical and biological soil properties. Besides the high rate of mineral P fertilizer, VC may play a paramount role in improving 1000-seed weight and other yield components. This is in consent with the reports of Negasi (2014), who stated that OM plays a significant role in plant nutrition through its positive effects on

Table 5. Effects of combined application of lime, vermicompost, and mineral P fertilizers on cob length, number of grain per cob, and 1000-seed weight of maize.

Lime and VC (t ha^{-1})		Yield parameters								
		Mineral P fertilizer (kg ha^{-1})								
		CL (cm)			NGPC			TSW (g)		
Lime	VC	0	20	40	0	20	40	0	20	40
	0	19.4^{k}	21.0^{jk}	23.2^{hijk}	343^{f}	389^{e}	436^{d}	255^{i}	297^{g}	375^{f}
0	2.5	20.4^{k}	25.4^{ghi}	27.1^{efg}	374^{e}	435^{d}	445^{cd}	283^{h}	426^{e}	454^{d}
	5	20.7^{jk}	29.8^{def}	30.4^{de}	388^{e}	463^{bcd}	470^{bc}	286^{h}	453^{d}	458^{d}
	0	24.5^{ghij}	21.6^{ijk}	22.3^{ijk}	453^{bcd}	442^{cd}	448^{bcd}	455^{d}	458^{d}	468^{c}
4	2.5	26.4^{fgh}	36.5^{bc}	37.8^{b}	475^{b}	444^{cd}	624^{a}	479^{b}	454^{d}	508^{a}
	5	32.7^{cd}	45.1^{a}	47.8^{a}	467^{bc}	620^{a}	644^{a}	458^{d}	505^{a}	505^{a}
CV (%)	-	-	11.92	-	-	5.47	-	-	1.24	-
F-test	-	-	**	-	-	***	-	-	***	-
SE (±)	-	-	1.38	-	-	10.37	-	-	2.14	-

Means sharing the same letter(s) are not significantly different according to DMRT at 5% level of significance. **, *** indicate significance at P ≤ 0.01 and 0.001, respectively. VC = Vermicompost; CL = Cob length; NGPC = Number of grain per cob; TSW = Thousand seed weight; CV=Coefficient of variation; SE = Standard error.

Table 6. Effects of combination of lime, vermicompost, and mineral P fertilizers on grain yield, above ground dry biomass yield, and harvest index of maize.

Lime and VC (t ha^{-1})		Yield parameters								
		Mineral P fertilizer (kg ha^{-1})								
		GY (t ha^{-1})			AGDBY (t ha^{-1})			HI (%)		
Lime	VC	0	20	40	0	20	40	0	20	40
-	0	2.18^{g}	2.36g	3.05^{e}	16.1^{g}	16.5^{g}	16.8^{fg}	13.6^{i}	14.4^{hi}	16.9^{ef}
0	2.5	2.30^{g}	3.03^{e}	3.95^{d}	16.3^{g}	17.0^{efg}	18.4^{de}	14.3^{hi}	17.9^{ef}	21.5^{bc}
-	5	2.36^{g}	4.25^{c}	4.03^{d}	16.5^{g}	18.6^{cde}	18.7^{cd}	14.5^{ghi}	23.0^{ab}	21.5^{bc}
-	0	2.20^{g}	2.77^{f}	2.94^{ef}	16.5^{g}	17.1^{efg}	18.2^{def}	13.4^{i}	16.3^{fg}	16.2^{fgh}
4	2.5	3.13^{e}	4.07^{cd}	4.87^{a}	17.1^{efg}	18.5^{cde}	20.0^{c}	18.3^{de}	22.0^{b}	24.4^{a}
-	5	4.02^{d}	4.55^{b}	4.73^{ab}	18.3^{def}	22.7^{b}	25.9^{a}	22.0^{bc}	20.1^{cd}	18.3^{de}
CV (%)	-	-	5.52	-	-	7.40	-	-	9.01	-
F-test	-	-	***	-	-	*	-	-	***	-
SE (±)	-	-	0.08	-	-	0.55	-	-	0.67	-

Means sharing the same letter(s) are not significantly different according to DMRT at 5% level of significance. *and *** indicate significance at P ≤ 0.5 and 0.001, respectively. VC = Vermicompost; GY = Grain yield; AGDBY = Above ground dry biomass yield; HI = Harvest index; CV = Coefficient of variation; SE = Standard Error.

nutrient supply to plant roots, in improving soil structure, water holding capacity, and other soil properties.

Above ground dry biomass yield (AGDBY)

The results of ANOVA indicated that there is a significant interaction effect of lime, VC, and mineral P fertilizer (P ≤ 0.001) on AGDBY of maize (Table 6). The highest mean AGDBY (12.18 t ha^{-1}) was recorded in plots treated with the highest rates of VC and mineral P along with lime, while the minimum (5.02 t ha^{-1}) was in the control with a difference of about 7.16 t ha^{-1}. This difference might be due to synergistic effects of lime, VC, and mineral P fertilizer as well as high doses of mineral P and VC used for luxuriant vegetative growth of plants. These results are in line with that of Makinde and Ayoola (2010), who demonstrated that the application of OM as fertilizers provides growth regulating substances and improves physicochemical and microbial properties of soils.

Grain yield (GY)

The results of ANOVA showed that, the highest mean grain yield (4.87 t ha^{-1}) was recorded in plots treated with40 kg P ha^{-1} and 2.5 t VC ha^{-1} with lime, while the lowest (2.18 t ha^{-1}) was recorded in the control (Table 6).

Table 7. Partial budget and dominance analyses of lime, vermicompost, and mineral P fertilizer on maize (2-years data pooled).

Lime (t ha^{-1})	P (Kg ha^{-1})	VC (t ha^{-1})	TVC (ETB ha^{-1})	Ad GY (t ha^{-1})	GFB (ETB ha^{-1})	NB (ETB ha^{-1})	Dominance
0	0	0	0	2.18	17467	17467	UD
4	0	0	200	2.20	17573	17373	D
0	20	0	1721	2.36	18907	17186	D
4	20	0	1921	2.77	22187	20266	UD
0	0	2.5	2660	2.30	18427	15767	D
4	0	2.5	2860	3.13	25013	22153	UD
0	40	0	3282	3.05	24387	21105	D
4	40	0	3482	2.94	23533	20051	D
0	40	2.5	4381	3.03	24267	19886	D
4	40	2.5	4581	4.07	32547	27966	UD
0	0	5	5160	2.36	18880	13720	D
4	0	5	5360	4.02	32160	26800	D
0	40	2.5	5942	3.95	31613	25671	D
4	40	2.5	6142	4.88	39013	32871	UD
0	20	5	6881	4.25	33960	27079	D
4	20	5	7081	4.55	36413	29332	D
0	40	5	8442	4.03	32240	23798	D
4	40	5	8642	4.73	37827	29185	D

VC = Vermicompost; TVC = Total variable cost; Ad GY = Adjusted grain yield; GFB = Gross field benefit; NB = Net benefit; D = dominated; UD = Undominated.

The maximum grain yield is due to high plant height, cob length, grain numbers per cob, and AGDBY. This is also supported by the correlation in which grain yield had highly significant ($P \leq 0.001$) and very strong positive correlations ($r = 0.81$, 0.78 and 0.81) with AGDBY, NGPC and CL, respectively (Table 9). This high discrepancy between the highest and lowest grain yields seems also to be due to synergistic effects of these treatments. From Table 6 it is obvious that liming alone did not increase yield and neither did VC when applied without liming and chemical P fertilizer. But combined use of lime and VC almost doubled the yield compared to the control even without chemical P fertilizer. Also, the effect of chemical P fertilizer was much greater when integrated with lime and VC. This is in agreement with reports of Bayu et al. (2006) and Makinde and Ayoola (2010) who concluded that high and sustainable crop yields are only possible with integrated use of mineral fertilizers and OM. Tilahun et al. (2013) also verified that integrated fertilizers application gave the maximum grain yield compared to the control. Similarly, Dilshad et al. (2010) reported that improvement in yield can be obtained if soil fertility is maintained through the combined use of organic and inorganic fertilizers. Furthermore, high doses of VC increased grain yield since it improved soil physicochemical and microbial conditions and then facilitating maize crop growth. This is supported by the findings of Adrien et al. (2010), who reported that the application of composted paper sludge led to high maize yields. Babbu et al. (2015) also reported that the highest maize grain yield was in treatment having NPK with FYM, whereas the lowest was in non-treated plots showing the beneficial effects of manure on crop performance.

Harvest index (HI)

Results of ANOVA revealed that HI was strongly and significantly ($P \leq 0.001$) affected by the interaction effects of lime, VC, and mineral P fertilizer (Table 6). The highest mean grain HI (24.4%) was observed in plots treated by 2.5 t VC ha^{-1} and 40 kg P ha^{-1} with lime, while the lowest (13.4%) was observed when only lime was applied without VC and mineral P fertilizer (Table 6). This might be due to the increment of the availability of essential nutrients for crops when the acidic soils were treated by the integration of VC and mineral P with lime. Along with this, Hamidia et al. *(*2010) suggested that mineral P plays great role for maximum utilization of nutrients in acidified soils.

Economic return

The production of maize in two different years under fertilizer management involved different costs that affected total cost of production based on different treatments that were applied in the growing seasons (Table 7). The treatments that received 4 t $CaCO_3$ ha^{-1}, 5 t VC ha^{-1}, and 40 kg P ha^{-1} showed the highest total variable cost of 8642 Birr ha^{-1} followed by 5 t ha^{-1} of VC

Table 8. Marginal rate of return analysis of lime, vermicompost and mineral P fertilizer for maize production (2-years data pooled.

Lime (t ha^{-1})	P_2O_5 (Kg ha^{-1})	VC (t ha^{-1})	TVC (ETB ha^{-1})	Ad GY (t ha^{-1})	GFB (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
0	0	0	-	2.18	17467	17467	-
4	20	0	1921	2.77	22187	20266	146
4	0	2.5	2860	3.13	25013	22153	201
4	20	2.5	4581	4.07	32547	27966	338
4	40	2.5	6142	4.88	39013	32871	314

VC = Vermicompost; TVC = Total variable cost; Ad GY= Adjusted grain yield; GFB = Gross field benefit; NB = Net benefit; MRR = Marginal rate of return.

and 40 kg ha^{-1} of mineral P with nil lime with total variable cost of 8442 Birr ha^{-1} (Table 7).

The adjusted average maize yields obtained from a hectare of land were highest at the rate of 4 t $CaCO_3$ ha^{-1}, 2.5 t VC ha^{-1} and 40 kg P ha^{-1} fertilizer with 4.88 t ha^{-1} followed by 4 t $CaCO_3$ ha^{-1}, 5 t VC ha^{-1}, and 40 kg P ha^{-1} fertilizer with 4.73 t ha^{-1}, whereas the lowest (2.18 t ha^{-1}) was at the control. The highest net benefit (32871 Birr ha^{-1}) of maize was obtained at the rate of 4 t $CaCO_3$ ha^{-1}, 2.5 t VC, ha^{-1} and 40 kg P ha^{-1} fertilizer followed by 4 t $CaCO_3$ ha^{-1}, 5 t VC ha^{-1}, and 20 kg P ha^{-1} fertilizer with 29332 Birr ha^{-1}, while the lowest (17467 Birr ha^{-1}) was at the control as shown in Table 7. This might be due to the fact that integrated application of organic and inorganic fertilizers in general and OM such as VC together with lime in particular improved the economic advantage of the farmers cultivating acidic soil areas.

Marginal rate of return was analyzed for the treatments which indicated that the highest is observed at treatment rates of 4 t $CaCO_3$ ha^{-1}, 2.5 t VC ha^{-1}, and 20 kg P ha^{-1} followed by 4 t $CaCO_3$ ha^{-1}, 2.5 t VC ha^{-1}, and 40 kg P ha^{-1} with 338 and 314 Birr, respectively. It seems that liming alone was not very profitable. The same applies to VC alone, and chemical P fertilizer alone. The highest benefits appeared to require combined use of different additions, and the use of chemical P fertilizer.
Hence, treatment with 4 t $CaCO_3$ ha^{-1}, 2.5 t VC ha^{-1}, and 20 kg P ha^{-1} gave a rate of return above the minimum acceptable rate of return (50%) considered in this study. The treatment with 4 t $CaCO_3$ ha^{-1}, 2.5 t VC ha^{-1}, and 20 kg P ha^{-1} had also the highest net benefit (27966 Birr ha^{-1}) next to the treatment of 4t $CaCO_3$ ha^{-1}, 2.5 t VC ha^{-1}, and 40 kg P ha^{-1} with the net benefit of 32871 Birr ha^{-1}. Therefore, treatment with 4 t $CaCO_3$ ha^{-1}, 2.5 t VC ha^{-1}, and 20 kg P ha^{-1} can be recommended for farmers in the study area as it can be taken as the best combination for optimum maize yield offering high marginal rate of return above the proposed minimum acceptable rate of return of 50 to 100% (CIMMYT, 1988) (Table 8).

Conclusion

Integrated nutrient management mainly use of vermicompost and mineral P fertilizers with lime has been getting attention because of its high ability to ameliorate soil acidity, improve soil fertility and eventually crop yield sustainably. The results of the study demonstrated that there was a significant increase in yield and yield components of maize due to the application of vermicompost and mineral P fertilizer with lime over the control. Since maize is a huge feeder of nutrients, application of high dose of mineral P fertilizer together with good nutrients sources of vermicompost has paramount importance in reclaiming soil acidity and enhancing soil fertility, and improving maize yield and yield components. From this study, it is possible to deduce that integrated application of organic and mineral fertilizers with lime amended the acidic soils and improved its fertility which in turn increased crop yields. Hence, combination of vermicompost at (2.5 t ha^{-1}) and mineral P fertilizer at (20 kg ha^{-1}) with lime at 4 t ha^{-1} is optimum and could be recommended for reclaiming soil acidity and improve nutrients for maize as it enhanced grain yield and yield components of maize plant in strongly acidic soils.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

We would like to thank Ministry of Education of the Federal Democratic Republic of Ethiopia for its financial support through Haramaya University. We also acknowledge Ebantu Woreda Agriculture Bureau for their support during field work.

REFERENCESS

Abreha K, Heluf G, Tekalign M, Kindie T (2013). Wheat crop response to liming materials and N and P fertilizers in acidic soils of Tsegedie highlands, northern Ethiopoa. Agric. For. Fish. 2(3):126-135.

Adrien N, Drapeau A, Nduwamungu C (2010). Fresh and Composted Paper Sludges Sustain Soil Productivity, Hindawi Publishing Corporation Int. J. Agron. 58:49-60.

Alemayehu S, Dorosh P, Sinafikeh A (2011). Crop Production in

Ethiopia: Regional Patterns and Trends. Development Strategy and Governance Division, International Food Policy Research Institute, Ethiopian Strategy Support Program II, Ethiopian Development Research Institute, ESSP II Working Paper No 0016. pp. 1-3.

Amenti A (1990). Studied rock units of western Ethiopia, Geological .Survey. Addis Ababa, Ethiopia. Bull. Note 305:14.

Angin L, Aksakal EL, Oztas T, Hanay A (2013). Effects of municipal solid waste compost (MSWC) application on certain physical properties of soilssubjected to freeze-thaw. Soil Tillage Res. 130:58-61.

Arancon NQ, Edwards CA, Bierman P, Metzger JD, Lucht C (2008). Effects of vermicompost produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. Pedobiologia 49:297-306.

Asmare M, Markku YH, Birru Y (2015). Effects of Lime, Wood Ash, Manure and Mineral P Fertilizer Rates on Acidity Related Chemical Properties and Growth and P Uptake of Wheat (*Triticum aestivum* L.) on Acid Soil of Farta District, Northwestern Highlands of Ethiopia. Int. J. Agric. Crop Sci. 8(2):256-269

Atarzadeh SH, Mojaddam M, Saki NT (2013). The interactive effects humic acid application and several of nitrogen fertilizer on remobilization star wheat. Int. J. Biosci. 3(8):116-123.

Babbu SB, Jagdeep S, Gurbir S, Gurpreet K (2015). Effects of Long Term Application of Inorganic and Organic Fertilizers on Soil Organic Carbon and Physical Properties in Maize–Wheat Rotation. Agronomy 5:220-238.

Barauah TC, Barthakulh HP (1997). A Text Book of Soil Analysis. Vikas Publishing House, New Delhi, India P 334.

Barbieri PA, Echeverria HE, Rozas HS, Andrade FH (2008). Nitrogen use efficiency in maize as affected by nitrogen availability and row spacing. Agronomy 100:1094-1100.

Bayu W, Rethman NFG, Hammes PS, Alemu G (2006). Application of farmyard manure improved the chemical and physical properties of the soil in a semi-arid area in Ethiopia. Biol. Agric. Hortic. 24(3):293-300.

Bouyoucos GH (1951). A recalibration of the hydrometer for making mechanical analysis of soils. Agric. J. 43:434-438.

Brady NC, Weil RR (2014). The Nature and properties of soils. 14th edition P. 960.

Brady NC, Weil RR (1996). The nature and properties of soils (11th ed.). Prentice Hall, New York. P 621.

Bray HR, Kurtz LT (1945). Determination of organic and available forms of phosphorus in soils. Soil Sci. 9:39-46.

Bremner JM, Mulvaney CS (1982). Nitrogen-total. In Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, 2 Ed. (Eds Page A.L, Miller R.H. and Keeney D.R.). Madison, WI: American Society of Agronomy. pp. 595-624.

Bunemann EK, Steinebruner F, Smithson PC, Frossard E, Oberson A (2004). Phosphorus dynamics in highly weathered soil as revealed by isotopic labeling techniques. Soil Sci. Soc. Am. J. 68:1645-1655.

Chaoui I, Zibiliske M, Ohno T (2003). Effects of earthworm casts and compost on soil microbial activity and plant nutrient availability. Soil Biol. Biochem. 35:295-302.

Chapman HD (1965). Cation exchange capacity by ammonium saturation. In: C.A. Black (ed.). Methods of Soil Analysis. Agronomy Part II, No. 9. American Society of Agronomy. Madison, Wisconsin, USA. pp. 891-901.

Chopra SH, Kanwar JS (1976). Analytical Agricultural Chemistry. Kalyani Publisher. P. 489.

CIMMYT (International Maize and Wheat Improvement Center) (1988). From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely Revised Edition. Mexico, D.F. pp. 13-76.

Clements B, McGowen I (1994). Strategic fertilizer use on pastures. NSW Agriculture. Agnote Reg. 4/57, Orange, NSW.

Central Statistical Agency (CSA) (2017). Agricultural Sample Survey, 2016/17. Report on Area and production of major crops (Private Peasant Holdings, meher season), Addis Ababa, Ethiopia.

Darzi MT, Haj Seyed Hadi MR, Rejali F (2011). Effect of vermicompost and phosphate biofertilizer, Stat. Bull. 278. Vol. I application on yield and yield components in Anise (*Pimpinella anisum* L.). Iran. J. Med. Arom. Plants 4(50):452-465.

Ethiopia Commodity Exchange Authority (ECEA) (2009). Understanding Maize: A Review of Supply and Marketing Issues, Economic Analysis, Addis Ababa, Ethiopia. pp. 5-41.

Elfstrand S, Bath B, Martensson A (2007). Influence of various forms of green manure amendment on soil microbial community composition, enzyme activity and nutrient levels in leek. Appl. Soil Ecol. 36:70-82.

Fairhurst TR, Lefroy R, Mutert E, Batijes N (1999). The importance, distribution and causes of phosphorus deficiency as a constraint to crop production in the tropics. Agrofor. Forum 9(4):2-8.

FAO (Food and Agriculture Organization of the United Nations) (2006). World reference base for soil resources: A framework for international classification, correlation and communication. 2nd Edition, World Soil Resources Reports No. 103. FAO, Rome. Italy.

FAO (Food and Agriculture Organization of the United Nations) (2015). FAOSTAT. Available online at: http://www.fao.org/faostat/en/#data/QC

Food and Agriculture Organization of the United Nations (FAO) (1990). Soil Map of the World: Revised legend, World soil resource report 60. FAO, Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO) (2001). Lecture notes on the major soils of the world. Driessen, P., J. Deckers, and F. Nachtergaele, (eds.). Food and Agricultural Organizations, Rome, Italy.

Gaume A, Mächler F, Frossard E (2001). Aluminium resistance in two cultivars of Zea mays L.: Root exudation of organic acids and influence of phosphorus nutrition. Plant Soil 234:73-81.

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research.2nd edition. John Wiley and Sons, Inc. pp. 84-118.

Gutiérrez-Miceli FA (2008). Sheep manure vermicompost supplemented with a native diazotrophic bacteria and mycorrhizas for maize cultivation. Bioresour. Technol. 99:7020-7026.

Haj Seyed Hadi MR, Darzi MT, Riazi GH, Ghandehari Z (2011). Effects of vermicompost and amino acids on the flower yield and essential oil production from *Matricaria chamomile* L. J. Med. Plants Res. 5(23):5611-5617.

Hamidia A, Khodabande N, Mohammad AD (2010). Plant density and nitrogen effects on some traits of maize (*Zea mays* L.). Plant Ecophysiol. 2:47-52.

Jamison VC, Weaver HH, Reed IF (1950). A hammer-driven soil core sampler. Soil Sci. 69:487-496.

Johannes K (2013). A Soiled Reputation: Adverse Impacts of Mineral Fertilizers in Tropical Agriculture. Association for Agriculture and Ecology, Christine Chemnitz (Heinrich Böll Foundation), WWF, Germany. pp. 6-58.

Jolien VH (2014). Evaluation of the effects of compost on soil properties, performance and yield of maize and beans in Kenya. M.Sc. Thesis. Universiteit Gent. Available at: https://lib.ugent.be/fulltxt/RUG01/002/166/414/RUG01-002166414_2014_0001_AC.pdf

Jones JB (2003). Agronomic Handbook: Management of Crops, Soils, and Their Fertility. CRC Press LLC, Boca Raton, FL, USA. 482p.

Kannan RL, Dhivya M, Abinaya D, Krishna RL, Krishnakumar S (2013). Effect of integrated nutrient management on soil fertility and productivity in maize. Bull. Environ. Pharm. Life Sci. 2(8):61-67.

Kanyanjua SM, Ireri L, Wambua S, Nandwa SM (2002). Acid soils in Kenya: Constraints and remedial options. KARI Technical Note No. 11.

Lazcano C, Revilla P, Malvar RA, Domínguez J (2011). Yield and fruit quality of four sweet corn hybrids (*Zea mays*) under conventional and integrated fertilization with vermicompost. J. Sci. Food Agric. In press.

Lordan J, Pascual M, Fonseca F (2013). Use of rice husk to enhance peach tree performance in soil switch limiting physical properties. Soil Till. Res. 129:19-22.

Mahdavi DA, Deihim FR, Mirzaei TPR (2007). Sustainable soils: role of organic matter in sustaining soil fertility. Martyr Beheshti University. pp. 91-95.

Makinde EA, Ayoola OT (2010). Growth, yield and NPK uptake by maize with complementary organic and inorganic fertilizers. African J. Food, Agric. Nutri. Dev. 10(3).

Manish KP, Prakash M, Salikram G (2017). Growth Attributing Traits of Maize Affected by Different Nutrient Management in Lamjung Nepal.

Int. J. Appl. Sci. Biotechnol. 5(1):98-101.
Materechera SA (2012). Using wood ash to ameliorate acidity and improve phosphorus availability in soils amended with partially decomposed cattle or chicken manure. Commun. Soil Sci. Plant Anal. 43:1773-1789.
Mbah CN, Nkpaji D (2010). Response of Maize (Zea mays L) to Different Rates of woodash Application in acid Ultisol in Southeast Nigeria. J. Am. Sci. 6(1):53-57.
Mesfin A (1998). Natures and Management of Ethiopian Soils. Alemaya University of Agriculture, Ethiopia. P. 272.
Mihiretu S (2014). Effect of application of lime ($CaCO_3$) and phosphorus on yield and yield components of maize (*Zea mays* L.) on Nitisols at Wolaita Sodo, Southern Ethiopia. M.Sc. Thesis. Haramaya University
Nagavallemma KP, Wani SP, Lacroix S, Padmaja VV, Vineela C, BabuRao M, Sahrawat KL (2004). Vermicomposting: Recycling wastes into valuable organic fertilizer. Global Theme on Agrecosystems Report no. 8. Patancheru 502-324, Andhra Pradesh, India: International Crops Res. Inst. Semi-Arid Trop. 20 pp.
Ndegwa PM, Thompson SA (2001). Integrating composting and vermicomposting in the treatment and bioconversion of solids. Bioresour. Technol. 76:107-112.
Negasi T (2014). Characterization of Soil Nutrient Management and Post-harvest Handling Practices of Onion (*Allium cepa* L.) and Response of the Crop to Fertilization in Central Rift Valley of Ethiopia, PhD Dissertation, Haramaya University, Haramaya, Ethiopia.
NMA (National Meteorological Agency) (2015). Gida Ayana Weather Station rainfall and temperature data. NMA, Assosa, Ethiopia. https://en.climate-data.org/location/765670/
Okalebo JR, Guthua KW, Woomer PJ (2002). Laboratory Methods of Soil and Plant Analysis: A Working Manual. Tropical Soil Biology and Fertility Programme -CIAT and SACRED Africa, Nairobi, Kenya 128 pp.
Okoko NK, Makworo S (2012). Evaluation of the Effect of Compost and Inorganic Fertilizer on Maize Yield in Nyamira District, Southwest Kenya. Kenyan Agricultural Research Institute, Regional Research Centre, Kisii, Kenya pp. 23-29.
Oluwatoyinbo FI, Akande MO, Adediran JA (2005). Response of Okra (*Abelmoschus esculentus*) to lime and PHOSPHORUS fertilization in an acid soil. World J. Agric. Sci. 1:178-183.
Onweremadu EU (2007). Predicting phosphorous sorption characteristics in highly weathered soils of South-Eastern Nigeria. Res. J. Environ. Sci. 1:47-55.
Opala PA, Kisinyo PO, Nyambati RO (2015). Effects of farmyard manure, urea and phosphate fertilizer application methods on maize yields in western Kenya. J. Agric. Rural Dev. Trop. Subtrop. 116(1):1-9.
Pawar RB, Patil CV, Prakash SS, Yeledhalli NA (1995). Dynamics of earthworm soil plant relationship in semiarid tropics. In*:* Abst. of Seminar on Conservation of National Resources for Sustainable Production*,* November 16-17 1995, University of Agricultural Sciences, Dharwad (India) P 37.
Pisa C, Wuta M (2013). Evaluation of composting performance of mixtures of chicken blood and maize stover in Harare, Zimbabwe. Int. J. Recycl. Organic Waste Agric. 2(5):1-11.
Radford PJ (1967). Growth analyses formula - their use and abuse. Crop Sci. 7:171-175.
Rautaray SK, Ghosh BC, Mittra BN (2003). Effect of fly ash, organic wastes and chemical fertilizers on yield, nutrient uptake, heavy metal content and residual fertility in a rice-mustard cropping sequence under acid lateritic soils. Bioresour. Technol. 90:275-283.
Rowell DL (1994). Method and Applications. Addison Wesley Longman Limited, England. P 350.
Roy RN, Finck A, Blair GJ, Tandon HLS (2006). Plant Nutrition for Food Security: A guide for integrated nutrient management. FAO fertilizer and plant nutrition bulletin. FAO, Rome P 348.
Sahlemedhin S, Taye B (2000). Procedures for soil and plant analysis. Technical paper 74, National Soil Research Center, Ethiopian Agricultural Research Organization (EARO), Addis Ababa.
Statistical Analysis System (SAS), 2004. SAS/STAT user's guide. Proprietary software version 9.2. SAS Inst., Inc., Cary, NC.
Tekalign T (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working document No. 13. International Livestock Research center for Africa, Addis Ababa.
Tesfaye B (2017). Composition of different composts and vermicompost and effects of their application rates on growth parameters of pot grown tomato. Afr. J. Agric. Res. 12(18):1514-1525.
Tilahun T, Nigussie D, Wondimu B, Setegn G (2013). Effect of farmyard manure and inorganic fertilizers on the growth, yield and moisture stress tolerance of rain-fed lowland rice. Am. J. Res. Commun. 1(4):275-301.
Uzun S, Celik H (1999). Leaf area prediction models (uzcelik-1) for different horticultural plants. Turk. J. Agric. For. 23:645-650.
Wael MN, Leon VR, Sarina C, Oswald B (2011). Effect of Vermicompost on Soil and Plant Properties of Coal Spoil in the Lusatian Region (Eastern Germany). Karl-Liebknecht Strasse 24-25, 14476.
Wakene N, Fite G, Abdenna D, Berhanu D (2007). Integrated Use of Organic and Inorganic Fertilizers for Maize Production. Utilization of diversity in land use systems: Sustainable and organic approaches to meet human needs. University of Rostock, Institute of Land Use, Justus-von-Liebig, Rostock, German pp. 1-18.
Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and proposed modification of the titration method. Soil Sci. 37:29-38.
Zarina B, Ullah N, Mmuh K, Akram A, Khan QU, Khan MJ, Batool S, Makhdoom K (2010). Maize response to integrated use of NP-fertilizers and compost, Department of Soil and Environmental Sciences, Faculty of Agriculture, Gomal University, Dera Ismail Khan, Pakistan. Pak. J. Bot. 42(4):2793-2801.
Zeinab AB, Hossein Z, Masoud R (2014). Effect of Vermicompost and Chemical Fertilizers on Growth Parameters of three Corn Cultivars. J. Appl. Sci. Agric. 9(9):22-26.