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Full Length Research Paper

Population growth and its environmental impact in Syria: A case study of Lattakia region

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This paper investigates and monitors the impact of population growth on the standard of living in the Lattakia region of Syria Arab Republic. It focuses on the effect of pollution on population growth in the region and how this affects the surface and groundwater resource. There has been symmetrical expansion of the agricultural and urban sectors in Lattakia as its population increased and this has caused negative effect on the water quality resource available in the region. For the purpose of this research, the region of Lattakia has been divided into four study areas; Firstly, Alsin River area, which is the main source of drinking water in the region, is designated as area (A1). While the east of Gable town is designated as area (A2), and area (A3) includes the main city of Lattakia and its countryside, and area (A4) is made up of the largest rivers in the costal basin. Chemical, biochemical and bacterial tests were carried out, and the results obtained shows the existence of chemical and bacterial contaminants and it was also observed that the surface and ground water in area (A1), which is the main source of drinking water in the region is polluted with bacteria *Escherichia coli*. Laboratory tests investigations carried out proved the existence of germs type *E. coli* in excessive concentration of bacteria from sewage, and high value of nitrate and nitrite ions in area A2 which are predominantly used for agricultural activities. The results from area (A3) and (A4) shows the existence of chemical and bacterial contaminations and the increase in the rates of pollution in area P1 (springs great north River Area) to the estuary area P2 (the estuary point the great north river in the sea) and the presence of a strong correlation between the number of inhabitants in the area of the river and increase in the rates and various types of pollution. This research was carried out just before the commencement of the crisis in The Syrian Arab Republic.

Key words: Lattakia, pollution, rain fall, great north river, nitrate, *Escherichia coli*, nitrite, biological oxygen demand (BOD).

INTRODUCTION

Population growth and rising demand for improve standard of living in terms of agricultural, industrial and housing activities by human being has led to many global environmental problems (McMichael, 2000). Water

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pollution is one of the most significant problem caused by anthropogenic activities by man, due to his neglect of environmental rules (wastewater, spraying pesticide, used fertilizers in agriculture, remnants of the olive oil industry, and salinity of sea water intrusion (Owens et al., 2005).

In the region of Lattakia, in Syria, wastewater (domestic, industrial and run off) is dispose off by combined sewage collection system which is discharged at several coastal sites to the north and south borders of the city. Lattakia city lacks waste water treatment facility, and all the waste water produced in the city is discharged directly to the coastal zone near tourist attraction centres and this usually causes harm and endangers the safety and health of inhabitants living in these places and negatively impact both tourist and aquatic activities (Sabouh and Chahin, 1997).

The situation in the countryside and in smaller towns in the region is much worse, sewage network covers only 30% of households and ends in the next valley, home cesspools are built without compliance with prescribed standards and becomes a source of pollution of the surrounding waters. The geological formations in the study area, such as rains, flood issue and soil erosion has a great effect on the determination of the concentration of chemical electrolytes in water and fill dams. The presence of ammonium ions is linked to a large degree of sewage leakage. And the art of drilling in areas that are not connected to sewage networks (http://www.damasuniv.edu.sy/mag/farm/old/agri_pdf/2002/18-1/kbeebo.pdf)

Microbial and biochemical tests carried out showed presence of intestinal bacteria, especially fecal coliforms (FC) at different levels of water bodies in many parts of Lattakia region, especially in the north great river estuary. This further increase the rate of pollution and contamination of water bodies in Lattakia, especially in areas prone to sewers and the rivers estuary. A good correlation was demonstrated between intestinal floras total coliforms (TC), *Escherichia coli* with FC In most areas (Salman and Mualla, 2003; http://www.arabscientist.org/english/page/369/). Significant increase in cases of diarrhea and intestinal infections was registered in specific seasons and changes in the taste and smell of the water bodies were observed (Directorate of Environment, 2008).

With the cooperation of the Directorate of Environment, Directorate of Agriculture and the Department of Water Resources, the study and test plans were designed to specify the types and sources of pollution and their specifications in order to find cheap and adequate solutions to these issues, especially bacterial and microbial pollution(its gross) and chemical fertility. At first, water samples from four different locations were taken, these covered the region from south to north. And next samples were taken from four other points located from east to west of the north river.

STUDY AREA

Demography and human activities

Lattakia region forms the North West part of the Syrian Arab republic with an area of 2302 km^2, and the population is over 1.200 thousand people before 2010. The total land mass of Lattakia is 1.24% of the total territory of Syria, and her population is 6% of the total population of Syria, and with a population density of 520 (minimum 21, maximum 9000 inhabitants/km^2) (Directorate of Environment, 2008). The population growth rate in Lattakia declined from 3.3% in the eighties of the last century to a current figure of about 2.2% (3 Winckler, Onn (ed.), 1998) (Figures 1 and 2). The region is divided into three zones: The first is the coastal plain with a width of 3-15 km and an altitude of 0-100 m, with very good fertile soil, living here is 60% of the total number of inhabitants of the area. The second zone is the plateau area with 100 to 400 m above sea level, this area is fertile and suitable for planting trees, such as citrus and olive trees, living here is 25% of the total number of inhabitants of the area .The third zone is the mountains and highlands, which is 400 to 1600 m, it has a milder fallout to the sea and forms a natural barrier against rainy clouds in the interior of state, living here is 15% of the total number of residents of the area (Directorate of Environment, 2008). There are intensive agricultural activities in the coastal areas, including 70,000 plastic greenhouses that led to excessive and uncontrolled use of fertilizers and pesticides. The most important agricultural crops in Lattakia come from olives and citrus (1.2 mil tons/year from citrus and 160 thousand tons olives oil from 87 million trees). The cultivation of large expanse of land of citrus plantations brings about the use of pesticide, which is used to prevent pest from the large agricultural investment (Directorate of Agriculture, 2006).

The number of dams on the rivers streams is 20, the storage capacity of the dams is about 600 million cubic meters, and this is mainly dedicated to the irrigation dams and Troy 56000 ha, these are mostly located in heights above 500 m (Directorate of Agriculture, 2006). 797 facilities is registered in Lattakia region and their distribution are as follows: 309 food establishments, chemical small factories, 292 Engineering Industries and 75 Textile Industries (Directorate of Environment, 2008).

Hydrology and human demand of water

Lattakia"s water supply comes from three main sources, these are: rainfall, groundwater and surface water (Directorate of Environment, 2008). The annual amount of rainfall on the coastal basin is about 4880 million cubic meters, of which the annual average surface runoff is 1464 million cubic meters. The average runoff available

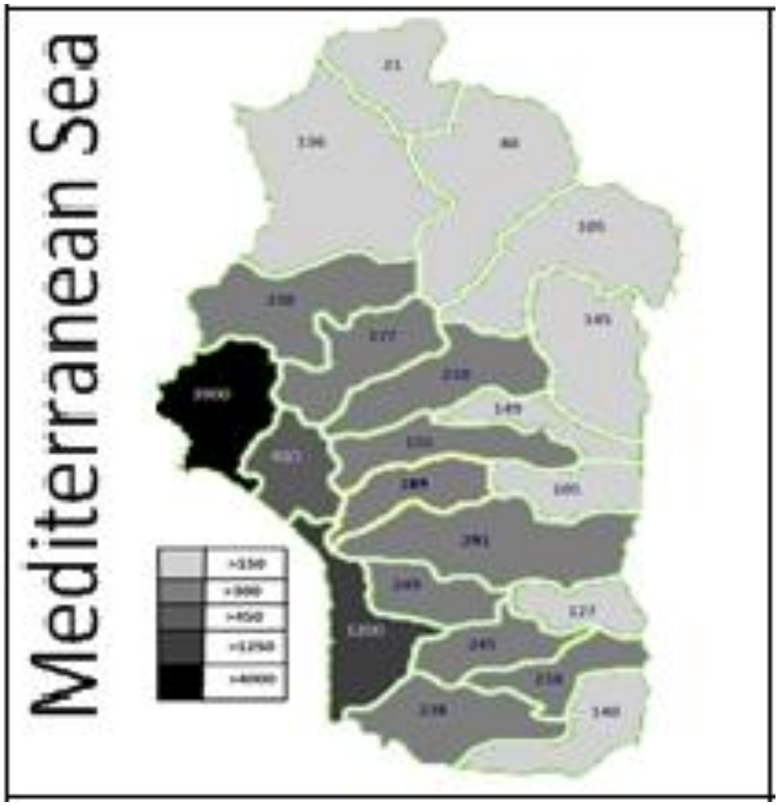

Figure 1. Population density in Lattakia (http://www.geographic.org/maps/new2/syria_maps.html).

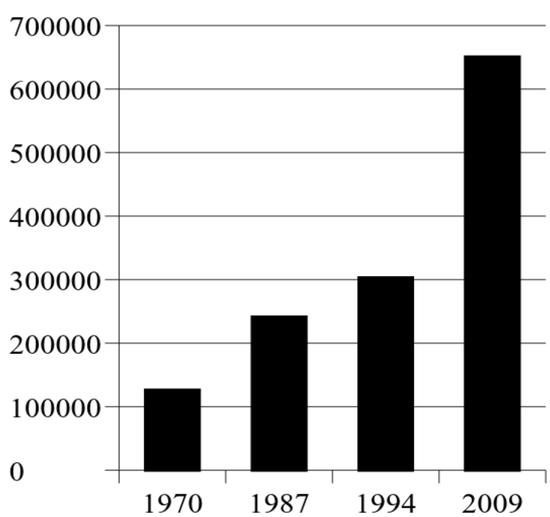

Figure 2. Population growth in Lattakia (Syrian Central Bureau of Statistics, 2010).

for use is 1414 million cubic meters of which about 560 million cubic meters is being currently used. The usage is captured as follows; drinking water is 35 million cubic meters, irrigation is 525 million meters in Mkaab.aa and the net surplus surface water is equal to 854 million cubic meters. The average annual runoff of underground water is 2830 million cubic meters, of which 1786 million cubic meters is not available due to its existence at a depth greater than 600 m. Only an average of 1044 million cubic meters runoff groundwater is available for use, of which only 478 million cubic meters is currently being used, 145 million cubic meters is used for drinking purpose, 273 million cubic meters is used for irrigation, and 60 million cubic meters is used for industrial purposes. Hence, there is a surplus of 566 million cubic meters groundwater in Mkaab.aa, from the foregoing, this area losses 586 million cubic meters by evaporation annually (Directorate of Agriculture, 2006). From the above, we find that the total available water resource, on average, each year is 2458 million cubic meters. Therefore, total runoff is 560 million cubic meters, of which groundwater flow is 478 million cubic meters. This gives a total surplus equal to 1420 million cubic meters in the basin (Figures 3 and 4).

Agriculture is the largest water-consuming sector in Lattakia accounting for about 88% of water use. The domestic and industrial water use stand at about 9 and 3% respectively (Bou-Zeid and Mutasem, 2002). The most important agricultural crops in Lattakia is olives and citrus, 1.2 Mil tons / year of citrus and 160000 tonnes of

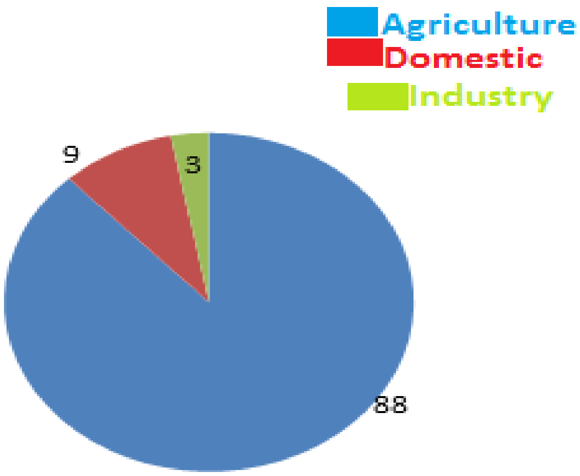

Figure 3. Water consumption in Lattakia (Syrian Central Bureau of Statistics, 2010).

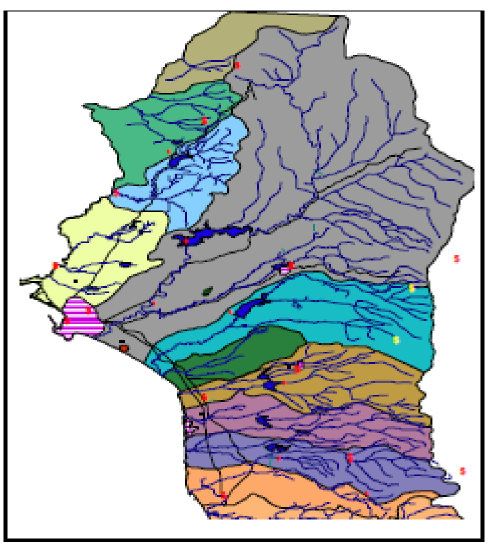

Figure 4. Water Map of Lattakia region (http://www.geographic.org/maps/new2/syria_maps.html).

olive oil of 87 million trees, the increase in the planting of these fruit trees brings about more use of pesticides (Directorate of Agriculture, 2006).

Waste water production and requirements for cleaning units

Lattakia region decided sometime ago to build a 51 wastewater plant as a response to the increase of water pollution in the region, This was actualized as five plants were built, the largest one, is located 20 km east of Lattakia with a population of about 10,000. The other end of the sewerage network is linked directly to the estuary (with 16 outlets in coastal areas) (Directorate of Environment, 2008). Currently, Lattakia city lacks waste water treatment facilities, and all the waste water produced discharge directly to the coastal area near tourist attractions which do harm and endanger the safety and health of inhabitants (Sabouh and Chahin, 1997). The countryside, where 70% of the population resides, houses are mostly equipped with cesspools, which do not correspond to basic sanitary conditions, which also has fatal consequences to the environment (Tameem, 2007) Sewage network covers 47% of total area at the countryside, In 2003, out of the 57 sewer line decided, only 27 was realized (Directorate of Environment, 2008).

METHODOLOGY

Four sections were chosen in Lattakia region namely; A1, A2, A3 and A4. The Alsen Basin area was designated as (A1). In this area contaminations in the water bodies were monitored and its relationship to the amount of rainfall values was investigated. In the Jableh area (A2). Values of bacterial and chemical pollutants in wells were compared before and after the establishment of the sewage site monitored. The main part of the experimental research was conducted in A3 and A4 (the north river basin) at four points, the first point (P1) was chosen directly upstream, the second point (P2) is located downstream, while (P3) and (P4) are located at the point of outflow of water from the Dam. Samples from area A2 and A3 and A4 were taken 6 times per year (6x/year) during the months of January, March, May, July, September, and November (1, 3, 5, 7, 9, 11) in the year 2009, 2010, and 2011. This was just before the commencement of the crises in Syria. Seasonal harvest of citrus and olive trees and rainy season were taken into consideration. The effects of rainfall on water pollution on the sites were also determined.

Measurements in area A4 (great north River) were taken to determine the kinds, level, and sources of pollution in the lake and river Basin (GNR), the relationships between human activities and high rates of pollution in the water from upstream to downstream were also determined, also the slope of the terrain corresponding with the flow of the river from the north-east to south-west was also taken into account (Figures 5 and 6).

The following pollution indicators in the four areas were observed throughout each season: (Water temperature, ph, Total hardness, Dissolved oxygen, microbiological, and nitrate and nitrite indicators). Some of these indicators were measured in the laboratory. And other measured on-site sampling, due to the fact that the sites were easily accessible and on-site inflow and outflow of water in lakes were observed, these qualities makes this points better locations for collecting samples for the research.

A digital thermometer was used to measure the water temperature, pH meter (GLI P53 analyzer) for pH measurement, (GLI D53 5600-DOS) and Winkler method was used for determining the values of oxygen demand. Also, samples to detect total fecal coliform and bacteria *E. coli* were obtained and taken to the laboratory; the chemical oxygen demand (COD) level was detected by using the measuring device Laviband ET108. The measuring Device to detect nitrate used was Nitrate sensor for lab IT-1201. The values of nitrite and nitrate were monitored. During the next bacteria measurement we concentrated on the presence *of E. coli*, Entero-Staphylo-Bactria Bacilli in water due to the increase in the value reached during the first measurement.

Bacteriological analyses were performed upon arrival of samples to the laboratory, which included counting the number of intestinal bacteria census and (FC). Water samples were collected for bacteriological and chemical analysis. Bacteriological analysis was

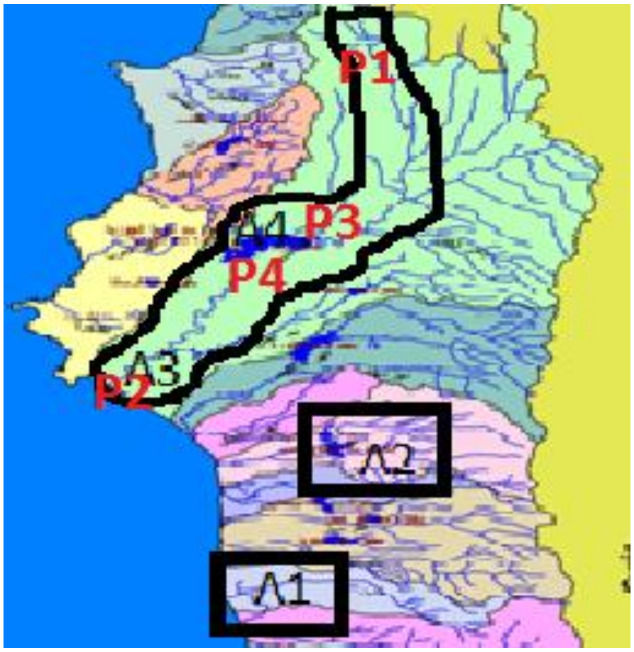

Figure 5. Studing points in region Lattakia (http://www.geographic.org/maps/new2/syria_maps.html).

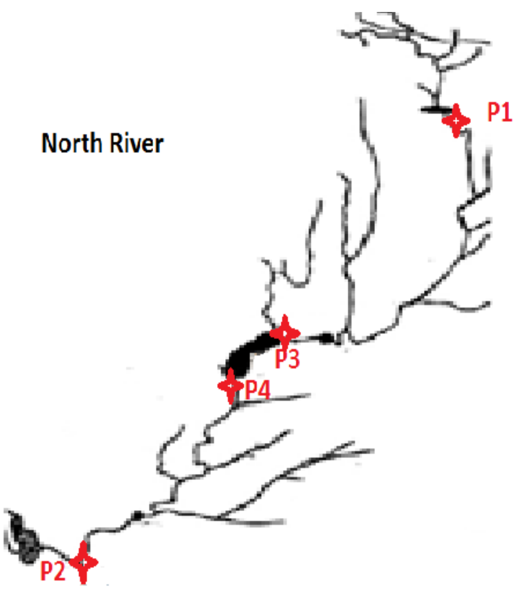

Figure 6. Great north river scheme (Directorate of Agriculture, 2006).

performed in the laboratory of Tishreen University in Lattakia, which included counting the number of (FC). For qualitative and quantitative results, the following methods were used to detect bacteria, these include: multiplier tubes, membrane filtration, brushes on the casting dish, and the dish.

A thermometer of mercury was used to measure the temperature. Further a pH meter was used to determine the degree of acidity. These methods were adopted to measure the nitrite anion to interact with stray Asalafanil acid amide in the middle of phthylamineAitelin de and Secretes composite Aso pink-N were also measured, and finally results in the diazo salt that reacts with N vaveth at wavelength 490 microns mg, and the ANOVA study was conducted using the statistical analysis of variance.

RESULTS AND DISCUSSION

Area A2

In area A2 Temperature affects the density and viscosity of water and the rate of dissolution of gases and the speed of chemical and biological reactions and thus affects the self-purification process of water. Temperature of water in the well remained within normal limits, ranging from 12.1 to 14.3 in the study period, increase in the rates of nitrates was observed in some months, this increase coincided with rainfall and agricultural activity season and close values of datas were observed in the study of the well as shown in Figure 7. Bacterial contamination values fell in the second and third year of the study, the reason is due to the completion of the drainage network building as shown in Figure 8.

Area A3, A4

In area A3 and A4 the temperature of water in the river remained within normal limits, ranging from 11.8 in January to 29.3 August. The Dam water temperature remained at a depth of 30 cm from 11.4 to 13.5 in the winter and a significant difference in the water temperature was observed at the irrigation canal, that is 13°C in the winter and the surface dam recorded 30°C in the summer (Figures 9 and 10).

BOD values slowly rose between point P1 and point P4, and there was a large difference between points P1 and point P2 located at the mouth of the river leading to the sea, this is because the impact of the increase of human activities in lattakia city and water quality in river. The BOD value remained at acceptable limits in the Dam, although the downstream water recorded the highest concentration when the annual average was 8.56 mg/L while at the Dam and at the lake it has a recording of 4.85 and 2.1 mg/L in the river, which is the lowest value as shown in Figure 9. Minimum values of *E. coli* in the water were registered in the spring and, the maximum values exceeded the permitted standards in the downstream, this is as a result of rainfall and seasonal climatic conditions and human seasonal agriculture activities as shown in Figure 10. The values of *E. coli* in A2 during realization sewers and after was noted, it was observed to have reduced from a maximum value of 245 bacterial to a minimum of around 5 bacterial. Hence, the water was then safe for drinking, all round the whole year, as it is free from bacterial as shown in Figure 8.

The pH value remained between the acceptable limits in the research sites during the study period. The

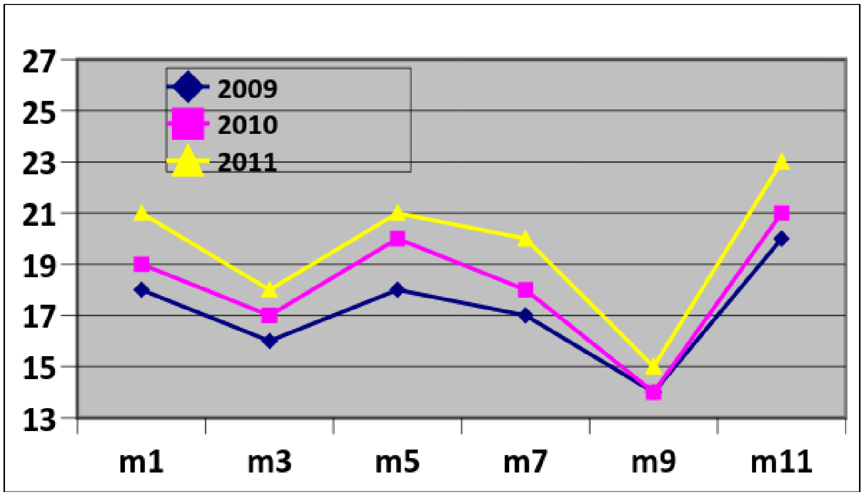

Figure 7. NO_3 value in wells area (A2).

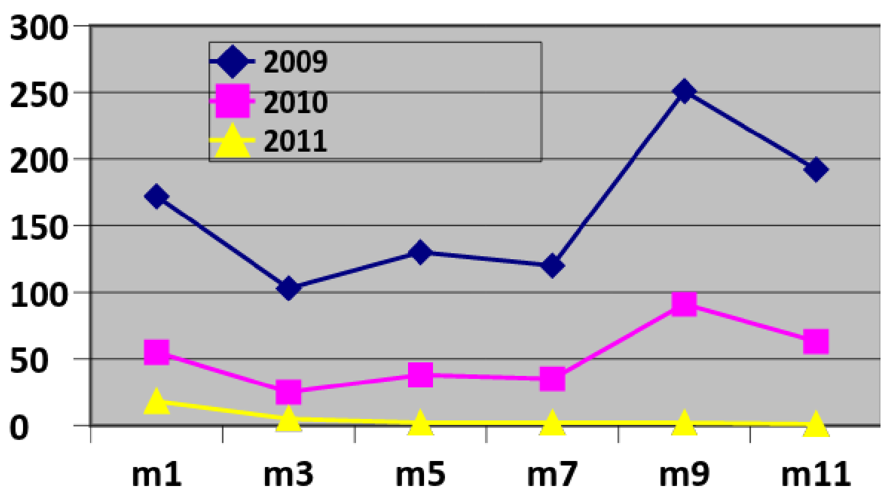

Figure 8. *E. coli* value in wells area (A2).

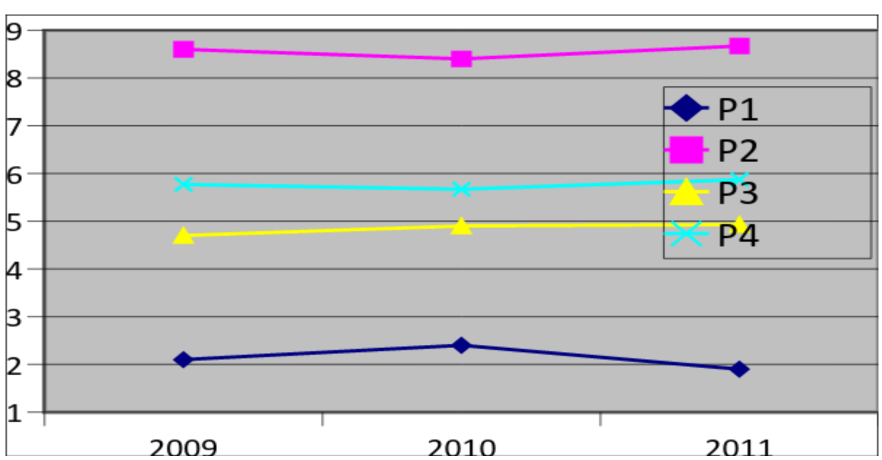

Figure 9. BOD levels in area (A3, A4).

Figure 10. *E. coli* levels (A3, A4).

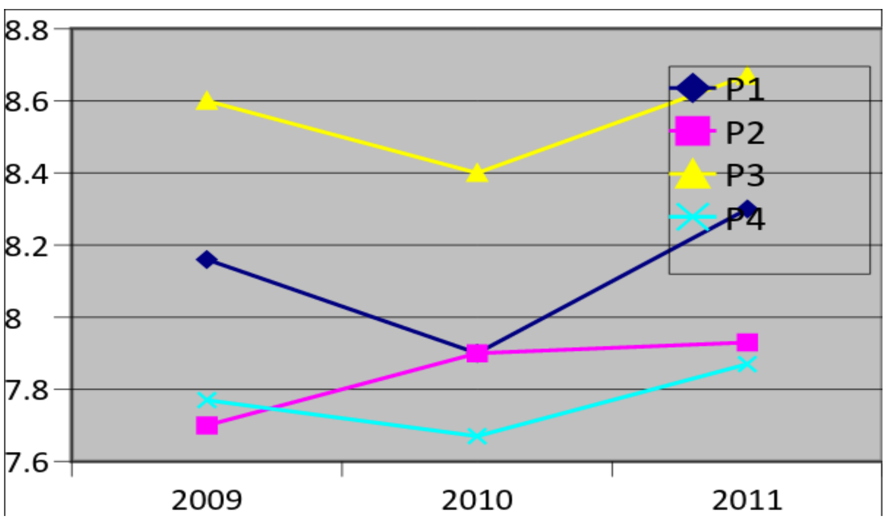

Figure 11. The pH levels in (A3, A4).

following annual average values were recorded; 8.4 in the dam lake, 8.2 in the river, and 8 in the irrigation canal. The high value of pH in both the lake and the river is due to photosynthesis of water plants that consumes a large share of CO_2 dissolved in water as shown in Figure 11, minimum values of nitrates were registered in the irrigation canal and maximum values exceeded the permitted standards in the downstream, this is as a result of changes in climatic conditions and human seasonal agricultural activities as shown in Figure 12.

Figure 13 describes the results of laboratory tests to show the validity of water usage for human, values obtained proved the existence of germs of type *E.coli* and excessive concentration of bacteria from sewage in P2.

The results show that the pollution is due to a very large extent on human activities and the results also show that the water is safe for drinking in terms of chemical contaminants and not safe for drinking in terms of bacterial in area higher than 800 m. Results obtained down the river show that, the water is not safe for drinking in every right, in areas lower than 800 m.

Conclusion

The study confirmed that, in coastal areas where there are intensive agricultural activities, water bodies are not safe for drinking as a result of contamination due to

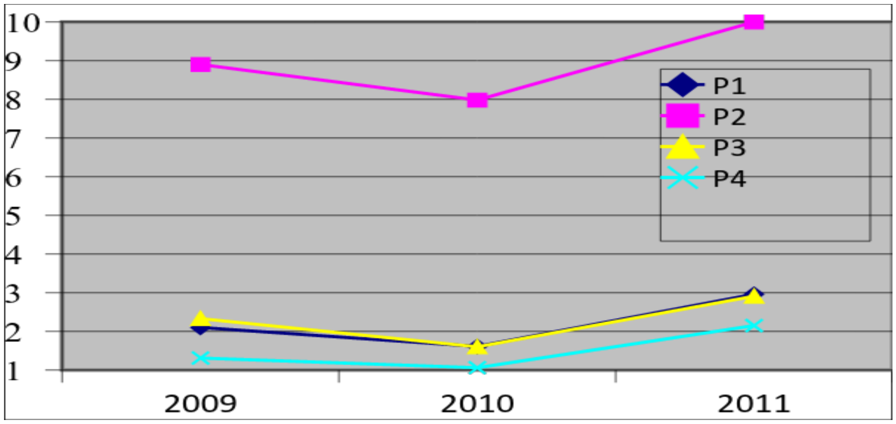

Figure 12. NO_3 levels in (A3, A4).

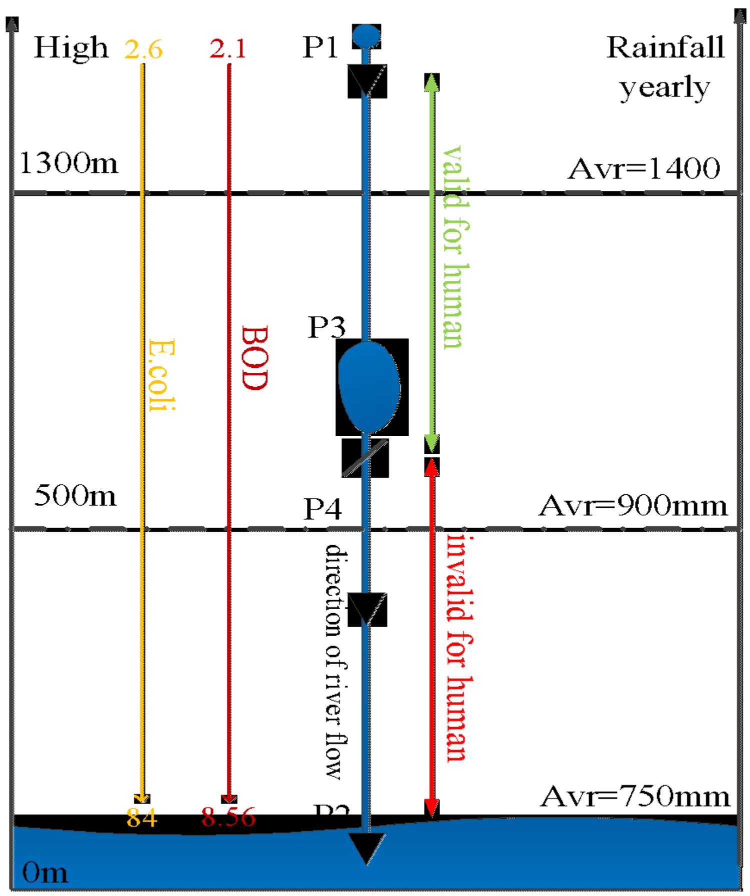

Figure 13. validity of water usage for human.

organic and chemical fertilizers. Water pollution in Lattakia as a result of the consequence of waste water constitutes more than 70% of the total pollution issues; also there is more presence of bacterial in water bodies, in the results for 2010 than in 2009, which arises as a result of the new network of wastewater treatment plants constructed. The experience in area A2 has shown that, the construction of sewage networks and treatment plants reduced the pollution of surface; ground and sea water by 75%. And it was observed that one of the chemical forms of water pollution in this area is due to pollution by nitrates and nitrites resulting from solid waste landfills and agriculture activates.

Generally, the studies observed that the impact of pollutants increases with increasing of human activity, also rainfall was impact factor to spread of pollutants, it was not mentioned that the existence of the pollution was from nature sources. Through co-operation with competent authorities, it was identified that most kinds of pollutions in the region, is as a result of the absence of basic environmental requirements (such as; infrastructure, culture, care, and proper planning). Hence, it was very important in this study to monitor these environmental requirements, measures them and obtains results. The monitoring of the impact of the construction of wastewater treatment plants in area A3.

RECOMMENDATIONS

(1) Emphasis should be on sewage treatment outcomes and address the situation of landfills located within the protection ranges from secondary and tertiary pollutants in the study area.
(2) There should be reduction in the use of chemical fertilizers and pesticides on lands within the scope of agriculture area, and of the various classes of danger that is poses on groundwater protection and rationalization.
(3) Rainwater should be harvested through the implementation of new rainwater harvesting techniques to be used for agriculture or groundwater recharge purposes. This would give an increase in available water resources, which means an additional increase in the amount of water available.
(4) Proper water management and development practices should be adhere to, most especially in sanitation and irrigation techniques. Implementing modern irrigation techniques and treated wastewater facilities means abundance of stable water supplies to the entire citizenry of Syria.
(5) There should be improved public awareness and participation in water projects at local, regional, and international levels, as this will eventually be a lasting solution to better sustainability and effective water conservation measures in the country. Also, renewable water resource management and utilization should be introduced in the school curriculum at primary, secondary and tertiary Education levels.
(6) Human resource development, critical knowledge and know-how transfer should always be in focus for renewable water projects development, project management, monitoring, evaluation, implementation and actualization in the country.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Effect of foliar application rates of Calcium and Boron on yield and yield attributes of soybean (*Glycine max*)

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Foliar fertilizers of soybeans have been widely reported in many field trials. Although Calcium and Boron are essential nutrients for soybean, research results have shown that foliar application of nutrients has been contradictory. The objective of this study was to evaluate the soybean response by applying different foliar fertilizer rates Calcium and Boron on yield components and soybean yield applied at flowering (stadia fenologic R3). Two experiments were carried out during two successive seasons 2009-2010 and 2010-2011, in the Quatro Pontes, Paraná State, Brazil. The area used was managed in no-tillage system consolidated. The experimental was randomized complete blocks design (RCBD), with six replicates. The treatments consisted of applying commercial fertilizer on the basis of Calcium and Boron (10% Ca^{2+} and 0.5% of B). Foliar fertilizer containing Ca^{2+} and B was applied 30 days after germination, when the plants were at the R3 stage. Also, five rates of commercial product (0, 1.5, 2.5, 3.5 and 4.5 L ha^{-1}) were applied. Analyzing the results, it was concluded that the application of the foliar fertilizer with Calcium and Boron, applied 30 days after germination did not affect yield components and soybean yield during successive seasons 2009-2010 and 2010-2011.

Key words: *Glycine max*, grain yield, fertilization.

INTRODUCTION

In recent years, Brazilian agriculture has resulted in successive increase in production. This performance is due to the technological development involving varieties, methods of pest control and management (Resende, 2004).

One of the technologies that allowed the increase in production was the use of foliar fertilizers, the same being composed of macronutrients and micronutrients. These products provide the rapid absorption of plant nutrients, serving as a complement to soil fertilization, providing the nutrients to plants in suitable time usually done before or early flowering for annual crops (Bevilaqua et al., 2002) for preventing and correcting deficiencies (Motta et al., 2007). Currently there are several foliar fertilizers available in the market, being a formulation much used that contains as main elements Calcium and Boron.

Although Calcium is a macronutrient, its foliar application with Boron has been indicated for the soybean crop. The objective of the application is to increase fertilization of flowers and consequently increase productivity. The main function of Calcium in the plant is to operate in the formation of Calcium pectate,

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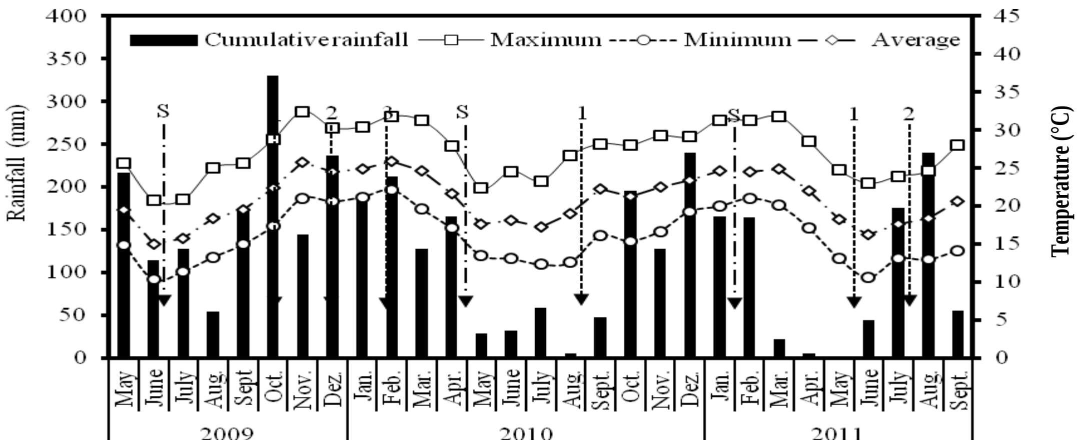

Figure 1. The period of 2009-2010 and 2010-2011 seasons.

present in the cell wall middle lamella, the fertility flowers and pollen tube growth (Faquin, 2005; Verrissimo et al., 2006; Epstein and Bloom, 2006).

Boron have important roles in sugar translocation, carbohydrate metabolism, flowering, activity of hormones (Marschner, 1995; Dechen and Nachtigall, 2006) and biological nitrogen fixation in soybean, acting as an activator of starch phosphorylase enzyme responsible for starch synthesis and seed reserve substances (Favarin and Marini, 2007).

Research shows that there are many differences in response to application of Calcium and/or Boron in soybeans. Many experiments showed an increase in productivity (Bevilaqua, et al., 2002; Souza,et al., 2008; Schon and Blevins, 1990) or physiological quality of seeds (Bellaloui et al., 2010), while others did not obtain beneficial effects in its use (Arantes et al., 2009; Pegoraro et al., 2008; Kappes et al., 2008; Silva et al., 2006; Macedo et al., 2002). It should be noted that the response of soybean fertilization with Ca^{2+} and/or B varies with cultivar (Slaton et al., 2004; Souza et al., 2008). This study aims to investigate the effect of Ca^{2+} and B foliar application rates on yield and yield components of soybean.

MATERIALS AND METHODS

Two experiments were carried out during two successive seasons 2009-2010 and 2010-2011 in the property Mr. Jose Silverio Egewarth, located in the Quatro Pontes, Paraná State, Brazil. The site altitude is 430 m, geographical coordinates are 24° 43' latitude South and 54° 14' longitude west.

Soil was classified as "Latossolo Vermelho Eutroférrico" (Embrapa, 2006) and Oxisol (Soil Survey Staff, 2006), with a clayey texture. The climate according to Köppen, is Cfa (humid subtropical with annual average temperatures ranging between 17 and 19°C and rainfall totals between 1200 and 2000 mm well distributed throughout the year and hot summers). The data of rainfall during the experiment in 2009-2010 and 2010-2011 seasons are presented in Figure 1. The area used is managed in no-tillage system consolidated.

The chemical analysis of soil was done before the deployment, made from samples collected at a depth of 0.0 to 0.10 and 0.10 to 0.20 m, according Silva (2009). The soil analysis showed the following chemical characteristics: pH (KCl 1 mol L^{-1})= 5.36; P (Mehlich)= 5.67 mg dm^{-3}; H^+ Al (SMP 7.5)= 5.06; Al (KCl 1 mol L^{-1})= 0.00 $cmol_c$ dm^{-3}; k (Mehlich)= 0.28 $cmol_c$ dm^{-3}; Ca^{2+} (KCl 1 mol L^{-1})= 6.66 $cmol_c$ dm^{-3}; Mg^{2+} (KCl 1 mol L^{-1})=2.30 $cmol_c$ dm^{-3}; CTC= 14.40 $cmol_c$ dm^{-3}; V%= 64.42; Cu= 28.50 mg dm^{-3}; Zn=6.50 mg dm^{-3}, Mn=188.00 mg dm^{-3} and B (barium chloride)= 0.25 mg dm^{-3}.

The experimental design was a randomized complete blocks design (RCBD) with six replications. The treatments consisted of spraying a commercial product containing 10.0% Ca^{2+} and 0.5% B in five rates: 0, 1.5, 2.5, 3.5 and 4.5 L ha^{-1}. This was applied by spraying with manual pressure capability of 0.6 MPa, equipped with fan nozzle empty cone, calibrated to a spray volume of 200 L ha^{-1}, as recommended by the supplier. The foliar application of the product was performed 30 days after germination, when the plants were at the R3 stage, determined by the scale phenological Ritchie et al., 1994).

The soybean planting in seasons 2009-2010 and 2010-2011 was held in October, using drill Semeator PH8 in no-tillage system, and the seeds of the variety Coodetec 215. The spacing used was 0.45 m between rows. 16 seeds per linear meter were sown to a depth of 0.04 m. At sowing, 250 kg ha^{-1} of a chemical fertilizer 2-20-18 (N-P_2O_5-K_2O) was used.

Each plot consisted of six rows 5 m long, comprising a total area of 324 m^2. For evaluation, we picked up only the two central rows, discarding the ends (0.5 m) of each plot, which resulted in an area of 3.6 m^2 per plot. Normal cultural practices of growing soybean were conducted in the usual manner followed by the famers of this district. At harvest a random sample from the two middle rows from each plot was taken to determine number of pods, number of grains per plant and 1000-seed weight, thereafter the area of all plot was harvested to determine seed yield/unit area and converted to seed yield/ha.

The data of the treatments were submitted to variance analysis, using the statistical software SAEG (Statistical Analysis System and Genetics) (2007).

RESULTS AND DISCUSSION

The results for pod number per plant, grains, number per pod, grain weights and productivity are shown in Table 1.

Table 1. Effect of foliar application rates of Ca^{2+} and B on number of pods per plant, grains number, seed index and seed yield/ha of soybean in 2009-2010 and 2010-2011 seasons.

Rates ($L\ ha^{-1}$)	Number of pods per plant	Number of grains per pod	1000 grain weights (g)	Productivity ($kg\ ha^{-1}$)
		Season 2009-2010		
0	42.00^{ns}*	2.44^{ns}*	108.91^{ns}*	3122^{ns}*
1.5	41.43	2.45	109.28	2833
2.5	42.16	2.46	107.04	2985
3.5	45.23	2.43	108.58	2034
4.5	46.00	2.45	107.86	3122
CV	23.57	2.50	3.0	7.91
		Season 2010-2011		
0	48	2.15^{ns}	124.16^{ns}	3340^{ns}
1.5	47	2.18	123.34	2971
2.5	53	2.20	123.94	3344
3.5	50	2.16	127.24	3386
4.5	57	2.15	211.66	3467
CV	16.60	2.94	12.65	8.63

ns- Not significant ($p<0.05$).

The yield obtained ranged from 2034 to 3122 kg ha^{-1}, in the first season (2009-2010), and 2971-3467 kg ha^{-1}, at the second season (2010-2011), was considered a good yield for the region. One explanation for the application of Calcium and Boron has no significant effect on productivity is that soil fertility, associated with the history of the area, which has been cultivated in the no-tillage system, promoted adequate conditions for the development of soybean, resulting in good productivity (3122 and 3340 kg ha^{-1}) for the treatment without foliar fertilizer.

The number of pods per plant ranged from 41.43 to 46.00 (2009-2010 season), until 47 to 57 (2010-2011 season), and there was no significant difference between treatments (Table 1). According to Ross et al. (2006), an increase in this variable was expected; also, the application of Ca^{2+} and B can affect the number of fertilized flowers and consequently the number of pods.

Analyzing the data, the results showed no difference between treatments. The application of a commercial product containing 10.0% Ca^{2+} and 0.5% B at rates did not affect yield components and seed yield ha^{-1} of soybean during 2009-2010 and 2010-2011 seasons. Other explanations for not obtaining significant effect on the application of Boron is that, although this element is an essential micronutrient for plants, some plants are more susceptible to their deficiency than others, and soybean is considered relatively insensitive to Boron deficiency (Ross et al., 2006).

Soil chemical such as pH and organic matter content and physical properties (texture) also influence the availability of Boron to plants and have likely contributed to getting inconsistent response to Boron fertilization (Moraghan and Mascagni, 1991; Ross et al., 2006). Given this consideration, the chemical condition of the experimental area may have influenced the result, because the Ca^{2+} and B were 9.81 $cmol_c\ dm^{-3}$ and 0.25 mg dm^{-3} respectively, and therefore suitable for culture. These chemical conditions, coupled with good management in no-tillage system, fostered conditions conducive to the development of culture and were able to meet the demand for soybeans with these elements resulting in a good yield on unfertilized control.

Work performed by Jamami et al. (2006), demonstrates that the application of Boron and Zinc in corn did not result in increased levels of foliar nutrients or productivity increases. The explanation is that the initial concentration of the B element and Zn were in the appropriate concentration for culture.

According to research conducted by Embrapa, foliar fertilization have shown significant responses only to Manganese (Mn), Cobalt (Co) and Molybdenum (Mo), which is why there is no recommendation for foliar fertilization with other nutrients (Staut, 2007).

Another factor that probably contributed to the achievement of these results was the precipitation, because the amounts of water available to plants influence the absorption of Ca^{2+} and B. Under conditions of water deficit, symptoms of deficiencies may occur (Dechen and Nachtigall, 2006) due to the fact that a probable reduction in the availability of micronutrients and foliar fertilization in this case is justified, as there would be a decline in productivity.

According to the meteorological data obtained from the region the amount of rainfall and its distribution during the crop cycle were adequate in the 2009-2010 and 2010-

2011 seasons harvest (Figure 1). Of the two crops, none have water deficit, especially during flowering. Probably, the absorption of these elements was adequate.

Corroborating the results, Freeborn et al. (2001), Macedo et al. (2002), Silva et al. (2006), Andrade Moreira et al. (2008), Kappes et al. (2008), Pegoraro et al. (2008) and Arantes et al. (2009) did not find significant differences in the application with Ca^{2+} and/or B with different concentrations.

Different results obtained in this experiment were observed by Ross et al. (2006). Fertilization with Boron promoted increase in production in three of four experiments from 4 to 130% in soybean, when compared to treatments without Boron, although the concentration of Boron present in the soil was deficient.

Conclusion

The application of foliar fertilizer rates on a commercial product containing Calcium and Boron and time of application considered in the work did not affect yield components and soybean seasons 2009-2010 and 2010-2011.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Agribusiness model in rural community economic: Indonesia perspective

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The paper presents an approach model to community empowerment, particularly rural community that tends to have limited economic access with descriptive analysis. Literature study from research in scientific journals is determined to be the main method in collecting secondary data. Agribusiness-based community empowerment model considers local potency development as a primary component and the whole main factors as the determining components in the success of the approach.

Key words: Agribusiness model, empowerment, rural community economic.

INTRODUCTION

The concept of agribusiness based community empowerment

Community empowerment is an economic development concept which sums up the concept values. This concept shows a new development paradigm, "people centered, participatory, empowering, and sustainable" (Chambers, 1995 in Kartasasmita, 1997; Baum, 2008). This concept is larger than simply fulfilling the basic need or providing mechanism in order to prevent the poor (safety net); the idea that is developed recently as an effort to seek alternative growth concepts in the past. This concept is developed by the effort of experts and practitioner in seeking of what Friedman (1992) stated as alternative development, that demands 'inclusive democracy, appropriate economic growth, gender equality and intergenerational equity (Kartasasmita, 1997).

Community empowerment can be seen from three points as follows:

a) To create a situation or climate that enables community's potential to develop (enabling). Here, the introduction stating that each person/community has potential that could be developed As the starting point. It means that there is no one powerless; if it is so, human being has vanished. The empowerment function is now attempting to build power by encouraging, motivating, and rising their consciousness and potency, and also in the attempt to develop it;
b) To strengthen and empower the community potency (empowering). Therefore, some more positive steps, rather than simply creating ambience and climate, should be taken. The empowering includes real steps and is related to providing all inputs, as well as opening access to opportunities that would empower the community. Some of them are elevating the education level, health, and access to the sources of economic progress, such as capital, technology, information, job opportunities and market.

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The inputs of empowering are related to basic physical structures and infrastructures such as irrigation, roads, and electricity, as well as social infrastructures such as school and health service facilities, which can be accessed by the bottom layer of community, as well as the availability of funding, training and marketing institutions in the rural areas where the least empowered community live.

Special programs dedicated to the less empowered community are needed since the general programs that are available nowadays are not always accessible for this community.

Therefore, the most important thing is the increase of community participation in decision making process related to both personal and communal lives. Eventually, community empowerment is closely related to the stabilization, civilization, and democracy application. Friedman (1992, as cited in Kartasasmita, 1997) stated:

"The empowerment approach, which is fundamental to an alternative development, places the emphasis on autonomy in the decision marking of territorially organized communities, local self-reliance (but not autarchy), direct (participatory) democracy, and experimental social learning".

c) To empower also means to protect. In the process of empowering, the weak should not ever become weaker due to their less empowerment in competing with the strong. Hence, protection and endorsement to the weak is basically needed in community empowerment concept. Protecting does not mean isolating and preventing interaction of the weak. Yet, it is more of the effort in preventing the imbalance competition and exploitation over the weak by the stronger side. Eventually, the sole purpose is to form independent and enabled community and build the ability to self-develop to sustainable better life.

This paper is trying to develop an approach model to community empowerment, particularly rural community that tends to have limited economic access. This approach is based on agribusiness, which is expected to become a new paradigm in building rural agriculture.

HISTORICAL BACKGROUND OF AGRIBUSINESS-BASED COMMUNITY EMPOWERMENT

Community empowerment is an effort to elevate the dignity of people who are today unable to unleash themselves from poverty and ignorance. Empowerment is to enable and to form an independent community. The empowerment concept occurs as a consequence of failure particularly the failures of economic development models in overcoming sustainable poverty and environmental problems, as well as expectation due to the development alternative which includes some democracy values, gender equality, and adequate economic growth.

AGRIBUSINESS-BASED COMMUNITY EMPOWERMENT DEVELOPMENT

The section identifies many inputs such as fund, structure, and infrastructure allocated for the community through some development programs which shall be considered as stimulation to intrigue the acceleration of community's social-economy life. The main approach in the community empowerment concept is that the community is not becoming the object of any development project, yet as a subject of their own development effort. Therefore, according to that concept, the community empowerment must follow the following approaches:

1) Directional: This is popularly known as endorsement. Such attempt is aimed to overcome problem as needed;
2) Done by the community: This program must be directly involve or even hold by the targeted community. Involving the targeted community has its several purposes. It is to make the activity to be effective as it is suitable with the community's will and knowing their ability and needs. Moreover, it is also created to increase the community ability by giving experience in designing, conducting, managing, and having responsibility in the effort of elevating their esteem and economy life;
3) Using group approach: Such approach is implemented to improve the social skill in overcoming poverty problems which are difficult to solve individually.

AGRIBUSINESS MODEL IN RURAL COMMUNITY EMPOWERMENT

In facing recent world situation, the economic policy must embrace a new paradigm which the community empowerment shall be the main concern. It is because most people live from the agriculture sector, and it is still providing big contribution to the nation's economic life. Therefore, community economic empowerment also means improving agricultural economic development. The economic development must concern on backward linkage with the agriculture sector or primary sector, on the other hand, the forward linkage must concentrate on management, which will increase the added value, and good marketing so that the product will not be in vain. This agricultural development is known as agribusiness (Saragih, 2001).

According to Saragih (2001), agribusiness system is all of the activities, starting from the stock and supply the production, to the agribusiness and agro-industry product marketing shall be related to one another. Agribusiness

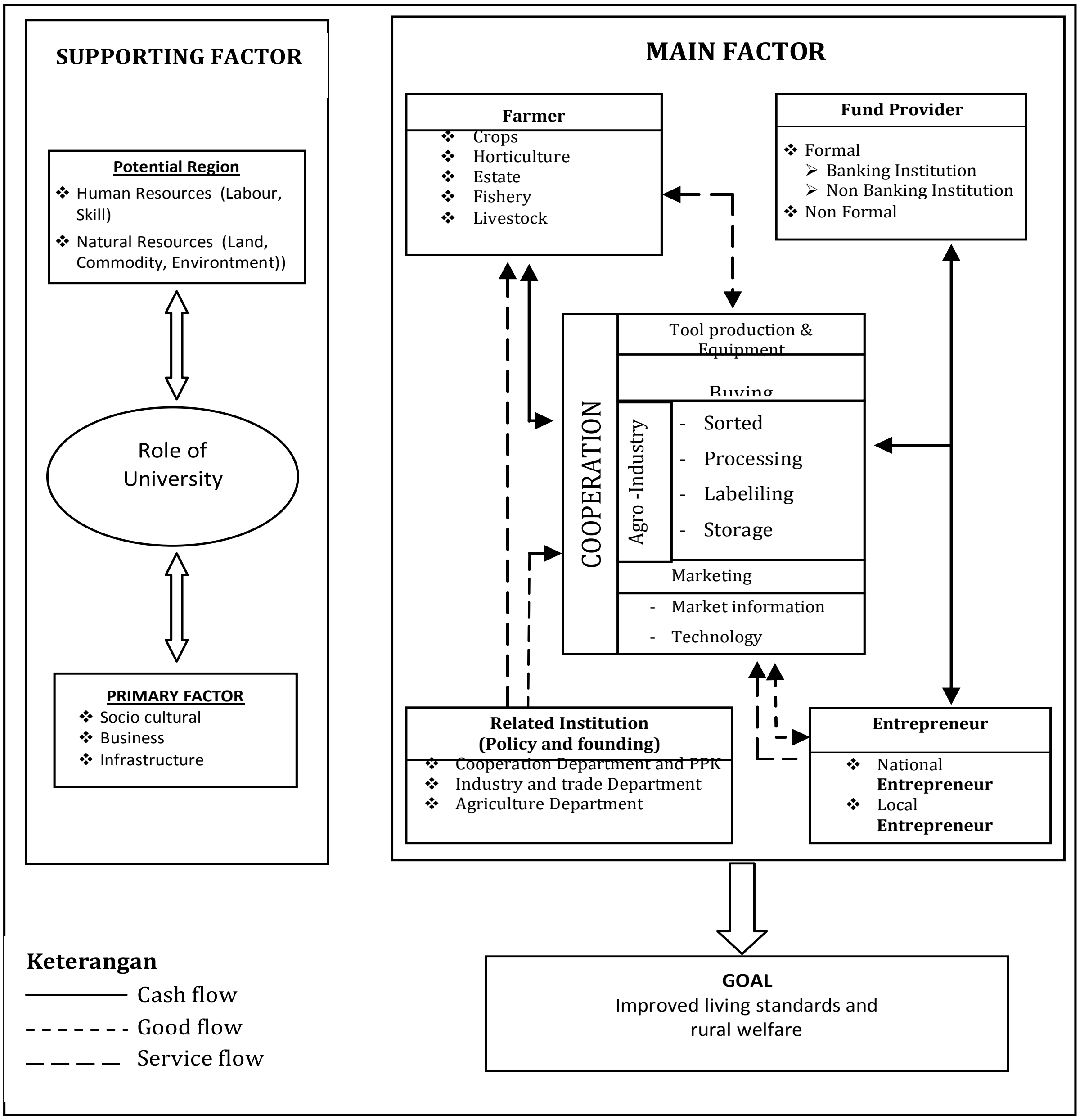

Figure 1. Agribusiness model in rural community economic empowerment.

of a system includes (1) subsystem of production which means procurement; (2) production subsystem; (3) product management subsystem; (4) marketing subsystem; (5) institutional subsystem. To run the subsystem properly, based on the agribusiness demand, a rural community economic empowerment model based on agribusiness should be designed by involving several supporting institutions.

Several supporting factors of agribusiness-based rural economic development are (a) primary factor which consists of the role of university to actualize the local and environment potency; (b) main factor consists of farmer/agribusiness executor, entrepreneur, banking institution, related institution, and local economic enterprise (Koperasi). The work sheet of primary factor and main factor in agribusiness based rural economic empowerment model is shown in Figure 1.

Primary factor: University, local potency, and environmental potency

University and college must be able to dig the potency of local natural resources, including land suitability, land availability, superior commodity, and human resources. Moreover, university is requested to dig the potency of rural community environment and any business opportunities that suits the socio cultural condition, including its availability of means and infrastructure. University must be able to be an independent institution in order to study and recommend, as well as control the rural agribusiness activity. The success of the role is the primary determining factor in the success of the model.

Main factor

Main factor is also called agribusiness partner factor in the rural area. This factor is a partnership synergy so that the agribusiness activity in a particular system could run well. There are five main factors involved in this activity: these are farmer, banking institution, economic enterprise (Koperasi) as a rural economic institution, related institution, and entrepreneur.

Farmer: Recent farmer's problems are farmer's knowledge, capital, market assurance, structure, and infrastructure, as well as the will to do farming. To overcome these problems, the solution could be done together through an organization which has the same purpose; it is Koperasi or local economic enterprise. The farmers could start their agribusiness by using the products of university's research about their local superior commodity, then the farmers could use Koperasi (local economic enterprise) as a fund provider. This kind of partnership will surely give some benefits such as market assurance for the farmer's product, hence preventing the farmer from the price fluctuation risk.

Banking institution: This institution is loan provider for the local economic enterprise (Koperasi) and the entrepreneur. The loan is through local Koperasi which already has agribusiness or agro-industry business. Koperasi demands for capital loan for the members (farmers) and loans for the Koperasi itself (as an agro-industry executor). The entrepreneur in this case will use the loan to develop their business.

Local economic enterprise: Koperasi shall function as an enterprise at the rural area as well as a mediator of production means and farming machine/tools to its members. Moreover, Koperasi also acts as the mediator of agricultural products produced by the members. Koperasi is also expected to manage the agricultural products (sorting, packing, and stocking) as needed by the market demand. Another service of Koperasi that shall be conducted is conveying market information to its members, so that the farmers have no doubt in performing agribusiness, as there is an assurance given by Koperasi that their products will be accepted. Syahza (2002) stated that the agro stat concept in the rural area could be developed through Koperasi. Investments done by the Koperasi is in form of transportation vehicles like farming machines (agro-industry). In addition, the farming machine shall be an investment on behalf of the member's name which means that each member has its stock on Koperasi's asset. Business fields that could be conducted through Koperasi, according to Syahza (2003), are (1) supplying and distributing production tools such as farming tools and machines; (2) agricultural products; (3) agro-industry; (4) marketing the agricultural products; and (5) banking service, transportation and stocking.

Related institution: In this case, the related institution involvement is represented by the government. It is expected that the involvement, specifically in term of policy and enrichment so that the rural community economic empowerment will be well implemented. The policy will relate to the terms and rules which provide mutual benefit among the agribusiness executors. Meanwhile, enrichments will be given to Koperasi and farmers, as well as the involvement of university or other professional institutions.

Entrepreneur: Entrepreneur here refers to the entrepreneur who owns capital and also trader (mediator, distributor, retailer). As a capital owner, they collaborate with Koperasi in providing production means and farming machines/ tools, and act as a technology supplier to support the rural agribusiness activity. The function as a trader is to distribute the agricultural products which have been through some process done by Koperasi that suit the trader's determined standard. Trader is also expected to give market information through Koperasi, either about market purchasing power, market opportunity, or experts who are in charge in Koperasi, especially on production, marketing, and quality control.

CONCLUSION

The agribusiness model based on community empowerment is an approach that takes into account several components with each different roles and functions. Agribusiness-based community empowerment model considers local potency development as a primary component as well as the whole main factors as the determining components in the success of the approach.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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Response of onion (*Allium cepa* L.) to sowing date and plant population in the Central Free State, South Africa

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The response of onion cv. Jaquar (*Allium cepa* L.) to sowing date and plant population was investigated in Bloemfontein (Free State Province, South Africa) during the year 2010. Jaquar seeds were sown on 11 and 25 May; and 8 June at five different populations (95, 83, 74, 67 and 61 plants m^{-2}) in a randomized complete block design with each treatment combination replicated three times. Plant height and leaf number were measured 18 weeks after emergence. Bulb yield and quality (bulb mass, diameter, firmness and neck diameter) were recorded at harvesting. Significantly taller plants were obtained with the early sowing date (11 May) and a population between 61 and 74 plants m^{-2}. Leaf production was not significantly influenced by any treatment. Bulb mass, yield and firmness were significantly higher with early sowing dates (11 or 25 May). Plant population significantly influenced bulb mass, but not yield. Bulb diameter increased as population decreased, irrespective of planting date. The three lowest populations (74, 67 and 61 plants m^{-2}) yielded significantly harder bulbs than denser plants (83 and 95 plants m^{-2}). The best sowing date for Jaquar in Bloemfontein was from 11 to 25 May at a population of between 61 and 74 plants m^{-2}.

Key words: Bulb diameter, bulb firmness, bulb fresh mass, bulb shape, leaf number, plant height, yield.

INTRODUCTION

The performance of onion (*Allium cepa* L.) is greatly influenced by environmental factors (photoperiod and temperature) and agronomic practices. The primary objective of any producer is to attain high yields and for onions the final yield depends on the amount of vegetative growth before bulb initiation (Adjei-Twum, 1980 cited by Ibrahim, 2010). Sowing date and plant population are the two major factors that influence the vegetative growth of onions. Early sowing of onions results in more vegetative growth (leaf length and quantity) (Mulungu et al., 1998), which ultimately reflects in the leaf area index (LAI) (Brewster, 1994). The yield of late sown plants will be lower than earlier sown plants because leaf blade production switches to bulb initiation while the LAI and light interception is still low (Pakyürek et al., 1994; Brewster, 2008). Therefore, sufficient time is

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needed for leaf production before bulb initiation. Both early sowing and an increase in plant population will increase the LAI (Mondal et al., 1986).

As plant population increases, onion bulb yield also increases because the leaf canopy intercepts a higher percentage of light (Brewster, 2008). In a field experiment done in Skierniewice, onion bulb yields of between 31 and 59 t ha^{-1} were recorded with a plant population ranging between 80 and 100 plants m^{-2} when grown from seed (Rumpel and Felczyński, 2000). However, with a plant population lower than 60 plants m^{-2} or more than 100 plants m^{-2} onion yield decreased. Kanton et al. 2002 also reported a yield increase with higher onion plant populations in Northern Ghana. Plant populations ranged from 37.04 to 156.25 plants ha^{-1} and the highest yield was recorded for a population of 76.92 plants ha^{-1}.

Bulb size is an important quality characteristic and different markets require different bulb sizes. According to Brewster (1994), a plant population between 50-100 plants m^{-2} will produce bulbs that are between 50-70 mm in diameter, which are preferred in most markets (Lai et al., 1994; Rumpel and Felczyński, 2000; Bosch Serra and Currah, 2002), while at a plant population of 25-50 plants m^{-2} large bulbs (>70 mm) suitable for the processing industry will be produced (McGeary, 1985; Shock et al., 2005).

Split bulbs downgrade onion bulb quality and are common in large bulbs, normally resulting from larger plants, and this is also associated with a lower plant population and a too early planting date. In Bangladesh, Khan et al. (2003) reported that at a low plant population (48 plants m^{-2}), 24.34% of the total bulb yield split, whereas only 14.38% split when bulbs were planted more densely with a population of 163 plants m^{-2}. Larger plants easily form split bulbs because of the development of more leaf bases further away from the apical meristem that eventually produce split bulbs (Rabinowitch, 1979). Plant population also influences the shape of onion bulbs, which also influences the marketability of onions. Round bulbs are preferred in South Africa (Eksteen et al., 1997). An increase in plant population leads to elongated bulbs (Hygrotech, 2010).

In the central Free State province of South Africa, mostly intermediate cultivars are sown. In the past few years, the onion market underwent a major turn around with the release of a number of new short, early and mid-intermediate cultivars. The new onion cultivars were introduced so that the sowing season would be lengthened from February until the end of June in the central areas of South Africa (Northern Cape and Free State provinces). Onion is one of the vegetable crops that are very sensitive to sowing and transplanting dates. Each cultivar, soil type and micro climate combination can result in different growth and yield responses and it is therefore important that all plantings start with the correct sowing date.

In a field experiment conducted in 2009 and repeated in 2010, four onion cultivars best suited for central South Africa (Southwood, 2009) were selected. These cultivars included one short, two early intermediate and one mid-intermediate onion cultivar. Jaquar (a mid-intermediate cultivar) performed the best in 2009 and this was confirmed in 2010 (Bosekeng and Coetzer, 2013).

The aim of this study was therefore to investigate the effect of delayed planting dates on Jaquar and to determine whether plant population could compensate for yield losses that may have occurred with late planting dates in Bloemfontein (central Free State Province, South Africa).

MATERIALS AND METHODS

A field experiment was conducted at the University of the Free State in Bloemfontein (South Africa) in the year 2010. Bloemfontein (29°06'S and 26°18'E, 1395 m above sea level) is located in the Central Free State on the southern edge of the Highveld within the semi-arid climate of the revised Köppen Climate Classification (Kruger, 2004). Summers are hot (annual average maximum temperature 24.4°C), and winters cold and dry, often with severe frost (annual average minimum temperature of 7.5°C). It is a summer rainfall area with an annual average rainfall of 559 mm. Table 1 shows a summary of weather conditions during the production season.

The onion cultivar Jaquar, was selected based on performance in a previous field experiment conducted during 2009 as was explained earlier where different cultivars were sown on different planting dates in Bloemfontein (Bosekeng and Coetzer, 2013). Seeds of the cv. Jaquar were sown on three sowing dates (11 May, 25 May and 8 June) at five different plant populations (95, 83, 74, 67 and 61 plants m^{-2}) (Table 2). The experiment was laid out as a randomized complete block design, with each treatment combination replicated 3 times.

Soil samples were collected according to the guidelines of the Fertilizer Society of South Africa (Fertilizer Society of South Africa, 2007), from a depth of 15 cm prior to land preparation, dried and sent for analysis. Analyses were carried out according to standard methods of The Non-Affiliated Soil Analysis Work Committee (1990). Some chemical and physical properties of the soil are indicated in Table 3. The soil is a sandy loam of the Bainsvlei form (Soil Classification Working Group, 1991), or Plinthustalf according to the Soil Survey Staff (2003).

Results of the analyses were used to determine nutrient requirements according to the nutrient withdrawal amounts for onions (Fertilizer Society of South Africa, 2007) at a targeted yield of 70 t ha^{-1}. These withdrawal amounts were 5, 0.5 and 2.4 kg ha^{-1} for N, P and K, respectively. According to the soil analysis, the phosphorus level of the soil was below the optimum for vegetable production and an additional 11 kg P ha^{-1} was applied. Phosphorus (46 kg ha^{-1}) and nitrogen (138 kg N ha^{-1}) was broadcast and incorporated into the soil for the total experimental area before sowing using 3.1.0(28). All the potassium (280 kg K ha^{-1}) was applied before sowing using potassium chloride. A split application of the residual nitrogen was done using urea at 6 (106 kg ha^{-1}) and 12 weeks (106 kg ha^{-1}) after sowing. This was calculated and applied per plot to assure that each plot received the same amount of fertilizer.

Before sowing, the soil was watered to field capacity. Seeds were sown by hand and covered with soil to a depth of 2 cm. A light irrigation was applied after sowing, using surface drip system with emitters spaced 30 cm in the line and with a delivery capacity

Table 1. Monthly average maximum and minimum temperatures, photoperiod and total rainfall from the weather station for 2010 (South African Weather, 2010; South African Astronomical Observatory, 2010).

Month	Temperatures (°C)		Photoperiod (hours)	Rainfall (mm)
	Maximum	Minimum		
January	27.86	17.13	13.45	131.10
February	29.07	16.73	13.31	124.70
March	27.78	14.74	12.06	77.70
April	22.96	10.58	11.22	48.50
May	20.75	6.63	10.39	39.90
June	16.96	1.64	10.18	20.10
July	18.44	4.04	10.28	0.30
August	21.05	3.84	11.30	0.00
September	26.35	9.14	12.11	0.30
October	27.10	10.96	12.57	20.60
November	28.47	13.19	13.34	30.20
December	28.51	14.65	14.13	113.00
Total Rainfall				606.40

Table 2. Different plant population and sowing date treatments, plant spacing, plot size and plants per row used.

Plant population		Plant spacing (cm)		Plot size (m^{-2})		Plants row^{-1}
m^{-2}	ha^{-1}	In row	Between row	gross	net	
95	952 381	3.5	30	1.8	0.95	34
83	833 333	4.0	30	1.8	0.94	30
74	740 741	4.5	30	1.8	0.92	26
67	666 667	5.0	30	1.8	0.90	24
61	606 061	5.5	30	1.8	0.88	21

Table 3. Measured chemical and physical properties of the soil samples and optimum soil analysis values for vegetables according to the Fertilizer Society of South Africa (2007)

Property	Measured value	Optimum value
$pH_{(KCl)}$	4.7	4.5-6
Nutrients (mg kg^{-1})		
P (Bray 1)	28.1	30-60
K (NH_4OA_C)	233.8	120-240
Ca (NH_4OA_C)	531	400-2500
Mg (NH_4OA_C)	156.3	100-400
Na (NH_4OA_C)	10.7	
CEC ($cmol_c kg^{-1}$)	4.73	
Particle size distribution (%)		
Sand	67	
Clay	12	
Loam	21	

of 2.1 L h^{-1}. A drip irrigation system was used to keep the soil as close as possible to field capacity and to assure each plot received the same amount of water. Irrigation (1.78 mm) was done on a daily basis, except on days that it rained, to prevent soil from forming a crust that would delay emergence (Mondal et al., 1986). After emergence, irrigation (3.25 mm) was done every second day during the vegetative phase and daily (2.33 mm) from the start of bulb development until maturity.

The seedlings were thinned to the required plant population (Table 2) three weeks after emergence. Weeds were controlled manually every week throughout the season. Sodium fluosilicate (Cutworm Bait- Efekto, Private Bag 215, Bryanston, 2021 South

Africa) was broadcast at a rate of 10 g m^{-2} over the planted area as soon as the first seedlings emerged. Mercapthothin (Malasol-Efekto, Private Bag 215, Bryanston, 2021 South Africa) was applied at a rate of 17.5 ml 10 L^{-1} H_2O using a knapsack sprayer whenever aphids or thrips were noticed on the onion plants.

Growth parameters were measured on 11 randomly selected plants located in the center of each plot. Growth data were collected every three weeks, starting from the third week after emergence until 10% of the foliage collapsed. Only final plant height and leaf number 18 weeks after emergence will be reported on in this study. Plant height was measured from the ground level to the tip of the highest leaf using a standard ruler. The numbers of fully developed active green leaves were counted. The focus of this study was mainly on the sellable product and therefore only yield (fresh mass) and external quality parameters were measured. External parameters that were measured such as bulb diameter (size) and shape play a major role in marketing, as well as neck diameter and bulb firmness in the storage life of the bulbs. These yield and quality parameters were assessed on bulbs from net plot size (Table 2) of the middle rows in each plot. Onions were lifted by hand when 100% of the foliage top per plot had collapsed. If necessary, the soil was first loosened using garden fork. Onion bulbs were transported immediately to the laboratory and not left to cure.

After harvesting, leaves and roots were cut from the bulbs, and bulbs cleaned by washing with water and dried with tissue paper. Bulbs were weighed separately to obtain fresh mass per bulb of 11 randomly selected bulbs harvested from the net plot. The fresh mass of all bulbs harvested from net plot size was expressed as g m^{-2}, and then converted to t ha^{-1} in order to indicate onion yield. The same 11 bulbs were also used to measure the bulb quality parameters (diameter, firmness, neck diameter, defects and shape). Bulb diameter was measured at right angles to the longitudinal axis at the widest circumference of the bulb using a digital caliper. Thereafter, the bulbs were graded into extra small (10 to 34 mm), small (35 to 39 mm), medium (40 to 69 mm), large (70 to 89 mm) or extra-large (≥ 90 mm) bulbs (Joubert et al., 1997). The firmness of bulbs was measured using a Seta-Matic penetrometer controller (Model 1720), automatically controlled with a constant load penotrometer (Model 1719 of Stanhope seta Ltd., England). Bulb defects such as decay, split and mechanical damage were observed to aid in determining marketable bulbs. Bulb shape was determined by observation using the norms of Boyhan and Kelley (2008).

Analysis of variance was calculated on all measured parameters to determine the significance of differences between means of treatments using the NCSS 2000 statistical program (Hintze, 1999), and Tukey's test for the LSD ≤ 0.05, except where stated.

RESULTS

The growth period for Jaquar (early intermediate cultivar) for the different sowing dates and plant populations are indicated in Table 4.

Plant height and leaf number

The interaction between plant population and sowing date did not significantly affect plant height or leaf number (Table 5). Although not always significant, plant height decreased as plant population increased. Plants planted at 95 plants m^{-2} were significantly shorter (46.40 cm) than plants from the three lowest populated plantings of 61, 67 and 74 plants m^{-2} (55.07, 51.13 and 52.21 cm, respectively). However, plants planted at lower densities of 61, 67 or 74 plants m^{-2}, did not significantly differ in height from each other. Onion plants sown early (11 May) were significantly taller than plants sown on 25 May or 8 June. The total number of onion leaves produced was not significantly influenced by either plant population or sowing dates (Table 5).

Bulb fresh mass and yield

The interaction between plant population and sowing date did not significantly influence onion bulb fresh mass and yield. Plant population, however, significantly influenced bulb fresh mass but not yield (Table 6). Bulb fresh mass decreased as plant population increased with the bulbs from plants at a density of 61 plants m^{-2} being significantly heavier than those planted at 83 or 95 plants m^{-2}. Bulbs harvested from those planted at the lowest population (61 plants m^{-2}) were 38.46 and 28.29% heavier than bulbs of plants planted at 95 or 83 plants m^{-2}, respectively. Fresh mass of bulbs harvested from plants sown at a density of between 61 and 74 plants m^{-2} did not differ significantly from each other. Even though plant population did not significantly influence yield, the highest yield was obtained from a plant population of 74 plants m^{-2} (38.68 t ha^{-1}) and the lowest from a plant population of 95 plants m^{-2} (36.00 t ha^{-1}). Yield increased as plant population decreased from 95 to 74 plants per m^{-2}, but with a further decrease in plant population bulb yield tend to decrease again, although not significantly.

Bulb diameter (size)

The interaction between plant population and sowing date significantly affected onion bulb diameter (Table 7). As plant population increased from 61 to 95 plants m^{-2} the size of bulbs decreased, irrespective of sowing date. All the bulbs were graded as medium size bulbs (40-69 cm), with the exception of bulbs harvested from plants sown on 11 or 25 May at the highest population planting of 95 plants m^{-2}. Bulb diameter responded differently to sowing date and plant population. Significantly larger bulbs were produced by plants at a density of between 61 and 67 plants m^{-2} when sown on 11 May; and those sown on the 8 June were only significantly larger when sown at 61 plants m^{-2} compared to that of bulbs from plants sown more densely between 83 and 95 plants m^{-2}. Bulbs harvested from the two lowest densities (61 or 67 plants m^{-2}) were significantly larger than bulbs at the three highest populated plantings (74, 83 or 95 plants m^{-2}) when sown on 25 May.

Neck diameter

The interaction between plant population and planting

Table 4. A summary of the growth period of Jaquar (early intermediate cultivar) as influenced by sowing date and plant population during 2010.

Plant Population (plants m^{-2})	Sowing date	Emergence date	Sowing to emergence (days)	Thermal time (600 degree days)	Earliest expected bulb initiation date	Emergence to expected bulb initiation (days)	Average maximum day temperature from emergence to expected bulb initiation (°C)	Harvesting dates	Sowing to harvesting (days)
	11 May	24 May	13	31 Aug		118	20.13	8 Nov	181
95	25 May	14 June	20	10 Sept	19 Sept	97	20.51	8 Nov	167
	8 June	6 July	28	17 Sept		76	21.59	8 Nov	153
	11 May	24 May	13	31 Aug		118	20.13	8 Nov	181
83	25 May	14 June	20	10 Sept	19 Sept	97	20.51	8 Nov	167
	8 June	06 July	28	17 Sept		76	21.59	8 Nov	153
	11 May	24 May	13	31 Aug		118	20.13	8 Nov	181
74	25 May	14 June	20	10 Sept	19 Sept	97	20.51	8 Nov	167
	8 June	6 July	28	17 Sept		76	21.59	8 Nov	153
	11 May	24 May	13	31 Aug		118	20.13	8 Nov	181
67	25 May	14 June	20	10 Sept	19 Sept	97	20.51	8 Nov	167
	8 June	6 July	28	17 Sept		76	21.59	15 Nov	160
	11 May	24 May	13	31 Aug		118	20.13	8 Nov	181
61	25 May	14 June	20	10 Sept	19 Sept	97	20.51	8 Nov	167
	8 June	6 July	28	17 Sept		76	21.59	15 Nov	160

date did not significantly influence onion bulb neck diameter (Table 7). The necks of onion bulbs from plants sown late (8 June) were 7.32 mm, significantly thinner than the earlier sown plants (11 or 25 May) of 9.50 and 9.64 mm, respectively. As plant population increased, bulb necks tended to be thinner, although not always significant. Bulb necks of onions planted at 74, 67 or 61 plants m^{-2} were significantly thicker than necks of bulbs planted at 95 plants m^{-2}.

Bulb firmness

Bulb firmness was significantly affected by both plant population and sowing date. The interaction between these two factors was, however, not significant (Table 6). As plant population decreased from 95 to 62 plants m^{-2}, bulbs became firmer. Bulbs harvested from plants sown at a density of 95 or 83 plants m^{-2} produced significantly softer bulbs than those harvested from plants at 74, 67 or 61 plants m^{-2}. Plants sown late (8 June) produced significantly firmer bulbs than those sown earlier (11 May or 25 May).

DISCUSSION AND CONCLUSION

Plant population significantly influenced plant height, bulb fresh mass, bulb diameter, bulb neck diameter and bulb firmness. As the plant population increased, plant height and bulb fresh mass decreased (Tables 5 and 6). Bulb quality (neck diameter and firmness) also showed a decrease with an increase in the plant population (Table 7). The reason for higher plants in less dense populations may be associated with competition between plants for available water and nutrients. Jilani et al. (2009) conducted a study using three planting populations (20, 30 and 40 plants ha^{-1}) and five onion cultivars in Pakistan and recorded higher plants from a less dense population (20 plants m^{-2}) than a denser population (40 plants m^{-2}). However, Dawar et al.

Table 5. Influence of sowing date and plant population on plant height (cm) and leaf number of the onion cv. Jaquar 18 weeks after emergence.

Plant population (PP) (plants m^{-2})	Plant height (cm)				Leaf number			
	Sowing date (SD)			Avg	Sowing date (SD)			Avg
	11 May	25 May	8 June	(PP)	11 May	25 May	8 June	(PP)
95	50.33	41.48	47.39	46.40[a]	8.00	7.67	7.00	7.56
83	52.55	45.33	50.00	49.29[ab]	7.67	7.33	7.67	7.56
74	53.46	50.03	49.91	51.13[bc]	7.33	7.67	7.67	7.56
67	54.24	52.42	49.97	52.21[bc]	7.33	7.00	7.33	7.22
61	57.91	55.54	51.76	55.07[c]	7.33	7.33	7.33	7.33
Average (SD)	53.70[A]	48.96[B]	49.81[B]		7.53	7.40	7.40	
$LSD_{T(0.05)}$	PP = 4.62	SD = 3.04	PP x SD = ns		PP = ns	SD = ns	PP x SD = ns	

PP: plant population; SD: sowing date; PP x SD: plant population interaction with sowing date; Avg: average; LSD: least significant difference; ns: not significant. Means with small cap (a, b and c) in the same column differ significantly from each other. Means with different cap letters (A, B and C) in the same row differ significantly from each other; P ≤ 0.05

Table 6. Influence of sowing date and plant population on bulb fresh mass and yield of the onion cv. Jaquar.

Plant population (PP) (plants m^{-2})	Bulb fresh mass (g)				Yield (t ha^{-1})			
	Sowing date (SD)			Avg (PP)	Sowing Date (SD)			Avg (PP)
	11 May	25 May	8 June		11 May	25 May	8 June	
95	39.32	45.40	28.67	37.80[a]	37.45	43.24	27.31	36.00
83	43.35	53.05	35.79	44.06[ab]	36.12	44.20	29.82	36.71
74	53.74	53.76	49.17	52.22[bc]	39.81	39.82	36.42	38.68
67	68.07	49.89	49.33	55.76[cd]	45.38	33.26	32.88	37.17
61	64.42	58.00	61.94	61.45[c]	39.04	35.15	37.53	37.24
Avg (SD)	53.78[A]	52.02[A]	44.98[B]		39.56[A]	39.13[A]	32.79[B]	
$LSD_{T(0.05)}$	PP = 10.34	SD = 6.80	PP x SD = ns		PP = ns	SD = 5.08	PP x SD = ns	

PP: plant population; SD: sowing date; PP x SD: plant population interaction with sowing date; Avg: average; LSD: least significant difference; ns: not significant. Means with small cap (a, b and c) in the same column differ significantly from each other. Means with different cap letters (A, B and C) in the same row differ significantly from each other; P ≤ 0.05.

(2007) investigated three plant populations (40, 60 and 80 plants 4 m^{-2}) using three onion cultivars under Peshawar conditions. They reported that as plant population increased from 40 to 80 plants 4 m^{-2}, plant height (leaf length) increased significantly from 47.79 to 52.51 cm. This was ascribed to competition for sunlight making the plants grow taller to exploit light to a maximum in denser plant populations. Conversely, the current study found that plant height decreased as the population increased from 61 to 95 plants m^{-2}.

The increase in competition for water and nutrients between plants under denser populations also reflected in bulb fresh mass, yield and diameter. The higher bulbfresh mass and larger bulbs in less dense populations may have been due to sufficient leaf growth and space for bulb development. In Northern Ghana, Kanton et al. (2002) transplanted onions (cv. Bawku Red) in the field using eight different plant populations (37.04 - 156.25 plants m^{-2}). They reported a decrease in bulb fresh mass as plant population increased from 37.04 to 156.25 plants m^{-2}. Bulbs planted at 37.04 plants m^{-2} were 128% heavier than bulbs at 156.25 plants m^{-2}. This phenomenon was also associated with sufficient leaf growth and space for bulb development (Kanton et al., 2002). Although yield was not significantly influenced by plant population in the current study (Table 6), yield increased as plant population increased from 61 to 74 plants m^{-2} (37.24 to 38.68 t ha^{-1}), but with a further increase to 95 plants m^{-2}, yield decreased to 36.00 t ha^{-1}. The yield of onions sown directly at six different plant populations (20, 40, 60, 80, 100 and 140 plant ha^{-1}) increased from 29.8 to 32.6 t ha^{-1} when plant population increased from 60 to 100 plants m^{-2}; but with an increase to 140 plants m^{-2}, a decreased yield of 31.1 t ha^{-1} was reported (Rumpel and Felczyński, 2000). With a plant population lower than 60 plants m^{-2}, onion yield also

Table 7. Influence of sowing date and plant population on bulb diameter, neck diameter and bulb firmness of the onion cv. Jaquar.

Plant Population (PP) (plants m^{-2})	Bulb diameter (mm)				Neck diameter (mm)				Bulb firmness (mm)			
	Sowing Date (SD)			Avg (PP)	Sowing Date (SD)			Avg (PP)	Sowing Date (SD)			Avg (PP)
	11 May	25 May	8 June		11 May	25 May	8 June		11 May	25 May	8 June	
95	39.22^{a}	39.74^{a}	42.68^{ab}	40.55	7.09	7.39	6.31	6.93^{a}	104.00	105.68	90.65	100.11^{a}
83	44.45^{abc}	44.29^{abc}	45.02^{abc}	44.59	8.16	8.17	6.69	7.67^{ab}	100.91	102.66	74.48	92.68^{a}
74	55.47^{cd}	46.98^{abc}	54.33^{cd}	52.26	10.25	9.35	7.15	8.92^{b}	77.55	85.82	56.57	73.31^{b}
67	64.97^{de}	59.61^{de}	54.14^{bcd}	59.57	10.62	11.18	8.42	10.07^{bc}	77.95	73.30	66.35	72.53^{b}
61	68.94^{e}	63.96^{de}	59.24^{de}	64.05	11.36	12.11	8.01	10.49^{c}	80.70	72.90	63.27	72.29^{b}
Avg (SD)	54.61	50.92	51.08		9.50^{A}	9.64^{A}	7.32^{B}		88.22^{A}	88.07^{A}	70.26^{B}	
$LSD_{T(0.05)}$	PP = 5.16	SD = 3.39	PP x SD = 11.66		PP = 1.26	SD = 0.83	PP x SD = ns		PP = 9.21	SD = 6.06	PP x SD = ns	

PP, plant population; SD, sowing date; PP x SD, plant population interaction with sowing date; Avg, average; LSD, least significant difference; ns; not significant. Means with small cap (a, b and c) in the same column differ significantly from each other. Means with different cap letters (A, B and C) in the same row differ significantly from each other; P≤0.05.

decreased from 26.4 to 20.5 t ha^{-1}. According to these researchers, the decrease in bulb yield as plant population increases may be due to early maturation of bulbs. As bulbs mature earlier, the period for leaf growth is also short resulting in a smaller LAI with less efficient light interception (De Visser, 1994). This was not the case in the current study because all bulbs were harvested on 8 November irrespective of the plant population, except the 61 and 67 plant m^{-2} plantings, which were harvested a week later on 15 November (Table 4). Hatridge-Esh and Bennett (1980) planted onions at four different plant populations (7, 40, 80 and 100 plants m^{-2}) in California and reported that bulb diameter decreased from 99 to 63 mm as plant population increased from 7 to 100 plants m^{-2}. This was caused by competition for nutrients and insufficient space restricting bulb enlargement when plant population increased. In the current study, the highest percentage of medium bulbs (81.8-93.9%) occurred at a plant population of 74 plants m^{-2} for all three planting dates.

Leaf number was, however, not significantly influenced by either plant population or sowing date and thus corresponded with the results of both Farooq-Ch et al. (1990) and Kanton et al. (2002). Farooq-Ch et al. (1990) stated that number of leaves produced by an onion plant is a genetic character, and is not influenced by plant population. Similarly, Bosekeng and Coetzer (2013) found that sowing dates did not significantly influence leaf number of Jaquar sown at a plant population of 61 plants m^{-2}.

Sowing date significantly influenced all other parameters. As sowing date was delayed from 11 May to 8 June, plant height, bulb fresh mass, bulb diameter and neck diameter decreased, and bulbs were harder. In a separate field experiment during the same season where Jaquar was sown on the same dates at a population of 61 plants m^{-2}, the same trends for the all parameters were recorded (Bosekeng and Coetzer, 2013). Onions will switch from leaf blade production to bulb initiation when the minimum day length requirements are met. For the same cultivar sown on different dates, bulb initiation will occur at more or less the same time. However, other factors such as temperature and plant size may also play a role (Brewster, 1994). When considering sowing date,day length and temperature data (Table 1 and 4) of the current study, the early sown plants (11 May) had a longer growth period of 118 days compared to 97 days (25 May) and 76 days (8 June) for the later sown plants. The average maximum temperatures during the different growth periods for the different sowing dates did not differ much, and ranged between 20.1 and 21.6°C (Table 4). These results are in agreement with those of Cramer (2003) who reported that early sown plants were taller than late sown plants due to a longer vegetative growth period. The longer growth period for early sown plants resulted in longer leaves (Table 5) that intercepted more light (Brewster 1994) and this eventually increased bulb fresh mass (Table 6), larger bulbs with thinner necks (Table 7) and softer bulbs.

In Eqypt, Leilah et al. (2003) reported that a yield of 46.95 t ha^{-1} was obtained with the December planting, followed by 38.10 t ha^{-1} for

January and 31.80 t ha^{-1} for February. Jaquar is known for its globe shaped bulbs (Hygrotech, 2009). From the current study, none of the plant populations or sowing dates produced globe shaped bulbs. Bulb shape changed with plant population. At a population of 95 or 83 plants m^{-2} bulbs were spindle shaped (epllitic) and changed to egg shaped pointed (oval) as plant population decreased to 74 or 67 plants m^{-2}. Bulb shape changed from egg shaped pointed, to a broad reversed (top) shape with a further decrease in plant population to 61 plants m^{-2}. The reason for the change in bulb shape was the limited space available for each bulb to develop. Elongated bulbs are the result of squeezing against each other (Hygrotech, 2010). McGeary (1985) studied planted onion cv. White Spanish under six different populations (178, 400, 6325, 816, 111and 1600 plants m^{-2} and reported a decline in number of round bulbs (13.3%) when population increased from 178 to 1 600 plants m^{-2}. Current results showed that all the bulbs (100%) changed shape as plant population changed.

The manipulation of plant population is a critical agronomic principle, which cannot be ignored as it plays a role in growth, yield and bulb quality (bulb mass, size and firmness) of onions. Jaquar produced the best growth, highest bulb fresh mass and yield; and best quality when sown from 11 to 25 May at a plant population of between 61 and 74 plants m^{-2} in Bloemfontein, Central Free State Province of South Africa. When sowing date is extended (8 June), a lower plant population must be used (61 plants m^{-2}) to compensate for losses and to harvest a relatively marketable yield.

Conflict of Interest

The authors have not declared any conflict of interest.

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Evaluation of physical and physiological characteristics of seeds and seedlings of physic nut genotypes

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The physic nut is an oleaginous plant that has distinguished itself as a drought tolerant native species, with a view to producing raw material for the biodiesel production. The purpose of the study reported here was to evaluate the quality of seeds and seedlings of five physic nut genotypes. The evaluated characteristics were: humidity content, mass of 1000 seeds, seed dimensions (using caliper gauge and sieves), germination tests, vigor tests (the first count of the germination test, electrical conductivity, accelerated ageing, seedling dry mass and length, emergence, emergence speed index and analysis of emerged seedlings). The experimental design was a completely randomized block with 4 replications. All data were submitted to analysis of variance by F test and the means were compared by the Tukey test at 5% probability. The physiological quality was not influenced by the seeds dimensions. The tests of accelerated ageing, emergence percentage, shoot dry mass, seedling length and dry mass were the bests at differentiating the genotypes. The Paraguaçu genotype presented characteristics that were superior in relation to the others in the evaluations of accelerated ageing, root length and seedling total length.

Key words: *Jatropha curcas,* germination, vigor, viability, seed size.

INTRODUCTION

The physic nut (*Jatropha curcas* L.) that belongs to the Euphorbiaceae family, is a shrub species which can reach a height of four meters, being widely distributed in tropical and subtropical areas, and offers a potential for biodiesel production (Sujatha et al., 2008).

One of the ways to enhance plant potential is the development of new technologies aimed to improve its production, to obtain qualified seeds to generate vigorous plants with high productivity. High germination capacity, vigor, appropriate humidity content and good appearance

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are indicators of good seed quality. These factors, when properly balanced, provide high plant vigor, high homogeneity and, consequently, higher quality and productivity (Lacerda, 2007).

The seed physiological quality is assessed using standardized methods, under laboratory controlled conditions, aiming to obtain its value for the sowing, maturation, and to compare the physiological quality that will contribute for the seed commercialization (Teixeira et al., 2010). Among the tests that evaluate seed quality, Souza (2007) refers to germination and vigor tests (seed viability, accelerated ageing, electrical conductivity, among others). The physical quality of seeds can be evaluated according to humidity, physical purity, mechanical damage, mass of 1000 seeds, size or volumetric weight and appearance (Peske et al., 2006). The seed size is a component of quality that has been evaluated for many species. According to Carvalho and Nakagawa (2000), larger seeds were better nourished during their development, presenting well-formed embryos with higher quantity of storage substances, being consequently more vigorous.

Given the lack of information referred to this culture, the present study aimed to evaluate the physical and physiological quality of seeds and seedlings of five physic nut genotypes, as well as to generate information for the standardization of tests as it is a under researched culture.

MATERIALS AND METHODS

The study was conducted in the Laboratory of Seed Technology, State University of Southwest of Bahia, Vitória da Conquista, Bahia, located at 923 m of altitude, of latitude 14°53' S and 40°48' West Longitude and in the Laboratory of Seed Analysis of the College of Agricultural Sciences (Faculdade de Ciências Agronômicas - FCA), of the State of São Paulo University (UNESP), in Botucatu, SP, located at 770 m of altitude, latitude of 22° 49' 31"S and 48° 25' 37" West longitude. The average daily temperature during the experimental evaluations remained between 16.87 and 20.73°C.

The seeds used in this study came from commercial planting of five physic nut genotypes collected in January 2008, in the city of Janaúba, MG. The characterization of seed physical quality was conducted using tests that evaluate the humidity content, mass of 1000 seeds and seed size.

The seed moisture content was determined by the stove method at 105±3°C, throughout 24 h (Brasil, 2009). The mass of 1000 seeds was determined using eight replications of 100 seeds (Brasil, 2009).

The dimensional evaluation of seeds was conducted using samples taken at random from 50 seeds and four replications for each genotype. A digital caliper gauge was used to measure the length, width and thickness of the seeds expressed in mm. In the seed classification with sieves, three samples of each genotype were taken. The seeds were classified by stirring per minute in manual sieves with oblong holes, dimensions of 9.52 × 19.05 mm, 8.73 × 19.05 mm, 7.94 ×19.05 mm, 7.14 ×19.05 mm, 6.35 × 19.05 mm and bottom. The seeds that were retained by the indicated sieve that had passed by the superior mesh were weighted and had their percentages calculated (Brasil, 2009).

The physiological quality of seeds and seedlings were determined by the test of germination and vigor (first count of the germination test, electrical conductivity, accelerated ageing, length and dry mass of the seedlings, emergence, emergence speed index and analysis of emerged seedlings.

The germination test was conducted using four replications of 50 seeds, in dampened paper towel under the proportion of 2.5 × the subtract mass (g), at the temperature of 30°C, with counts at four and seven days after test set up. First germination counting (FGC) was performed together with germination test, which is the percentage of regular plants from four days after sowing. The mass system with four replications of 50 seeds per batch was used for electrical conductivity determination (Marcos Filho, 1987). The accelerated ageing was determined using four replications of 50 aged seeds at 40°C for 72 h (Krzyzanowski et al., 1999). After this stage, the seed moisture content (MC) and germination percentage (GER) were measured. At 9 days after sowing, the seedlings root length (R), shoot (S) and total (TOT) were determined using four replications of 10 seeds per genotype, sown on a line drawn on the upper third of the paper towel Germitest, according to recommendations of Vieira and Carvalho (1994). All seedlings from seedling length test were used to evaluate dry mass separated in two portions - root and shoot, dried in stoves at 60±5°C until they reach uniform weight. The results were expressed in grams as in Nakagawa (1999).

Percentage and speed emergence were simultaneously conducted in disposable aluminum dishes containing 2-liter substrate made of 2/3 washed sand and 1/3 soil (under field conditions) with four replications of 50 seeds each batch. The counting was conducted daily, after the emergence (EMERG) of the first seedling until 36 days after the sowing. The emergence speed index (ESI) was calculated using the formula proposed by Maguire (1962). To analyse the emergence at 36 days after sowing, seedlings were removed from aluminium dishes and number of leaves was recorded (NL), trunk diameter (TD), seedling height (SH), root length (RL), root dry mass (RDM) and shoot dry mass (SDM). The stove method was used for the dry mass analysis at 70°C±3 throughout 72 h.

The used experimental design was totally randomized with four replications for all treatments. The data were submitted to F test variance analysis and means compared by the Tukey test (P≤0.05).

RESULTS AND DISCUSSION

One thousand seed average mass values are shown in Table 1. By these values, it is possible to observe significant differences among batches, pointing out Filomena batch as the highest mass seeds and Gonçalo as the least one. Differences found in the 1000 seed evaluation would possibly be explained by the genetic characteristic differences as field conditions were similar for genotypes. Braga (2010) assessing seed quality of 5 batches of physic nut, found an initial moisture content between 6.7 and 7.7% and 1000 seed average mass varying from 680.38 and 730.29 g. Silva et al. (2008), evaluating physic nut seed physical and physiological quality, found 9.47% humidity and 468.95 g for 1000 seed mass. Considering the initial moisture content as a crucial factor for evaluation standardization, the results ensure data credibility in which there was no difference between the moisture contents of the genotypes.

The average values of seed classification, indicates Filomena and Oracília as the largest seeds and Gonçalo

Table 1. One thousand seed mass, moisture content and seed dimensions of five physic nut genotypes. Vitória da Conquista, BA, Brazil, 2008.

Genotypes	1000 seed mass (g)	Moisture content (%)	Length (m)	Dimensions (mm)	
				Width	Thickness
Bento	688.48^{c*}	6.89^{a}	18.0778^{b}	10.7282^{b}	8.5748^{a}
Filomena	745.68^{a}	7.40^{a}	18.2082^{ab}	11.1826^{a}	8.7394^{a}
Gonçalo	566.37^{e}	7.77^{a}	16.7642^{e}	10.5870^{b}	7.8604^{b}
Oracília	722.71^{b}	7.88^{a}	18.6728^{a}	11.2840^{a}	8.6812^{a}
Paraguaçu	657.19^{d}	6.07^{a}	18.1284^{b}	10.7206^{b}	8.4962^{a}
CV (%)	1.85	11.57	4.93	5.27	5.56

* Averages followed by the same lower case letter in the column do not differ from each other by the Tukey test at 5% of probability (P<0.05%).

Table 2. Seed fractions (%) by sieve of five physic nut genotypes. Vitória da Conquista, BA, Brazil, 2008.

Genotypes	Sieves					
	9.52	8.73	7.94	7.14	6.35	Bottom
Bento	4.29^{Bab}*	42.01^{Ac}	48.09^{Aa}	5.33^{Bc}	0.31^{Ba}	0.00^{Ba}
Filomena	7.38^{Ca}	64.64^{Aa}	26.12^{Bc}	1.50^{Dc}	0.12^{Da}	0.00^{Da}
Gonçalo	0.60^{Db}	10.20^{Cd}	36.26^{Bd}	50.37^{Aa}	2.43^{Da}	0.07^{Db}
Oracília	6.84^{Ca}	54.09^{Ab}	34.89^{Bd}	4.17^{CDc}	0.00^{Da}	0.00^{Da}
Paraguaçu	5.81^{Cab}	37.92^{Ac}	41.56^{Ab}	13.97^{Bb}	1.07^{Ca}	0.31^{Ca}
Coefficient of variation			15.97			

*Means followed by the same capital letter in line and lower case in column do not differentiate from the other by the Tukey test at 5% of probability (P<0.05%).

as the smallest one (Table 1), confirming the results found for 1000 seed evaluation in which the Filomena showed the highest mass.

The variance analysis means of sieve classification showed the significant effect of different genotypes and sieves used (Table 2).

There was a higher percentage of retained seeds in the sieve 8.73 × 19.05 mm of the Filomena genotype, representing more than 64% as observed in the mass evaluation. The Gonçalo genotype is highlighted by its small dimensions with most seeds equal or smaller than 7.14 mm of diameter (52.87%) (7.14 × 19.05 mm, 6.35 × 19.05 mm and bottom sieves).

Pádua et al. (2010) assessing soybean seeds (*Glycine max*), noticed that seeds of different sizes showed differences in physiological quality, in which bigger seeds (7.0 mm sieve) showed higher germination percentages and vigor. Martins et al. (2005) verified that heaviest papaya seeds also presented the highest germination power and vigor. Valdés-Rodríguez et al. (2013a) highlighted that both productivity and seed quality in terms of weight and size can be influenced by soil fertility, climate and agricultural management.

Through the germination assessment, it was possible to differentiate Filomena genotype from the others as it presented the lowest germination average. The data of the first germination counting, conducted in the seventh day after the sowing, presented differences on the germination percentage. It can also be verified that Filomena genotype did not present any germinated seed in the first counting (Table 3).

A possible explanation for the lower percentage and germination absence of Filomena can be due to dormancy related to environmental conditions and/or genetics itself, once these genotypes were cultivated and harvested at the same time. Joker and Jepsen (2003) asserted that the physic nut freshly harvested seeds present dormancy and need a rest period after the harvest to germinate. This is a statement that can be applied to the Filomena.

In the evaluation of the first counting, the Oracília and Gonçalo genotypes stand out from the others with better performance; however, the Gonçalo genotype was also statistically similar to the Paraguaçu genotype. Even though Carvalho and Nakagawa (2000) ensured that bigger seeds produce more vigorous seedlings, the results showed that size classification does not comply with results of germination. When evaluating physic nut seed germination at constant temperature of 30°C, Silva et al. (2008) found 77.5%. Martins et al. (2008), evaluating the germination and the first count of physic nut seeds, obtained an average of 76 and 61%, respectively.

For the accelerated ageing test, it is recommended to

Table 3. Germination percentage (GER) and first germination count (FGC) of seed five physic nut genotypes. Vitória da Conquista, BA, Brazil, 2008.

Genotypes	GER (%)	FGC (%)
Bento	86.0[a]*	22.5[c]
Filomena	32.5[b]	0.0[d]
Gonçalo	82.5[a]	38.5[ab]
Oracília	83.5[a]	42.5[a]
Paraguaçu	85.0[a]	29.0[bc]
CV (%)	7.4	20.7

* Averages followed by the same lower case letter in the column do not differ from each other by the Tukey test at 5% of probability (P<0.05%).

Table 4. Germination percentage (GER) and moisture content (UMI) after accelerated ageing test and electrical conductivity (EC) seed of five physic nut genotypes. Vitória da Conquista, BA, Brazil, 2008.

Genotypes	GER (%)	UMI (%)	EC (µS.cm^{-1}.g^{-1})
Bento	69.0[c]	24.02[a]	0.1123[a]*
Filomena	73.0[bc]	23.88[a]	0.1121[a]
Gonçalo	80.0[b]	23.64[a]	0.1046[a]
Oracília	67.0[c]	23.95[a]	0.1071[a]
Paraguaçu	91.0[a]	23.49[a]	0.1059[a]
CV (%)	5.77	2.86	5.17

* Averages followed by the same lower case letter in the column do not differ from each other by the Tukey test at 5% of probability (P<0.05%).

Table 5. Root length (R), shoot (S), total (TOT) and seedling dry mass (SDM) of five physic nut genotypes, at 9 days after sowing. Botucatu, SP, Brazil, 2008.

Genótipos	R (mm)	S (mm)	TOT (mm)	SDM (mg)
Bento	76.9[c]*	54.1[b]	130.9[c]	0.662[b]
Filomena	91.0[bc]	54.9[b]	145.9[bc]	0.731[b]
Gonçalo	97.3[b]	63.2[b]	160.5[bc]	0.839[ab]
Oracília	103.0[b]	68.0[ab]	171.1[b]	0.950[ab]
Paraguaçu	121.9[a]	80.0[a]	204.9[a]	1.286[a]
CV (%)	8.43	11.91	8.87	26.17

* Averages followed by the same lower case letter in the column do not differ from each other by the Tukey test at 5% of probability (P<0.05%).

compare seed samples with alterations higher than 2% in the initial moisture content, not undermining the results because of moistening speed variations and seed deterioration during the test (Marcos Filho, 2000). By observing the humidity means of seeds after ageing, the differences in moisture content among samples were lower than 2%, not decreasing result credibility (Table 4). According to Hampton and TeKrony (1995), the recommended humidity for soybean seeds after ageing conditions to have reliable results in the germination test ranges from 27 to 30%. In the present study, after the ageing conditions the seeds presented humidity varying from 23.9 to 24.02%. This characteristic might be justified by the difference in oil content, since the physic nut present higher oil content compared to soybean.

The results of germination and accelerated ageing presented in Tables 3 and 4, respectively, showed that Gonçalo and Paraguaçu genotypes presented similar performances, also showing a performance increase of Paraguaçu after the ageing. The genotypes Bento and Oracília had a loss of viability after the accelerated ageing test, while Filomena genotype presented better performance after accelerated ageing study. The conditions provided to the seed ageing might have favored dormancy break of Filomena seeds, since there was a test improvement compared to the germination one.

According to Mello and Tillmann (1987), there are result variations of standardization by the use of accelerated ageing test, with the major causes being the initial moisture content, the species, the cultivar, the exposition period and temperature.

In the results of the electrical conductivity test, there was no difference between the evaluated genotypes, as this test was not efficient to differentiate the studied genotypes (Table 4).

Vanzolini and Nakagawa (1998) studying the electrical conductivity in peanut seeds, concluded that the comparison of peanut genotypes by electrical conductivity tests suffers interference by the different seed sizes. However, despite these differences (Tables 1 and 2), it was not possible to differentiate seeds evaluated by the electrical conductivity test, once the conductivity value is directly related to the cellular membrane integrity (Hampton and TeKrony, 1995).

The seed moisture content is extremely important for the electrical conductivity test standardization. In general, it has been observed that very low moisture contents (<10%) or very high (>17%), present significant influence on the results. A greater effect has been observed when the seed moisture content is very low (<10%), causing a significant increase in the test results for many species (Hampton et al., 1992). By observing the moisture content in the studied batches (Table 1), it is verified that the contents were below 10%, a factor that might have contributed to the non-occurrence of significant differences between the genotypes in the electrical conductivity evaluation.

The means obtained from the data of root system and aerial part length, total length and dry mass of the seedlings from the seeds of different physic nut genotypes were statistically different (Table 5).

The Paraguaçu genotype presented higher means in

Table 6. Emergence speed index (ESI), percentage emergence (EMERG), number of leaves (NL), trunk diameter (TD), seedling height (SH), root length (RL), root dry mass (RDM) and shoot dry mass (SDM) of five physic nut genotypes, at 36 days after sowing. Vitória da Conquista, BA, Brazil, 2008.

Genotypes	ESI (%)	EMERG (%)	NL	TD (mm)	SH (mm)	RL (mm)	RDM (g)	SDM (g)
Bento	19.5[a]*	84.5[ab]	2.6[a]	53.0[a]	49.0[a]	109.0[a]	6.2[a]	15.7[ab]
Filomena	19.5[a]	85.5[ab]	2.8[a]	53.0[a]	45.0[a]	111.0[a]	5.7[a]	16.5[a]
Gonçalo	20.0[a]	78.0[b]	2.9[a]	53.0[a]	42.0[a]	124.0[a]	7.0[a]	13.0[b]
Oracília	20.0[a]	83.0[ab]	2.7[a]	52.0[a]	46.0[a]	111.0[a]	5.7[a]	15.2[ab]
Paraguaçu	22.8[a]	87.5[a]	2.8[a]	57.0[a]	46.0[a]	108.0[a]	6.7[a]	17.0[a]
CV (%)	12.11	4.66	5.54	4.60	8.81	11 .78	22.82	9.70

* Averages followed by the same lower case letter in the column do not differ from each other by the Tukey test at 5% of probability (P<0.05%).

the evaluated parameters of root length and seedling total length, and along with the Oracília genotype, the shoot length means were higher than the others. The Paraguaçu genotype was statistically similar to Oracília and Gonçalo in the seedling dry mass evaluation; nevertheless, the Bento and Filomena genotypes were statistically similar to Gonçalo and Oracília.

According to Nakagawa (1999), in order to have an accurate batch quality evaluation, it is important that jointly with the results from seedling growth test, the germination is also considered. This statement is also valid to situations where the batches present a high germination percentage and a low value of seedling average length, as well as a batch with low germination percentage but with high seedling average length value.

In emergence speed index tests, leaf number, trunk diameter, seedling height, root length and root dry mass there were no significant differences in vigor among the evaluated genotypes. The shoot dry mass parameter presented significant differences between the evaluated materials showing a difference in vigor. The Paraguaçu, Filomena, Bento and Oracília genotypes were statistically similar and had higher means. In the seed emergence results, there were statistical differences among the evaluated genotypes, in which Paraguaçu genotype presented a higher mean in relation to the Gonçalo one (Table 6).

The seedling emergence percentage in field was similar to germination test, only differing for Filomena genotype that presented 32.5% in the germination test (Table 3) and 85.5% in the emergence test (Table 6). Silva et al. (2008), when evaluating physic nut seeds, found 79% of emergence and 1.86% of ESI, while Braga (2010) found 45 to 85% of emergence and a variation of 2.60 to 5.10 of ESI. Valdés-Rodríguez et al. (2013b), evaluating varied soil texture effect on non-toxic *Jatrophas curcas* L. seed germination, observed that the highest seedling survival occured in sand substrate (99%), followed by sandy-loam (99%) and clayey loam (87%). According to Marcos Filho (1999), the emergence of seedlings in field depends directly on the batch history and environment conditions. As these conditions usually are not controllable, the evaluation of the physiological quality of the seeds must be effectively performed to enable the precise identification of the batches with higher potential to be established in field.

Conclusions

The seed size did not influence the physiological quality of the evaluated genotypes. The tests that better differentiated the genotypes were the accelerated ageing, seedling length and dry mass, shoot emergence and dry mass. In the face of the conducted evaluations, in general, the Paraguaçu genotype presented desirable characteristics, being highlighted from the other genotypes.

Conflict of Interest

The authors have not declared any conflict of interests.

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Potassium fertilization of lettuce in potassium-rich Eutrudox soil

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Soils intensively cultivated with vegetable crops may show potassium accumulation and this may cause damage to the environment and the plant. Viewing to evaluate the response of lettuce 'Amanda', of the crisphead group, to five doses of potassium (0, 25, 50, 75, and 100 kg/ha K_2O) in a potassium-rich Rhodic Eutrudox soil, two experiments were carried out at two different planting times from 05/05 to 07/23/2008 (PT_1) and from 03/24 to 05/14/2010 (PT_2), in Jaboticabal, state of São Paulo, Brazil. The experimental units were distributed in the field, according to a randomized complete block design with four replications. Potassium content in the leaves (KL), number of leaves (NL), leaf area (LA), the plant aerial part fresh weight (APFW), the plant aerial part dry weight (APDW), and potassium content in the soil (KS) were determined. Significant interactions of the factors K rates and PT were not observed upon evaluated characteristics. The PT affected all characteristics. In PT_1, the plants showed larger values of NL, LA, KL, and KS and in PT_2, larger values of APFW and APDW. The KL adjusted to quadratic model with maximum (61.8 g/kg) obtained with 55 kg/ha K_2O, while KS after experiments adjusted to linear model, showing 1.5 $mmol_c/dm^3$ when the crop was fertilized with K and 1.9 $mmol_c/dm^3$ when fertilized with 100 kg/ha de K_2O. The potassium fertilization had no influence on NL, LA, APFW, and APDW, and therefore, it was not recommended to fertilize lettuce with K in soils with high content of K. Aiming to keep the K content in the soil in the initial levels, the amounts of K accumulated by lettuce crop should be applied, in this case, 100.8 and 202.7 kg/ha K in the first and second planting time, respectively.

Key words: Growing season, growth, *Lactuca sativa*, production.

INTRODUCTION

Lettuce became the most important leafy plant consumed by man since its domestication. In the state of São Paulo, Brazil, the cultivated area with lettuce is 9508 ha with an annual production of 6 697 934 crates, each one capable of boxing 9 dozens of plants (IEA, 2012). The crisphead type of lettuce is predominant in Brazil, with 70% of the market. The American group has 15% of the market, the group of smooth leafed plants has 10%, while the other groups (Red, Mimosa, and Romaine) have the remaining 5% (Sala and Costa, 2005).

Mineral fertilization is one of the most influential practices affecting yield since horticultural crops are

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highly demanding of nutrients (Filgueira, 2008).

Unfortunately, most of the horticultural crops growers mismanage this practice and apply too large amounts of soil fertilizers frequently, resulting in accumulation of nutrients in the soil. One of the main reasons for this is that, usually lettuce growers do not have their soil chemically analyzed before planting the crop, that is, the amounts of fertilizers they apply are not based on results of chemical analyses and these are usually large amounts of fertilizers. This plus the fact that lettuce is a short cycled crop usually results in high rates of fertilizers in soils for horticultural production.

Although, potassium plays several functions in the plant (Epstein and Bloom, 2006) and is required by the plants in levels superior to the other nutrients (Beninni et al., 2005; Grangeiro et al., 2006; Sanchez, 2007; Kano et al., 2010) if supplied in excess to the plants, it becomes a cause of yield reduction in addition to increasing costs and negative effects on the environment (Reis Júnior and Monnerat, 2001). According to Padilla (1998), when potassium content in the soil is high its absorption by the plant may be four times that of nitrogen, this being characterized as luxury consumption. In excess, K may unbalance lettuce plant nutrition characterized by a reduction in calcium and manganese absorption (Malavolta, 2006). This unbalance may cause necrosis in the leaf edges, a physiological disorder known as tipburn and other negative implications mainly in enzymes activity. There is divergence of recommendation of K to lettuce in soils with high content of the nutrient. In this condiction, Fontes (1999) and Vilela et al. (2004) did not recommend applying K while Trani et al. (1997) recommend 50 kg/ha K_2O, Comissão de Química e Fertilidade do Solo (2004) and 120 kg/ha K_2O.

In the literature, results about soil fertilization with potassium for lettuce in potassium-rich soils are not supported in these recommendations. Thus, the objective of this research was to evaluate doses of potassium on the growth, nutrition, and production of lettuce in a potassium-rich soil.

MATERIALS AND METHODS

Growing conditions

Two experiments were conducted in two planting times (PT), one during Autumn/Winter (from 05/05 to 07/23/2008 – PT_1), and another during Autumn (from 03/24 to 05/14/2010 - PT_2), in Jaboticabal, state of São Paulo, Brazil, at latitude of 21°15’22’’ S, longitude of 48°18’58’’ W and a mean altitude of 575 m above sea level. The soil of the experimental area is typical Rhodic Eutrudox (Soil Survey Staff, 1999). Previously to the experiments installation, the soil was cultivated with lettuce crops. The soil was sampled at 0-20 cm layer, and before the first experiment the soil chemical characteristics were: pH($CaCl_2$) 5.8; organic matter = 24 g/dm^3; P = 136 mg/dm^3; K^+ = 3.4 mmol$_c$/dm^3; Ca^{2+} = 43 mmol$_c$/dm^3; Mg^{2+} = 8 mmol$_c$/dm^3; CEC = 106 mmol$_c$/dm^3, and soil base saturation = 79%; and before the second experiment were: pH$_{(CaCl2)}$ 5.6; organic matter = 22 g/dm^3; P = 272 mg/dm^3; K^+ = 3.1 mmol$_c$/dm^3; Ca^{2+} = 47 mmol$_c$/dm^3; Mg^{2+} = 18 mmol$_c$/dm^3; CEC = 99 mmol$_c$/dm^3, and soil base saturation = 70%. Available P and exchangeable K^+, Ca^{2+} and Mg^{2+} were extracted with resin method (Raij et al., 2001). K content larger than 3.0 mmol$_c$/dm^3 is considered high content (Raij et al., 1997). During the experiments, the mean maximum, minimum, and mean temperatures were 27.1, 13.5, and 19.2 (PT_1) and of 29.2, 17.6, and 22.1 (PT_2) respectively. Mean relative humidity was of 68.9% in the first experiment and 79.4% during the second. Mean pluvial precipitation was 28.1 mm in the first and 96.4 mm during the second experiment.

Treatments and experimental design

Potassium doses in both experiments were 0, 25, 50, 75, and 100 kg/ha K_2O, as potassium chloride. The doses were based on the recommendation by Trani et al. (1997) to cultivate lettuce in potassium-rich soils (levels above 3.0 mmol$_c$/dm^3 K), according to Raij et al. (1997). The experimental plots were distributed according to a randomized complete block design with four replications. The experimental plot (1.75 m^2) constituted of 28 plants formed by four lines with seven plants each. The area in which measurements were made was of 1.25 m^2 (1.00 x 1.25 m) since the plants at the beginning and at the end of each line as well as those of the lateral lines were not used for measurement purposes.

Plant material and crop management

Based on the soil chemical analyses it was decided not to apply lime since the soil saturation bases was close to the ideal value for lettuce cultivation, according to Trani et al. (1997). The application of organic fertilizer was not made either. At planting, in both experiments 40 kg/ha N, 200 kg/ha P_2O_5, and 1 kg/ha B as urea, single superphosphate, and boric acid were applied. ‘Amanda’ lettuce seedlings were produced in 200 cell polypropylene trays in a commercial substratum (Plantmax HA™). Lettuce seedlings, having four leaves, were transferred on June 6 of 2008 and on March 24 of 2010 in the first and second experiments, respectively. The distance between rows and that between plants were both of 25 cm. Soon after transplantation, the seedlings were irrigated by the conventional sprinkler system. At first the water lamina was of 2 mm/day and then, when the plant cycle was reaching its end, it went up to 5 mm/day. In both experiments, 90 kg/ha N was side dressed to the plants 10, 20, and 30 days after transplantation (DAT), with basis on recommendation by Trani et al. (1997). Insecticides and fungicides were applied to the plants according to recommendations. Weed control took place whenever necessary. Harvesting took place when 80% of the plants of the best treatment reached the commercial point, that is, on 07/23/2008 in the first and on 05/14/2010 in the second experiment, 47 and 51 DAT, respectively.

Measurements

In both experiments, the following variables were evaluated: a) potassium level in the diagnostic leaf: when the plants reached two thirds of their cycle, a sample of the recently developed leaf was taken (Trani and Raij, 1997). Leaf sampling was accomplished at the beginning of the day, between 6 and 7 A.M. Right after collection, the leaves were taken to the laboratory and washed in running water. After that, they were quickly dipped in a deionized water solution of hydrochloric acid and then dipped again in deionized water. After removal of the water excess with the help of paper towel, the leaf samples were placed in paper bags and taken to a forced ventilation oven at 65°C, till a constant weight was reached. After that, each sample was ground in a Willey mill. The extract in which K content was determined by atomic absorption

Table 1. Analysis of variance for experiments (planting time) on the potassium content in leave (KL), number of leaves (NL), leaf area (LA), fresh (APFW) and dry (APDW) weight of the plant aerial part of lettuce, and potassium level in soil (KS) as influenced by potassium rates.

Causes of variation	KL	NL	LA	APFW	APDW	KS
Planting time (PT)	124.84**	55.72**	47.25**	24.95**	1124.17**	133.88**
Rates of K (K)	10.71*	1.03^{ns}	0.99^{ns}	1.33^{ns}	1.98^{ns}	40.15**
PT x K	0.18^{ns}	0.84^{ns}	0.69^{ns}	0.48^{ns}	0.36^{ns}	0.05^{ns}
CV (%)	10.28	8.04	21.89	22.35	13.25	18.89

(^{ns}) non significant,(**) significant at the 1% level of probability, and (*) significant at the 5% level of probability, according to the F test.

Table 2. Potassium leaf content (KL), number of leaves (NL), leaf area (LA), plant aerial part fresh weight (APFW), plant aerial part dry weight (APDW) of lettuce, and potassium soil content (KS) as influenced by potassium rates in two planting times (PT_1: 05/05 to 07/23/2008 and PT_2: 03/24 to 05/14/2010).

Planting time	KL (g/kg)	NL (per plant)	LA (cm^2/plant)	APFW (g/plant)	APDW (g/plant)	KS (g/kg)
E_1	63.2^{A1}	26.6^{A}	$3,227.45^{A}$	312.26^{B}	15.95^{B}	1.81^{A}
E_2	54.8^{B}	22.4^{B}	$2,187.66^{B}$	394.58^{A}	37.05^{A}	1.57^{B}

[1] Means in the same column, followed by the same letter, are not statistically different at the 5% level of probability, according to Tukey's test.

spectrometry was prepared according to instructions found in Carmo et al. (2000); b) Plant aerial part fresh weight (APFW): 6 plants were, between 6 and 7 A.M., randomly taken from the central part of each plot and weighed, after dead and senescent leaves were removed; c) Number of leaves (NL): the number of leaves per plant was determined in the plants collected to determine APFW; d) Leaf area (LA): leaf area was measured in leaves of the plants collected to determine APFW, with the help of an electronic measuring device (LICOR, model 3100); e) Plant aerial part dry weight (APDW): the plants used to determine APFW, NL, and LA were washed and placed inside paper bags to dry in a forced ventilation oven at 65°C till a constant weight; f) Potassium content in the soil: immediately after harvest of lettuce, soil samples (0-20 cm) were obtained from 8 subsamples per plot, and exchangeable K was determined using resin method (Raij et al., 2001).

Statistical analysis

The experimental data were submitted to variance analysis (F test). The planting times means were compared by the Tukey's test at the 5% level of probability, and the K rates by polynomial regression.

RESULTS AND DISCUSSION

Potassium content in the diagnostic leaf (KL) was individually influenced by K doses and by the time of cultivation (Table 1). The means of the K content in the diagnostic leaf showed an adjustment to the quadratic model ($Y = 55.19 + 0.2425x – 0.00222x^2$; $R^2 = 0.97^*$) as the doses of K increased. Even in the soil with high content K, 3.1 and 3.4 $mmol_c/dm^3$ (Raij et al., 1997), the leaf K content increased from 55.2 g/kg (0 kg/ha) to 61.8 g/kg, with 55 kg/ha de K_2O. With rates higher than 55 kg/ha K_2O, the leaf K content decreases achieving close to that obtained without fertilization with potassium. Neuvel et al. (2000), evaluating the effects of doses of K between 0 and 480 kg/ha K_2O during three cropping cycles and in different planting times in sandy and clayish soils, verified increasing levels of K in the plant tissue of two lettuce cultivars. Potassium content in the leaves as K dose increased from 0 to 100 kg ha^{-1} were verified to be within the limits of adequacy proposed by Trani and Raij (1997) for lettuce, that is, between 50 and 80 g kg^{-1}.

With regards to planting time, the largest potassium leaf content was found in the first experiment, that is 63.2 g/kg followed by the value found in the second experiment - 54.8 g/kg (Table 2). The high level of K in the soil, associated with the potassium fertilization of up to 100 kg/ha K_2O, resulted in no visual symptoms in the lettuce plants of deficiency of the other mineral nutrients, specially Ca, for, according to Malavolta (2006), K, when in high levels in the soil, has a relation of competitive inhibition with Ca. Probably the absence of the nutritional disorder tipburn resulted from the fact that the environmental conditions while the experiment was installed and conducted were favorable for lettuce growth. According to Wissemeier and Zühlke (2002), environmental conditions (temperature, duration and luminous intensity) favoring plant growth also favor the probability of disorder occurrence.

NL was significantly influenced only by planting time (Table 1). At the Autumn/Winter time the number of leaves was larger than that of the second experiment (Autumn) with a difference between them of 4.2 leaves plant (Table 2). This difference is thought to be due to the low levels of precipitation during the first experiment water in excess reduces leaf formation, a fact also verified by Purquerio et al. (2007) in a study in which arugula was sown at the same times of this experiment. Feltrim et al. (2009) reported to have lettuce plants of different cultivars growing in a K-rich soil with a mean number of leaves of 30.5, that is, higher than the values found in this work. Radin et al. (2004), verified in an experiment conducted during Autumn time NL values lower than those were reported: 16.5 leaves/plant in the cultivar Verônica and 15.4 leaves/plant in the cultivar Marisa, both lettuce cultivars of the crisphead group.

Similarly to what was observed for NL, LA was influenced only by planting time (Table 1). The largest LA was verified in the first experiment (3227.45 cm^2/plant); in the second experiment LA was of 2187.66 cm^2/plant, resulting from the higher NL of that planting time (Table 2). The results reported by Feltrim et al. (2009), similarly to those verified for NL, indicate that the highest LA of the different cultivars was verified in the Winter time (5100.22 cm^2/plant). Differently from the results of this work were the data published by Radin et al. (2004) – the lowest LA were observed for crisphead lettuce cultivars (a mean of 999.1 cm^2/plant) grown during Autumn time. Fresh weight of plant aerial part (APFW) was significantly influenced only by planting time (Table 1). The largest value was verified during the second experiment – the plants of this experiment showed a difference of 82.32 g/plant in comparison with those of the first (Table 2), that is, a difference of 26%. It was observed that the highest values of LA and NL verified during the first experiment did not result in larger APFW values. This result may be attributed to the presence of the stem in the composition of the weight of the shoot, and that in the second planting time (autumn) is usually larger than the first planting time (autumn-winter) because their growth is favored by higher temperatures, as reported by Silva et al. (1999) and Luz et al. (2009).

The lack of response by lettuce plants growing in a potassium-rich soil (4.3 $mmol_c/dm^3$) to which up to 120 kg/ha K_2O had been supplied was also reported by Sousa and Grassi Filho (2001). Similar results were also reported by Hoque et al. (2010). Neuvel et al. (2000) reported no effect of potassium fertilization on lettuce plants growing in a sandy soil but significant effects when the plants grew in a clayish soil. Cancellier et al. (2010) reported no morphophysiological (specific leaf area, liquid assimilation rates, absolute and relative growth, foliar, stem, and root mass ratio) responses of lettuce plants when the soil was fertilized with up to 300 kg/ha. On the other hand, Madeira et al. (2000), Mota et al. (2003), and Koetz et al. (2006) reported positive responses to doses of K_2O applied to soils with low to medium levels of potassium.

Similarly to what was observed for LA, NL, and APFW, dry weight of plant aerial part (APDW) was influenced only by the time of cultivation (Table 1). The largest APFW was attained in the second experiment. In Winter cultivation, Feltrim et al. (2005) found an average of 21.43 g/plant in their second experiment, a value larger than that observed in their first experiment although the APDW reported by Feltrim et al. (2005) was smaller than that found in the second experiment. Potassium content in the soil (KS) values, evaluated after the experiments were finished, similarly to what was observed for KL, were significantly influenced by both K doses and time of cultivation in an individual form (Table 1). The estimated values of K in the soil ranged from 1.5 to 1.9 $mmol_c/dm^3$, and the increase of KS in response to the increased K rate (0-100 kg/ha K_2O) to the culture adjusted to a linear model ($Y = 1.51 + 0.0036x$; $R^2 = 0.95$*).

Potassium levels in the soil, following both experiments, were found to be lower than the values found (3.4 and 3.1 $mmol_c/dm^3$ respectively) previously. After the experiments, potassium levels obtained (1.5-1.9 $mmol_c/dm^3$) in the soil became medium levels, according to classification by Raij et al. (1997). Potassium reduction in the soil may be explained by the high levels of K demanded by lettuce plants (Beninni et al., 2005; Grangeiro et al., 2006; Sánchez, 2007; Kano et al., 2010). Considering the lack of response of the lettuce plants to the potassium fertilization, it is hypothesized that a potassium-rich soil is capable of supplying all the potassium needed by the plants, that is, adding potassium fertilizers to this type of soil is not needed. But, due to the high level of K consumption by the lettuce plants (at the end of the experiments, potassium levels in the soil had fallen to 1.5 and 1.9 $mmol_c/dm^3$, when potassium rates were 0 and 100 kg/ha, respectively) and also to the fact that the majority of lettuce growers do not have their soils chemically analyzed for the cultivation of the crop immediately following that of lettuce, the most advisable procedure would be that of supplying the soil with a potassium rate sufficient to be able to preserve the levels of potassium in the soil. For this fertilization, the amounts of K to be applied may correspond to that accumulated by the lettuce plants and determined by the measurements of APDW and KL in each planting time (Table 2).

Conclusion

In this research work, considering 100,000 plants per hectare, the lettuce crop accumulated 100.8 and 202.7 kg/ha K or 121.5 and 244.3 kg/ha K_2O in the first and second planting time, respectively. On the other hand, it is very important to know which group the lettuce cultivars belong to so as to make a more appropriate fertilization of the soil - different cultivars will export different amounts of K due to their differences in mass and the levels attained by that nutrient in the foliar tissue. In K-rich Eutrudoxs, fertilizing the soil with this nutrient is not necessary for growth and production of lettuce plants of the crisphead group. A maintenance fertilization following lettuce cultivation is, nonetheless, recommended viewing to preserve soil fertility.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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Intake and some indicators of the metabolic status of native ewes in pregnancy and supplemented in grazing system

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The present study was to evaluate the effect of level of concentrate supplementation on the intake and some indicators of the metabolic parameters of native ewes in pregnancy and supplemented in a grazing system. 28 lactating ewes were selected: 14 Morada Nova (MN) and 14 Santa Inês (SI) were distributed in an experimental design completely randomized in 2x2x3 factorial arrangement with two breeds (MN and SI), two levels of supplementation (0.5 and 1.5% body weight) and three experimental periods (75, 105 and 135 days of pregnancy). The concentrate intake and total dry matter intake (DMI) was higher (P <0.05) on SI ewes and, in animals supplemented with 1.5% of concentrate, where the pregnancy progresses promoted the progressive decrease of DMI. There was breed effect (P <0.05) on metabolic parameters evaluated, in which the two breeds presented the same trend of mobilization of body reserves with decrease (P <0.05) in the body condition score close of parturition. Supplementation did not influence in the metabolic parameters. The metabolic parameters were influenced by breed, however, with normal values, indicating a good adaptability of the MN and SI breeds at the experimental conditions, promoting an evolution of production rates with 0.5% of concentrate supplementation.

Key words: Blood metabolites, native ewes, nutrition, semi-arid.

INTRODUCTION

Sheep farming is an important activity that contributes to the food supply in semiarid region of northeastern of Brazil, generating occupations, income and improved quality of life. It is also necessary to develop economic importance through little arable land by characterizing extensive production system. However, it results maximum production with minimum cost due to animals mostly depends on natural pastures and use of non-specialized genotypes.

Intensified use of Morada Nova and Santa Inês breeds

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Table 1. Chemical composition of experimental ingredients, concentrate supplement and Andropogon *(A. gayanus).*

Ingredients	Chemical composition (% DM)							
	DM	CP	EE	TDN	NDF	ADF	Ca	P
Corn meal	87.19	9.98	5.19	67.50	24.55	5.87	0.05	0.49
Soybean meal	88.48	48.76	1.75	80.73	15.37	9.64	0.33	0.57
[1]Mineral mixture	97.91	-	-	-	-	-	18.00	13.00
Concentrate	88.04	19.17	4.06	67.43	21,02	6,51	0.90	1.13
Pasture (Andropogon)	27.45	7.50	2.02	53.56	74.70	41.97	0.33	0.11

DM = Dry matter; CP = Crude protein; EE = Ether extract; TDN = Total digestible nutrients; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; Ca = Calcium; P = Phosphorus. [1]Mineral mixture: 1,600 mg zinc, 600 mg copper, 1,500 mg manganese, 1,100 mg iron, 10 mg cobalt, 27 mg iodine and 22 mg selenium. q.s.p. 1,000 g.

are being important for their good prolificacy, feed conversion, endoparasites resistant and climate adaptation of semiarid region (Vilpoux et al., 2013). However, demand for production system improvements is mainly depends on nutritional requirements of sheep intensifies mainly during the final third of pregnancy, which fetal growth maintenance and development of the mammary gland that contribute to possible occurrence of negative energy balance in the postpartum.

Use of concentrate supplementation is one of strategy to solve several problems on current livestock issues (Souza et al., 2013). Concentrate and pasture has been widely used for desired level of performance. However, it is essential to consider feeding methods and nature of the diet offered to the animals (Gipson et al., 2007; Paim et al., 2013).

According to González (2000) suggested that, it is vital to assess blood metabolic parameters for identification and adaptation of suitable diet to the ewes during pregnancy. Therefore, Objective of the present study is to evaluate the effects of native ewes supplement with different level of concentrate and blood metabolic parameters in pregnancy under semiarid grazing system.

MATERIALS AND METHODS

The experiment was conducted at Research Unit in Small Ruminants of Campus Cinobelina Elvas, Federal University of Piauí, Bom Jesus – PI (09°04'28" South Latitude and 44°21'31" West Longitude; at an altitude of 277 m and 635 km distant) from the capital Teresina. The experiment was conducted with the approval of the ethical committee for animal experimentation of Federal University of Piauí (ECAE/UFPI) under the number 091/2010.

Twenty four ewes (12 Santa Inês and 12 Morada Nova) were used with pluriparous pregnancy inseminated artificially at fixed time (AIFT) with Dorper Breed semen. After 30 days of artificial insemination, pregnancy diagnosis was performed through trans-abdominal ultrasound and pregnant ewes from each genetic group were selected. These sheep remained until the middle of pregnancy in Andropogon pasture grass (*Andropogon gayanus*) paddocks and afterwards allocated in collective pens with cement floor. Water were provided *ad libitum* level until next day.

Experiment initiated at 75 days of pregnancy, sanitary management were followed by deworming and vaccination against clostridial diseases along with routine preventive care. During experimental period, Ewes were kept morning at Andropogon pasture grass (*A. gayanus*) paddocks and allocated to individual pens where they received concentrate supplementation (Table 1) according to the weight of ewes (0.5 and 1.5% of body weight) being adjusted weekly.

Treatments were formed based on percentage of concentrate supplementation according to recommendations (NRC, 2007) for pregnant animals. It is, confirmed a total requirements of protein and metabolizable energy was found to be 146 g / day and 3.86 Mca /day respectively, in which the level of 1.5% BW concentrated provided approximately 70% of the daily requirements.

The body weight of the ewes and body condition score (BCS) were weekly performed as per the method described by Thompson and Meyer (2006). Later, averages were calculated for the periods 75, 105 e 135 days of pregnancy. The measurements were made on a scale from 1 to 5 (1 = underweight and 5 = overweight). Blood samples were collected from 75 days of pregnancy for every 14 days. Blood was collected in the morning, before the sheep were released to grazing by jugular venipuncture using needles coupled to vacuum tubes (10 ml) without anticoagulant. The serum was obtained after the centrifugation at 3500 rpm during 15 min in a refrigerated centrifuge and stored in micro tubes at -20°C until the time of laboratory analysis, which consisted of determinations of serum glucose, triglycerides, cholesterol, urea and creatinine.

All the biochemical analysis were performed in semi-automatic biochemical analyzer (Espectrum BS- 001 000 013) using commercial kits of Labtest® following the manufacturer's recommendations.

To estimate the intake and apparent digestibility of nutrients, internal indicator was used as indigestible dry matter (iDM). In order to estimate the levels of indigestible components of feed (grass: 0.4 g; concentrate: 0.4 g) and feces (0.4 g) were filled in 50 µm nylon bags (8x12). iDM was obtained after 264 h of incubation under "*in situ*" conditions (Casali et al., 2009), being used one rumen cannulated animal under the same production system.

After bags were removed from rumen and washed with water until disappearance of unwanted material. Bags were immediately transferred to the forced-ventilation greenhouse (60°C) during 48 h. Sequentially, it is dried in a non-ventilated oven (105°C for 45 min) and kept in a desiccator and weighed (Detmann et al., 2001) for obtaining undigested MS. NDF and ADF were determined as per methods described by Van Soest et al. (1991).

The content of iDM was obtained by the difference of dry weight of the material before incubation and dry weight of the residue after incubation.

Pooled feces were collected daily from the rectum based on the pre-dry weight per animal. During collection period, daily samplings of feed were collected properly. Samples were frozen then dried (60°C) processed in a grinder with a 1 mm sieve and determination

Table 2. Averages body weight (kg) and body condition score (BCS) of Morada Nova and Santa Inês ewes based on breed, supplementation level and period of pregnancy.

Periods	Morada Nova		Santa Inês	
	Body weight			
	0.5%	1.5%	0.5%	1.5%
75 days	31.8 ± 1.8^{bB}	32.1 ± 1.4^{bB}	56.6 ± 2.1^{bA}	55.7 ± 1.2^{cA}
105 days	34.6 ± 1.4^{aC}	36.1 ± 1.5^{aC}	58.0 ± 1.9^{aB}	63.5 ± 2.5^{aA}
135 days	32.1 ± 1.9^{bC}	31.5 ± 1.9^{bC}	52.4 ± 2.3^{cB}	58.2 ± 1.4^{bA}
	Body condition score			
75 days	2.9 ± 0.3^{aBC}	3.5 ± 0.2^{aA}	3.0 ± 0.1^{aBC}	3.1 ± 0.2^{aB}
105 days	2.5 ± 0.2^{b}D	3.4 ± 0.3^{aA}	2.9 ± 0.1^{abC}	3.1 ± 0.2^{aB}
135 days	2.5 ± 0.3^{bC}	3.1 ± 0.3^{bA}	2.8 ± 0.2^{bB}	2.9 ± 0.1^{bB}

*Means followed by same letter, lowercase in the columns and uppercase in the rows, are not significantly different from Tukey´s test at a 5% probability.

of DM, CP, NDF, ADF were carried out according to the methodology described by Silva and Queiroz (2002). Calculations of digestibility and DM intake through the following equations:

(i) DDM (%) = 100 – [100 x (indicator in the diet / indicator in the feces)]
(ii) Fecal output (g/day) = [ingested indicator (g) / indicator in the feces (g/g DM)]

(iii) $$\text{DMI (g/day)} = \frac{\{[(\text{DMfecal x \% indicator in the feces}) - \text{indicator in the diet}]\} + \text{DMIsuppl. \%}}{\text{Indicator in the forage}}$$

Where: DDM – Digestibility of dry matter, DMI – Dry matter intake, DMIsuppl. – Dry matter intake of supplementation.
To evaluate the intake, variation among weight gain as well as body condition score with the experimental design was randomized into 2x2x3 factorial arrangement with two breeds (MN and SI), two supplementation levels (0.5 and 1.5% body weight) and three experimental periods (75, 105 and 135 days of pregnancy).

For blood variables, a randomized design was used in which the blood samples were evaluated using a split-plot arrangement. The main plot was supplementation and the secondary plot, harvest periods with measures repeated in time. The comparison between the levels of supplementation was carried by SNK's test at a 5% probability. Intake, variation among weight gain as well as body condition score were evaluated using analysis of variance and means were compared by Tukey's test at a 5% probability. The results of blood variables were submitted to ANOVA using the PROC GLM procedure of SAS (SAS, 2003) according to the following statistical model:

$$Y_{ijk} = \mu + S_i + B_j + (SB)_{(ij)} + P_k + (SP)_{(ik)} + (SBP)_{(ijk)} + e_{(ijk)},$$

Where: Y_{ijk} = value observed for the characteristic analyzed; μ = overall average; S_i = effect of the level of concentrate supplementation i = 1, 2; B_j = effect of breed j = 1, 2; SB $_{(ij)}$ = effect of the interaction supplementation level and breed i; P_k = effect of period k = 1, 2 and 3; SP $_{(ik)}$ = effect of interaction between supplementation level i and period k; SBP $_{(ijk)}$ = effect of interaction among concentrate supplementation i, effect of breed j and period k; $e_{(ijk)}$ = random error associated with the observation Yijk.

RESULTS AND DISCUSSION

The values for average weight (kg) and body condition score (BCS) for different breeds, levels of concentrate supplementation and gestational periods were presented in Table 2. In body weights at different periods showed significant effect (P <0.05) with an increase during the second period, which probably due to fetal development and associated membranes. However, at 135 days, ewes showed a decrease (P <0.05) in weight due to result of higher utilization of body reserves coupled with the ability to lower food intake may be compression rumen by the fetus (Agenas et al., 2003).

There was concentrate supplementation effect (P <0.05) on weight of Santa Inês ewes for the periods of 75 and 105 days. However, there was less dry matter intake due to compression by fetus and level of 1.5% supplementation promoted better weight maintenance during period of higher nutritional requirement. Zambom et al. (2006) reported that, fundamental for increased intake of energy and protein avoiding mobilization of body tissues and to minimize the consequences of negative energy balance.

Table 2 shows that the body condition score were decrease near parturition with regardless of breed and level of supplementation. It may be justified due to higher mobilization of reserves as a result of the need for nutrients (Husted et al., 2008).

Morada Nova ewes supplemented with 1.5% presented superiority (P <0.05) in scores in all period of pregnancy and maintaining the pattern of score for controlled breeding program or insemination (Thompson and Meyer, 2006). Better nutrient management with maintenance of body condition score near parturition and improvement in a nutrient balance of all functions in adverse conditions (stress, negative energy balance, lactation). However, there is a necessary to provide, higher amount of milk for their offspring and higher performance of lambs at an early return to reproductive activity (Costa et al., 2009). During pregnancy, concentrated intake estimated by indigestible dry matter (iDM) was higher (P <0.05) in Santa Inês ewes, which

Table 3. Estimated intake of ewes grazing in different periods of pregnancy.

Item	Supplementation levels						Effect		
	0.5%			1.5%					
	Periods			Periods					
	75 days	105 days	135 days	75 days	105 days	135 days	T	P	T*P
				Morada Nova					
DMI (g/dia)	159.01^{bB}	173.0^{bB}	160.50^{bB}	481.83^{aB}	543.21^{aB}	484.17^{aB}	**	ns	ns
DMI (g/kg$^{0.75}$)	11.86^{bB}	12.12^{bB}	11.89^{bB}	35.59^{aB}	36.71^{aB}	35.64^{aB}	**	ns	ns
DMIc (g/dia)	146.56^{bB}	159.45^{bB}	147.93^{bB}	444.10^{aB}	500.67^{aB}	446.26^{aB}	**	ns	ns
DMIc (g/kg$^{0.75}$)	10.94^{bB}	11.17^{bB}	10.96^{bB}	32.81^{aB}	33.84^{aB}	32.85^{aB}	**	ns	ns
				Santa Inês					
DMI (g/dia)	283.06^{bA}	285.07^{bA}	273.81^{bA}	828.90^{aA}	952.04^{aA}	871.75^{aA}	**	ns	ns
DMI (g/kg$^{0.75}$)	13.70^{bA}	13.69^{bA}	13.55^{bA}	40.55^{aA}	42.30^{aA}	41.27^{aA}	**	ns	ns
DMIc (g/dia)	260.90^{bA}	263.02^{bA}	252.37^{bA}	763.99^{aA}	877.49^{aA}	803.49^{aA}	**	ns	ns
DMIc (g/kg$^{0.75}$)	12.63^{bA}	12.62^{bA}	12.49^{bA}	37.38^{aA}	38.98^{Aa}	38.04^{aA}	**	ns	ns

*Means followed by the same letter lowercase in rows and uppercase in columns did not differ, for effect of treatment, from Tukey´s test at a 1% probability.

was expected due to larger size. Thus greater the consumption capacity (Silva Sobrinho, 2006; Facó et al., 2008) indicating that weight gain not only depends on the genetic potential of the animals but also quantity and quality contained in the diet (Table 3). In the evaluation of the concentrate supplementation, ewes submitted to 1.5% BW showed higher intake and also being different (P <0.05) for all variables.

In the present study it was a significant effect (P <0.05) on concentrate intake among periods. Morada Nova and Santa Inês ewes showed a variation in the intake with advancing pregnancy indicating that mainly due to the inability of distension ruminal as a result of compression by the fetus and higher demand for nutrients for maintenance and fetal growth (Agenas et al., 2003). These may cause substitutive effect on roughage intake, once Andropogon grass had good nutritional percentage of stems and green leaves in the period evaluated does not supply needs of the ewes in this phase, according to Menezes et al. (2010). Hence, this is unsuitable roughage diet for the animals in present study even this grass highly diffused in semiarid region due to great climate adaptation.

It is also observed that Santa Inês ewes exhibit a linear intake behavior with decreasing values near parturition in contrast to the Morada Nova ewes. However, results were evaluated carefully and emphasize about the total intake (that is), effects of level offered on forage intake, pasture and also checked if there is excess offer of concentrate, thereby reducing the roughage intake. Nonetheless, this is the period of highest fetal growth and, main factor that restricts the roughage intake. In the evaluation of dry matter intake (DMI) in g/day and concentrate intake was significant effect (P <0.05) on breed with Santa Inês ewes consuming larger quantities (Table 4).

In the effect of concentrate supplementation was observed significant difference between treatments with dry matter intake (g/day) was higher in ewes receiving 1.5% BW. However, it was verified that the sheep supplemented with 0.5% BW had a higher utilization of roughage intake. In contrast, we have occurred substitutive effect of intake, ewes that were fed 1.5% of concentrate supplementation tended to a lower forage intake during grazing. Further, replacement of roughage intake by the concentrate affects the ruminal homeostasis due to modifying the microbiota in this compartment. Therefore, ratio of short-chain fatty acids may cause changes in the serum concentrations of metabolites (Costa et al., 2009).

In evaluating DMI (g/kg$^{0.75}$) had significant effect (P <0.05) of breed and treatment with advancing pregnancy. Morada Nova ewes exhibited a lower consumption according to Santos et al. (2009) reporting that near parturition, there was a decrease without any metabolic disorder has been confirmed. This fact emphasizes the adaptive capacity of these animals with little decrease in the DMI, once that the low offer of energy derived from the diet associated with a decrease in nutrient intake could promote serious metabolic disorders.

In order to verify such situation, the effects of interaction between DMI (g/kg$^{0.75}$) and periods of pregnancy was carried, with the pregnancy progresses was verified a decreased progressive in the DMI (g/kg$^{0.75}$) except in the 105 days in Morada Nova supplemented (0.5% BW) with an increase in the roughage intake.

Morada Nova ewes showed less intake due to smaller size, selection of better feed, according to Lachica and

Table 4. Estimated intake of total dry matter based on indigestible dry matter (iDM) in Morada Nova and Santa Inês ewes supplemented on pasture at different periods of pregnancy.

Item	Supplementation levels						Effect		
	0.5% PV			1.5% PV					
	Period			Period					
	75 days	105 days	135 days	75 days	105 days	135 days	T	P	T*P
Morada Nova									
DMI (g/dia)	628.07^{Ba}ϕ	518.72^{Ba}ϕ	565.55^{Ba}ϕ	775.77^{Aab}ϕ	814.41^{Aa}ϕ	728.20^{Ab}ϕ	*	*	*
DMI (g/kg$^{0.75}$)	47.16^{Ba}ϕ	36.35^{Bb}ϕ	41.96^{Bab}ϕ	57.60^{Aa}ϕ	55.37^{Ab}ϕ	54.15^{Aa}ϕ	*	*	**
DMI (%PV)	1.99^{Bab}ϕ	1.49^{Ba}ϕ	1.76^{Bab}ϕ	2.43^{Aa}ϕ	2.26^{Aa}ϕ	2.28^{Aa}ϕ	*	*	*
Santa Inês									
DMI (g/dia)	1401.79^{Ba}†	1297.38^{Ba}†	1176.21^{Ba}†	1665.63^{Aab}†	1694.06^{Aa}†	1476.21^{Ab}†	*	*	ns
DMI (g/kg$^{0.75}$)	68.06^{Bab}†	63.82^{Bab}†	59.41^{Bb}†	81.80^{Aab}†	75.43^{Aab}†	71.27^{Aab}†	*	*	ns
DMI (%PV)	2.48^{Bab}†	2.34^{Bb}†	2.20^{Bb}†	2.99^{Aa}†	2.67^{Aa}†	2.60^{Aa}†	*	*	ns

Means followed by the same lowercase letter in rows did not differ, for effect of period, from Tukey's test (* -1%; ** - 5% of probability). Means followed by the same uppercase letter in rows did not differ, for effect of treatment, from Tukey´s test (* -1%; ** - 5% of probability). Means followed by the same symbol in columns are not significantly different, for effect of breed, by Tukey´s test (* -1%; ** - 5% of probability). DMI = Dry matter intake; DMIc = Dry matter intake of concentrate, T = Effect of treatment; P = Effect of period; T*P = Interaction between treatment and period.

Table 5. Averages of serum concentrations of metabolic parameters of ewes during pregnancy according to breed and supplementation level.

Variables	GLI (mmol/L)	TRI (mmol/L)	COL (mmol/L)	URE (mmol/L)	CRE (µmol/L)
Reference Values **	1.7-3.6	---	1.05-1.50	3.0-10	70-105
Breed					
Morada Nova	2.94^{b}	0.40^{a}	1.37^{b}	7.31^{b}	61.62^{b}
Santa Inês	3.18^{a}	0.29^{b}	1.52^{a}	5.46^{a}	72.68^{a}
Supplementation level					
0.5% BW	3.00	0.35	1.44	6.32	66.92
1.5% BW	3.12	0.33	1.39	6.45	67.38
Variation sources					
Breed	*	*	*	*	*
Supplementation level	ns	ns	ns	ns	ns
Breed x Supplementation level	ns	ns	ns	ns	ns

Means followed by the same letter in columns are not significantly different from test Student-Newman Keuls (SNK); *- significant ($p<0.05$); ns– not significant ($p<0.05$); **Kaneko et al. (2008), Glucose - GLU, triglycerides - TRI, cholesterol - CHO, Urea – URE, Creatinine – CRE.

Aguilera (2005) in adult animals. These breed needs higher energy requirements, emphasizing that the requirements for pregnancy and lactation could be lower due to the high metabolic capacity adjustment in this phase.

The results showed effects of genetic group (P <0.05) on the dynamics of some energy and protein parameters during pregnancy (Table 5). However, the supplementation level did not influence on blood concentrations of metabolites evaluated. We, assuming that, regardless of the concentrate level both the homeorrético as homeostatic adjustments were similar throughout pregnancy. In contrast to the present experiment with sheep of different breeds and requirements (Tanaka et al., 2008), as well as of experiment carried with sheep in physiological period, breed and similar nutritional requirements (Torreão et al., 2008).

Higher values (P <0.05) of glucose in Santa Inês ewes, although the values were within normal range (Kaneko, 2008). Regardless of breed or concentrate level observed in this study and others experiments (Peixoto et al., 2010; Catunda et al., 2013) the glucose is less reliable due to the efficient homeostatic mechanism of digestive physiology of ruminants. However, according to Gonzalez and Silva (2006) reported glucose is the constituent that represents the most energy mechanisms in mammals.

Triglycerides concentrations in Morada Nova were 27.5% higher than Santa Inês ewes indicating a higher accumulation in the liver with the objective to supply the deficit between energy intake and requirements in this exceptional period. Probably, Santa Inês ewes are promoting greater use of this mechanism for fetal growth, whereas, 80% occurs in this phase (final third of pregnancy) to the mammary gland for colostrum synthesis (Kozloski et al., 2001) and still the maintenance requirements. The significant difference ($P < 0.05$) in cholesterol levels demonstrates that the Morada Nova ewes have more effective homeostatic mechanisms during pregnancy than Santa Inês ewes, however, both breeds were presented normal values according to Kaneko et al. (2008).

In experimental conditions and animals with 0.5% of supplementation was effective in the maintaining of urea level normal, but it does not require a supply of higher levels of concentrate for maintaining homeostasis during this period of intense mobilization. Important results in terms of efficiency of the productive system mainly depend to reduce the production costs. The serum creatinine was higher ($P < 0.05$) for Santa Inês ewes may be due to higher intake of concentrate or mobilization of body reserves as result of this phase.

Conclusions

Metabolic parameters were influenced by breed, however, with normal values, indicating a high adaptability of the Morada Nova and Santa Inês breeds at the experimental conditions, which promotes production rates with 0.5% of concentrate supplementation.

Conflict of Interest

The authors have not declared any conflict of interest.

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Possible role of calcium, phosphorous and magnesium shift in blood, urine and calculi in calves affected by urolithiasis

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Clinical study over a period of seven months at referral University Veterinary Hospital in Kashmir, India, was done on male calves clinically affected with urolithiasis was undertaken to manage them surgically and to study the mineral and haemato biochemical profile in an attempt to find out the probable cause of the malady and to ascertain the possible role of calcium, magnesium and phosphorous shift in urine blood and calculi. During obstructive urolithiasis, alterations in haematobiochemical profile were of no clinical significance, however, increased blood urea nitrogen (BUN), Creatinine, Calcium, and Inorganic Phosphorus could form a good index to determine the severity of the disease. Struvite calculi are most common urinary calculi observed in calves with heavy concentrate feeding especially wheat bran. The study revealed that the calculi contain 70% phosphorous, 20% calcium and 10% oxalate. This was clinically substantiated by the proportionate decrease in blood Ca and urine Ca levels. However, levels of creatinine and urea in urine blood and calculi revealed calcium phosphorous and their interrelation during the phase of urolithiasis, it could be conceived that ingestion of a ruminant feed containing high amounts of phosphates by a ruminant, physiologically with a non-functional rumen results in high absorption of the phosphates. This results in depletion of calcium absorption and calcium being excreted through urine.

Key words: Urolithiasis, Calves, biochemical, calculi.

INTRODUCTION

The urinary calculi turns clinically devastating when they obstruct the urinary conducts, result a disease condition known as obstructive urolithiasis. It may either be total or complete and partial, or incomplete with the resultant accumulation of urine and excretory metabolites in the urinary bladder. The retrograde pressure developed causes necrosis of the Urethral mucosa and leads to the perforation of the urethra, if the condition remains

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Plate 1. Ultrasonography of a calf suffering from obstructive urolithiasis being undertaken.

unresolved.

Ruminants fed high-grain diets with low calcium to phosphorus ratio are at increased risk of developing struvite uroliths, low calcium: phosphorus ratio which augments urinary excretion of phosphorous and limited water intake or dehydration. While ruminants grazing on silica-rich soil are predisposed to form silica uroliths (Gianesella et al., 2010; Makhdoomi and Gazi, 2012).

The intracystic pressure develops in pace with duration of obstruction, depending upon the capacity of detruser muscles the rupture of bladder occurs any time for 56 post obstructive hour onwards. In the event of rupture of the urethra, urine leakage occurs into the connective tissue of the ventral abdominal wall and prepuce resulting fluid swelling, cellulitis and urine scald exhibited by massive haematomas in ventral abdomen that can extend up to thorax. In event of rupture of the bladder, the patient experiences a slight relief from discomfort clinically but the excretory metabolites get accumulated in body and even increases so long as the cause is not corrected, the animal shows clinical signs of uraemia and toxaemia (Gazi et al., 2014).

If the condition is not diagnosed and corrected, uraemia continues to rise and the prognosis of the patient deteriorates and death becomes inevitable due to metabolic imbalances in which predominating conditions are hyponatraemia, hypochloraemia, and possibly hyperkalaemia (Radostitis et al., 2000).

MATERIALS AND METHODS

The study was conducted at Teaching and Veterinary Clinical Services Complex, SKAUST-K for a period of nine months in bovine calves aged 3 to 18 months manifesting the clinical urolithiasis. The mineral and haemato-biochemical profile of calves clinically affected with urolithiasis were taken into consideration and animals were managed surgically. An attempt has been made to find out the probable cause of the Urolithasis and to ascertain the possible role of calcium, magnesium and phosphorous shift in urine, blood and calculi.

Grouping

On the basis of visible reflexes, plasma urea nitrogen and creatinine levels, ultrasonography of urinary system (Plate 1), duration of obstruction and position of calculi, the calves were divided into five groups of 6 animals each except one group having 3 animals only as under :

Group A (Alert clinically): They included animals with urinary obstruction of 24 h duration. They were clinically alert with viable reflexes, plasma urea nitrogen up to 50 mg/dl and creatinine 2-3 mg/dl respectively. They had intact bladder and the calculi were lodged in urinary bladder.

Group B (Below danger line): They included animals with urinary obstruction of 48 h duration, were clinically alert with sluggish reflexic, plasma urea nitrogen up to 50 to 100 mg/dl and serum creatinine 3 to 4 mg/dl respectively, with intact bladder (distended) and calculi were lodged in the neck of urinary bladder.

Group C (Critical): They included animals with urinary obstruction of 96 h duration. They were clinically dull with poor reflexic with plasma urea nitrogen above 100mg/dl but up to 150mg/dl and serum creatinine 4 to 5 mg/dl respectively. The animals had ruptured bladder and the calculi were lodged in the neck of urinary bladder and sigmoid flexure (Plate 3).

Group D (Danger line): They included animals with urinary obstruction of 120 h duration. They were clinically recumbent with areflexic with plasma urea nitrogen above 150 mg/dl up to 200

Plate 2. Long fibrinous layer protruding out and salts accumulate in the layers to form calculi.

mg/dl and serum creatinine 5 to 6 mg/dl respectively. The animals had ruptured bladder and calculi lodgement was in the neck of urinary bladder, ischial urethra and sigmoid flexure.

Group T (Terminal n=3): They included animals with urinary obstruction beyond 120 h duration. They were clinically recumbent, grossly areflexic with plasma urea nitrogen above 250 mg/dl and serum creatinine 7 mg/dl respectively. The animals had ruptured bladder and calculi lodgment was in the neck of urinary bladder, ischial urethra, sigmoid flexure and penial urethra.

Pre-operatively fluid and supportive therapy was given to animals with severe dehydration and or uremia as per the requirement of the case (Plate 4). The animals were allowed to stabilize and prepared for surgery at the earliest as per standard routine procedures suited to them as demanded by the clinical status of the animals. In all the groups during surgery, the calculi were removed and collected. They were dried in Whatmans filter papers and the calculi were subjected to washing and drying. The calculus mass was weighed. The calculi were stored at 4°C in refrigerator till further analysis of their approximate composition. The chemical composition of the calculi was determined as per (Varley, 1988). The biochemical constituents of blood and urine viz, calcium, phosphorous, magnesium, urea nitrogen and creatinine also done on days 0, 8 and 16 day or on the day of removal of catheter. The urine samples were collected aseptically at the time of admission and 8th, 16th and at the time of removal of catheter post-operatively. The samples were filtered using Whatmans filter paper no. 1 to remove any crystalline material and mucous etc. The samples were centrifuged and the supernatant taken for the estimation of Calcium (Kaser and Stekol, 1979), Phosphorus and Magnesium (Amador and Urban, 1977), urea nitrogen (Harold, 1976) and creatinine (Henry et al., 1974) using kits* while as the sediment at the bottom was used for the microscopic examination of crystals. Samples were collected in heparinised vials and plasma was separated and subjected to Calcium (Kaser and Stekol, 1979), Phosphorus and Magnesium (Amador and Urban, 1977), Plasma urea nitrogen (Harold, 1976) and Creatinine (Henry et al., 1974) on days 8 and 16.

Statistical analysis

The data so procured was classified and subjected to statistical analysis. The inferences were drawn using analysis of variance (ANOVA) and Duncan's Multiple Range test (Snedecor and Cochran, 1976).

RESULTS

Crystals

Heavy score of crystals was recorded in the animals of all groups on the day zero without any significant difference among them (Plate 2). Postoperatively the crystal showed progressive declining trend irrespective of the severity of the disease.

Biochemical results

The Mean±SE values of plasma urea nitrogen (mg/dl) and creatinine (mg/dl) in calves of different groups at different intervals are presented in Table 1. At day zero, plasma urea nitrogen was high (50.15±0.06 to 234.13±16.03) mg/dl. After instituting treatment, the levels of plasma urea nitrogen drastically decreased such that on day 8th, the average value of plasma urea nitrogen was 27.66±0.50 to 28.33±0.83 among different groups which varied insignificantly (P>0.05). At day 16th, the values ranged between 24.50±0.66 to 25.50±0.50 and at the time of removal of catheter, it ranged between 6.50±0.16 to 7.16±0.33. In general, there was significant (P>0.05) decreasing trend in the plasma urea nitrogen after the treatment irrespective of the groups. Higher than normal values for Plasma urea nitrogen were recorded during this study. These findings are in agreement with those of Villar et al. (2003); Tsuchiya and Sato (1991)

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Plate 3. The animals had ruptured bladder and the calculi were lodged in the neck of urinary bladder and sigmoid flexure.

Plate 4. Pre-operatively fluid and supportive therapy given to animals with severe dehydration and or uraemia.

and Gera and Nigam (1981) who also reported elevated levels of BUN values to the extent of 160 mg/dl (114.24 mmol/L), 120 mg/ dl (85.00 mmol/L) and 181.96 mg/dl (129.91 mmol/L) respectively in cases of obstructive urolithiasis. The findings are also in agreement with those of Sheehan et al. (1994) who reported impaired

Table 1. Mean±SE of the plasma urea nitrogen (mg/dl) and creatinine (mg/dl) at different intervals in calves with obstructive Urolithiasis.

Groups	0 day	8 day	16 day	*At the time of removal of catheter
Alert clinically(A)	**50.15 ± 0.06^{aD}**	**27.66 ± 0.50^{aC}**	**24.50 ± 0.66^{aB}**	**6.66 ± 0.33^{aA}**
	$2.48+0.16^{aC}$	$1.78+0.13^{aB}$	$1.56+0.10^{aB}$	$1.13+0.09^{aA}$
Below danger line(B)	**86.55 ± 4.93^{bC}**	**28.00 ± 0.33^{aB}**	**24.83 ± 0.50^{aB}**	**6.66 ± 0.33^{aA}**
	$3.63+0.08^{bD}$	$1.93+0.03^{aC}$	$1.59+0.06^{cB}$	$1.13+0.09^{aA}$
Critical(C)	**127.32 ± 4.24^{cC}**	**28.00 ± 0.66^{aB}**	**25.66 ± 0.50^{aB}**	**7.16 ± 0.33^{aA}**
	$5.18+0.21^{cC}$	$2.41+0.01^{bB}$	$1.40+0.11^{aA}$	$1.14+0.01^{aA}$
Danger line(D)	**181.33 ± 5.46^{dC}**	**28.33 ± 0.83^{aB}**	**25.50 ± 0.16^{aB}**	**6.50 ± 0.16^{aA}**
	$6.52+0.14^{dD}$	$2.34+0.05^{bC}$	$1.39+0.13^{aB}$	$1.10+0.03^{aA}$
Terminal(T)	**234.93 ± 16.03^{e}**			
	$7.51+1.00^{e}$			

*Above thirty days, Means with different superscripts differ significantly (P<0.01). Small letters show comparison between groups. Capital letters show comparison between treatments. Values in bold depict urea nitrogen levels.

clearance of urea and creatinine in urinary tract obstruction. Urea is a nitrogenous waste product, which is formed in the liver as the end product of amino acid breakdown and is excreted by kidney into urine (Kerr, 2002). In obstructive Urolithiasis, urine gets accumulated into the urinary bladder for more than normal period of time. The urea gets reabsorbed into the systemic circulation and causes uraemia. Blood urea nitrogen in the cases of ruptured urinary bladder was higher than that in the intact urinary bladder cases, which could be due to movement of urea from the high concentration in peritoneal cavity to the interstitial and intravascular compartments. The higher values for Plasma urea nitrogen in ruptured bladder cases are in total consonance with those of Smith (2002) and Donecker and Bellamy (1982) who reported more profound biochemical alterations in cases with ruptured bladder. In ruminants, large amount of urea is excreted in the saliva and enters into the rumen where it is hydrolysed by urease to ammonia, which is drained to venous blood but reconverted into urea by liver (Watts and Campbell, 1971). This mechanism may help in maintaining the blood urea level in normal range for some time but in long standing cases, high blood urea nitrogen may occur in spite of recycling of urea through rumen (Sharma et al., 2006).

DISCUSSION

In all the groups, the serum creatinine levels were more than the normal in all the groups with the severity of disease which varied significantly (P<0.05). Postoperatively, the creatinine values decreased progressively in all the groups from day eighth onwards, after removing urethral obstruction.

At day zero there was increasing trend in the serum creatinine with the severity of the disease and it ranged between 2.48±0.16 to 7.51±1.00 in clinically lesser to most severe cases. At day 8th, the average value of serum creatinine was 1.78±0.13 to 2.34±0.05 among different groups which varied non-significantly (P>0.05). At day 16th, the values ranged between1.56±0.10 to 1.39±0.13 and at the time of removal of catheter, it ranged between 1.13±0.09 to 1.10±0.03. In general, there was significant (P>0.05) decreasing trend in the serum creatinine after the treatment. The value for creatinine in the calves with obstructive Urolithiasis was much higher than the normal before treatment. This observation of the present study is in consonance with the findings of Gera and Nigam (1981) and Villar et al. (2003) who also reported higher values of creatinine in cases of obstructive Urolithiasis. Similar findings have also been reported by Singh et al. (1985) increases mainly because of excretory dysfunction and renal damage. Its concentration in blood is not influenced by diet, therefore, creatinine levels in blood could be a better prognostic indicator of renal function as compared to urea (Doxey, 1983; Kelly, 1984; Carlson, 1990; Kerr, 2002). The rise in the creatinine level might be due to increased resorption of creatinine from the bladder due to prolonged stasis of urine in the intact urinary bladder and renal damage due to hydronephrosis (Singh, 2005). Saliva plays a great role in making adjustments in plasma creatinine value in the bovine. In both cattle and buffaloes, saliva creatinine concentration increases markedly in anorak state (Watts and Campbell, 1971; Singh et al., 1985; Sockett et al., 1986). In the present study, the plasma levels of creatinine were higher in the cases of ruptured urinary bladder than in the cases of intact urinary bladder. These findings are in agreement with those of Smith (2002) and Donecker and Bellamy (1982) who reported more profound serum biochemical alterations in ruptured bladder cases than those without ruptured bladder. Higher values of creatinine in the ruptured cases could be due to movement of creatinine from the peritoneal fluid to blood (Donecker and Bellamy, 1982). Kerr (2002) reported that urinary creatinine levels

Table 2. Possible role of calcium in urine, blood and calculi at different intervals of study.

Groups	Urine (mg/dl)			Blood (m mol/l)			Proximate composition of calculi	
	Onset phase	Middle phase	Recovery phase	Onset phase	Middle phase	Recovery phase		
A	5.83±0.06^{aC}	9.36±0.20^{aB}	11.42±0.46^{aA}	1.36±0.05^{aA}	2.41±0.09^{aB}	3.05±0.01^{aC}	Total ash Acid insoluble ash	78.80% 30.38%
B	4.83±0.16^{bA}	9.81±0.20^{aB}	11.86±0.09^{aC}	1.38±0.06^{aA}	2.37±0.09^{aB}	3.07±0.02^{aC}	Calcium	3.74%
C	4.96±0.23^{bA}	9.83±0.14^{aB}	12.02±0.09^{aC}	1.38±0.06^{aA}	2.37±0.06^{aB}	3.07±0.02^{aC}	Phosphorous	1.15%
D	3.96±0.13^{cA}	9.83±0.45^{aB}	11.87±0.02^{aC}	1.36±0.05^{aA}	2.41±0.07^{aB}	3.05±0.01^{aC}	Oxalate	1.35%

Means with different superscripts differ significantly (P<0.01). Small letters show comparison between groups. Capital letters show comparison between treatments.

Table 3. Possible role of phosphorous in urine, blood and calculi at different intervals of study.

Groups	Urine (mg/dl)			Blood (mmol/l)			Proximate composition of calculi	
	Onset phase	Middle phase	Recovery phase	Onset phase	Middle phase	Recovery phase		
A	6.81±0.08^{aB}	6.45±0.15^{aB}	5.83±0.21^{aA}	5.30±0.08^{aC}	3.10±0.01^{aB}	2.65±0.03^{aA}	Total ash Acid insoluble ash Calcium Phosphorous	78.80% 30.38% 3.74% 1.15%
B	6.98±0.11^{abC}	6.50±0.15^{aB}	6.01±0.08^{aA}	5.58±0.07^{bC}	3.27±0.13^{aB}	2.57±0.10^{aA}		
C	6.95±0.06^{abC}	6.71±0.06^{aBC}	6.21±0.16^{aA}	5.58±0.07^{bC}	3.27±0.11^{aB}	2.57±0.10^{aA}	Oxalate	1.35%
D	7.15±0.06^{bD}	6.66±0.13^{aC}	5.78±0.05^{aA}	5.30±0.08^{bC}	3.10±0.01^{aB}	2.65±0.03^{aA}		

Means with different superscripts differ significantly (P<0.01). Small letters show comparison between groups. Capital letters show comparison between treatments.

elevate more quickly than urea levels at the start of the disease, and also decrease more quickly when an improvement takes place, thus it could be used for early diagnosis and recovery from the disease. However, during this study changes in BUN and urinary creatinine levels were almost similar and both could be used to ascertain the efficacy of treatment.

The mean ± SE values of plasma calcium (mmol/l) in the calves with obstructive Urolithiasis in different groups are represented in Table 2. Plasma calcium levels at 0 day were (1.30±0.05 to 1.38±0.06) lower than normal in all the groups. By day eighth, there was a progressive recovery toward normal in the plasma calcium levels and by day 16th irrespective of the severity of disease. The severity of the disease affect non- significantly (P>0.05) on the levels of plasma calcium at any stage of the disease (Gianesella et al., 2009). There was significant (P<0.05) variation in the plasma calcium levels from the day of zero towards recovery.

The urinary calcium levels at day zero were lower than normal in all the groups (5.83±0.06 to 3.66±0.08). By day 8th, there was recovery toward normal in the levels and by day sixteenth irrespective of the severity of disease, the urinary calcium was within the physiological range. The severity of the disease affect non- significantly (P>0.05) on the urinary calcium levels at any stage of the disease. There was significant (P<0.05) increase in the urinary calcium levels from the day of admission of the calves in the clinics to the phase of recovery. The proximate composition of the calculi showed that they contained calcium 3.74% and the animals of groups D and T showed calcium/Amorphous phosphate, Calcium carbonate, Calcium oxalate, Uric acid 25 to 35%.

The mean±SE values of plasma phosphorous (m mol/l) levels in calves with obstructive Urolithiasisare presented in Table 3. At day zero hyperphosphataemia was recorded in all the groups. After instituting treatment, the plasma phosphorous followed a decreasing trend towards normal at days 8th and 16th. At the time of removal of catheter, the decrease was however, significant (P<0.05) decreasing trend in the inorganic phosphorous levels within normal range at day sixteenth irrespective of the severity of the disease. The study revealed that the levels of Phosphorous in urine and blood followed a similar trend. Increased levels of Phosphorous in all the groups ranged from 6.81±0.08 to7.15±0.06 in urine in all the groups, A to D at the onset phase, while it remained within 5.30±0.08 to 5.58±0.07 m mol/l in blood at the onset phase and showed a slight decrease afterwards. However, the decrease was clinically within near normal range in all the four groups (2.57+0.103 group B and C and 2.65+0.03 group A and D) in blood. At the recovery phase, the levels of urinary Phosphorous reached to 5.83+0.21 in group A and 5.78+0.05, 6.01+0.08 and 6.21+0.16 in groups D, B and C respectively. An analysis of calculi revealed that the calcium levels were 3.74%.

Percentage of different crystals in urine in calves showed Prismatic, coffin lid shaped, star shaped elongated rod, feathery or fern like Triple phosphate crystals in A, B and C up to 65 to 75. While the proximate composition of the calculi Phosphorous was 1.15%.

The mean±SE values of plasma magnesium (mmol/l) levels in calves with obstructive Urolithiasis are presented in Table 3. At day zero increased values were recorded in all the groups. After instituting treatment, the plasma magnesium followed a decreasing trend towards normal at days 8^{th} and 16^{th}. At the time of removal of catheter, the decrease was however significant ($P<0.05$) decreasing trend in the plasma magnesium levels within normal range at day sixteenth irrespective of the severity of the disease. At day zero, there was increase in urinary magnesium levels with the severity of disease in all the groups under study.

However, at day 8th and at the time of removal of catheter, the variability levels in urinary magnesium among different groups was varying non-significantly ($P>0.05$). With the advancement of post-treatment period, there was significant ($P<0.05$) decreasing trend in the urinary magnesium levels within normal range at day sixteenth irrespective of the severity of the disease (Table 3). Inter relation of the magnesium in urine plasma and calculi goes, the studies revealed about (65 to 75%) of the calculi composed of magnesium ammonium phosphate and rest were comprised of calcium phosphate, calcium carbonate, calcium oxalate and uric acid.

Urinary Calcium Phosphorous and Magnesium

A gradual increase in urinary calcium was recorded in the animals of all groups. The postoperative observations of urinary phosphorous were almost reverse to the calcium levels and postoperative lowering of urinary phosphorous was observed in the animals of all groups at all the postoperative intervals.

The improvement in the calcium range, decrease in phosphorous and magnesium levels towards normalcy could be due to regain of appetite, restoration of normal acid-base balance, discontinuation of ruminant ration (Gianesella et al., 2010). The inverse effect of the elevated calcium level in the blood has been reported by Emerick and Embry (1963); Udall and Chow (1965); Bushman et al. (1965a,b); Bushman et al. (1967); Goulden (1969) and Singh et al. (1983a).

Possible role of calcium and phosphorous in urine, blood and calculi

As far the role of calcium phosphorous and their interrelation during the phase of urolithiasis goes, it could be conceived that ingestion of a ruminant feed containing high amounts of phosphates by a ruminant, physiologically with a non-functional rumen results in high absorption of the phosphates which is clinically substantiated in Tables 2 and 3. This results in depletion of calcium absorption and calcium being excreted through urine. This is obvious from our previous findings of screening; wherein crystals of calcium have been found present well before the manifestation of clinical symptoms of urolithiasis. In absence of the acid base studies regarding the subject how the crystallization of the calculi takes place cannot be elucidated. Various factors come to play the role in the composition of the calculi, particularly geography, species, age, sex, composition of feed, pH of urine, urinary tract infection etc (Radostitis et al., 2000). During this study, composition of feed seemed to be the profound predisposing factor, as wheat bran alone or in combination with other feeding stuffs was given to the maximum number of calves. Rations high in grains but with limited amount of roughages leads to ammonium phosphate urolithiasis in feedlot cattle (Belknap and Pugh, 2002).

The feeding schedule of the calves revealed that they were fed concentrate mixture which was high in the phosphorous and low in calcium. The findings are in total agreement with those of Munakata et al.(1974a,b); Ahmed et al. (1989); Finlayson (1974) who reported that highly digestible, low roughage ration having more phosphorus than calcium e.g. high grain feeding lead to the formation of insoluble struvite calculi. Presence of calcium phosphate deposits between the struvite crystals represented the epitaxial growth, which signifies the growth of one type of crystal upon another type. Determination of chemical composition of the calculi revealed that they contain 70% P, 20% Ca and 10% oxalate. This was clinically substantiated by the proportionate decrease in blood Ca and urine Ca levels. Obstructive urolithiasis causes severe alterations in haematobiochemical profile that could be of no clinical significance, however, increased BUN, Creatinine, Calcium, and Inorganic Phosphorus could form a good index to determine the severity of the disease.

Conflict of Interest

The authors have not declared any conflict of interest.

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Seed yield and agronomic performance of seven improved cowpea (*Vigna unguiculata* L.) varieties in Ghana

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Cowpea is well adapted to environmental conditions that affect crop production such as drought, high temperatures and other biotic stresses compared with other crops. Notwithstanding, growth and development of many cowpea cultivars are affected by drought and high temperatures, especially during floral development. This is because cowpea cultivars tend to have narrow range of adaptation as cultivars developed for one zone usually are not very productive in other zones. A study on the yield and growth performance of seven cowpea varieties was conducted during the 2012 major and minor rainy seasons at the CSIR-Crops Research Institute, Kwadaso-Kumasi, Ghana to compare the performance of the seasonal variation on each variety. These improved varieties Nhyira, Tona, Asetenapa, Asomdwe, Hewale, Videza and IT 89KD374-57 were evaluated using a randomized complete block design and replicated three times. The results showed that varieties Hewale, Videza and Nhyira gave higher seed yields, whereas IT 89KD374-57 and Asetenapa had lower seed yields. Nhyira and Hewale gave comparatively better seed yields under both conditions. Hewale was the highest seed-yielding genotype under both major and minor raining season. Cowpea production could be a profitable agribusiness for cowpea growers in Ghana considering the higher returns in terms of grain yield obtained in both seasons.

Key words: Cowpea, agronomic performance, improved varieties.

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the most ancient human food sources and has probably been used as a crop plant since Neolithic times (Summerfield et al., 1974). Cowpea is grown extensively in 16 African countries, with the continent producing two-thirds of the world total (Winrock, 1992). The crop is of major importance to the livelihoods of millions of people in the tropics. For resource-poor small-holder farmers, the crop serves as food, animal feed, cash and manure. Going beyond its importance for food and feed, cowpea can be

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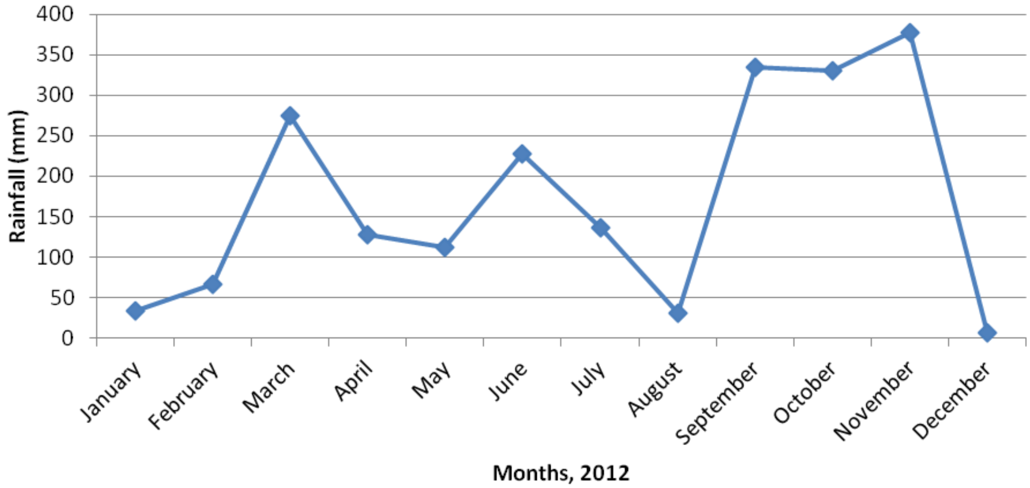

Figure 1. Rainfall distribution in 2012.

regarded as a pivot of sustainable farming in regions characterized by systems of farming that make limited use of purchased inputs like inorganic fertilizer. The crop can fix about 240 kg ha^{-1} of atmospheric nitrogen and make available about 60 to 70 kg ha^{-1} nitrogen for succeeding crops grown in rotation with it (CRI, 2006; Aikins and Afuakwa, 2008).

Cowpea is well adapted to environmental conditions that affect crop production such as drought, high temperatures and other biotic stresses compared with other crops (Martin et al., 1991). The aforesaid growth and development of many cowpea cultivars are affected by drought and high temperatures, especially during floral development (Dadson et al., 2005).

In Ghana, cowpea covers 156,000 ha (IITA, 1993). The yields of the crop, however, are among the lowest in the world, averaging 310 kg/ha (Ofosu-Budu et al., 2007). Meanwhile, the crop is one of the widely cultivated legumes, mainly in the savannah and transition zones of Ghana (CRI, 2006). Hence, efforts have been made to improve cowpea production in all agro-ecological zones of Ghana through various means including the introduction of new varieties such as those used in this study.

In recent years, several studies have evaluated the performance of cowpea genotypes in several ecological zones of Ghana. In selecting appropriate genotypes for different agro-ecological environments, it is important to know how various soils and climatic factors affect the growth and development of these new varieties in order to interpret the observed yields under these environments.

Appropriate agronomic practices to improve the performance of new varieties of improved and dual-purpose cowpea under different agro-ecological zones are generally important for breeding and production purposes. Yield and growth performance could be increased through the evaluation of all these varieties under different agro-ecological zones for a better understanding of their morphological, physiological and biochemical response to the environment. This underscores the importance of evaluating the agronomic performance of cowpea varieties as a food security crop under the current and foreseeable future scenarios. The objective was to evaluate key yield related parameters among seven cowpea genotypes in the Forest zone of Ghana.

MATERIALS AND METHODS

Study site

The study was carried out at the research field of the CSIR-Crops Research Institute, Kwadaso-Kumasi, Ghana. The area has a bimodal rainfall pattern, the major season (April to July) with maximum rainfall normally in June and the minor season (September to November) with the maximum normally in October. Figure 1 shows the rainfall amount and distribution during the study year of 2012. The area receives a mean annual rainfall of 1500 mm with an average monthly temperature range of 24 to 28°C.

Soil analysis

Soil samples were randomly collected before planting from four different cores at 0 to 15 cm and 15 to 30 cm for determination of soil physical and chemical properties using soil auger. The soil is a sandy loam classified as Ferric Acrisol (FAO, 1990), equivalent to Typic Haplustult in the USDA soil classification system. Table 1 gives the initial soil analysis.

Experimental materials, design and treatments

Cowpea varieties Tona, Nhyira, Asetenapa and newly developed genotypes; Asomdwe, Hewale, Videza and IT 89KD374-57 used in this study were collected from the CSIR-Crops Research Institute,

Table 1. Chemical properties of soils at horizons 0 to 15 cm and 16 to 30 cm at Kwadaso.

Variables					Bray's available		Exchangeable cations m.e. 100^{-1}g				Variables			
Depth	**pH**	**O.C**	**O.M**	**N**	**ppmK**	**ppmP**	**Ca**	**Mg**	**K**	**Na**	**TEB**	**Ex. Acidity**	**ECEC**	**% B.S**
0-15 cm	5.3	1.87	3.2	0.12	100.4	106.3	3.5	0.8	0.1	0.04	4.42	0.45	4.87	90.76
15-30 cm	5.4	1.56	2.7	0.1	55.8	3.75	2.9	0.8	0.1	0.03	3.82	0.4	4.22	90.52

Table 2. Yield potentials and general description of the seven Cowpea varieties used.

Varieties	Yield potential (t/ha)	Seed coat texture	Growth habit	Seed shape	Maturity date (days)
Asomdwe	2863 kg/ha	Smooth	Semi-erect	Globose	65-72
Videza	3043 kg/ha	Smooth	Semi-erect	Ovoid	68-77
Hewale	3130 kg/ha	Smooth-rough	Semi-erect	Rhomboid	64-72
Tona	2390 kg/ha	Smooth	Erect	Ovoid	71-80
Nhyira	2460 kg/ha	Rough	Erect	Globose	65-68
Asetenapa	2500 kg/ha	Smooth	Erect	Ovoid	63-70
IT 89KD374-57		Smooth	Semi-erect	Globose	65-72

(Crop Research Institute(CRI), 2010).

Kwadaso-Kumasi, Ghana. Seeds of the varieties were planted during the major and minor seasons after the experimental sites have been disc-ploughed and disc-harrowed. The seeds were sown in March and August, 2012 for the major and minor seasons respectively. Each of the genotypes was grown into a six-row plot of 3.0 × 5.0 m with a spacing of 50 and 20 cm between and within rows respectively. The experimental design was a randomized complete block design with three replications. Two inner rows were harvested to determine the final seed yield. Other parameters such as plant height, root length, nodule count and number of branches were measured on 10 randomly selected plants from each plot.

Data collection

Using the stratified sampling method, plants from an area of 1 m^2 were carefully uprooted from each plot. In all, 21 plots were sampled and for each sample, the roots were cut using a pair of secateurs, placed in an envelope and labelled before they were sent to the laboratory for dry matter analysis. The roots were carefully washed to remove attached soil. Fresh weight, root length and dry matter were taken from the sampled plants. Plants were placed in an oven maintained at 80°C for 48 h. Samples from the 21 plots were sent to the laboratory for dry matter analysis (Table 2).

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using the Genstat Discovery 4th Edition statistical package with subsequent mean separation using LSD at 5% level of significance.

RESULTS

Results of the seasonal variation studies on the agronomic and yield performance of the improved cowpea varieties are presented in Tables 3 and 4. Significant differences ($p<0.05$) were observed among the varieties for grain and fodder production (Table 3). The average seed yield of the seven cowpea varieties varied between 1499.2 kg/ha and 2261.0 kg/ha for the major season and 1208.3 to 2091.0 kg/ha for the minor season. The maximum yield was obtained from Nhyira (2091.7 kg/ha) for the minor season and Videza (2261.3 kg/ha) for the major season with IT 89KD374-57 producing the least seed yield of 1208.0 kg/ha for the minor season. The trend however, was not replicated during the major season. Videza recorded the highest seed yield (2261.3 kg/ha) for the major season with IT 89 KD374-57 recording the lowest seed yield (1499.2 kg/ha). During the minor season, Nhyira produced

Table 3. Seed and dry matter yields of seven cowpea varieties.

Treatment	Seed Yield (Kg/ha)		100 Seed weight (g)		Dry matter (gm^2)		Plant Height (cm)		Days to 50% Flowerin	
	Minor	Major	Minor	Major	Minor	Major	Minor	Major	Maj	Min
Nhyira	2091.7	2179.0	14.8	19.2	19.2	20.6	54.7	65.6	48	48
Tona	1895.8	1910.7	14.5	17.7	24.6	24.5	63.6	64.2	48	48
Hewale	1625.0	2250.3	17.3	24.2	25.5	30.6	58.3	73.3	53	54
Asomdwe	1437.5	2105.4	14.1	17.53	17.5	18.3	61.6	61.3	49	48
Asetenapa	1291.7	1606.7	15.5	22.2	32.3	24.0	70.0	63.3	49	49
Videza	1375.0	2261.3	19.2	25.1	14.2	24.3	56.6	82.3	41	42
IT 89KD374-57	1208.3	1499.2	14.8	16.23	16.3	19.0	67.0	68.9	47	48
Mean	1560.7	1973.2	15.7	20.3	21.4	23.0	61.7	68.4	47	48
Lsd (0.05)	581.9	148	1.8	0.51	15.7	1.23	6.4	1.1	0.6	0.7
CV (%)	20.58	4.22	6.58	1.42	25.3	3.01	5.2	5.8	6.7	7.4

Table 4. Root length, nodule count, stem diameter and number of branches for cowpea varieties.

Treatment	Root length (cm)		Nodule count		Stem diameter (m)		Number of branches	
	Major	Minor	Major	Minor	Major	Minor	Major	Minor
Nhyira	21.8	19.0	15.3	12.0	0.86	0.88	6	5
Tona	18.3	16.6	15.3	13.2	0.63	0.80	6	6
Hewale	18.4	17.6	16.3	12.0	0.83	0.83	6	5
Asomdwe	17.9	16.7	17.3	13.0	0.56	0.72	6	6
Asetenapa	18.8	18.3	15.3	14.0	0.84	0.84	5	5
Videza	18.5	15.7	20.3	20.0	0.68	0.78	7	8
IT89KD374-57	15.3	13.7	18.7	15.0	0.80	0.86	5	5
Mean	18.4	16.8	16.9	14.2	0.7	0.8	5.8	5.7
Lsd (0.05)	0.96	4.6	1.5	9.5	0.16	0.08	1.2	1.2
CV(%)	2.92	15.3	5.14	37.3	5.93	4.48	11.13	13.75

seed yield (2091 kg/ha) superior to the recently released Videza and Hewale varieties (1375 and 1625 kg/ha) respectively.

Dry matter yields were highest in Hewale (30.6 g) and Asetenapa (32.3 g) compared to the other varieties for the major and minor seasons respectively (Table 3). Hundred seed weight (HSW) ranged from 14.1 to 19.2 g with a mean of 15.8 g for the minor season and 16.2 to 25.1 g for the major season. The highest 100 seed weight was obtained from Videza for both the major and minor growing season (Table 3). Plant height was higher during the long rainy season compared to the short rainy season (Table 3).

Tap root length was significantly higher in Nhyira (21.8 cm) and least in IT89KD374-57 (15.3 cm) in the major season (Table 4). Nhyira again maintained the greatest root length in the minor season (19.0 cm) however this was only significantly different from IT89KD374-57 which had the least root length ((13.7 cm) ($p<0.05$) (Table 4). Nodule count ranged from 15 to 20 and 12 to 20 for the major and minor seasons respectively. Videza recorded the highest nodule count for both the major and minor seasons (20.3 and 20.0 respectively), ($p=0.05$).

Nhyira produced the highest stem diameter (0.86 and 0.88 mm) for the minor and major seasons respectively with Asomdwe recording the lowest (0.56 and 0.72 cm) for the minor and major seasons respectively (Table 4). Number of branches per plant (NBP) among the cowpea varieties ranged from 5.0 to 8.0 and 5.0 to 7.0 for the minor and major seasons respectively (Table 4). Videza attained the highest number of branches in both the major and minor season (Table 4). First pod height for the minor season was not significantly different among the seven cowpea varieties (Figure 2). The major season produced first pod heights which were higher than the minor season. IT 89KD374-57 produced the highest first pod height (64 cm) and Nhyira producing the lowest FPH (52 cm).

On the other hand, final plant height at harvest was significantly different among the seven varieties for both seasons (Table 3). Videza recorded the highest height plant height of 82.3 cm whiles Tona recorded the lowest plant height of 54.2 cm for the major season (Figures 3 to 4).

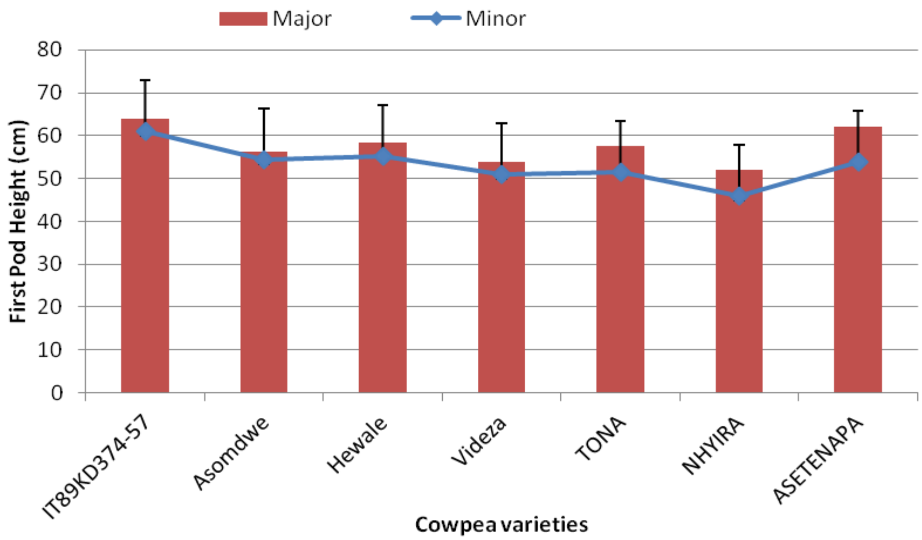

Figure 2. First pod height of the seven cowpea varieties.

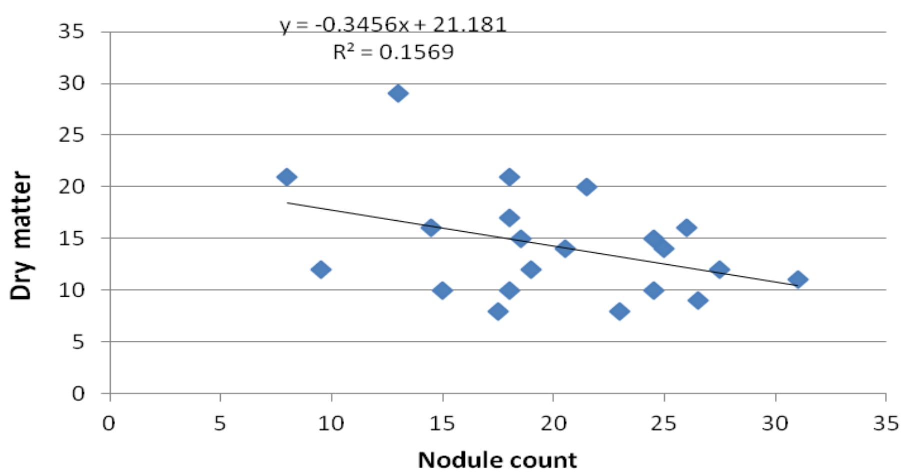

Figure 3. Relationship between Nodule count and Dry matter for the short rainy season.

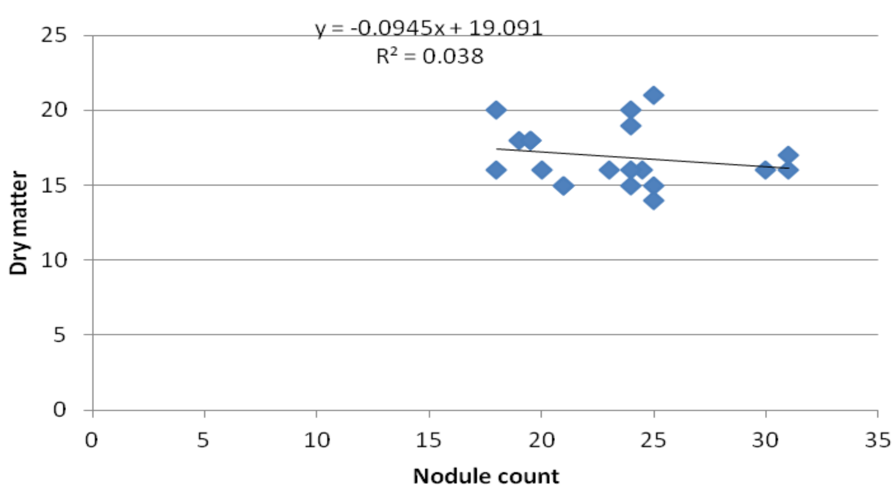

Figure 4. Relationship between Nodule count and Dry matter for the long rainy season.

DISCUSSION

The results of this study showed that rainfall is enough to support the growth and yield of cowpea in Kwadaso-Kumasi, Ghana, if other enabling factors are present in both the minor and major rainfall seasons. However, the cowpea varieties used in this study responded differently to the prevailing soil and climatic conditions. The highest yield of Videza was related to the continuous water supply. The results indicates that Nhyira and Videza will be more profitable than the other varieties in the minor and major seasons respectively and could serve as an alternative crop because of its desirable attributes and resistance to major biotic and abiotic constraints.

Videza, Hewale and Asomdwe in this study gave lower seed yield under short raining season than the seed yield of the same variety grown under long raining season (Table 2). This is because cowpea cultivars tend to have a narrow range of adaptation, as cultivars developed for one zone with distinct climatic factors usually are not very productive in other zones with different climatic factors (Hall et al., 2003). Irrespective of the potentials of these varieties as a drought resistant crop, failure of rainfall or lack of irrigation is a frequent cause of shortfall in production especially in Ghana where cowpea production is primarily grown in dry areas. Drought could be considered as an important factor among several seed yield-reducing factors. Clearly, there is a potential for further increase in seed yield by planting high-yielding genotypes, providing optimum irrigation, adding fertilizers (Quin, 1997), planting early and spraying with suitable insecticides. Therefore, selection of cowpea genotypes that have higher tolerance to drought is needed to obtain higher and more stable seed yields and in this regard Nhyira, Tona and Hewale appear to have some drought tolerance potential due to their higher yield during the minor season.

IT89KD-374-57 was observed to be low yielding due to its production of fewer nodules and dry matter. Low production of nodules means less nitrogen fixation by the variety. Production of relatively more leaves and branches with erect leave architecture in most cases reflect higher light interception and more photo-assimilate production that may result in increase yield.

In the development and growth of most cowpea varieties in the Sub Saharan Africa, yield and seed development require the production of assimilates in leaves, translocation of these assimilates to the fruits, unloading of assimilates from phloem of the seed coat into cells of cotyledons and synthesis of the various seed storage compounds. Yield losses resulting from water stress are generally associated with decreases in the activity of these physiological factors and dry matter production. Among the varieties that provided the highest biological yield under short raining season conditions in 2012 were Asetenapa and Hewale, whereas under the long raining season conditions the highest biological yield was provided by Hewale and Tona. The growth habits of these genotypes were bushy, erect or semi-erect, characteristic which can be used as a cover crop as well as for grain.

As observed in the grain yield, the biomass of the cowpea varied between the two seasons but the magnitude of the variation within the minor season was less than that observed in the major season. Differences in the seasonal fodder production of some varieties were not significantly different which showed that apart from rainfall some climatic factors like sun radiation might have influenced biomass production. Differences in day length between the major season and minor season in Ghana are that significant to affect crop production (Berchie et al., 2013).

The significant differences observed with the dry matter showed that attainment of reproductive phase was a varietal characteristic related to the genetic constitution of the varieties. Dry matter production in the minor season was more affected by genetic composition of the variety than the seasonal variation. This perhaps may be due to the ability of cowpea to survive under extreme water limiting conditions and could respond against the later drought. This was mainly achieved by slowing growth and reducing transpiration, as reported by Vianello and Sobrado (1991) that drought stress during vegetative stage provides diminution of the growth in most crop leaves and stems.

In this study, nodule numbers usually were lower at harvest than at earlier stages. The decline in number was especially noteworthy for nodules from taproots. Varietal differences account for nodule differences since the pattern of nodulation, most often, reflects the physical distribution of the root system in the soil. As reported by Hansen (1994), nodulation capacity is known to vary between and within legume species rather than rainfall variations as observed in this study. Varieties producing more nodules possess the capacity to fix nitrogen into the soil. However, genotypic effects on determinants of N_2 fixation resulting from nodulation are known to be complex. Lawn et al. (1974) suggested that the control of soybean nodule initiation occurs primarily in the root itself, but the control of nodule fresh weight occurs solely in the shoot and is related to the supply of assimilates.

The result of this study has shown better crop performance in terms of vegetative and grain yield during the long rainfall season than the short rainfall season. The reason could be attributed to relatively higher rainfall and milder temperature experienced during the production season of major rainfall. According to the annual report of the Science Daily (2008), plants growing under water limiting conditions tend to grow taller in an effort to scramble for below nutrients around the growth environment. These present results are consistent with previous study on cowpea by Hayatu and Mukhtar (2010), who reported that the results for plant height at final harvest showed that, increases in plant height under both moderate and severe water stress were recorded at the expense of seed yield in IT00K-835-45 and IT98K-819-118.

Plant population is reported to have effect on stem diameter, however, the results obtained from this study may be attributed to the better soil moisture availability, decreased plant competition and increased light penetration through plant canopy at such low plant population. The variation in stem diameter among cultivars might be due to genotypic differences.

Conclusion

From the results obtained in this study, it could be concluded that the performance of the three local and four improved varieties in terms of yield was higher in the major than minor season. Hewale and Videza are more suitable for high rainfall areas whereas Nhyira and Tona will be more productive and profitable in the drier areas. This study supports the clarion call that cowpea should become a successful legume crop for dry regions of Ghana.

Conflict of Interest

The authors have not declared any conflict of interest.

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Salmonella Enteritidis and Typhimurium in informally sold broilers

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In order to evaluate the sanitary conditions of fresh chicken carcasses sold in public markets in the city of Feira de Santana, Bahia, a study was conducted in carcasses collected from six different establishments, during ten weeks, totaling up to 60 samples, to evaluate the occurrence of Salmonella in broilers. Results show a 28.3% occurrence of the pathogen and current investigation underscored the diagnosis of Salmonella Enteritidis and Salmonella Typhimurium in the samples. The serotype Enteritidis was isolated in establishments A, B and C and the serotype Typhimurium in establishments E and F. The results of this study indicate that many chicken products sold in Feira de Santana, Bahia, Brazil, are contaminated with different serotypes of Salmonella, especially Salmonella Typhimurium and Salmonella Enteritidis and should, therefore, be suitable for cooking and handling prevention of salmonellosis outbreaks.

Key words: food, microbiology, veterinary public health.

INTRODUCTION

Salmonellae are widely distributed in nature and are capable of infecting both humans and animals. Poultry infected by paratyphus salmonellae may develop the disease either clinically or asymptomatically by harboring the agents and becoming potential sources of salmonellosis for humans (Nagaraja et al., 1991; Barrow, 1993; Santos et al., 2000).

From the 1980s henceforth, food toxic-infections caused by *Salmonella* increased and Rodrigue et al. (1990) and Santos et al. (2000) attribute this fact to intake of eggs and other sub-products contaminated by *Salmonella enterica*. However, *Salmonella* in broilers´ carcasses should never be discarded (Rampling et al., 1989; Boer and Zee, 1992; Giessen et al., 1992; Poppe, 1994; Scuderi et al., 1996; Costa, 1996; Sakai and Chalermchaikit, 1996; Ward and Threlfall, 1997; Santos et al., 2000).

Chicken meat in England and Wales caused outbreaks

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and sporadic cases of the disease (Rampling et al., 1989; Santos et al., 2000), with approximately 30,000 cases of food toxic-infections in humans (Ward and Threlfall, 1997; Santos et al., 2000). Tavechio et al. (1996) reported an increase in the isolation of *S. enterica* in Brazil as from 1993. Between 1991 and 1994, Italy experienced 1699 food-caused outbreaks, with *Salmonella* causing 81% of which 34% were of *S. enterica* (Scuderi et al., 1996; Santos et al., 2000).

Animal-originating products, especially from poultry, are an important source of human protein. In the Brazilian retail market, cooled or frozen poultry carcasses are available, even though cooling fails to eliminate bacteria as those of the genus *Salmonella* (Santos et al., 2000).

Scarcity of analysis on this subject is a highly notorious fact in Northeastern Brazil where a fast development in poultry industries is currently occurring. New researches on the occurrence of *Salmonella* spp. in the poultry chain of this region are urgently required. Further, regional differences that affect the development of these micro-organisms should also be taken into account.

Current assay investigates the occurrence of *Salmonella* spp. in several food establishments in Feira de Santana BA Brazil, which exhibits the 'hot chicken' commercialization. Results in current analysis may contribute towards the identification and introduction of more specific and effective control measures directed towards local specificities. Greater visibility will also be established with regard to the risks that the population and consumers undergo by providing the controlling authorities with highly useful microbiological data.

MATERIALS AND METHODS

Current assay was performed in Feira de Santana BA Brazil, a city in the central-north meso-region of the State of Bahia, Brazil. The method comprised the collection of samples of poultry carcasses from illegal abattoirs. The carcasses were bought from several commercial firms in one of the city districts. The methodology included certain advantages such as low cost, easiness in collecting the material and microbiological analyses developed without any further costs.

Six firms, called A, B, C, D, E and F, which sell broiler carcasses directly from the illegal abattoir, were chosen at random. A sampling plan was established by which sixty samples were analyzed. Carcasses from each firm were collected weekly, in the morning, during 10 weeks, between September and October 2013.

Internal temperature was measured at the carcass´s thermal center, or rather, at the supracoracoid region and pectoral muscles. Data were collected by a portable thermometer immediately after the collection of the carcasses and on the same premises. Samples were then conditioned in an isothermal container and sent to the Laboratory of Food and Water Microbiology of a food-processing industry in the city.

The samples were collected in the morning and the material was sent to the microbiology laboratory for the analysis of *Salmonella* spp immediately after collection. Analysis was based on the methodology following Norm 62 by MAPA (Brasil, 2003). Samples had the same visual standard, characterized by a yellowish color, with wrapped offal placed within the celomatic cavity of the carcass.

Results were given following proposal in the two-class sampling plan, or rather, when the sample could be acceptable or not (Brasil, 2001). The plan was applied in the *Salmonella* research due to the bacterium´s epidemiological characteristics.

A long thermometer (stainless steel rod, 120 mm long and scale ranging between -50 and 200°C) verified the temperature of each carcass on the collection site. Temperature was taken in the pectoralis muscle with the thermometer rod penetrating some 4 cm in the region. Room temperature of the premises where collection was performed was also measured.

RESULTS AND DISCUSSION

Ten samples from each firm were evaluated during 10 weeks (a sample collected per week) in August, September and October 2013. Results for research on *Salmonella* for each firm are given, coupled to the temperature at collection.

Tables 1, 2 ,3, 4, 5 and 6 show frequencies for each firm, with firms A, B and C demonstrating critical results due to their high positive frequency. Firms E and F showed similar frequencies, with lower rates than the others. On the other hand, firm D failed to show any positive frequency for the pathogen under analysis, between the start and end of the investigation. Table 6 provides results for positive samples of *Salmonella* during the whole assay.

Current investigation underscored the diagnosis of *Salmonella* Enteritidis and *Salmonella* Typhimurium in the samples. The serotype Enteritidis was isolated in establishments A, B and C and the serotype Typhimurium in establishments E and F.

The above fact probably suggests other species of *Salmonella*, similar to those reported by Hofer et al. (1997), who, in their studies on serovars of *Salmonella* isolated from poultry in Brazil, registered *Salmonella* Gallinarum, *Salmonella* Pullorum, *Salmonella* Heidelberg and *Salmonella* Infantis, besides *Salmonella* Enteritidis and *Salmonella* Typhimurium.

Increase of sporadic cases and outbreaks of human salmonellosis in several countries is related to the increase of infection by *Salmonella* due to the intake of poultry meat, eggs and other contaminated derived products. Several studies show that the occurrence of *Salmonella* spp. in broiler carcasses may vary between 0.024 and 85.0%. It is actually an important transmission vehicle of the bacterium (Aloccer et al., 2006).

Studies by Sakugawa et al. (2008) revealed that *Salmonella* spp. (71.7%), *Escherichia coli* (95%) and *Staphyloccocus aureus* (43.35%) were extant in samples on the retail market of João Pessoa PB Brazil. Although quality is underscored, several species of *Salmonella* are present in broilers' meat sold in the market.

In Brazil, some more commonly found in birds are serovars *Salmonella* Enteritidis, *Salmonella* Typhimurium, *Salmonella* Derby, *Salmonella* Heidelberg, *Salmonella* Senftenberg, *Salmonella* Agona and *Salmonella* Mbandaka. *Salmonella* Enteritidis and *Salmonella* Typhimurium are among the most prevalent in chickens

Table 1. Results of microbiological analyses and temperature, per week, at firm A. Feira de Santana, BA, Brazil, 2014.

Week	Number of positive samples	Frequency (%)	Temperature of carcass (°C)
1	0	0	35.9
2	1	10	37.7
3	0	0	34.7
4	0	0	37.8
5	1	10	32.7
6	1	10	33.4
7	1	10	32.6
8	0	0	36
9	1	10	34.4
10	1	10	31.5
Total	**6**	**60**	**36 (Mean)**

Table 2. Results of microbiological analyses and temperature, per week, at firm B. Feira de Santana, BA, Brazil, 2014.

Week	Number of positive samples	Frequency (%)	Temperature of carcass (ºC)
1	1	10	36.6
2	0	0	34.8
3	0	0	36
4	0	0	35
5	0	0	30
6	0	0	32.2
7	1	10	33.4
8	1	10	35.1
9	1	10	32.3
10	0	0	31.5
Total	**4**	**40**	**33.7 (Mean)**

Table 3. Results of microbiological analyses and temperature, per week, at firm C. Feira de Santana, BA, Brazil, 2014.

Week	Number of positive samples	Frequency (%)	Temperature of carcass (°C)
1	1	10	33.8
2	0	0	35
3	1	10	35.8
4	1	10	34.1
5	0	0	31.3
6	0	0	32.2
7	1	10	35.6
8	1	10	36
9	0	0	34.1
10	0	0	31.1
Total	**5**	**50**	**35.5 (Mean)**

and have great importâmcia to public health (Aloccer et al., 2006; BACK, 2010).

From the mid-80’s in Europe and after the beginning of the 90s in Brazil, *Salmonella* Enteritidis has become one of the most prevalent serotypes in cutting and laying birds. At the beginning of this new century, the *Salmonella* Enteritidis in Brazil has shown significant reduction. It is possible that the widespread use of killed

Table 4. Results of microbiological analyses and temperature, per week, at firm D. Feira de Santana, BA, Brazil, 2014.

Week	Number of positive samples	Frequency (%)	Temperature of carcass (ºC)
1	0	0	33.3
2	0	0	30
3	0	0	36
4	0	0	32
5	0	0	32
6	0	0	36
7	0	0	32.2
8	0	0	33.7
9	0	0	34.9
10	0	0	35.3
Total	**0**	**0**	**33.2 (Mean)**

Table 5. Results of microbiological analyses and temperature, per week, at firm E. Feira de Santana, BA, Brazil, 2014.

Week	Number of positive samples	Frequency (%)	Temperature of carcass (°C)
1	0	0	36.5
2	0	0	31.4
3	0	0	34.3
4	0	0	32
5	0	0	34
6	0	0	31.1
7	0	0	35
8	0	10	32.2
9	0	0	34.5
10	0	0	32.2
Total	**1**	**10**	**33.6 (Mean)**

Table 6. Results of microbiological analyses and temperature, per week, at firm F. Feira de Santana, BA, Brazil, 2014.

Week	Number of positive samples	Frequency (%)	Temperature of carcass (°C)
1	0	0	31
2	0	0	30.5
3	1	10	34
4	0	0	34
5	0	0	35
6	0	0	30.1
7	0	0	38.4
8	0	0	33.8
9	0	0	35.7
10	0	0	32
Total	**1**	**10**	**33.2 (Mean)**

vaccine in broiler breeders contributed to this fact. The predominant phage type 4 in *Salmonella* Enteritidis birds is considered one of the most pathogenic to humans, although there is variation in pathogenicity between different samples of this phage type. Although the transmission of *Salmonella* Enteritides has not been demonstrated in a classical way, there are investigations showing that of 10,000 eggs positive plot, one can isolate *Salmonella* Enteritidis internal contents of 2 to 3 eggs, which indicates that some chicks may be born infected. It is very difficult to eradicate the *Salmonella* Enteritidis from an infected batch and the bird stands for eliminating the bacterial life. The biosecurity system and monitoring should be strict to prevent the infection establishment in the lot and to identify lots that eventually become positive, respectively (BACK, 2010).

Current analysis provides visibility on the occurrence of *Salmonella* sp. in poultry products (carcass of whole broilers) sold in Feira de Santana BA Brazil, or rather, precisely the products derived from illegal abattoirs with no official sanitary certificate on commercialization. This boils down to the fact that the origin, production methods and hygiene processes are unclear.

Tables 1, 2, 3, 4, 5, and 6 clearly demonstrate that temperatures of all the broilers' carcasses from all the firms did not meet the standards demanded by current legislation during the ten weeks in which these conditions were investigated. The above is of great concern since the carcasses with such temperature are prone to the growth of mesophyll micro-organisms (high rates of deteriorating and pathogenic micro-organisms) at a best growth temperature between 25 and 40°C. It should be emphasized that the best temperature for the growth of most pathogenic bacteria, among which may be mentioned *Salmonella* sp., is approximately 37°C (Jay, 2005). Therefore, the consumer of such poultry meat is exposed to high biological risk.

Results of the microbiological analysis of the commercial firms A, B, C, E and F, respectively provided in Tables 1, 2, 3, 5 and 6, definitely co-relate them to the origin of the slaughtered animals, the possibility of cross-contamination during slaughter and meat processing and exposure to poor storage and conservation conditions.

Similar storage conditions were evidenced in all the commercial firms under analysis. All the meat products were exposed on tables without any temperature control and, therefore, subjected to oscillations in room temperature. No specific refrigeration or otherwise was detected in any commercial firm that would maintain the temperature of the meat products under control. Commercial firms must comply with Law 304 published in 1996 based on beef and pork, or rather, in the case of cattle and swine abattoirs they must deliver only cooled meat and offal for retail at a temperature up to 7°C; also, commercial firms must maintain such temperature (Brasil, 1996).

It is actually a highly relevant factor since meat products should not be left to deteriorate due to inadequate handling within the distribution chain, which may in fact, be evidenced during transport and unloading at the selling depot (Brasil, 1996). In the case of poultry meat, the technical regulation for technological inspection is provided by Law 210 (Brasil, 1996) which underscores two conservation methods, namely, the temperatures and the procedures that abattoirs and commercial firms should comply with.

Law 210 deals with the conservation methods by cooling, or rather, the process of refrigeration and maintenance of temperature between 0 and 4°C in the case of poultry meat (carcasses, cuts, offal and other derived products), with a tolerance of 1°C, measured within the interior of the products. It also deals with the freezing process and the maintenance of a temperature not higher than -12°C for poultry products (carcasses, cuts, offal and other derived products), with a tolerance of up to 2°C, measured within the interior of the products (Brasil, 1996).

The results from Firm D, reported in Table 4, reinforce a monitoring process. In spite of the adverse conditions mentioned above, there was a 0% frequency for *Salmonella* sp., although this fact may be co-related to the occurrence of the pathogen at the poultry origin and not to storage conditions.

When all the samples in all the commercial firms have been analyzed, it may be evidenced that 17 samples were positive for *Salmonella* sp. The contaminated samples amounted to 28% frequency for all the samples evaluated. Microbiological analyses revealed a higher number of positive samples in commercial firm A, with 35%, followed by C with 29%, B with 24%, E and F with 6% each and D without any contamination. Figure 1 shows the results.

Maldonado (2008) identified the percentage of bacteria in carcasses and offal of cooled broilers sold in fairs and in a municipal market in the western region of São Paulo SP Brazil, in May 2007, featuring a high index of *Salmonella*. During the period mentioned above, 75 samples were analyzed, of which 65% were contaminated with some species of bacteria and 35% by *Salmonella*.

Another investigation by Silva et al. (2006) showed that in a sample of 60 birds sold in commercial firms and in open fairs in the western region of São Paulo SP Brazil, approximately 40% of the poultry were positive to *Salmonella* spp.

Figure 2 demonstrates the percentages of positive samples detected during the 10 weeks, taking into account the ten weeks of repetition. Highest frequency occurred on weeks 1, 3, 7 and 9 within the interval proposed.

According to Silva et al. (2006), *Salmonella* spp. is redundant in wild poultry breeding when compared to poultry in breeding houses. This fact may be corroborated by research in granges in the northern region of the State of Paraná, Brazil and in a poultry abattoir in Jacarezinho, PR Brazil.

According to Silva (2014), Silva and Duarte (2006) and Silva et al. (2006), illegal poultry slaughter is a high concern for public health due to exposure to infectious and parasite agents transmitted to humans by animals in the intake of quality-lacking food and by environmental contamination. The unknown origin of animals and breeding methods place impediments and challenges on the monitoring process and exposes workers to zoonosis.

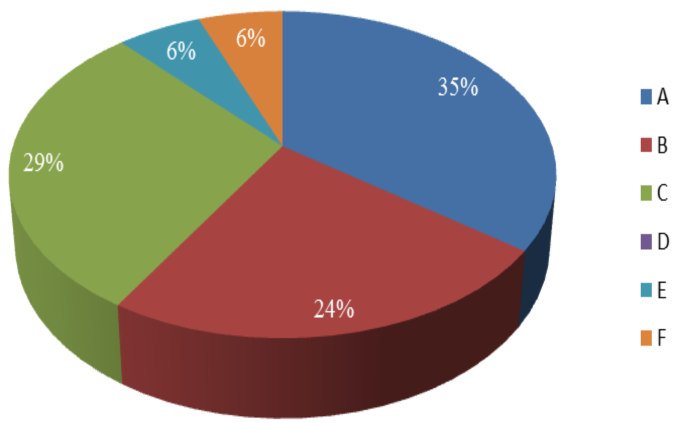

Figure 1. Frequency of total positive samples per commercial firm. Feira de Santana, BA, Brazil, 2014.

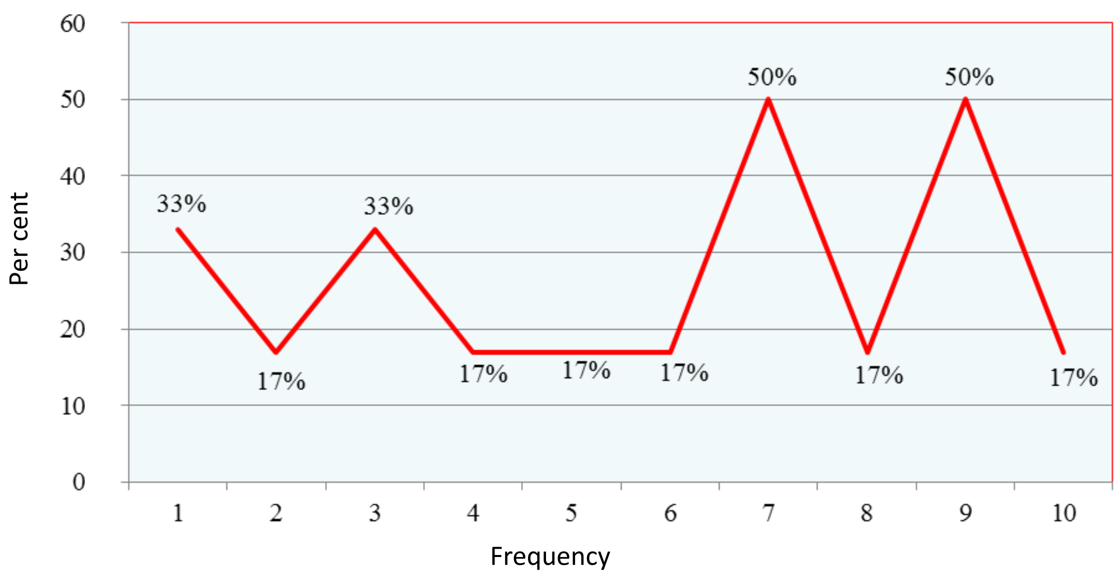

Figure 2. Frequency of positive samples throughout the period (weeks). Feira de Santana, BA, Brazil, 2014.

It should be underscored that illegal poultry slaughter is a crime against consumers, which must be hindered by all means by the health authorities. The dissemination of activities based on sanitary education by the conscience-awareness of consumers in all the social classes should be underscored.

Food in general, especially from animal origin, such as meat, eggs and milk, is the receiving end of many bacteria, resulting in Food-Borne Diseases (FBD). Rampling et al. (1989), Boer and Zee (1992), Giessen et al. (1992) and Maldonado (2008) reports that the inherent characteristics favor the presence and multiplication of bacteria, collaborated by the occurrence of FBDs with the intake of such food.

Salmonella is one of these microorganisms in products of animal origin, such as cattle, swine and poultry, which contribute heavily in the contamination of humans, with a subsequent issue for public health, even in developed countries which are also responsible for FBDs. According to Poppe (1994), Scuderi et al. (1996), Costa (1996) and Maldonado (2008), FBDs, especially those caused by *Salmonella* spp., currently represent one of the main concerns of health authorities due to the difficulty in controlling the production chain and in accessing the number of people affected by the pathogen.

In the case of meat control, the biosafety process should start during breeding where control should be drastically undertaken. According to Sakai and Chalermchaikit (1996), Ward and Threlfall (1997), Santos et al. (2000) and Maldonado (2008), *Salmonella* in poultry breeding without aiming any type of industrialization is rife due to the absolute lack of control and quality. As has been remarked by Tiroly and Costa (2006), "in Brazil, the occurrence of *Salmonella* is relevant due to deficiencies in basic health conditions and to bad hygiene and sanitary conditions in most of the population, coupled to poor quality control of certain food industries and of small poultry abattoirs".

To have better control of pathogens detected in samples from the commercial firms mentioned above, a monitoring process in the production chain should be established by research on the site of slaughtering process up to poultry breeding houses.

Conclusion

The results of this study indicate that many chicken products sold in Feira de Santana, Bahia , Brazil , are contaminated with different serotypes of *Salmonella*, especially *Salmonella* Typhimurium and *Salmonella* Enteritidis and should , therefore, be suitable for cooking and handling prevention of salmonellosis outbreaks.

Conflict of Interest

The authors have not declared any conflict of interests.

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Full Length Research Paper

Postharvest dehydration of Syrah grapes (*Vitis vinifera* L.) under controlled temperature conditions with real-time monitoring of mass loss

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The partial dehydration of grapes after harvest aimed at winemaking has been shown to be a process that brings increased concentration of sugar and phenolic compounds in the must, which affects the quality of the wines produced. However, the works developed so far have studied the process for temperatures up to a maximum of 25°C and air velocity lower than 1 m.s^{-1}. This study aimed to analyze the physical-chemical changes concentration of total soluble solids (TSS) and phenolic compounds (PC) after partial dehydration of 'Syrah' grapes subjected to two treatments combining two temperatures and one air velocity (T_1= 22.9°C/1.79 m.s^{-1} and T_2 = 37.1°C/1.79 m.s^{-1}) and relative humidity of 40%. The water loss of the grapes was approximately 14% and the drying process lasted between 34 and 68 h for treatments T_2 and T_1, respectively. We experimentally and statistically verified that the treatments promoted significant increase in TSS and PC; however, for PC at the temperature of 37.1°C, the increase accounted for approximately 27%, whereas, for the temperature of 22.9°C, it was only 12%. For TSS, the increase was on average 12.47±0.9% between both treatments. The results demonstrate that it is possible to moderately dry grapes, which consequently results in improvements in their chemical composition and can improve the quality of wine.

Key words: Wine, polyphenols, soluble solids, drying, instrumentation.

INTRODUCTION

In the last decade, studies began emerging confirming that controlled postharvest dehydration could enable not only cost savings with adjust of grape must, but also provide superior quality wines (Bellincontro et al., 2004; Constantini et al., 2006; Moreno et al., 2008; Barbanti et al., 2008). The literature reports that advanced studies

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have been developed in Europe aiming to identify the effect of postharvest dehydration on specific components of the grapes. De Sanctis et al. (2012) identified wide variations in the composition of the main carotenoids, genistein and diazine of white grapes dehydrated at low temperature with forced air ventilation. In Rizzini et al. (2010), changes in the gene transcription profile of 'Raboso Piave' grapes were identified after dehydration of up to 30% of grapes. Recently, Panceri et al. (2013) highlighted the effects of moderate dehydration in the mineral content, phenolic compounds and antioxidant activity in 'Merlot' and 'Cabernet Sauvignon' grapes.

According to Zoccatelli et al. (2013), physical-chemical changes caused by harvesting reflect specially activated metabolic processes, which not only modify the composition, but also the structure, such as the cell wall polymers of the skin. The understanding on the especially activated metabolic processes and their effects has been reported by Santonico et al. (2010), Cirilli et al. (2012) and Bonghi et al. (2012). Note that the submission of the product to a condition of stress results in the action of defense mechanisms, especially secondary metabolites, which are precursors of important components of the grape for the winemaking process. According to Xi et al. (2013) the stress caused by temperature difference induces the synthesis of phenolic compounds and aromatic substances, Mencarelli and Tonutti (2013) justify the postharvest partial dehydration of grapes in low temperature because of the benefits of the increased phenolic content and concentration of sugars, since important organic components are volatilized at certain temperature levels above the room temperature (Mori et al., 2005).

In this study we sought to analyze the potential of the partial dehydration under controlled temperature conditions to increase the soluble solids and total phenolic content in the grape must of the Syrah cultivar.

MATERIALS AND METHODS

Raw material

Grapes of the Syrah cultivar (*Vitis vinifera* L.) of the June 2013 harvest were collected in the city of Indaiatuba, State of São Paulo. The grapes were stored in cardboard boxes with a capacity of 7 kg and transported to the Laboratory of Thermodynamics and Energy of the School of Agricultural Engineering at the University of Campinas (LTE - UNICAMP). After completion of the pre-cleaning of the grape clusters to remove stems and grapes damaged or compromised by the presence of fungi, we carried out the distribution of samples according to the heat treatment to be applied and the subsequent analyses of the physical-chemical characterization.

Partial dehydration of grapes

For each treatment, the fruits were stored in plastic package with 25% of effective opening area (50 x 30 x 25 cm), containing 7 kg of grapes, being the bunches longitudinally arranged. The package was inserted inside an adapted tunnel (80 x 40 x 80 cm) with a cooling system with forced air (air flow rate of 2,900 $m^3. h^{-1}$), which is installed inside a cooling room (cooling capacity of 4,400 $kcal.h^{-1}$ at -10°C) (Figure 1a). The system is instrumented with sensors for temperature, relative humidity of the air and mass measurement (Figure 1b). The system instrumentation was already carried out in previous works of Silva and Teruel (2011).

The temperature sensors are of the Pt 100 type (FM= 0 at 100°C; model TR106; 4 to 20 mA; accuracy = ±0.2%); the ones to measure the relative humidity are of the RHT-WM type with compact electronic module and transmitter of values (FM= 0 at 100%UR; 4 to 20 mA; accuracy = ± 1.5%); and to measure mass, we used a weighing system comprising a load cell, model PW12C3 – IMB (50 N (50 kgf), sensibility of 2±0.1% $mV.V^{-1}$).

The application for the real-time monitoring was developed in the graphical environment of the Labview programming software (National Instruments). The information related to the sensing instruments is integrated into a central processing and data acquisition unit according to the diagram in Figure 2.

The data acquisition of the temperature and relative humidity was carried out by the data acquisition board (PCI-NIDAQ 6229) coupled to the connector block (CB-68LP) both from National Instruments. This board has as inputs the analogical values of temperature and relative humidity expressed between 4-20 mA and as outputs a voltage that acts on the frequency inverter compressor and exhaust fan and can vary between 0 and 10 V depending on the desired cooling efficiency and air velocity. The digital data of the electrical meters and weighing system are transmitted to the microcomputer systems via Modbus protocol through the RS485 serial port, thus enabling data to be read and stored.

All signals obtained with the instrumentation system, after being processed by the computer, are displayed in real time on the application of supervision and are available as a source of information and support to the decision-making related to changes in the parameters governing the kinetics of the process, such as temperature and velocity of the drying air. The data are structured from sample means at each minute and stored in spreadsheets for further analysis.

Physical-chemical analyses

Before and at the end of each test, samples were selected for the physical-chemical analyses. We proceeded with the random removal of six berries per bunch from a total of 28 bunches by treatment, after which the berries were separated in three repetitions. Remotion of berries was considered in the methodology proposed by Araújo et al. (2009), in which the selected berries must have their representative location for the regions of the base, middle and apex of the bunch. Then, the selected samples are macerated for must preparation followed by the respective analyses. The characterization of the must was based on specific methodologies standardized by the Adolfo Lutz Institute (2005). To analysis of Total Soluble Solids (TSS) in °Brix was used a refractometer model Pocket Pal-1, manufactured by ATAGO.

Moisture content, in dry basis, was determined by drying a sample (100 g) in an oven (model MA035/1, manufacturer Marconi) with forced air circulation at 60°C, until reaching the constant weight of the sample.

The concentration of Total Phenolic Compounds (TPC) was quantified in mg of gallic acid per 100 g of must, according to the methodology described by Obanda and Owuor (1997), in which an extraction solution consisting of 90% ethanol solutions and concentrated HCl is applied in each sample of must content. From the aqueous extract of each sample, 0.5 ml is put in a vial and 4.75 ml of distilled water and 0.3 ml of Folin-Ciocalteu reagent are added. The solution is homogenized and, after 3 min, 0.9 ml of a

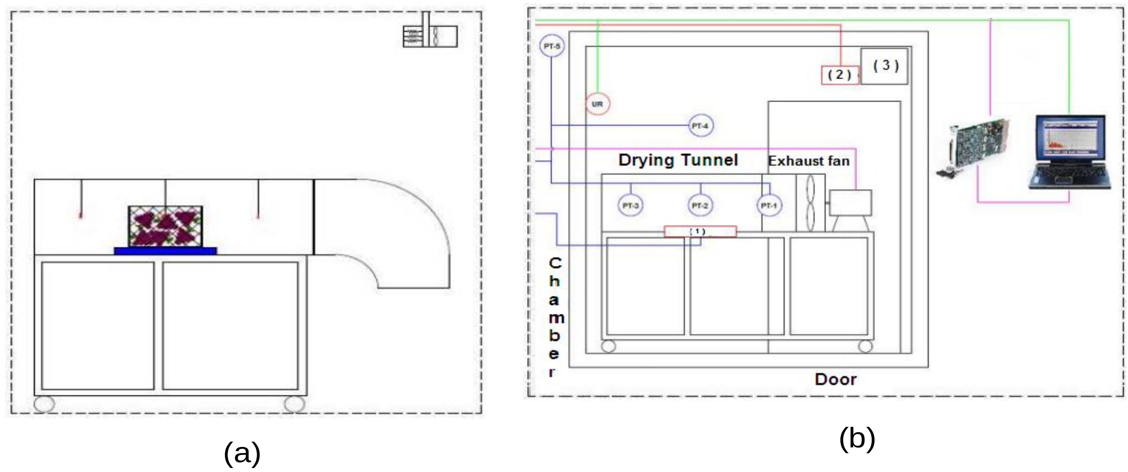

Figure 1. (a) Schematic of the structure of forced-air drying; (b) Schematic of the system instrumentation. Legend: (1) Scales; Resistance (2); Evaporator (3).

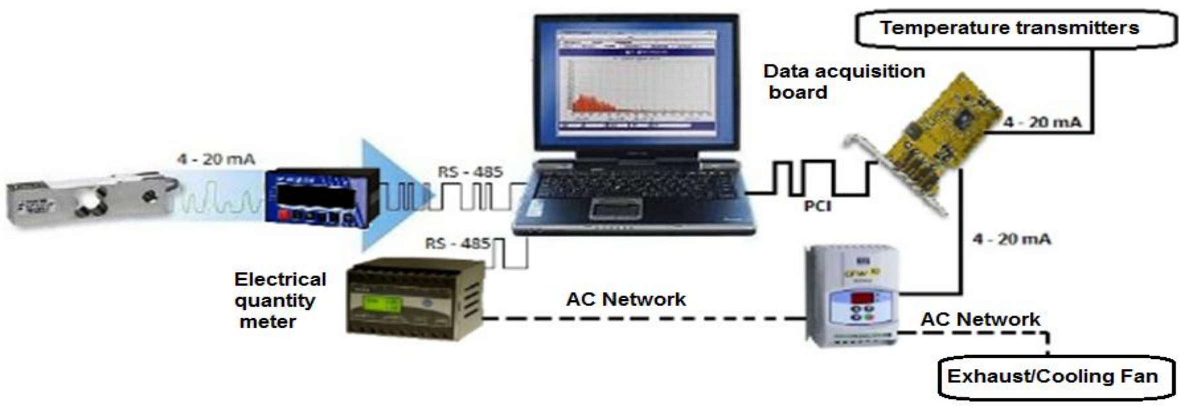

Figure 2. Diagram of the instrumentation.

saturated solution of $NaCO_3$ is added. After resting for one hour at the temperature of 75°C, absorbance readings are performed in triplicate to each must sample in a spectrophotometer at 465 nm. Gallic acid was used as standard, at the concentrations of 100, 150, 250, 500 and 1000 mg.l^{-1} to construct a calibration curve (Figure 3). From the straight line obtained, we carried out the calculation of the total phenolic content, expressed in milligrams of Gallic acid. 100 g^{-1} of grape must (vargas, 2008).

Experimental design

The experimental design was completely randomized with two treatments; the effects of treatments were evaluated in pairs by comparing the values before and after treatment. The treatments were a combination of two temperatures (T_1 = 22.9°C and T_2 = 37.1°C) with an air velocity of 1.79 m s^{-1}. These temperature values were defined based on subsidies obtained from previous works (Santiago et al. 2013) in which a range of temperature between 20 and 50°C were studied, and the best results obtained for the concentration of soluble solids and phenolic compounds with greater weight loss were the temperature values of 22.9 and 37.1°C. All the values of the physical-chemical analyses are the averages of three repetitions of the samples (± SE). The analysis of variance (ANOVA) was performed on the data obtained and the Tukey's test was conducted to identify significant differences of $p < 0.05$ between the samples.

RESULTS AND DISCUSSION

Partial dehydration of grapes

The preliminary characterization of the grapes in the processing units fully favors the decision making for the process, because, according to studies developed by Barnabé and Filho (2006), it is recommended that the comprising of some parameters in a specific range of values for winemaking or juice. Therefore, decisions regarding the need to adequate raw materials, as well as the technique to be used in their suitability that provides a lower cost can be taken more effectively. Seeking the better ways to improve the wine quality, Santiago et al.

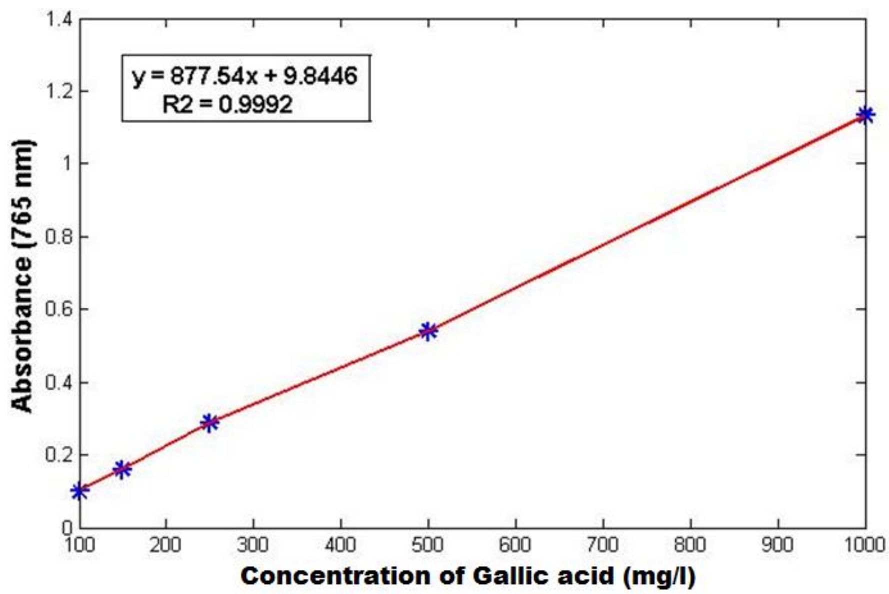

Figure 3. Calibration curve for total polyphenol concentration.

Table 1. Physical-chemical characterization and analysis of variance for the concentration of total soluble solids (TSS) and concentration of phenolic compounds (CPC) in the must.

Test (ºC. m.s^{-1})	TSS (°Brix)		CPC (mgGallicAc.100 g^{-1} must)		TA (mEq. L^{-1})		pH		MC (d.b.)	
	Before	After	Before	After	Before	After	Before	After	Before	After
T_1 (22.9/1.79)	19.93	22.33*	849.33	1080.66*	115.91	133.10*	3.32	3.10*	3.22	2.84*
T_2 (37.1/1.79)	19.93	22.50*	995.33	1118.00*	115.91	122.54*	3.32	3.03*	3.22	2.88*
Mean	19.93	22.42	922.33	1099.33	115.91	127.82	3.32	3.06	3.22	2.86

*Parameters with significant change at 95% confidence level compared to initial value.

(2013) studied the potential of the process of partial dehydration of grapes "Niagara rosada" in improving/adjusting the quality of the grape must to make wine. The authors had high index of changes on phenolic compounds and total soluble solids, but long time to process was necessary. The results of the physical-chemical analyses of the characterization of the grapes before the treatments for the parameters soluble solids, expressed as a percentage of soluble solids concentration, polyphenol content in mg of gallic acid/mg of juice, hydrogen potential (pH), titratable acidity and moisture on wet base are presented in Table 1.

The results confirm one of the premises already investigated to date, which demonstrates that the effects of controlling the thermal and psychometric parameters of the dehydration process provide beneficial changes in the concentration of phenolic compounds and total soluble solids. The acidity in food is the result of the organic acids present in its composition and those occurring after physical-chemical changes in the composition. In the case of grapes, the acidity is also affected by the effect of certain fermentation yeasts that can produce organic acids, as well as the dissolution of minerals and acids released from the skin and pulp (Rizzon and Miele, 2002). The values found were similar to those observed in the literature for the cultivars used in winemaking in Brazil (Rizzon and Miele, 2002; Manfroi et al., 2004).

The mean final of moisture content in dry basis of the samples after the treatments was 2.86%. The results for TSS ranged from 19.93 to 22.50%, while the content of phenolic compounds varied from 849.33 to 1118.00 mg of Gallic acid.100 g^{-1} of grape must, showing statistically significant changes for all parameters evaluated at both temperatures. The significant effect of the treatment at 37.1°C may be associated with the fact that the high temperature can disrupt or break the pectin molecules of the skin, thus allowing the release of the phenolic compounds present there (Vedana et al., 2008).

Although there are advances in the quality obtained using European cultivars (*Vitis Vinifera*) as Syrah grapes,

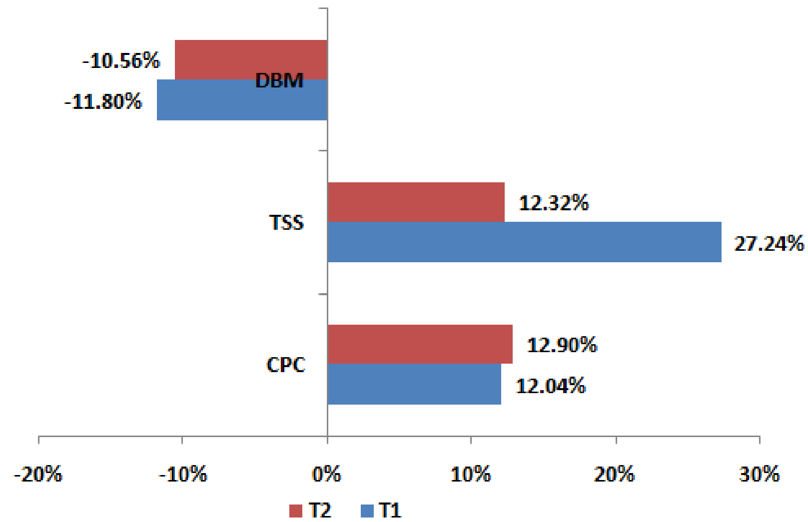

Figure 4. Gain ratio by TSS and CPC through partial dehydration of grapes.

further efforts are needed to ensure that the final product can become superior to the point of being competitive with those imported. Traditionally, the main postharvest process used in brazilian wineries to increase the quality or suitability of the raw material for winemaking has been the chaptalization (Rizzon and Miele, 2005). Chaptalization is the addition of sucrose to the wine must before or during fermentation stage; this technique is normally used for the enrichment of alcohol grading of wine when the must used to make this cannot naturally reach the desired level (Rizzon and Miele, 2005; Pineau et al., 2011). So, the results displayed on Figure 4 indicate that partial dehydration of grapes to winemaking have a great potential to replace the chaptalization technique in brazilian wineries, once which the results from this research agree with previous results descripted on scientific literature (Bellincontro et al., 2004; Barbanti et al., 2008; Mencarelli and Tonutti, 2013).

In the evaluation of the effectiveness of applied heat treatment, it is noted that both conditions are promising and could be applied if carried out under controlled conditions, once the smaller gains for the main physicochemical parameters evaluated were 12.04 and 12.32% to phenolic compounds and total soluble solids, respectively. Furthermore, the identified changes show that temperatures above the ambient and under controlled conditions can lead to increased levels of phenolic compounds without causing volatilization of compounds or damages the final quality of the wines, providing a new analysis of previous work done in Europe, where dehydration has been performed only at temperatures between 10 and 25°C (Bellincontro et al., 2004; Barbanti et al., 2008; Zoccatelli et al., 2013). According to Barbanti et al. (2008), usually the loss of water in grapes at psychrometric ambient conditions and without control may last from 90 to 120 days to reach the optimum vinification, and the grapes may still lose up to 40% of mass, exceeding the 20% limit recommended by the International Code of Oenological Practices (2006).

In a study carried out by Zoccatelli et al. (2013) with three cultivars of *Vitis vinifera* grapes ("Corvina", "Sangiovese" and "Oseleta"), maximum water loss was 30% at temperature ranging from 7 to 16°C. Dehydration lasted up to 100 days (2400 h), for the cultivars "Corvina" and "Sangiovese", and 47 days (1128 h), for the variety "Oselata". Evaluating the results of the parameter total soluble solids in the same dehydration pattern achieved in this work (approximately 11%), we can note that the mean of the values observed herein was 6.4 and 4.1% higher than those for the cultivars "Corvina" and "Oseleta" and 0.6% lower than the value obtained for the cultivar “Sangiovese," respectively. It is important to highlight that while the dehydration of the three cultivars at the approximate level of 11% of water loss was 13 days (312 h), the maximum time required for the samples of this work to reach the same level of water loss was 3 days (72 h), that is, the dehydration method using the forced air system and the temperatures of 22.9 or 37.1°C provides a reduced process time and a statistically significant increase of the quality parameters of the partially dehydrated grape must.

Conclusion

The results obtained so far open a new perspective of application from this technology of partial dehydration of grapes on temperature of 22.9°C for the wine sector, helping with both the standardization of pre-fermentation from must and with the increase of final quality of wines done from Syrah grapes on Brazil. The significant reduction of time spent to remove the amount of water content on the grapes before the winemaking together with the increase of physicochemical properties evaluated would contribute for the advancement of relationship cost-benefit of processes involved inside the wine productive chain.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENTS

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Full Length Research Paper

Supremacy of rice genotypes under aerobic condition for mitigating water scarcity and future climate change

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The increase in water scarcity, now made the researchers to look for various ways to decrease water use in rice production and increase the water use efficiency. One of the approaches that lead to a considerable amount of savings in water use by rice is aerobic cultivation, which minimizes the methane emission also. In this light of view, an investigation was carried out to study the morpho-physiological traits and yield potential of six rice genotypes *viz*., PMK 3, ASD 16, MDU 3, MDU 5, CO 47 and RM 96019 under aerobic condition. The parameters *viz.,* plant height, total drymatter production, leaf area index, R:S ratio were found to be higher in the rice cultivar PMK 3. The physiological and biochemical traits *viz.,* proline content, total phenolics, catalase and superoxide dismutase enzymes activities were found to be significantly higher in PMK 3 rice cultivar. Yield and yield components such as panicle length, number of productive tillers, number of spikelets per panicle, fertility co-efficient, panicle harvest index, grain yield and harvest index were recorded. The genotype PMK 3 recorded higher yield (4298 kg/ha) followed by ASD 16 (3068 kg/ha) and CO 47 recorded lower yield (1407 kg/ha) under aerobic condition.

Key words: Aerobic rice, morphology, physiological traits and yield.

INTRODUCTION

Rice occupies the enviable prime place among the food crops cultivated around the world and it is the most important food crop in Asia. Water is a looming crisis due to competition among agricultural, industrial, environmental and domestic users. By 2025 AD, 30% of the human population would be threatened by water scarcity because of the fact that, 70% of water withdrawals is used in irrigated agriculture worldwide (IRRI, 2001). In Asia, more than 50% of irrigation water is used for irrigating rice. Rice is a heavy consumer of water requiring some 4000 to 5000 L to produce 1 kg of rice (Shen et al., 2001). A growing scarcity of fresh water will pose problems for rice production in future years. No wonder as the water shortage crisis has already reached parts of China as well as central and west parts of India, Pakistan and some parts of Bangladesh. Hence, shifting gradually from traditional rice production system to growing rice aerobically, especially in water scarce irrigated lowlands, can mitigate occurrence of water related problems. China has pioneered in the

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development of aerobic rice and so the IRRI is studying Chinese methods. The rice is called aerobic rice where the plants are grown under non-puddled and non-flooded soil condition. Growing rice aerobically saves water by: (i) eliminating continuous seepage and percolation (ii) reducing evaporation and (iii) eliminating wetland preparation (Castaneda et al., 2002). Aerobic rice cultivation is one of the ways to minimize the methane emission wherein rice is grown under non-flooded condition and it also saves 55 to 60% of water. Nevertheless, varieties adopted for aerobic condition are being tested in several countries particularly India, but are yet to be widely adopted. Hence, plant physiologists and breeders have to address the challenges in breeding varieties with better physiological adaptations for higher yields under aerobic conditions and also developing new ideotype concept for rice under aerobic environment.

MATERIALS AND METHODS

The field experiment was carried out at Tamil Nadu Agricultural University, Coimbatore (11°N, 77°E, elevation of 426.72 m). The soil of the experiment site is clay loam. The available soil nitrogen, phosphorus and potassium were 247.5, 15.0 and 527.0 kg ha^{-1} respectively (Soil p^H 7.3; EC 0.5 dSm^{-1}). Six rice varieties *viz*., PMK 3, ASD 16, MDU 3, MDU 5, CO 47 and RM 96019 were directly sown at a spacing of 20 x 10 cm (Appendix 1).

The experiment was laid out in randomized block design with six treatments (genotypes) and four replications. Irrigation was given once in five days based on IW/CPE ratio (= 0.8) and hence the aerobic condition was maintained. Fertilizers at 120:38:38 N P K kg / ha was applied along with irrigation. The full dose of phosphorus applied as basal and N, K applied at three splits as topdressing. Proper weed management and plant protection measures were carried out at the appropriate time as per the recommendation. Plant samples were drawn at maximum tillering (50 to 55 DAS), panicle initiation (60 to 65 DAS), flowering (80 to 85 DAS) and maturity (110 to 115 DAS) stages for recording various morphological, physiological, biochemical and yield characters.

The height of the plant was measured from the base of the shoot to the longest leaf at different stages and mean worked out for the four plants in each replication and expressed in cm. For estimating total dry matter production (TDMP), the entire plant was pulled out with the root system intact, at different stages. The shoot and root portions were weighed separately after drying the plants at 80°C for 24 h and the TDMP was expressed in g $plant^{-1}$. The leaf area index (LAI) was calculated by employing the formula of Williams (1946). Using shoot and root dry weight the root- shoot ratio (R:S ratio) was arrived. Stomatal conductance and transpiration rate were measured between 10.30 am to 11.30 am using a Steady State Porometer (PP systems, EGM 4 - PMR 5, version 5.02) at different phenological stages. The measurements were recorded on the topmost fully expanded leaf from five plants. The average values were computed and expressed as mmol m^{-2} s^{-1} for both the parameters. Proline content of the leaves was estimated by the method described by Bates et al. (1973). Phenol content of leaf extract was determined by using the method of Malik and Singh (1980) and expressed in mg g^{-1} fresh weight. Catalase activity was determined by titrimetric method using $KMnO_4$ (Gopalachari, 1963) and expressed as µg H_2O_2 g^{-1} min^{-1}. Super oxide dismutase activity was determined using Nitro Blue Tetrazolium (NBT) by the method of Beau Champ and Fridovich (1971) and expressed as enzyme units mg^{-1} of protein. The yield components *viz.,* number of productive tillers, panicle length, fertility co-efficient, panicle harvest index (ratio of grain weight to panicle weight) and 1000 grain weight were determined. The data collected was subjected to statistical analysis in randomized block design (Gomez and Gomez, 1984).

RESULTS

The morphological characters viz., plant height, TDMP, Root: Shoot ratio and LAI were measured. Irrespective of the genotypes, the plant height increased significantly from maximum tillering to maturity stage of the crop (Figure 1). Among the genotypes, PMK 3 showed higher plant height under aerobic condition. It has grown up to 84.15 cm followed by RM 96019 (74.55 cm) at maturity stage. The shortest plant height was recorded in MDU 5 (43.99 cm). TDMP showed significant variation in all the six rice genotypes (Table 1). The variety PMK 3 exhibited 22.75 g and CO 47 recorded the lowest value of 14.04 g at maturity stage. Highest LAI was observed at flowering stage for all the genotypes (Table 1). Among the genotypes, PMK 3 recorded higher LAI (4.92) and CO 47 (3.08) exhibited the least value. The maximum R:S ratio was noticed in PMK 3 (1.62) followed by ASD 16 (1.57) and CO 47 recorded lower value (1.25) when compared to other genotypes (Table 1). Data on stomatal conductance revealed that the cultivar CO 47 recorded higher value in all the stages and lower stomatal conductance was observed in MDU 3 under aerobic condition (Figure 2). Generally an increasing trend in transpiration rate was observed upto flowering for all the rice genotypes (Figure 3). PMK 3 recorded less transpiration rate (1.89 mmol m^{-2} s^{-1}) followed by MDU 3 (2.20 mmol m^{-2} s^{-1}) and RM 96019 (2.22 mmol m^{-2} s^{-1}) at flowering stage and there after declining trend was observed at maturity stage in all genotypes. CO 47 showed higher transpiration rate in all the stages.

The data on proline content at various stages are furnished in Figure 4. Among the genotypes, PMK 3 recorded higher proline content of 987.50, 1223.75, 1768.75 and 843.25 µg g^{-1} at maximum tillering, panicle initiation, flowering and maturity stages respectively. The genotype CO 47 recorded the least value from tillering to maturity with a value of 652.50 to 982.40 µg g^{-1}. At maturity stage, all the genotypes showed on par with each other except CO 47 for proline content. The data showed increasing trend in total phenolics from tillering to flowering stage after that significant reduction was observed. Accumulation of total phenolics was observed in all the genotypes under aerobic condition and the highest accumulation being recorded in PMK 3 and the lowest in CO 47 (Figure 5). In general, all the six rice genotypes recorded maximum value at flowering stage for total phenolics. The enzyme catalase activity exhibited increasing trend from tillering to flowering and afterwards declining trend was noticed (Figure 6). Among all the genotypes, PMK 3 expressed higher enzyme activity followed by ASD 16 and MDU 5. The genotypes MDU

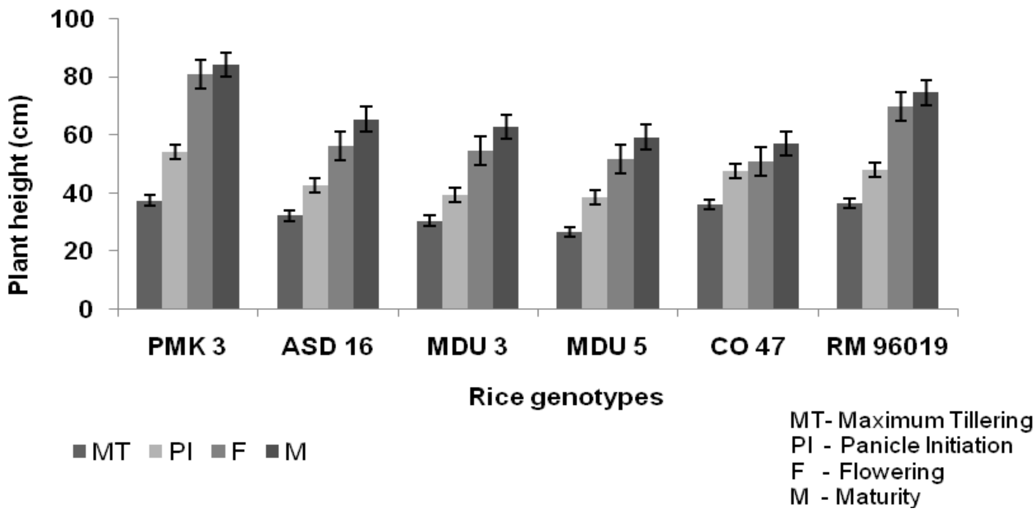

Figure 1. Plant height (cm plant^{-1}) of rice genotypes under aerobic condition. *Vertical bars indicate SE of four replicates for different growth stages of rice.

Table 1. Total drymatter production (TDMP), Leaf area index (LAI) and Root-Shoot ratio (R:S ratio) of rice genotypes under aerobic condition.

Genotypes	TDMP (g/plant)			LAI		R:S ratio
	Maximum Tillering stage	Flowering stage	Maturity stage	Panicle initiation	Flowering	Maturity stage
PMK 3	5.90	12.90	22.75	3.67	4.92	1.62
ASD 16	5.20	11.88	20.38	3.42	4.14	1.57
MDU 3	4.56	11.49	18.60	3.10	4.21	1.35
MDU 5	4.36	11.16	15.45	2.96	3.79	1.48
CO 47	3.87	9.86	14.04	2.48	3.08	1.25
RM 96019	4.67	11.85	18.45	3.46	4.26	1.48
Mean	4.65	11.21	17.89	3.21	4.11	1.41
S Ed	0.291	0.709	1.14	0.221	0.244	0.075
CD (P=0.05)	0.634	1.511	2.43	0.472	0.521	0.164

5 and RM 96019 are on par with each other.

All the genotypes recorded higher superoxide dismutase enzyme activity during flowering stage and the least activity was observed in CO 47. This enzyme activity showed similar response like catalase activity. It exhibited increasing trend from tillering to flowering then gradual decline was noticed at maturity stage. PMK 3 recorded higher enzyme activity compared to other genotypes at all the stages of observation followed by ASD 16 and MDU 3 (Figure 7).

In related to yield and yield components (Table 2), the genotype MDU 3 recorded more numbers of productive tillers (516.24) followed by ASD 16 (504.36) and PMK 3 (468.25). The genotype CO 47 recorded the least number of productive tillers among all the genotypes. The rice genotypes PMK 3, RM 96019, ASD 16, MDU 5, MDU 3 and CO 47 recorded the panicle length as 22.83, 21.35, 19.38, 18.80, 18.78 and 17.51 cm respectively. Among them, PMK 3 recorded maximum panicle length. The data on panicle harvest index exhibited significant difference among all the genotypes. Between the genotypes, PMK 3 registered higher value of 79.65% followed by ASD 16 (77.82%), RM 96019 (76.84%) and MDU 3 (76.28%). The genotype CO 47 recorded lower value of 63.13%. PMK 3 recorded more number of spikelets per plant (116.12) followed by ASD 16 (111.26) and MDU 3 (106.02). The genotype CO 47 recorded the least value (98.96) among all the genotypes for number of spikelets per plant. The genotype PMK 3 recorded the spikelet fertility co-efficient of 85.31% followed by RM 96019 (84.79%) (Table 2). The genotype PMK 3 recorded the maximum 1000 grain weight of 21.12 g followed by ASD 16 (20.06g), RM 96019 (19.54g), MDU 3 (19.46 g), MDU 5 (19.42 g) and CO 47 (19.18 g).

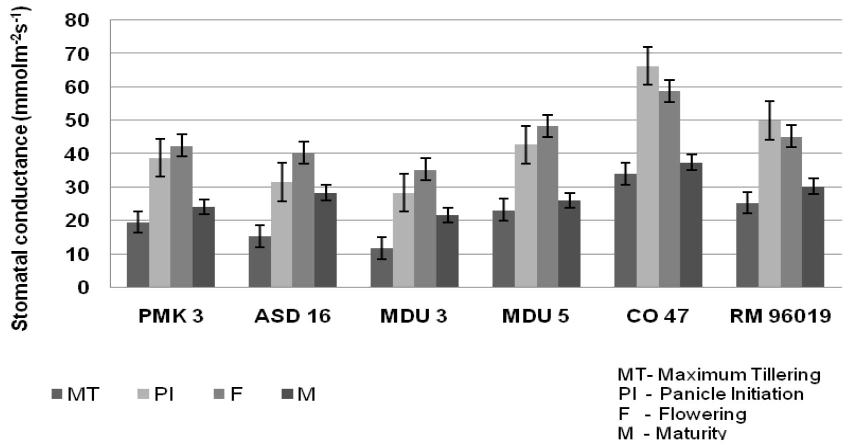

Figure 2. Stomatal conductance (mmol m^{-2} s^{-1}) of rice genotypes under aerobic condition. *Vertical bars indicate SE of four replicates for different growth stages of rice.

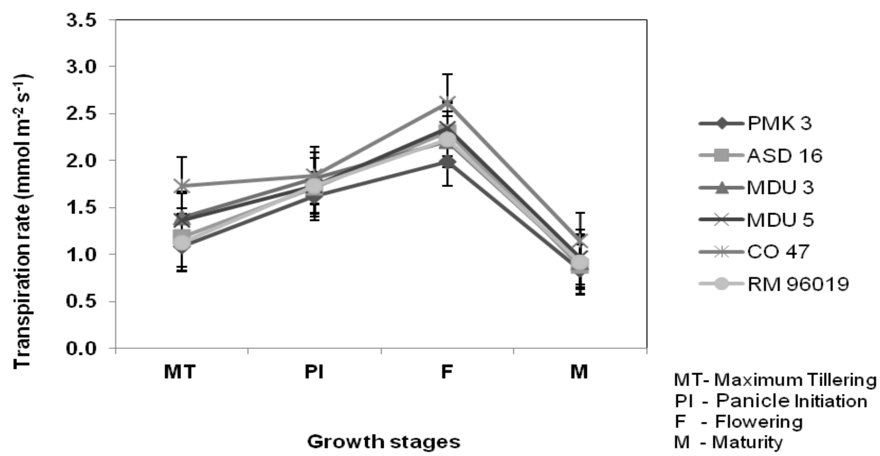

Figure 3. Transpiration rate (mmol m^{-2} s^{-1}) of rice genotypes under aerobic condition. *Vertical bars indicate SE of four replicates for different rice genotypes.

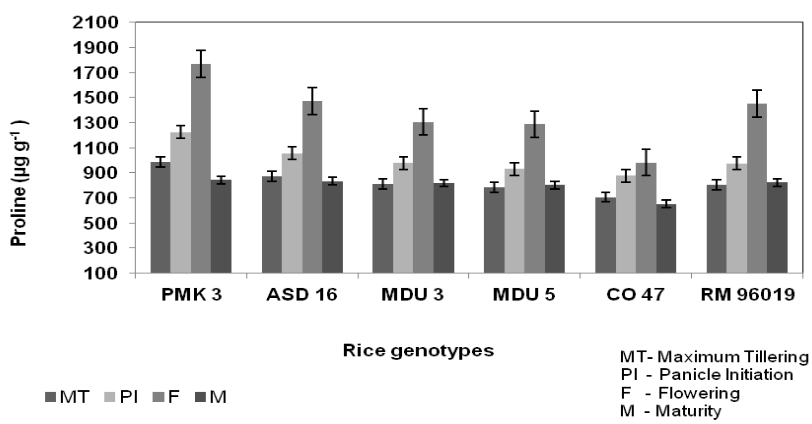

Figure 4. Proline content (µg g^{-1}) of rice genotypes under aerobic condition. *Vertical bars indicate SE of four replicates for different growth stages of rice.

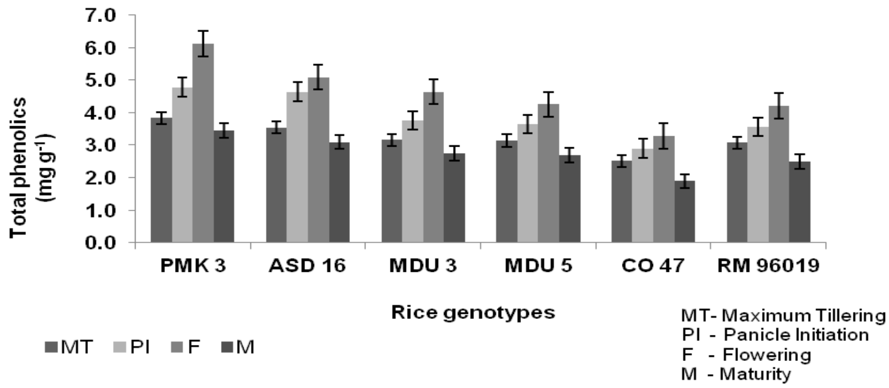

Figure 5. Total phenolics content (mg g^{-1}) of rice genotypes under aerobic condition.*Vertical bars indicate SE of four replicates for different growth stages of rice.

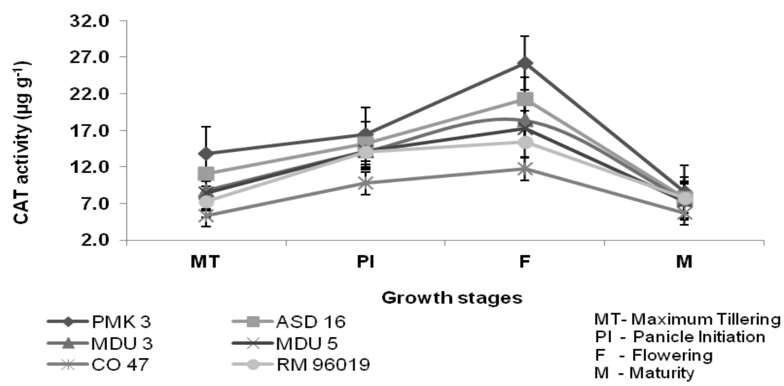

Figure 6. Catalase activity (µg H_2O_2 g^{-1} min^{-1}) of rice genotypes under aerobic condition.*Vertical bars indicate SE of four replicates for different rice genotypes.

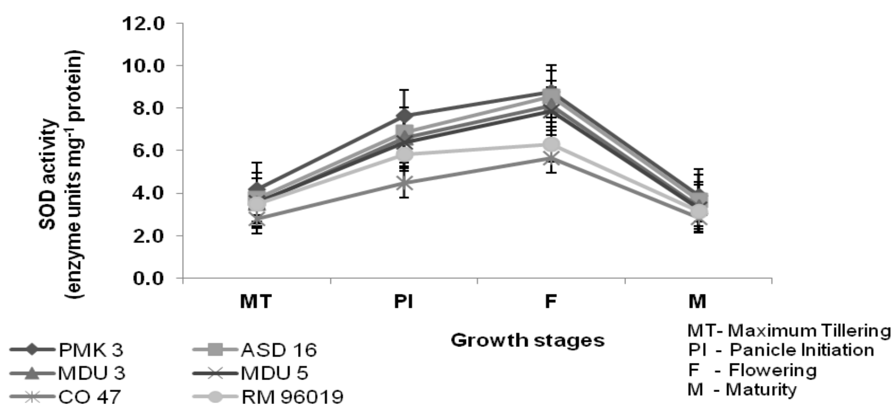

Figure 7. Superoxide dismutase activity (enzyme units mg^{-1} protein min^{-1}) of rice genotypes under aerobic condition.*Vertical bars indicate SE of four replicates for different rice genotypes.

Among the six rice genotypes, PMK 3 recorded the highest yield of 4298 kg ha^{-1} followed by ASD 16 (3068 kg ha^{-1}). The other genotypes, MDU 3, MDU 5, RM 96019 and CO 47 registered 2833, 2807, 2227 and 1407

Table 2. Yield and yield components of rice genotypes under aerobic condition.

Genotypes	No. of productive tillers m^{-2}	Panicle length (cm)	Panicle harvest index	No. of spikelets per panicle	Spikelet fertility co-efficient	1000 grain weight (g)	Grain yield (Kg ha^{-1})	Harvest index
PMK 3	468.25	22.83	79.65	116.12	85.31	21.12	4298	0.39
ASD 16	504.36	19.38	77.82	111.26	81.04	20.06	3068	0.36
MDU 3	516.24	18.78	76.28	106.02	81.20	19.46	2833	0.32
MDU 5	402.15	18.80	73.52	99.24	73.68	19.42	2227	0.30
CO 47	341.82	17.51	63.13	98.96	55.80	19.18	1407	0.25
RM 96019	441.32	21.35	76.84	113.03	84.79	19.54	2807	0.33
Mean	433.53	19.26	72.57	104.58	74.95	19.27	2710	0.31
SEd	22.52	0.984	3.79	5.38	3.90	0.505	134.03	0.012
CD (P=0.05)	48.01	2.108	8.08	11.47	8.32	1.210	285.68	0.037

kg ha^{-1} respectively for grain yield. The data on harvest index showed significant differences among the rice genotypes. PMK 3 recorded higher harvest index of 0.39 followed by ASD 16 (0.36) and RM 96019 (0.33). The genotype CO 47 recorded the least value of 0.25 due to lower grain yield.

DISCUSSION

Irrespective of the genotypes, the plant height increased significantly from maximum tillering to maturity stage of the crop (Figure 1). Among the six rice genotypes, PMK 3 showed higher plant height under aerobic condition when compared with other genotypes. The present findings were in accordance with the findings of Russo (2000) and Gowri et al. (2005). Insalud et al. (2004) reported that the genotype Kae Noi had increased root length and decreased shoot length in well drained soil. Tomar and Prasad (1996) reported that the plant height in rice was associated with thick and deep root system. The total dry matter production showed significant variation in all the rice genotypes (Table 1). The variety PMK 3 accumulated more dry matter at maturity stage followed by ASD 16 and the genotype CO 47 recorded the lowest value. Lilley and Fukai (1994) reported that water stress reduced the biomass production in rice varieties and the degree of reduction depended upon the severity of moisture stress. The maintenance of higher biomass during stress may be viewed as one of the criteria to decide drought tolerance. Drymatter yield of rice genotypes were reduced by 11 to 37% and 30 to 65% under mild and severe moisture stress, respectively (Yang et al., 1995). Sritharan et al. (2004) also reported similar results in rice under stress condition. Gowri (2005) observed that under aerobic condition drymatter production was reduced drastically compared to flooded condition. Nieuwenhuis et al. (2002) reported that continuous aerated condition produced 32% lower biomass than continuously flooded treatment. It may be because of low moisture stress induced impaired tillering (Yoshida, 1981) or due to accelerated leaf senescence and hence decreased photosynthetic area under moisture stress (Simane et al., 1993) leading to lower drymatter production.

Leaf area index (LAI) particularly at reproductive stage has a specific role in deciding drymatter production and grain yield of rice (Yoshida, 1981). In the present investigation, PMK 3 recorded higher LAI (4.92) but CO 47 (3.08) exhibited the least value (Table 1). Gowri (2005) also reported the reduction in LAI under aerobic condition in ADT 43 compared to PMK 3. The reduction in LAI might be due to rapid decline in leaf elongation as reported by Lilley and Fukai (1994). It was observed that, the root to shoot ratio (R:S ratio) of rice plant increases with drought (Yoshida, 1981). Root characteristics in rice are genetically controlled but they are also strongly affected by soil conditions and crop management practices (Sharma et al., 1987 and Thangaraj and Sivasubramanian., 1990). The R:S ratio was high in drought resistant upland rice cultivars than susceptible cultivars (Lu and Hua, 1994). In the present study, PMK 3 registered higher R:S ratio (1.62) than other genotypes (Table 1). Similar findings were also recorded by Gowri (2005) on PMK 3 rice variety under aerobic condition.

Stomata are minute pores through which gases diffuse out and into leaves. In the present study, MDU 3 recorded lower stomatal conductance under aerobic condition compared to other genotypes (Figure 2). Higher diffusive resistance in response to water stress is a characteristic behaviour of upland varieties (O' Toole and Cruz, 1980) because of their higher stomatal sensitivity (Dingkuhn et al., 1989) and it is one of the drought avoidance mechanisms in rice. However, the higher stomatal conductance was recorded in CO 47 as this variety might have suffered severely from water deficit due to aerobic condition. Increased diffusive resistance was found to be associated with accumulation of phenols suggesting that phenolics might lead to stomatal closure. This is corroborated by the reports of Manthe et al. (1992). The cultivar PMK 3 showed lower transpiration rate than other genotypes (Figure 3). Thus, this genotype might have reduced the water loss. Similar observations were also reported by Dingkuhn et al. (1989) and Chauhan et al. (1996).

Proline accumulation under water stress may occur in different ways *viz.,* stimulation of synthesis from glutamic acid perhaps due to loss of feedback inhibition of the synthesis of the intermediate 4' – pyroline - 5 - carboxylate; inhibition of proline oxidation; impaired incorporation of free proline into protein and reduced export of proline via phloem. Reasonable hypothesis based on the possible role of proline accumulation under water stress condition has been advanced as a nitrogen store, energy store, NH_3 – detoxification product and cytosolic osmoregulation. Results of the present study indicated that the cultivar PMK 3 recorded higher proline accumulation than the other genotypes due to aerobic condition (Figure 4). Similar finding was reported by Gowri (2005) stated that PMK 3 accumulated higher amount of proline than ADT 43 under aerobic condition. Sritharan and Mallika (2006) also reported that higher proline content under moisture stress condition in the tested rice genotypes.

There are diverse groups of phenolic compounds found in all plant parts. Phenols are known to regulate a range of growth and development processes in plants. Accumulation of total phenolics was observed in all the genotypes under aerobic condition and the highest accumulation was recorded in PMK 3 and the lowest in CO 47 (Figure 5). Similar results were reported by Ashraf et al. (1994) under water stress in wheat. Manthe et al. (1992) opined that phenolic compounds at higher concentration reduced the transpiration rate by closing the stomata. This observation could be confirmed in the present study as the tolerant cultivar PMK 3 recorded more phenolics content and lower transpiration rate. Characterization of the accumulated phenolic compounds might provide clear information regarding the role played by phenolics in unsaturated soil moisture condition.

Decreasing water potential and stomatal closure resulted in the accumulation of activated oxygen species (Sgherri et al., 1993). Increased photorespiration under water stress also elevate glycolate oxidase activity resulting in H_2O_2 production (Mittler and Zilinskas, 1992). Allen (1995) reported that generation of activated oxygen species under water stress might be responsible for most of the damage caused to cellular components. Shigenaga et al. (1994) further reported that superoxide, peroxide and hydroxyl radicals were highly reactive and were linked to degenerative diseases and aging. The present study revealed that the antioxidant enzymes *viz.,* catalase and superoxide dismutase activity were over expressed under aerobic condition regardless of genotypes (Figures 6 and 7). Further, the activity of these enzymes in tolerant genotype PMK 3 was much higher than in susceptible cultivar CO 47. This result was in conformation with the findings of Zelitch (1990) who reported that drought induced damage was negated with increasing activities of SOD and catalase. The lesser activity of these enzymes in the susceptible cultivar CO 47 indicated that these enzymes degraded at higher rate under aerobic condition, while their synthesis might have been inhibited. Similar observations were also reported by Zhang and Kirkam (1994) and Ranjita et al. (1994) in wheat species and Srivalli et al. (2003) in upland rice.

Yield and yield attributing parameters are the ultimate manifestation of a plant's ability to survive, grow and produce yield under drought regardless of the tolerance mechanisms involved. Aerobic condition significantly reduced grain yield in CO 47, mainly through reduction in filled grain percentage, spikelets number per panicle and number of productive tillers per hill, but the cultivar PMK 3 recorded higher yield components and grain yield (Table 2). Fukai et al. (1991) reported close relationship of grain yield under water stress with grain number and grain weight was relatively stable across environments. Further grain number was determined by spikelet number and filled grain percentage.

The reduced spikelet number per panicle may probably be due to reduced LAI. Increased diffusive resistance might have reduced photosynthesis leading to reduced assimilate supply as suggested by Cruz and O'Toole (1984) Boonjung (1993).

The present study revealed that the cultivar CO 47 showed reduced panicle harvest index (PHI), poor fertility co-efficient and harvest index. These observations were supported by earlier reports of Boonjung (1993) and Lilley and Fukai (1994). Limitations of assimilate supply particularly during reproductive stage affected spikelet number per panicle and filled grain percentage (Cruz and O'Toole, 1984). Reduction in leaf water potential at anthesis caused poor panicle exertion (Ekanayake et al., 1989) and this might be the reason for less number of grains due to pollination abnormalities. This is in conformity with the findings of Gowri (2005) in rice under aerobic condition.

Conclusion

The variety PMK 3 has showed higher root:shoot ratio, dry matter production as well as antioxidant enzymes activities which leads to more yield under aerobic condition. These findings are much important for identification of traits for the wider adaptation of aerobic rice under water limited conditions. Hence, shifting gradually from traditional rice production system to growing rice aerobically, especially in water scarce irrigated lowlands, can mitigate occurrence of water related problems and there by lesser green house gas emission.

Conflict of Interest

The authors have not declared any conflict of interest.

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Potentials of indigenous communication media for agricultural information dissemination in south-western Nigeria

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This study was carried out to assess the potentials of indigenous communication media in disseminating agricultural information in South-Western Nigeria. A multi stage random sampling technique was employed to select 120 respondents from 24 villages drawn at equal proportions from the two selected states within the southwestern geopolitical zone of Nigeria. Data were collected with the aid of an interview schedule. Descriptive statistics was used to analyse and categorize personal and socio-economic characteristics of the respondents, while 5 points-like rating scale was used to evaluate the respondents' perception of indigenous communication media, and Chi-square was used to evaluate the significant relationship between socio-economic characteristics of respondents and their perception of indigenous communication media effectiveness. The result revealed that the mostly used indigenous media is town crier (60.0%), followed by traditional music (18.3%), folk songs (12.5%) and drama (9.2%). Also, 19.2% of respondents believed that indigenous media was cheaper than other media, 25.0% believed it was energy saving, 39.2% believed it gives prompt feedback, while 16.7% believed it was timely. Reasons for not using indigenous media often as indicated by the respondents were modernization (63.4%) and lack of interest (36.6%). Most of the respondents perceived that indigenous media were effective in disseminating agricultural information, simple to understand and effective in introducing new innovations, but that it was geographically restricted. Chi-square analysis showed a significant relationship between age (χ^2 = 50.500, p = 0.006), marital status (χ^2 = 39.025, p = 0.000), educational qualification (χ^2 = 13.900, p = 0.001), primary occupation (χ^2 = 20.197, p = 0.001), religion (χ^2 = 20.278, p = 0.000), sex (χ^2 = 41.200, p = 0.0001) and perception of the respondents.

Key words: Indigenous communication, agricultural information, dissemination media.

INTRODUCTION

The role of information in any society, community, or organization cannot be over emphasized. Communication is the transfer of information from one person to another through a medium. Such medium could be oral, written, or electronic. According to Ugboajah (1985) who described information as the knowledge communicated for useful purpose. Information is very useful in decision making; its availability enables the individuals, groups, or

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organization to take rational decisions and to reduce their level of uncertainty. Onwubiko (1991) asserted that communication is peculiar to specific societies because they are borne out of people's culture, religious convictions and experiences, hence their interpretation may vary from one society to the other, since they do reveal the ethics of each society.

Popoola (2007) categorized information into hard and soft information. The former is obtained from research while the latter is casual and so not too serious. For both cases, information is of great value to any society. Modern day agricultural information sources available in the country include the internet, libraries and publications by national, regional and international research institutions and organizations such as FAO (Food and Agricultural Organization), Agricultural Development Banks, radio and television programmes and newspapers, are available but are yet to be fully exploited unlike traditional media. Although, this information sources exist, most of them especially in books, journals and other printed forms are either not accessible or available for rural farmers. However, the traditional methods of information dissemination include folk media, village debates, town crier, traditional music, exchanged visits and local radio. Ansah (1989) concluded that the most effective (and most used) tool is the village debates, in so far as this approach reflects the communication habit of rural communities.

Communication tools commonly used in traditional Societies

Traditional methods of information dissemination include folk media, village debates, town crier, traditional musician, exchanged visits and local radio. Folk Media are the vehicles the common people or rural farmers employ for delivery of their messages such as fold scripture, folk music, folk dance or folk painting (Ngombe and Van Der stichele 2000). There is a need to describe some of these folk media:

(1) Village Debates: This normally takes place under the shade of the a tree, around the market place, under the village leader's learn-to, around the well. The visit is used to provide concrete answers to the questions that prove difficult for a facilitator to respond to. It is however an effective tool because it pays attention to cost.

(2) Town Crier: Is similar to that of radio, television or postal, in so far as he is the person who responsible for providing information to the public and moderating in the context, illiteracy that characterize our villages, the town crier and his tam-tam play a leading role in meetings. The town crier announces visits and meetings as well as to facilitate debates. This is on other hand can be used for agricultural information dissemination.

(3) Traditional Musician: The traditional musician was favoured over other communication tools such as video, demonstration booklet and the GRAAP series. It was necessary to find an inexpensive, easily accepted and popular method for promoting an activity and organizing the community. They sang about theories related to the forest, its importance for the community and the benefit it can provide. The musician also sang about advantages of becoming organized and the strength to be found in unity (Toumousseni and Linia 1993). The song made the rounds of cabarets, weddings and other festivities. The traditional musician as a communication tool produced good result. However, when using this approach, it is a good idea to take the precaution of following up with field visits to support the initiatives by ensuring the words are converted into actions.

(4) Exchange Visits: This is a communication tool that allows villagers to visit a well managed forest to see what it looks like, to learn cutting techniques and to understand how to manage a cutting site. In cases where exchange visits are not possible or where budgets are limited, videos of experiment under way are good tool for comparison and for stimulating debates; however, this tool is subject to certain constraints due to lack of equipment and electricity in some villages (Toumousseni and Linia, 1993).

Agricultural innovations that are capable of boosting farmers' productivity hardly get to the farmers as a result of defective agricultural information dissemination machinery (Ozowa 1995 and CTA 2003). Therefore, the search for appropriate media for agricultural information dissemination for agricultural development has been the receiving attention of researchers. Many scholars have suggested that indigenous media should be used effectively to reach farmers (Van dan Ban and Hawkins 1996). According to Van Dan Ban and Harkins (1996) interest in the use of folk media is increasing in less developed countries because the so called modern mass media have been less successful in agricultural information dissemination. The Food and Agricultural Organization reported that there is a definite potential in applying folk media for rural development. This was therefore designed to:

(a) Identify the socio economic characteristics of farmers.
(b) Assess farmers' preference for indigenous communication media
(c) Determine reasons for the usage of these media types in south-western Nigeria.
(d) Ascertain perception of traditional media utilization for agricultural information dissemination.
(e) Determine relationship that exists between socio-economic characteristics of farmers and their perception of indigenous communication media for agricultural information dissemination.

Hypothesis

There is no significant relationship between socio-economic characteristics of respondents and perception of indigenous communication media for agricultural information dissemination.

Methodology

The study was carried out in south-western, Nigeria. The region is made up of six states which are Ogun, Osun, Ekiti, Ondo, Oyo and Lagos states. The south western region has two distinct seasons. These are the rainy season (April-October) and the dry season (November -March). Temperature ranges between 21 °C and 28 °C with high humidity. The south-western and the north-east trade wind blows in the rainy and dry (Harmattan) seasons respectively. They predominantly speak Yoruba language and farming is their major occupation.

A multi stage random sampling techniques was used to select respondents for the study. Firstly, 2 states were selected from the region. Secondly, 4 Local Government Areas were selected from each of the States; thirdly, 3 villages were selected from each of the Local Government Areas. Lastly, 5 respondents were selected from each of the villages. A total of 120 respondents were selected for interview.

Data was collected with the aid of interview schedule containing closed and open-ended questions. This was augmented with personal observation on the respondents' environment. Data were collected on personal and socio-economic characteristics such as age, sex, marital status, household size e.t.c, and also on the perception and use of indigenous communication media among the respondents. Descriptive statistics such as mean, frequency count and percentage were used to describe the personal and socio-economic characteristics of the respondents. A 5 points-like rating scale was used to evaluate the perception of the respondents towards the use of indigenous communication media. Chi-square was used to evaluate the significant relationship between the socio-economic characteristics of respondents and their perception of indigenous communication media effectiveness for agricultural dissemination.

RESULT AND DISCUSSION

Socio-Economic characteristics of respondents

The summary statistics of the socio-economic variables involved in the study is presented in Table 1. The mean age of the respondents was 46.8 with a standard derivation of 12.3. The table revealed that 12.5% of the respondents were within the age bracket 20-30 years; while only 25% of the respondents were above 60 years of age. The gender distribution of respondents revealed that 65% were male while 35% were female. This depicts that both male and female sexes were appreciably involved in the study. The marital status of the respondents' shows that 59.2% of them were married and only 30% were single revealing that most of them have family responsibilities. The household size of respondents indicated that 45.8% had household size between 1-4, while 44.2% had household size of 5-8 and 10% had household size of 9-12. This also supports the earlier assertion of their family responsibility.

The distribution of respondents based on religion reveals that 70% were Christians and only 8.3% were traditional worshipers. The primary occupation of respondents shows that 46.6% were farmers, 16.7% artisans and 4.2% were civil servants. This revealed that farming is the most practiced occupation among the respondents. The respondent's distributions based on the level of education shows that most of the respondents (45%) had primary education and 1.7% had no formal education. This implies that due to low level of education of the respondents they might not have access to sophisticated channel of agricultural information hence indigenous media will be most suitable for them.

The distribution of the respondents based on their annual income (Table 2) revealed that 15.8% earned income between ₦ 228,000 and ₦ 360,000 while 22.5% earned income of ₦ 1,200,000 - ₦ 3,000,000 annually. This annual income depends on the occupation and level of involvement of the respondents. This implies that the respondents can generate income that is able to sustain their families.

The distribution of respondents based on the type of indigenous communication media available and used in their area, revealed that 15% of the respondents used folks song media in their area, 66.7% used town crier, 14.2% used traditional music and 4.2% used drama as channel of information in the studied area. The distribution of respondents based on communication type preference showed that 47.5% prefer folk song, 31.7% prefer town crier, and 10% prefer traditional music while 10.8% gave preference to drama. The indigenous communication media used mostly by the respondents shows that 12.5% of the respondents used folk media, 60.0% used town crier, 18.3% used traditional musician and 9.2% used drama. The choice of indigenous communication media revealed that 19.17% make their choices based on the fact that it is expensive, 39.67% because of prompt feedback, 16.67% because of its time consciousness and 25.0% because it is energy saving.

The reasons why indigenous communication media are no longer patronized shows that 63.6% blamed it on modernization while 36.4% blamed it on lack of interest. This implies that the interest of the people in the use of traditional media can be improved upon by using modern technology for these indigenous media so that they can be used for agricultural information dissemination.

Attitude of respondents towards use of indigenous media

Table 3 shows the attitude of respondents towards use of indigenous communication media in the studied area. Majority (78.7%) strongly agreed that indigenous media are cheap, 56.5% strongly agreed that they are energy saving, only 28.7% perceived they are effective for dissemination of agricultural innovation. Also, 11.4 and 65.5% strongly agreed and agreed respectively, that indigenous communication media are used to introduce

Table 1. Distribution of Respondents according to their Socio-Economic Characteristics.

Variables	Frequency	Percentage
Age (years)		
Less than 30	15	12.5
31-40	22	18.3
41-50	40	33.3
51-60	25	20.8
61-70	15	12.5
Above 70	3	2.5
Gender		
Male	78	65.0
Female	42	35.0
Marital Status		
Single	36	30.0
Married	71	59.2
Divorced	8	6.7
Widowed	5	4.2
Household Size		
Less than 4	55	45.8
5-8	53	44.2
9-12	12	10.0
Religion		
Christian	84	70.0
Muslim	26	21.7
{African Traditional Religion}	10	8.3
Primary Occupation		
Civil Servant	5	4.2
Trading	34	28.3
Artisan	20	16.7
Farming	56	46.7
Others	5	4.2
Level of Education		
No Education	2	1.7
No Formal Education	30	25.0
Primary Education	54	45.0
Secondary Education	29	24.2
Tertiary Education	5	4.2
Annual Income (₦)		
228,000 - 360,000	19	15.8
384,000 - 456,000	21	17.5
600,000 - 720,000	28	23.3
720,000 - 1,080,000	25	20.8
1,200,000 – 3,000,000	27	22.5

Source: Field Survey, 2011.

new technology for effective extension work. About 46.9% strongly agreed, and 28.7% agreed that information dissemination is simple to understand.

On the other hand, 53.3% strongly agreed that there is delay in feedback, 46.9 and 42.0% strongly agreed, and agreed they are geographically located and 42.7% agreed that they might not be timely. Most of the respondents (68.9%) disagreed that they enhance practical demonstration of innovations. Table 4 revealed that Age (χ^2 = 50.500, p = 0.006), Marital status (χ^2 =

Table 2. Communication Media Employed by the Respondents.

Communication Media Employed	Frequency	Percentage
Type of communication media available in the area		
Folk songs	18	15.0
Town crier	80	66.7
Traditional musician	17	14.2
Drama	5	4.2
Facility used mostly		
Folk songs	15	12.5
Town crier	72	60.0
Traditional musician	22	18.3
Drama	11	9.2
Reasons for choice of communication media		
Less expensive	23	19.2
Prompt feed back	47	39.2
Timely	20	16.6
Energy saving	30	25.0
Reasons for not using indigenous communications again		
Modernization	77	63.6
Lack of interest	43	36.4

Source: Field Survey, 2011.

Table 3. Attitudinal Response to Indigenous Media in the Studied Area.

Statement	Strongly Agreed	Agreed	Undecided	Disagree	Strongly Disagreed	Total
I.C.M are cheaper than other media	96(78.7)	20(18.1)	2(1.6)	1(0.8)	1(0.8)	120(100.0)
I.M use are energy saving	68)56.5)	45(36.9)	4(4.2)	2(1.6)	1(0.8)	120(100.0)
There is delay feedback in I.C.M	65(53.3)	32(27.8)	6(4.9)	9(7.4)	8(6.6)	120(100.0)
I.C.M are restricted geographically	56(46.9)	51(42.0)	8(6.7)	2(1.6)	3(2.8)	120(100.0)
I.C.M are effective in disseminating agricultural innovations	35(28.7)	1(0.8)	82(68.9)	1(0.8)	1(0.8)	120(100.0)
I. C.M might not be timely southwestern Nigeria	14(13.3)	52(42.7)	48(38.2)	4(4.2)	2(1.6|)	120(100.0)
I.C.M can be used to introduce new technology	12(11.4)	80(65.5)	8(6.7)	9(7.4)	11(9.0)	120(100.0)
Information disseminated through I.C.M can be simple to understand	56(46.9)	35(28.7)	16(13.2)	8(6.7)	5(4.5)	120(100.0)
I.C.M enhances practical demonstrations of innovation	4(4.2)	7(6.0)	8(6.7)	82(68.9)	19(13.2)	120(100.0)

Source: Field Survey, 2011.

39.025, p = 0.000), Level of education (χ^2 = 22.917, p = 0.001), Religion (χ^2 = 40.278, p = 0.000), Sex (χ^2 = 41.200, p = 0.001) and primary occupation (χ^2 = 20.917, p = 0.000) of the respondents have significant effects on the perception of indigenous communication media for disseminating agricultural information in the studied area. On the other hand, annual income does not have effect on the perceptions of indigenous communication media for agricultural information dissemination in the study area.

Conclusion

As result of the major findings of the study, the following conclusion was drawn: The types of folk media identified

Table 4. Relationship between Socio-economic Characteristics and Perception of Indigenous Media for Agricultural Information.

Socio Economic Characteristics	Chi-Square Value	Df	P-Value	Decision
Primary Occupation	20.917	4	0.000	Significant
Annual Income	5.000	4	0.999	Not Significant
Age	50.500	5	.006	Significant
Marital Status	39.025	2	.000	Significant
Level of Education	22.917	2	.001	Significant
Religion	40.278	2	.000	Significant
Sex	41.200	2	0.001	Significant

Source: Field Survey, 2011.

in the study area in order of usefulness were town crier, traditional music, folk songs and drama. The most commonly mentioned problems associated with the use of folk media were modernization, infidelity and poor knowledge of the advantages of folk media which had led to the lack of interest by the indigenes. Most of the respondents strongly agreed that indigenous media are cheaper than other channels of information while many of the respondents feel indifferent that indigenous media is effective for agricultural information dissemination. Among the socio-economic characteristics tested, marital status, age, level of education, religion and sex can be used to determine the readiness of individuals in receive agricultural information through indigenous media.

RECOMMENDATIONS

Consequently, in order to use folk media effectively among farmers in the study area, these problems must be considered. In view of this, the following recommendations were made:
(1) In disseminating agricultural information to farmers using folk media, policy makers and practitioners may choose the appropriate media considering the level of usefulness and frequency of use to ensure adequate impact.
(2) Folk media usage should be incorporated in to the programmes of rural development agencies especially agricultural information dissemination for extension service delivery in south-western Nigeria.
(3) Traditional communication media should form part of the innovation package to encourage adoption of innovations.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Influence of morphological traits on resistance of groundnut genotypes for thrips

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The field experiments were conducted with 69 groundnut genotypes in a randomized block design during kharif, 2011 and 2012 with three dates of sowing to identify resistant entries for thrips in groundnut at Sri Venkateswara S. V. Agricultural College Farm, Tirupati, Andhra Pradesh A.P. The studies revealed that the entries viz., IVK-I-2007-I-16, K-1814, K-1789, K-9, K-1811, TCGS-1114, TCGS-1137, TCGS-1218, TCGS-1274, TCGS-1043, ICGV-07045, ICGV-06039, ICGV-07045, ICGV-00351, ICGV-07234, ICGV-87846, ISK-I-2011-16 and ISK-I-2011-14 have shown resistance to thrips and also recorded higher pod yield in all the three dates of sowing during both kharif, 2011 and 2012. The resistance to thrips in these genotypes might be due to high leaf and stem trichomes, more leaf thickness and dark green foliage. Genotypes viz., K-9, K-1789. ISK-I-2011-16, ISK-I-2011-14, TCGS-1218 and TCGS-1043; some of the genotypes had the characteristic features of wavy margin leaves and downward folding of the leaves, which contribute to the restriction of thrips movement. These genotypes might be used as source of resistance to thrips in groundnut breeding programme.

Key words: Morphological, genotypes, yield, thrips, groundnut.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a leading oilseed crop in India and an important oilseed crop of tropical and subtropical regions of the world (Encylopedia of Agricultural Science, 1994). In India, it is grown on 52.64 lakh ha with a production of 69.64 lakh tonnes (Anonymous, 2012) and contributing to 55 per cent of the total oil seed production in the country and ranks first in the world in total area and 2nd in production. In Andhra Pradesh, it is grown in an area of 13.45 lakh hectares with a production of 11.09 lakh tonnes and a productivity of 825 kg ha^{-1} (Directorate of Economics and Statistics, 2013).

Pests and diseases are the major biotic factors affecting the groundnut yield (Frazer and Gilbert, 1976). Groundnut crop is attacked by lepidopteran as well as sucking pests. Among the sucking pests attacking the groundnut crop, thrips species occur as a complex, starting from vegetative stage till the harvest of the crop (Vijayalaksmi et al., 2009). Both nymphs and adults inhabit the leaf terminals and flowers and cause irregular streaks on the opened leaves, distortion and sometimes contamination of the foliage with fecal matter. All the species of thrips are polyphagous in nature occurring in almost all the groundnut growing countries in Asia and

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Table 1. Rating scale for thrips damage in groundnut.

Scale	Percent damage	Reaction
1	1 - 10	Resistant
2	11 - 20	Moderately susceptible
3	21 - 30	Susceptible
4	31 - 40	Highly susceptible
5	41 - 50	Highly susceptible
6	51 - 60	Highly susceptible
7	61 - 70	Highly susceptible
8	71 - 80	Highly susceptible
9	81 - 90	Highly susceptible

cause extensive damage to the crop (Scott et al., 2010). The use of peanut cultivars with resistance to thrips is one of the most promising alternate control measures ((Krishnaiah et al., 2012) since it is economically and environmentally safe and can easily be integrated with other control measures. Hence, the present investigation was taken up with an aim to identify resistant genotypes against thrips in groundnut.

MATERIALS AND METHODS

The experimental material comprised of 69 genotypes along with two check entries viz., Narayani and K-6 were taken from Regional Agricultural Research Station (RARS), Tirupati, Agricultural Research station (ARS), Kadiri, International Crop Research Institute for Semi-arid Tropics (ICRISAT), Hyderabad and Directorate of Groundnut Research, Junagadh. The field experiments were conducted in a randomized block design during *Kharif,* 2011 and 2012 with three dates of sowing at S.V. Agricultural College Farm, Tirupati. The first date of sowing was taken up in July 2011 (D1- 15th July) and the remaining two sowings were taken up at 15 days interval (D2- 30th July and D3-10th August, 2011). During *Kharif,* 2012, the crop was sown on 29th June (D1), 15th July (D2) and 1st August 2012 (D3). Each genotype was grown in 4 m row length with spacing of 30 × 10 cm in three replications. For every 5 rows (genotypes), 1 row of susceptible check varieties that is, Narayani and Kadiri-6 were sown. Crop was raised as per the recommended package of practices except plant protection measures for thrips. Observations on morphological parameters like plant height, leaf trichomes, stem trichomes and leaf thickness and yield attributes (number of mature pods per plant and pod yield) were recorded from 69 groundnut genotypes. Phenols were estimated as per the method suggested by Malick and Singh (1980).

Percent damage of thrips (Table 1) was calculated by using following formula:

$$\text{Percent damage} = \frac{\text{Number of damage leaflets}}{\text{Total number leaflets}} \times 100$$

RESULTS AND DISCUSSION

The screening results of groundnut genotypes for morphological and yield traits are presented in Tables 2, 3, 4 and 5.

Kharif 2011

Morphological and yield

In first date of sowing: Plant height varied from 31.30 cm (ICGV-07227) to 58.20 cm (ISK-I-2011-59). The mean plant height of genotypes was 47.86 cm. Higher number of leaf trichomes were found in TCGS-1043 (37.1 /cm^2), whereas it was lower in Vemana (10.9 /cm^2) with a mean number of 24.6 /cm^2 of leaf trichomes. The number of stem trichomes ranged from 44.3 /cm^2 (Kadiri-5) to 88.1 /cm^2 (ICGV-07022) with a mean of 61.79/cm^2). The maximum leaf thickness was recorded in TCGS-894 (0.41 mm), whereas it was lowest in ISK-I-2011-14 (0.22 mm) with general mean of leaf thickness being 0.30 mm. Highest number of mature pods per plant was produced by ICGV-07230 (26.80 pods/plant) and ISK-I-2011-9 recorded as low as 6.20 pods/plant with a general mean of 16.65 mature pods/plant. The range of variation for mean pod yield per hectare was between 413 kg ha^{-1} (ISK-I-2011-2) and 1760 kg ha^{-1} (ICGV-07101). Thirty two (32) entries registered more pod yield than general mean (1099 kg ha^{-1}).

In second date of sowing: Plant height ranged from 35.37 cm (ICGV-07227) to 58.77 cm (ISK-I-2011-59). The mean plant height of genotypes was 47.86 cm. Higher number of leaf trichomes was observed in TCGS-1043 (38.2 /cm^2), whereas it was lower in Vemana (10.7 cm^2) with a mean number of 25.4 /cm^2. The number of stem trichomes ranged from 45.2 cm^2 (Kadiri-5) to 89.8 cm^2 (ICGV-07022) with a mean of 62.75 /cm^2. The maximum leaf thickness was recorded in TCGS-894 (0.48 mm), whereas it was the lowest in ISK-I-14 (0.26 mm) with general mean of leaf thickness being 0.35 mm. Highest number of mature pods/plant was produced by ICGV-07356 (29.50) and ISK-I-2011-9 recorded as low as 7.08 with a general mean of 18.92 mature pods/plant. The range of variation for mean pod yield per hectare was between 486 kg ha^{-1} (ISK-I-2011-2) and 2070 kg ha^{-1} (ICGV-07101). Thirty two (32) entries registered more pod yield than general mean (1289 kg ha^{-1}).

Table 2. Performance of groundnut genotypes with respect to morphological traits.

S/N	Genotypes	Plant height (cm)								Leaf trichomes /cm^2							
		Kharif 2011				*Kharif* 2012				*Kharif* 2011				*Kharif* 2012			
		D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
1	K-1812	49.40	55.82	43.97	49.73	58.29	61.40	48.36	56.02	23.5	24.2	22.0	23.3	25.2	24.7	24.0	24.6
2	Kadiri-7	50.20	56.73	44.68	50.53	59.24	62.40	49.15	56.93	22.0	22.7	20.6	21.8	23.6	23.1	22.4	23.1
3	K-1782	55.40	62.60	49.31	55.77	65.37	68.86	54.24	62.82	18.4	19.0	17.2	18.2	19.7	19.3	18.7	19.3
4	Anantha	55.00	62.15	48.95	55.37	64.90	68.37	53.85	62.37	22.1	22.8	16.6	20.5	23.7	23.2	22.5	23.1
5	K-1814	53.70	60.68	47.79	54.06	63.37	66.75	52.57	60.90	25.7	26.5	24.0	25.4	27.5	27.0	26.2	26.9
6	K-1809	55.40	62.60	49.31	55.77	65.37	68.86	54.24	62.82	19.0	19.6	17.8	18.8	20.4	20.0	19.4	19.9
7	Kadiri-5	50.60	57.18	45.03	50.94	59.71	62.90	49.54	57.38	32.7	33.7	30.6	32.4	35.1	34.4	33.3	34.3
8	JL-24	51.10	57.74	45.48	51.44	60.30	63.52	50.03	57.95	20.9	21.5	15.6	19.3	22.3	21.9	21.2	21.8
9	K-1789	54.80	61.92	48.77	55.17	64.66	68.12	53.65	62.14	24.8	25.6	18.6	23.0	26.6	26.1	25.3	26.0
10	K-1787	56.70	64.07	50.46	57.08	66.91	70.48	55.51	64.30	16.6	16.3	12.5	15.1	17.0	17.5	16.9	17.1
11	Kadiri-8	47.50	53.68	42.28	47.82	56.05	59.04	46.50	53.87	26.1	25.6	24.4	25.4	26.6	27.4	26.6	26.9
12	Vemana	40.80	46.10	36.31	41.07	48.14	50.71	39.94	46.27	10.9	10.7	10.2	10.6	11.1	11.5	11.1	11.2
13	K-1815	50.10	56.61	44.59	50.43	59.12	62.27	49.05	56.81	26.5	26.0	24.8	25.8	27.0	27.9	27.0	27.3
14	K-1813	52.00	58.76	46.28	52.35	61.36	64.64	50.91	58.97	24.4	23.9	22.8	23.7	24.9	25.6	24.8	25.1
15	KH.Andhra	50.10	56.61	44.59	50.43	59.12	62.27	49.05	56.81	24.4	23.9	26.4	24.9	24.9	25.6	24.9	25.1
16	Kadiri-9	42.10	47.57	37.47	42.38	49.68	52.33	41.22	47.74	22.5	22.0	21.0	21.8	22.9	23.6	22.9	23.1
17	Kadiri-4	46.50	52.55	41.39	46.81	54.87	57.80	45.52	52.73	22.7	22.2	21.2	22.0	23.1	23.8	23.1	23.3
18	K-1811	51.20	57.86	45.57	51.54	60.42	63.64	50.12	58.06	36.4	35.7	34.0	35.3	37.1	38.2	37.1	37.4
19	K-1805	48.50	54.81	43.17	48.82	57.23	60.29	47.48	55.00	26.8	26.2	25.0	26.0	27.3	28.1	27.2	27.5
20	TCGS-1114	43.00	48.59	38.27	43.29	50.74	53.45	42.10	48.76	34.2	33.6	32.0	33.3	34.9	36.0	34.9	35.2
21	TCGS-1115	50.40	56.95	44.86	50.74	59.47	62.65	49.34	57.15	30.4	29.8	28.4	29.5	31.0	31.9	31.0	31.3
22	TCGS-1146	48.90	55.26	43.52	49.23	57.70	60.78	47.87	55.45	12.2	12.0	11.4	11.9	12.4	12.8	12.4	12.6
23	TCGS-1156	54.60	61.70	48.59	54.96	60.43	62.87	53.45	58.92	34.5	35.5	32.2	34.0	36.9	36.2	35.1	36.1
24	TCGS-1137	49.00	55.37	43.61	49.33	57.82	60.91	47.97	55.57	21.6	22.3	20.2	21.4	23.2	22.7	22.0	22.6
25	TCGS-1218	53.00	59.89	47.17	53.35	62.54	65.88	51.89	60.10	18.8	19.4	20.1	19.4	20.1	19.7	19.1	19.7
26	TCGS-1270	52.80	59.66	46.99	53.15	62.30	65.63	51.69	59.88	21.6	22.3	20.2	21.4	23.2	22.7	22.0	22.6
27	TCGS-1274	54.90	62.04	48.86	55.27	64.78	68.24	53.75	62.26	23.8	24.5	22.2	23.5	25.4	24.9	24.2	24.9
28	TCGS-1278	49.20	55.60	43.79	49.53	58.06	61.16	48.17	55.79	30.5	31.4	22.9	28.3	32.7	32.1	31.1	32.0
29	TCGS-894	47.30	53.45	42.10	47.62	55.81	58.79	46.31	53.64	34.3	35.3	25.7	31.7	36.7	36.0	34.9	35.9
30	TCGS-991	50.80	57.40	45.21	51.14	59.94	63.14	49.73	57.61	21.8	22.5	16.4	20.2	23.4	22.9	22.2	22.9
31	TCGS-1043	51.50	58.20	45.84	51.84	60.77	64.01	50.42	58.40	37.1	38.2	34.7	36.7	39.8	39.0	37.8	38.9
32	TCGS-1045	49.10	55.48	43.70	49.43	57.94	61.03	48.07	55.68	18.6	19.2	17.4	18.4	19.9	19.5	19.0	19.5
33	TCGS-1073	53.40	60.34	47.53	53.76	63.01	66.38	52.28	60.56	27.2	28.0	25.4	26.9	29.1	28.5	27.7	28.4
34	TPT-4	53.60	60.57	47.70	53.96	63.25	66.62	52.47	60.78	19.0	19.6	17.8	18.8	20.4	20.0	19.4	19.9

Table 2. Contd.

35	Rohini	41.80	47.23	37.20	42.08	49.32	51.96	40.92	47.40	15.6	16.1	14.6	15.4	16.7	16.4	15.9	16.3
36	Greeshma	38.40	43.39	34.18	38.66	45.31	47.73	37.59	43.55	26.8	27.6	25.0	26.4	28.7	28.1	27.2	28.0
37	Abhaya	39.60	44.75	35.24	39.86	46.73	49.22	38.77	44.91	23.5	24.2	22.0	23.3	25.2	24.7	24.0	24.6
38	ICGV-07227	31.30	35.37	27.86	31.51	36.93	38.91	30.64	35.49	29.1	30.0	27.2	28.8	31.2	30.6	29.6	30.5
39	ICGV-06040	37.40	42.26	33.29	37.65	44.13	46.49	36.61	42.41	22.7	23.4	21.2	22.4	24.3	23.8	23.1	23.7
40	ICGV-08204	37.70	42.60	33.55	37.95	44.49	46.86	36.91	42.75	33.6	34.6	31.4	33.2	36.0	35.3	34.2	35.2
41	ICGV-06039	45.80	51.75	40.76	46.11	54.04	56.93	44.84	51.94	27.0	27.8	25.2	26.6	28.9	28.3	27.5	28.2
42	ICGV-07059	39.30	44.41	34.98	39.56	46.37	48.85	38.47	44.57	22.5	23.1	21.0	22.2	24.1	23.6	22.9	23.5
43	ICGV-94358	39.02	44.09	34.73	39.28	46.04	48.50	38.20	44.25	22.3	22.9	20.8	22.0	23.8	23.4	22.7	23.3
44	ICGV-07045	45.70	51.64	40.67	46.00	53.93	56.81	44.74	51.82	27.6	28.4	25.8	27.3	29.6	29.0	28.1	28.9
45	ICGV-06040	48.60	54.92	43.25	48.92	57.35	60.41	47.58	55.11	25.7	26.5	24.0	25.4	27.5	27.0	26.2	26.9
46	ICGV-00350	47.60	53.79	42.36	47.92	56.17	59.17	46.60	53.98	19.7	20.3	18.4	19.5	21.1	20.7	20.1	20.6
47	ICGV-91114	50.10	56.61	44.59	50.43	59.12	62.27	49.05	56.81	22.0	22.7	20.6	21.8	23.6	23.1	22.4	23.1
48	ICGV-06045	47.60	53.79	42.36	47.92	56.17	59.17	46.60	53.98	22.5	23.1	21.0	22.2	24.1	23.6	22.9	23.5
49	ICGV-07101	41.70	47.12	37.11	41.98	49.21	51.83	40.82	47.29	27.6	28.4	25.8	27.3	29.6	29.0	28.1	28.9
50	ICGV-93261	45.30	51.19	40.32	45.60	53.45	56.31	44.35	51.37	15.8	16.3	14.8	15.6	17.0	16.6	16.1	16.6
51	ICGV-07356	44.30	50.06	39.43	44.60	52.27	55.06	43.37	50.24	20.1	20.7	18.8	19.9	21.5	21.1	20.5	21.1
52	ICGV-00351	49.30	55.71	43.88	49.63	58.17	61.28	48.26	55.91	31.5	32.4	29.4	31.1	33.7	33.0	32.0	32.9
53	ICGV-07022	51.50	58.20	45.84	51.84	60.77	64.01	50.42	58.40	26.8	27.6	25.0	26.4	28.7	28.1	27.2	28.0
54	ICGV-07234	31.70	35.82	28.21	31.91	37.41	39.40	31.03	35.95	28.7	29.5	26.8	28.3	30.7	30.1	29.2	30.0
55	ICGV-07053	41.60	47.01	37.02	41.88	49.09	51.71	40.73	47.17	16.1	16.5	15.0	15.9	17.2	16.9	16.3	16.8
56	ICGV-87846	49.90	56.39	44.41	50.23	58.88	62.03	48.85	56.59	27.8	28.7	26.0	27.5	29.8	29.2	28.3	29.1
57	ICGV-07230	41.30	46.67	36.76	41.58	48.73	51.34	40.43	46.83	27.8	28.7	26.0	27.5	29.8	29.2	28.3	29.1
58	ISK-I-2011-1	43.70	49.38	38.89	43.99	51.57	54.32	42.78	49.56	17.6	18.2	13.2	16.3	18.9	18.5	18.0	18.4
59	ISK-I-2011-2	48.10	54.35	42.81	48.40	56.76	59.79	47.09	54.55	25.6	26.3	19.2	23.7	27.4	26.8	26.0	26.8
60	ISK-I-2011-16	43.30	48.93	38.54	43.59	51.09	53.82	42.39	49.10	33.8	34.8	25.3	31.3	36.2	35.4	34.4	35.3
61	ISK-I-2011-28	53.60	55.57	47.70	53.96	55.25	59.62	54.47	56.45	28.9	29.8	27.0	28.5	30.9	30.3	29.4	30.2
62	ISK-I-2011-29	58.20	58.77	51.80	58.59	68.68	72.34	56.98	66.00	25.7	29.9	24.0	26.5	31.1	27.0	26.2	28.1
63	ISK-I-2011-15	52.30	59.10	46.55	52.65	61.71	65.01	51.20	59.31	22.5	26.2	21.0	23.2	27.2	23.6	22.9	24.6
64	ISK-I-2011-9	49.50	55.94	44.06	49.83	58.41	61.53	48.46	56.13	26.3	30.3	19.7	25.4	31.5	27.6	26.8	28.6
65	ISK-I-2011-10	54.80	61.92	48.77	55.17	62.66	60.12	53.65	58.81	24.4	28.4	22.8	25.2	29.6	25.6	24.8	26.7
66	ISK-I-2011-13	51.30	57.97	45.66	51.64	60.53	63.77	50.22	58.17	24.8	28.9	23.2	25.6	30.1	26.1	25.3	27.1
67	ISK-I-2011-14	39.30	44.41	34.98	39.56	46.37	48.85	38.47	44.57	24.8	28.9	23.2	25.6	30.1	26.1	25.3	27.1
68	Kadiri-6 (Check)	50.90	57.52	45.30	51.24	60.06	63.27	49.83	57.72	21.4	22.9	20.0	21.4	23.8	22.5	21.8	22.7
69	Narayani (Check)	48.30	54.58	42.99	48.62	56.99	60.04	47.29	54.77	26.5	26.9	24.8	26.1	28.0	27.9	27.0	27.6
	Mean	47.86	53.91	42.60	48.12	56.27	59.20	46.89	54.12	24.6	25.4	22.3	24.1	26.4	25.8	25.1	25.8
	SD±	5.88	6.47	5.23	5.92	6.81	7.12	5.79	6.54	5.5	5.7	5.2	5.4	5.9	5.8	5.6	5.8

Table 2. Contd.

	CV%	12.29	12.00	12.29	12.30	12.10	12.02	12.35	12.08	22.40	22.49	23.38	22.30	22.49	22.40	22.40	22.33

S/N	Genotypes	Stem trichomes /cm^2								Leaf thickness (mm)							
		***Kharif* 2011**				***Kharif* 2012**				***Kharif* 2011**				***Kharif* 2012**			
		D1	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**	**D1**	**D2**	**D3**	**Mean**
1	K-1812	45.6	46.5	45.1	45.7	47.0	46.5	45.1	46.2	0.254	0.298	0.240	0.264	0.272	0.318	0.218	0.269
2	Kadiri-7	56.4	57.5	55.8	56.6	58.1	57.5	55.8	57.1	0.346	0.404	0.326	0.359	0.370	0.433	0.296	0.366
3	K-1782	53.8	54.9	53.2	54.0	55.4	54.9	53.3	54.5	0.257	0.300	0.242	0.266	0.274	0.321	0.220	0.272
4	Anantha	66.5	67.9	65.8	66.7	68.5	67.9	65.9	67.4	0.299	0.350	0.282	0.310	0.320	0.374	0.256	0.317
5	K-1814	66.7	68.1	66.0	67.0	68.8	68.1	66.1	67.6	0.329	0.384	0.310	0.341	0.352	0.411	0.281	0.348
6	K-1809	44.5	45.4	44.0	44.6	45.8	45.4	44.1	45.1	0.288	0.337	0.272	0.299	0.309	0.361	0.247	0.305
7	Kadiri-5	44.3	45.2	43.8	44.4	45.6	45.2	43.8	44.9	0.305	0.357	0.288	0.317	0.327	0.382	0.261	0.323
8	JL-24	60.4	61.6	59.8	60.6	62.2	61.6	48.0	57.3	0.252	0.295	0.238	0.262	0.270	0.316	0.216	0.267
9	K-1789	62.7	63.9	62.0	62.9	64.6	63.9	49.8	59.4	0.263	0.308	0.248	0.273	0.281	0.329	0.225	0.278
10	K-1787	62.9	64.2	62.2	63.1	64.8	64.2	50.0	59.7	0.273	0.320	0.258	0.284	0.293	0.342	0.234	0.290
11	Kadiri-8	51.8	52.9	51.3	52.0	53.4	52.9	51.3	52.5	0.288	0.337	0.272	0.299	0.309	0.361	0.247	0.305
12	Vemana	48.2	49.1	47.7	48.3	49.6	49.1	47.7	48.8	0.288	0.337	0.272	0.299	0.309	0.361	0.247	0.305
13	K-1815	53.6	54.6	53.0	53.7	55.2	54.6	53.0	54.3	0.267	0.313	0.252	0.277	0.286	0.334	0.229	0.283
14	K-1813	54.9	56.0	54.3	55.0	56.5	56.0	54.3	55.6	0.280	0.327	0.264	0.290	0.299	0.350	0.240	0.296
15	KH.Andhra	55.9	57.1	55.4	56.1	57.6	57.1	55.4	56.7	0.338	0.395	0.270	0.335	0.316	0.370	0.298	0.328
16	Kadiri-9	46.2	47.1	45.7	46.4	47.6	47.1	45.8	46.8	0.309	0.361	0.247	0.305	0.288	0.337	0.272	0.299
17	Kadiri-4	46.4	47.4	45.9	46.6	47.8	47.4	46.0	47.1	0.288	0.337	0.230	0.285	0.269	0.315	0.254	0.279
18	K-1811	61.3	62.6	60.7	61.5	63.2	62.6	60.7	62.2	0.312	0.365	0.294	0.323	0.333	0.390	0.267	0.330
19	K-1805	58.1	59.3	57.5	58.3	59.9	59.3	57.5	58.9	0.254	0.298	0.240	0.264	0.272	0.318	0.218	0.269
20	TCGS-1114	46.0	46.9	45.5	46.2	47.4	46.9	45.6	46.6	0.265	0.310	0.250	0.275	0.284	0.332	0.227	0.281
21	TCGS-1115	44.4	45.3	43.9	44.5	45.7	45.3	44.0	45.0	0.254	0.298	0.240	0.264	0.272	0.318	0.218	0.269
22	TCGS-1146	54.2	55.3	53.7	54.4	55.9	55.3	53.7	54.9	0.250	0.293	0.236	0.260	0.268	0.313	0.214	0.265
23	TCGS-1156	49.0	48.5	48.5	48.7	49.0	48.5	48.6	48.7	0.295	0.345	0.278	0.306	0.315	0.369	0.252	0.312
24	TCGS-1137	66.7	66.1	66.1	66.3	66.7	66.1	66.1	66.3	0.254	0.298	0.240	0.264	0.272	0.318	0.218	0.269
25	TCGS-1218	59.8	59.2	59.2	59.4	59.8	59.2	59.2	59.4	0.354	0.414	0.334	0.367	0.379	0.443	0.303	0.375
26	TCGS-1270	56.9	56.3	56.3	56.5	56.9	56.3	56.4	56.5	0.324	0.380	0.306	0.337	0.347	0.406	0.278	0.344
27	TCGS-1274	54.4	53.9	53.9	54.1	54.4	53.9	53.9	54.1	0.341	0.399	0.322	0.354	0.365	0.427	0.292	0.362
28	TCGS-1278	64.4	63.8	63.8	64.0	64.4	63.8	51.2	59.8	0.280	0.327	0.264	0.290	0.299	0.350	0.240	0.296
29	TCGS-894	71.7	71.0	71.0	71.2	71.7	71.0	57.0	66.6	0.407	0.476	0.384	0.422	0.436	0.510	0.348	0.431
30	TCGS-991	76.0	75.2	75.2	75.5	76.0	75.2	60.4	70.5	0.348	0.407	0.328	0.361	0.372	0.435	0.298	0.368
31	TCGS-1043	80.9	80.1	80.1	80.4	80.9	80.1	64.3	75.1	0.280	0.327	0.264	0.290	0.299	0.350	0.240	0.296
32	TCGS-1045	55.3	54.7	54.7	54.9	55.3	54.7	54.8	54.9	0.261	0.305	0.246	0.271	0.279	0.326	0.223	0.276

Table 2. Contd.

33	TCGS-1073	62.6	63.9	62.0	62.8	64.5	63.9	62.0	63.5	0.331	0.387	0.312	0.343	0.354	0.414	0.283	0.350
34	TPT-4	63.7	65.0	63.1	63.9	65.6	65.0	63.1	64.6	0.301	0.352	0.284	0.312	0.322	0.377	0.258	0.319
35	Rohini	67.4	68.7	66.7	67.6	69.4	68.7	66.7	68.3	0.274	0.321	0.220	0.272	0.257	0.300	0.242	0.266
36	Greeshma	67.6	69.0	66.9	67.8	69.6	69.0	66.9	68.5	0.306	0.358	0.245	0.303	0.286	0.335	0.270	0.297
37	Abhaya	73.0	74.5	72.3	73.3	75.2	74.5	72.3	74.0	0.333	0.390	0.267	0.330	0.312	0.365	0.294	0.323
38	ICGV-07227	67.0	68.3	66.3	67.2	69.0	68.3	66.3	67.9	0.307	0.360	0.290	0.319	0.329	0.385	0.263	0.326
39	ICGV-06040	65.2	66.5	64.6	65.4	67.2	66.5	64.6	66.1	0.295	0.345	0.278	0.306	0.315	0.369	0.252	0.312
40	ICGV-08204	70.0	71.4	69.3	70.2	72.1	71.4	69.3	70.9	0.284	0.332	0.268	0.295	0.304	0.356	0.243	0.301
41	ICGV-06039	67.2	68.5	66.5	67.4	69.2	68.5	66.5	68.1	0.273	0.320	0.258	0.284	0.293	0.342	0.234	0.290
42	ICGV-07059	74.7	76.2	74.0	75.0	77.0	76.2	74.0	75.7	0.316	0.370	0.298	0.328	0.338	0.395	0.270	0.335
43	ICGV-94358	63.7	65.0	63.1	63.9	65.6	65.0	63.1	64.6	0.271	0.317	0.256	0.282	0.290	0.340	0.232	0.287
44	ICGV-07045	64.6	65.9	63.9	64.8	66.5	65.9	64.0	65.5	0.343	0.402	0.324	0.356	0.367	0.430	0.294	0.364
45	ICGV-06040	62.9	64.1	62.2	63.1	64.8	64.1	62.2	63.7	0.297	0.347	0.280	0.308	0.318	0.372	0.254	0.314
46	ICGV-00350	51.0	52.0	50.5	51.1	52.5	52.0	50.5	51.7	0.303	0.355	0.286	0.315	0.324	0.380	0.260	0.321
47	ICGV-91114	63.9	65.2	63.3	64.1	65.9	65.2	63.3	64.8	0.273	0.320	0.258	0.284	0.293	0.342	0.234	0.290
48	ICGV-06045	52.1	53.1	51.5	52.2	53.6	53.1	51.5	52.8	0.288	0.337	0.272	0.299	0.309	0.361	0.247	0.305
49	ICGV-07101	68.7	70.1	68.0	68.9	70.8	70.1	68.0	69.6	0.290	0.340	0.274	0.301	0.311	0.364	0.249	0.308
50	ICGV-93261	68.7	70.1	68.0	68.9	70.8	70.1	68.0	69.6	0.299	0.350	0.282	0.310	0.320	0.374	0.256	0.317
51	ICGV-07356	68.6	70.0	67.9	68.9	70.7	70.0	54.5	65.1	0.322	0.377	0.304	0.334	0.345	0.403	0.276	0.341
52	ICGV-00351	62.7	63.9	62.0	62.9	64.6	63.9	49.8	59.4	0.263	0.308	0.248	0.273	0.281	0.329	0.225	0.278
53	ICGV-07022	88.1	89.8	87.2	88.4	90.7	89.8	70.0	83.5	0.305	0.357	0.288	0.317	0.327	0.382	0.261	0.323
54	ICGV-07234	65.9	67.2	65.2	66.1	67.9	67.2	65.2	66.8	0.358	0.419	0.338	0.372	0.383	0.449	0.307	0.380
55	ICGV-07053	67.0	68.3	66.3	67.2	69.0	68.3	66.3	67.9	0.290	0.340	0.274	0.301	0.311	0.364	0.249	0.308
56	ICGV-87846	69.1	70.5	68.4	69.4	71.2	70.5	68.4	70.0	0.263	0.308	0.248	0.273	0.281	0.329	0.225	0.278
57	ICGV-07230	76.9	78.4	76.1	77.2	79.2	78.4	76.1	77.9	0.331	0.387	0.312	0.343	0.354	0.414	0.283	0.350
58	ISK-I-2011-1	63.9	65.2	63.3	64.1	65.9	65.2	63.3	64.8	0.299	0.350	0.282	0.310	0.320	0.374	0.256	0.317
59	ISK-I-2011-2	72.4	73.8	71.6	72.6	74.5	73.8	71.7	73.3	0.290	0.340	0.274	0.301	0.311	0.364	0.249	0.308
60	ISK-I-2011-16	72.0	73.4	71.3	72.2	74.2	73.4	71.3	73.0	0.297	0.347	0.280	0.308	0.318	0.372	0.254	0.314
61	ISK-I-2011-28	69.3	70.7	68.6	69.6	71.4	70.7	68.7	70.3	0.223	0.260	0.210	0.231	0.238	0.279	0.191	0.236
62	ISK-I-2011-29	74.5	76.0	73.8	74.8	76.8	76.0	73.8	75.5	0.276	0.322	0.260	0.286	0.295	0.345	0.236	0.292
63	ISK-I-2011-15	69.8	71.2	69.1	70.0	71.9	71.2	69.1	70.7	0.276	0.322	0.260	0.286	0.295	0.345	0.236	0.292
64	ISK-I-2011-9	75.8	77.3	75.1	76.1	78.1	77.3	75.1	76.8	0.297	0.347	0.280	0.308	0.318	0.372	0.254	0.314
65	ISK-I-2011-10	46.7	47.6	46.2	46.8	48.1	47.6	46.2	47.3	0.284	0.332	0.227	0.281	0.265	0.310	0.250	0.275
66	ISK-I-2011-13	54.2	55.3	53.7	54.4	55.9	55.3	53.7	54.9	0.265	0.311	0.212	0.263	0.248	0.290	0.234	0.257
67	ISK-I-2011-14	55.9	57.1	55.4	56.1	57.6	57.1	55.4	56.7	0.329	0.385	0.263	0.326	0.307	0.360	0.290	0.319
68	Kadiri-6 Check)	55.7	56.8	55.2	55.9	57.4	56.8	55.2	56.5	0.306	0.358	0.245	0.303	0.286	0.335	0.270	0.297
69	Narayani check)	61.1	62.4	60.5	61.3	63.0	62.3	60.5	62.0	0.310	0.362	0.292	0.321	0.331	0.387	0.265	0.328

Table 2. Contd.

Mean	61.79	62.75	61.17	61.90	63.38	62.75	59.21	61.78	0.30	0.35	0.27	0.30	0.31	0.36	0.25	0.31
SD±	9.76	9.88	9.67	9.76	9.98	9.88	8.99	9.36	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.03
CV%	15.79	15.75	15.80	15.77	15.75	15.75	15.19	15.15	10.85	10.85	11.81	10.84	11.46	11.46	11.00	11.04

Kharif 2011: D1- 1st Date of sowing: 15-07-2011; D2- 2nd Date of sowing: 30-07-2011; D3- 3rd Date of sowing: 10-08-2011.
Kharif 2012: D1: 1st Date of sowing: 29-06-2012; D2: 2nd Date of sowing: 15-07-2012; D3: 3rd Date of sowing: 01-08-2012.

In third date of sowing: Plant height ranged from 27.86 cm (ICGV-07227) to 51.80 cm (ISK-I-2011-59). The mean plant height of genotypes was 42.60 cm. Higher number of leaf trichomes were found in TCGS-1043 (34.7 /cm^2), whereas it was lower in Vemana (10.2 cm^2) with a mean number of 22.3 /cm^2 of leaf trichomes. The number of stem trichomes ranged from 43.8 /cm^2 (Kadiri-5) to 87.2 /cm^2 (ICGV-07022) with a mean of 62.75 /cm^2. The maximum leaf thickness was recorded in TCGS-894 (0.38 mm), whereas it was the lowest in ISK-I-2011-14 (0.21 mm) with general mean of leaf thickness being 0.27 mm.

Highest number of mature pods per plant was produced by ICGV-07101 (22.41) and ISK-I-2011-9 recorded as low as 4.98 with a general mean of 13.88 mature pods/plant. Among the 69 genotypes mean pod yield per hectare was ranging between 316 kg ha^{-1} (ISK-I-2011-2) and 1345 kg ha^{-1} (ICGV-07101). Fifty-five entries registered more pod yield than general mean (848 kg ha^{-1}).

Screening of groundnut genotypes against thrips

In first date of sowing

Mean incidence of thrips in first date of sowing indicated that the lowest thrips incidence was recorded in K-1811 (4.40%) and highest incidence was observed in K-1789 (52.7%). The genotypes K-1811, ICGV-00351, ICGV- 07045, ICGV-070230, ICGV-06039, TCGS-1218, ICGV-00351, ICGV-08204 and ICGV-07022 have shown low incidence in second and third week after sowing. Forty (40) genotypes showed lower incidence than general mean (18.93%). Thrips incidence was less at 21 days after sowing (DAS) when compared to the incidence recorded at 14 DAS (Table 3).

In second date of sowing

Thrips incidence recorded in second date of sowing revealed that the thrips incidence was lowest in K-1811 (4.40%) and highest in ISK-I-2011-13 (46.50%). The genotypes, ICGV-00351, ICGV-06039, K-1811, ICGV-07234, ICGV-07230, ICGV-07022, TCGS-1043, K-5, ICGV-07101, ICGV-08204 and TCGS-1218 have shown low incidence in second and third week after sowing. Forty genotypes recorded lower thrips incidence than general mean (19.53%). In general, thrips incidence observed at 14 DAS was low than at 21 DAS.

In third date of sowing

Thrips incidence in third date of sowing revealed that the lowest thrips incidence was recorded in ICGV-00351 (3.99%) and highest incidence in ISK-I-2011-10 (46.24%). The genotypes, TCGS-1043, TCGS-1114, ICGV-07230, ICGV-00351, ICGV-07234, ICGV-06039, ICGV-07022, ICGV-07045, TCGS-1137 and K-1812 have shown low incidence in second and third week after sowing. Thirty-seven genotypes showed lower incidence than general mean (26.64%).

Rating of groundnut genotypes against thrips incidence

Sixty-nine groundnut genotypes can be classified into different categories by considering the level of thrips damage (Table 4).

Low incidence (1 to 10%)

They are IVK-I-2007-16, K-1814, K-1789, K-9, K-1811, TCGS-1114, TCGS-1137, TCGS-1218, TCGS-1274, TCGS-1043, ICGV-06039, ICGV-070485, ICGV-00351, ICGV-07022, ICGV-07234, ICGV-87846, ICGV-07230, ISK-I-2011-16, and ISK-I-2011-14.

Moderate incidence (11 to 20%)

They are K-8, K-1809, TCGS-1278, TCGS-894, TCGS- 1045, ICGV-06045, and ISK-I-2011-28.

Table 3. Performance of groundnut genotypes with respect to yield traits.

S/N	Genotypes	Mature pods/plant								Pod yield (kg ha^{-1})							
		Kharif 2011				*Kharif* 2012				*Kharif* 2011				*Kharif* 2012			
		D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
1	K-1812	12.20	14.16	9.96	12.04	13.68	16.01	11.35	13.68	979.0	1151.8	748.6	959.8	1175	1382	898	1152
2	Kadiri-7	16.00	18.88	13.28	16.05	18.24	21.34	15.14	18.24	1040.4	1224.0	795.6	1020.0	1249	1469	955	1224
3	K-1782	10.40	11.80	8.30	10.03	11.40	13.34	9.46	11.40	794.8	935.0	607.8	779.2	954	1122	729	935
4	Anantha	15.60	15.34	10.79	13.70	14.82	17.34	15.30	15.82	936.4	1101.6	716.0	918.0	1124	1322	859	1102
5	K-1814	16.00	18.88	16.28	16.95	18.24	21.34	15.14	18.24	1078.7	1269.1	824.9	1057.5	1294	1523	990	1269
6	K-1809	12.40	14.16	9.96	12.04	13.68	16.01	11.35	13.68	729.0	857.7	557.5	714.7	875	1029	669	858
7	Kadiri-5	19.20	22.42	15.77	19.06	21.66	25.34	17.98	21.66	1390.8	1636.3	1063.6	1363.5	1669	1964	1276	1636
8	JL-24	15.50	15.34	10.79	13.74	14.82	17.34	12.30	14.82	811.4	954.6	620.5	795.5	974	1146	745	955
9	K-1789	8.40	9.44	6.64	8.03	11.20	10.67	7.57	9.80	541.9	637.5	414.4	531.3	650	765	497	638
10	K-1787	12.60	14.16	9.96	12.04	13.68	16.01	11.35	13.68	833.8	980.9	637.6	817.4	1001	1177	765	981
11	Kadiri-8	14.40	16.52	11.62	14.05	15.96	18.67	13.25	15.96	1047.6	1232.5	801.1	1027.1	1257	1479	961	1233
12	Vemana	11.80	12.98	9.13	11.04	12.54	14.67	10.41	12.54	717.4	844.1	548.6	703.4	861	1013	658	844
13	K-1815	15.60	17.70	12.45	15.05	17.10	20.01	14.19	17.10	1156.0	1360.0	884.0	1133.3	1387	1632	1061	1360
14	K-1813	16.20	18.88	13.28	16.05	18.24	21.34	15.14	18.24	1273.8	1498.6	974.1	1248.8	1529	1798	1169	1499
15	KH.Andhra	14.80	16.52	14.62	15.03	15.96	18.67	16.25	16.96	1047.6	1232.5	801.1	1027.1	1257	1479	961	1233
16	Kadiri-9	11.00	12.98	9.13	11.04	12.54	14.67	13.41	13.54	867.0	1020.0	663.0	850.0	1040	1224	796	1020
17	Kadiri-4	14.50	16.52	11.62	14.05	15.96	18.67	13.25	15.96	1192.1	1402.5	911.6	1168.8	1431	1683	1094	1403
18	K-1811	20.00	23.60	16.60	20.07	22.80	26.68	18.92	22.80	1331.6	1566.6	1018.3	1305.5	1598	1880	1222	1567
19	K-1805	14.00	21.24	18.94	18.06	20.52	24.01	17.03	20.52	1270.9	1495.2	971.8	1246.0	1525	1794	1166	1495
20	TCGS-1114	14.60	16.52	11.62	14.05	15.96	18.67	13.25	15.96	1079.4	1269.9	825.4	1058.3	1295	1524	991	1270
21	TCGS-1115	11.20	12.98	9.13	11.04	12.54	14.67	10.41	12.54	967.4	1138.2	739.8	948.5	1161	1366	888	1138
22	TCGS-1146	10.60	11.80	8.30	10.03	11.40	13.34	9.46	11.40	851.1	1001.3	650.8	834.4	1021	1202	781	1001
23	TCGS-1156	11.00	12.98	9.13	11.04	12.54	14.67	10.41	12.54	927.7	1091.4	709.4	909.5	1113	1310	851	1091
24	TCGS-1137	10.50	11.80	8.30	10.03	11.40	13.34	9.46	11.40	867.0	1020.0	663.0	850.0	1040	1224	796	1020
25	TCGS-1218	19.40	22.42	15.77	19.06	21.66	25.34	17.98	21.66	1300.5	1530.0	994.5	1275.0	1561	1836	1193	1530
26	TCGS-1270	21.30	22.96	16.26	22.43	22.08	21.34	20.82	25.08	1322.9	1556.4	1011.6	1297.0	1588	1868	1214	1556
27	TCGS-1274	18.80	21.24	14.94	18.06	20.52	23.01	17.03	20.52	1280.3	1506.2	979.0	1255.2	1536	1807	1175	1506
28	TCGS-1278	19.40	22.42	15.77	19.06	21.66	23.34	17.98	21.66	1273.0	1497.7	973.5	1248.1	1528	1797	1168	1498
29	TCGS-894	21.20	24.78	17.43	21.07	23.94	24.01	23.27	25.00	1264.4	1487.5	966.9	1239.6	1517	1785	1160	1488
30	TCGS-991	15.40	17.70	12.45	15.05	17.10	20.01	14.19	17.10	903.1	1062.5	690.6	885.4	1084	1275	829	1063
31	TCGS-1043	18.20	18.88	15.28	17.40	18.24	21.34	15.14	18.24	1050.5	1235.9	803.3	1029.9	1261	1483	964	1236
32	TCGS-1045	9.10	10.62	7.47	9.03	8.50	12.00	10.30	10.26	770.2	770.2	770.2	770.2	820	916	793	843
33	TCGS-1073	12.40	14.16	9.89	12.04	13.68	16.01	11.35	13.68	939.3	1105.0	718.3	920.8	1127	1326	862	1105
34	TPT-4	13.50	15.34	10.79	14.04	14.82	17.34	12.60	14.82	939.3	1105.0	718.3	920.8	1015	1123	847	995

Table 3. Contd.

35	Rohini	14.00	15.34	11.79	13.04	14.92	17.84	12.30	14.82	909.6	1070.2	695.6	891.8	1092	1284	835	1070
36	Greeshma	15.60	17.70	12.45	15.05	17.10	20.01	14.19	17.10	1056.3	1242.7	807.8	1035.6	1268	1491	969	1243
37	Abhaya	15.00	17.70	13.45	16.05	17.40	20.51	14.19	17.10	985.5	1159.4	753.6	966.2	1183	1391	904	1159
38	ICGV-07227	22.20	23.96	18.26	22.07	23.08	25.34	20.82	25.08	1488.4	1751.0	1138.2	1459.2	1786	2101	1366	1751
39	ICGV-06040	22.40	24.80	21.75	24.08	25.50	27.85	21.66	28.50	1615.5	1900.6	1235.4	1583.8	1939	2281	1483	1901
40	ICGV-08204	24.20	25.50	20.75	24.08	25.00	26.35	20.66	27.20	1331.6	1566.6	1018.3	1305.5	1598	1880	1222	1567
41	ICGV-06039	21.40	25.50	19.75	25.78	24.40	27.35	23.16	28.10	1408.9	1657.5	1077.4	1381.3	1691	1989	1293	1658
42	ICGV-07059	21.00	24.78	17.43	21.47	23.94	25.61	19.87	23.94	1613.3	1898.1	1233.7	1581.7	1936	2278	1481	1898
43	ICGV-94358	20.60	23.60	16.60	20.07	22.80	26.68	18.92	22.80	1458.7	1716.2	1115.5	1430.1	1751	2059	1339	1716
44	ICGV-07045	21.60	24.78	17.43	21.07	23.94	27.01	19.87	23.94	1300.5	1530.0	994.5	1275.0	1561	1836	1193	1530
45	ICGV-06040	22.40	25.50	19.75	24.08	26.50	28.35	23.66	28.50	1533.1	1803.7	1172.4	1503.1	1840	2164	1407	1804
46	ICGV-00350	23.70	26.14	19.09	23.08	25.22	26.68	21.76	26.22	1348.2	1586.1	1031.0	1321.8	1618	1903	1237	1586
47	ICGV-91114	22.00	25.32	19.92	24.08	25.36	27.01	21.71	27.36	1228.3	1445.0	939.3	1204.2	1474	1734	1127	1445
48	ICGV-06045	24.20	28.32	19.92	24.08	25.36	27.11	22.11	25.36	1478.2	1739.1	1130.4	1449.3	1774	2087	1357	1739
49	ICGV-07101	24.00	26.86	22.41	27.09	25.38	28.01	21.55	30.78	1760.0	2070.6	1345.9	1725.5	2112	2485	1615	2071
50	ICGV-93261	24.00	28.32	19.92	24.08	26.36	28.41	21.71	27.36	1483.3	1745.1	1134.3	1454.2	1780	2094	1361	1745
51	ICGV-07356	25.30	29.50	20.75	25.08	28.50	33.35	21.26	28.50	1562.0	1837.7	1194.5	1531.4	1875	2205	1433	1838
52	ICGV-00351	20.60	23.60	16.60	20.07	22.80	26.68	18.92	22.80	1300.5	1530.0	994.5	1275.0	1561	1836	1193	1530
53	ICGV-07022	24.00	28.32	19.92	24.08	25.36	29.01	22.71	27.36	1541.8	1813.9	1179.0	1511.6	1850	2177	1415	1814
54	ICGV-07234	24.20	25.50	20.75	25.08	26.50	28.35	24.66	28.50	1478.2	1739.1	1130.4	1449.3	1774	2087	1357	1739
55	ICGV-07053	25.00	27.50	20.75	25.08	26.90	28.85	23.66	28.50	1439.9	1694.1	1101.1	1411.7	1728	2033	1321	1694
56	ICGV-87846	22.30	25.96	18.26	22.07	25.08	29.34	20.82	25.08	1408.9	1657.5	1077.4	1381.3	1691	1989	1293	1658
57	ICGV-07230	26.80	28.68	21.58	26.09	26.64	28.68	24.60	29.64	1473.2	1733.2	1126.5	1444.3	1768	2080	1352	1733
58	ISK-I-2011-1	7.00	8.26	5.81	7.02	7.98	9.34	6.62	7.98	481.9	567.0	368.5	472.5	578	680	442	567
59	ISK-I-2011-2	8.40	9.44	6.64	8.03	9.12	10.67	7.57	9.12	413.3	486.2	316.0	405.2	496	583	379	486
60	ISK-I-2011-16	23.20	25.14	19.09	23.08	24.22	27.68	21.76	26.22	1309.9	1541.1	1001.7	1284.2	1572	1849	1202	1541
61	ISK-I-2011-28	9.40	10.62	7.47	9.03	10.26	12.00	8.52	10.26	641.6	754.8	490.6	629.0	770	906	589	755
62	ISK-I-2011-29	8.00	9.44	6.64	8.03	9.12	10.67	7.57	9.12	746.3	878.1	570.7	731.7	896	1054	685	878
63	ISK-I-2011-15	12.20	14.16	9.96	12.04	13.68	16.01	11.35	13.68	915.4	1077.0	700.0	897.5	1099	1292	840	1077
64	ISK-I-2011-9	6.20	7.08	4.98	6.02	6.84	8.00	5.68	6.84	489.1	575.5	374.0	479.5	587	691	449	575
65	ISK-I-2011-10	8.40	9.44	6.64	8.03	9.12	10.67	7.57	9.12	523.1	615.4	400.0	512.8	628	739	480	615
66	ISK-I-2011-13	9.40	10.62	7.47	9.03	10.26	12.00	8.52	10.26	651.7	766.7	498.4	638.9	782	920	598	767
67	ISK-I-2011-14	24.60	28.32	19.92	24.08	22.40	32.01	27.71	27.36	856.9	1008.1	655.3	840.1	1028	1210	786	1008
68	Kadiri-6 (Check)	12.60	14.16	9.96	12.04	13.68	16.01	11.35	13.68	846.8	1008.0	865.2	906.7	916	1090	818	941
69	Narayani (Check)	15.80	17.70	12.45	15.05	17.10	20.01	14.19	17.10	997.4	1067.5	903.9	989.6	1077	1161	965	1068
	Mean	16.65	18.92	13.88	16.49	18.22	20.72	15.73	18.22	1099.33	1289.99	848.49	1079.27	1312.9	1541.5	1011.1	1288.5
	SD±	5.57	6.27	4.92	5.90	5.95	6.39	5.46	6.68	320.67	380.23	242.16	313.36	389.8	461.3	292.7	381.2

Table 3. Contd.

CV%	33.44	33.15	35.47	35.77	32.68	30.83	34.73	36.63	29.17	29.48	28.54	29.03	29.7	29.9	28.9	29.5

Kharif 2011: D1- 1st Date of sowing: 15-07-2011; D2- 2nd Date of sowing: 30-07-2011; D3- 3rd Date of sowing: 10-08-2011.
Kharif 2012: D1: 1st Date of sowing: 29-06-2012; D2: 2nd Date of sowing: 15-07-2012; D3: 3rd Date of sowing: 01-08-2012.

Moderately severe (21 to 30%)

They are ISK-I-2011-29, ISK-I-2011-15, ISK-I-2011-9, TCGS-1073, TCGS-991, Abhaya, ICGV-06040, ICGV-08204, ICGV-07059, ICGV-94358, ICGV-07101, ICGV-93261, ICGV-07356, K-1787, Vemana, K-1815, K-1813, Kadiri Harithandhra and TCGS-1270.

Severe incidence (> 30%)

K-1782, Anantha, K-5, TCGS-1156, K-4, TCGS-1115, TCGS-1146, TCGS-1156, Rohini, Greeshma, ICGV-06040, ICGV-00350, ICGV-91114, ISK-I-2011-1, ISK-I-2011-2, ISK-I-2011-10, ISK-I-2011-13, K-6 and Narayani.

***Kharif* 2012**

Morphological, physiological and yield

In first date of sowing: Plant height ranged from 36.93 cm (ICGV-07227) to 68.68 cm (ISK-I-2011-59). The mean plant height of genotypes was 56.27 cm. Maximum number of leaf trichomes was observed in TCGS-1043 (39.8 /cm^2), whereas it was lower in Vemana (11.1 /cm^2) with a mean number of 26.4 cm^2 of leaf trichomes. The range of number of stem trichomes varied from 45.6 /cm^2 (Kadiri-5) to 90.7 /cm^2 (ICGV-07022) with a mean of 63.38 /cm^2. The maximum leaf thickness was recorded in TCGS-894 (0.44 mm), whereas it was the lowest in ISK-I-2011-14 (0.24 mm) with general mean of leaf thickness being 0.31 mm. SPAD Chlorophyll meter reading (SCMR) at 60 DAS ranged from 34.86 (TCGS-1278) to 52.72 (TCGS-1274) with a general mean of 44.0.

Maximum number of mature pods/plant was produced by ICGV-07356 (28.50 pods/plant) and ISK-I-2011-9 recorded as low as 6.84 with a general mean of 18.22 mature pods/plant. The range of variation for mean pod yield per hectare was between 495 kg ha^{-1} (ISK-I-2011-2) and 2112 kg ha^{-1} (ICGV-07101). Thirty (30) entries registered more pod yield than general mean of 1313 kg ha^{-1}.

In second date of sowing: Plant height ranged from 38.91 cm (ICGV-07227) to 68.68 cm (ISK-I-2011-59). The mean plant height of genotypes was 56.27 cm. Higher number of leaf trichomes was produced in TCGS-1043 (39.0 /cm^2), whereas it was lower in Vemana (11.1 /cm^2) with a mean number of 25.8 cm^2. The number of stem trichomes varied from 45.2 /cm^2 (Kadiri-5) to 89.8 cm^2 (ICGV-07022) with a mean of 62.75 /cm^2. The maximum leaf thickness was recorded in TCGS-894 (0.51 mm), whereas it was the lowest in ISK-I-2011-14 (0.28 mm) with general mean of leaf thickness being 0.36 mm. The SCMR among 69 genotypes recorded at 60 DAS ranged from 36.96 (TCGS-1278) to 53.13 (TCGS-1274) with a general mean of 46.08.

Highest number of mature pods/plant was produced by ICGV-07356 (33.35) and ISK-I-2011-9 recorded as low as 8.0 with a general mean of 20.72 mature pods/plant. Mean pod yield ha^{-1} was ranging between 583 kg ha^{-1} (ISK-I-2011-2) and 2484 kg ha^{-1} (ICGV-07101). Thirty-one entries registered more pod yield than general mean (1542 kg ha^{-1}).

In third date of sowing: Plant height ranged from 30.64 cm (ICGV-072 27) to 56.98 cm (ISK-I-2011-59). The mean plant height of genotypes was 46.89 cm. Higher number of leaf trichomes was recorded in TCGS-1043 (37.8 cm^2), whereas it was lower in Vemana (11.1 cm^2) with a mean number of 25.1 cm^2 of leaf trichomes. The number of stem trichomes ranged from 43.8 /cm^2 (Kadiri-5) to 76.1 /cm^2 (ICGV-07230) with a mean of 59.21 /cm^2. The maximum leaf thickness was recorded in TCGS-894 (0.35 mm), whereas it was the lowest in ISK-I-2011-14 (0.19 mm) with general mean of leaf thickness being 0.25 mm. The range of variation for SCMR at 60 DAS ranged from 36.22 (TCGS-1278) to 53.93 (TCGS-1274) with a general mean of 45.19.

Highest number of mature pods/plant was produced by ISK-I-2011-14 (27.71) and ISK-I-2011-9 recorded as low as 5.68 with a general mean of 15.73 mature pods/plant. The range of variation for mean pod yield/ha was between 379 kg ha^{-1} (ISK-I-2011-2) and 1615 kg ha^{-1} (ICGV-07101). Fifty-two (52) entries registered more pod yield than general mean (1011 kg ha^{-1}).

Screening of groundnut genotypes against thrips

In first date of sowing

Thrips incidence in first date of sowing indicated that the thrips incidence was lowest in ICGV-

Table 4. Reaction of groundnut genotypes against thrips incidence.

S/N	Genotypes	Mean per cent damage due to thrips					
		First date of sowing (D1)		Second date of sowing (D2)		Third date of sowing (D3)	
		Kharif 2011	*Kharif* 2012	*Kharif* 2011	*Kharif* 2012	*Kharif* 2011	*Kharif* 2012
1	K-1812	15.1	12.2	16.9	11.9	6.92	6.52
2	Kadiri-7	16.5	10.1	14.0	13.0	14.01	10.13
3	K-1782	38.5	31.2	43.3	30.4	43.27	33.25
4	Anantha	14.1	11.4	15.8	11.1	45.82	40.40
5	K-1814	13.0	8.9	12.4	10.3	8.99	8.98
6	K-1809	35.7	28.9	40.1	28.2	10.14	11.91
7	Kadiri-5	10.2	5.0	6.9	8.0	39.93	43.50
8	JL-24	37.5	30.3	42.2	29.6	42.15	46.92
9	K-1789	52.7	32.7	19.2	21.7	9.24	6.69
10	K-1787	31.9	25.8	35.8	25.2	25.79	28.97
11	Kadiri-8	22.7	15.2	21.1	18.0	31.06	28.75
12	Vemana	31.3	25.3	35.2	24.7	25.16	24.15
13	K-1815	15.9	12.9	17.9	12.6	27.89	28.88
14	K-1813	17.7	11.1	15.4	14.0	25.35	26.82
15	KH.Andhra	14.1	11.4	15.8	11.1	25.81	27.16
16	Kadiri-9	14.7	11.9	16.5	11.6	6.52	5.44
17	Kadiri-4	20.3	19.6	27.3	16.0	37.23	45.65
18	K-1811	4.4	3.5	4.9	3.4	4.89	6.80
19	K-1805	15.9	12.8	17.8	12.5	7.84	5.40
20	TCGS-1114	10.4	10.1	14.0	8.2	3.96	6.88
21	TCGS-1115	18.4	14.9	20.7	14.6	30.73	27.65
22	TCGS-1146	26.5	19.8	27.5	20.9	32.55	47.46
23	TCGS-1156	14.2	11.5	16.0	11.3	36.01	29.47
24	TCGS-1137	17.7	11.1	15.4	14.0	5.44	7.42
25	TCGS-1218	6.5	5.2	7.3	5.1	7.28	4.22
26	TCGS-1270	12.3	9.9	13.8	9.7	23.81	27.81
27	TCGS-1274	11.2	6.7	9.3	8.9	9.25	5.69
28	TCGS-1278	14.7	7.8	10.9	11.6	10.85	6.21
29	TCGS-894	11.3	7.5	10.4	8.9	10.42	5.10
30	TCGS-991	22.8	16.8	23.4	18.0	23.40	42.75
31	TCGS-1043	12.7	4.6	6.4	10.0	6.40	5.08
32	TCGS-1045	26.0	21.0	29.2	20.5	19.17	27.31
33	TCGS-1073	16.0	12.9	17.9	12.6	23.93	29.05
34	TPT-4	20.0	16.2	22.5	15.8	48.49	41.24
35	Rohini	22.2	17.9	24.9	17.5	44.99	42.36
36	Greeshma	19.0	15.4	21.3	15.0	41.32	40.66
37	Abhaya	21.6	17.5	24.3	17.1	24.32	23.81
38	ICGV-07227	12.7	6.2	8.6	10.0	8.62	10.72
39	ICGV-06040	9.9	7.2	10.0	7.8	24.94	24.37
40	ICGV-08204	8.2	5.0	7.0	6.5	27.00	32.26
41	ICGV-06039	6.3	3.5	4.8	5.0	4.80	7.11
42	ICGV-07059	16.0	13.0	18.0	12.7	28.03	29.61
43	ICGV-94358	13.6	11.0	15.3	10.8	25.33	26.26
44	ICGV-07045	5.9	4.0	5.5	4.7	5.53	5.15
45	ICGV-06040	9.4	6.0	8.3	7.4	38.36	20.82
46	ICGV-00350	12.5	10.1	14.0	9.8	40.03	35.54
47	ICGV-91114	17.5	14.2	19.7	13.9	39.67	43.01
48	ICGV-06045	17.2	13.9	19.3	13.6	19.25	34.27
49	ICGV-07101	8.2	5.0	7.0	6.5	26.93	33.86

Table 4. Contd.

50	ICGV-93261	20.0	16.2	22.5	15.8	22.53	34.89
51	ICGV-07356	19.0	15.3	21.3	15.0	21.29	30.15
52	ICGV-00351	6.6	2.9	4.0	5.2	3.99	7.26
53	ICGV-07022	8.3	4.3	6.0	6.6	5.99	5.70
54	ICGV-07234	4.8	3.9	5.4	3.8	5.38	5.39
55	ICGV-07053	19.0	15.4	21.4	15.0	31.43	40.46
56	ICGV-87846	8.8	5.5	7.6	6.9	7.57	5.84
57	ICGV-07230	6.2	4.2	5.8	4.9	5.80	6.58
58	ISK-I-2011-1	36.8	29.8	41.4	29.1	40.86	47.24
59	ISK-I-2011-2	41.2	33.3	46.3	32.6	41.91	26.48
60	ISK-I-2011-16	21.6	15.0	20.9	17.1	8.58	7.90
61	ISK-I-2011-28	37.3	30.2	41.9	29.5	19.46	22.31
62	ISK-I-2011-29	16.6	13.4	18.6	13.1	21.63	26.41
63	ISK-I-2011-15	17.4	14.0	19.5	13.7	24.54	25.37
64	ISK-I-2011-9	19.2	15.6	21.6	15.2	26.45	31.50
65	ISK-I-2011-10	32.7	24.8	34.5	25.8	46.24	41.72
66	ISK-I-2011-13	41.4	33.5	46.5	32.7	45.52	39.55
67	ISK-I-2011-14	27.3	18.9	26.2	21.6	5.69	5.10
68	Kadiri-6 (Check)	38.0	28.3	39.3	30.0	49.39	42.21
69	Narayani (Check)	21.0	18.6	25.8	16.6	45.80	42.09
	Mean	18.93	14.33	19.53	14.66	24.64	23.96
	SD±	10.45	8.46	11.33	7.63	14.79	14.50
	CV%	55.2	59.0	58.0	52.1	61.28	

Table 5. Rating of groundnut genotypes against thrips incidence.

S/N	Severity	Incidence (%)	*Kharif* 2011	*Kharif* 2012
1	Low incidence	1 - 10	IVK-I-2007-16, K-1814, K-1789, K-9, K-1811, TCGS-1114, TCGS-1137, TCGS-1218, TCGS-1274, TCGS-1043, ICGV-06039, ICGV-070485, ICGV-00351, ICGV-07022, ICGV-07234, ICGV-87846, ICGV-07230, ISK-I-2011-16, ISK-I-2011-14	IVK-I-2007-16, K-1814, K-1789, K-9, K-1811, K-1809, TCGS-1114, TCGS-1137, TCGS-1218, TCGS-1274, TCGS-1278, TCGS-894, TCGS-1043, ICGV-08204, ICGV-06039, ICGV-07045, ICGV-00351, ICGV-07022, ICGV-07234, ICGV-87846, ICGV-07230, ISK-I-2011-14 and ISK-I-2011-16.
2	Moderate incidence	11 - 20	K-8, K-1809, TCGS-1278, TCGS-894, TCGS-1045, ICGV-06045, ISK-I-2011-28	K-8, K-1809 and ICGV-07227
3	Moderately severe	21 - 30	ISK-I-2011-29, ISK-I-2011-15, ISK-I-2011-9, TCGS-1073, TCGS-991, Abhaya, ICGV-06040, ICGV-08204, ICGV-07059, ICGV-94358, ICGV-07101, ICGV-93261, ICGV-07356, K-1787, Vemana, K-1815, K-1813, Kadiri harithandra and TCGS-1270.	ISK-I-2011-2, ISK-I-2011-15, ISK-I-2011-28, ISK-I-2011-29, Abhaya, ICGV-06040, ICGV-07059, ICGV-94358, ICGV-06040, K-1787, K-8, Vemana, K-1815, K-1813, Kadiri harithandra, TCGS-1045, TCGS-1115, TCGS-1156 and TCGS-1270.
4	Severe	>30	K-1782, Anantha, K-5, TCGS-1156, K-4, TCGS-1115, TCGS-1146, TCGS-1156, Rohini, Greeshma, ICGV-06040, ICGV-00350, ICGV-91114, ISK-I-2011-1, ISK-I-2011-2, ISK-I-2011-10, ISK-I-2011-13, K-6 and Narayani.	K-1282, Anantha, K-5, JL-24, K-4, TCGS-1146, TCGS-991, Rohini. Greeshma, ICGV-08204, ICGV-00350, ICGV-91184, ICGV-06045, ICGV-07101, ICGV-93261, ICGV-07356, ICGV-07053, ISK-I-2011-1, ISK-I-2011-9, ISK-I-2011-10, ISK-I-2011-13, K-6 and Narayani.

00351 (2.90%) and highest incidence ISK-I-2011-13 (33.5%). The genotypes, ICGV-00351, K-1811, ICGV-07234, ICGV-07045, ICGV-07230, TCGS-1043, K-5, ICGV-07022, ICGV-08204, TCGS-1218, ICGV-87846, ICGV-06040, ICGV-07227 and TCGS-1274 have shown low incidence in second and third week after sowing. Forty-two (42) genotypes showed lower incidence than general mean (14.33%).

In second date of sowing

Thrips incidence in second date of sowing indicated that the thrips incidence was lowest in K-1811 (3.40%) and highest incidence of thrips in ISK-I-2011-13 (32.70%). The genotypes K-1811, ICGV-07234, ICGV-07045, ICGV-07230, ICGV-06040, TCGS-1218, ICGV-00351, ICGV-87846 and ICGV-08204 have shown less thrips incidence in second and third week after sowing. Forty-three (43) genotypes showed lower incidence than general mean (14.66%).

In third date of sowing

Thrips incidence in third date of sowing indicated that the incidence of thrips was lowest in TCGS-1218 (4.22%) and highest incidence in ISK-I-2011-1 (47.24%). The genotypes, TCGS-1218, TCGS-894, TCGS-1274, ICGV-07045, ICGV-87846, ISK-I-2011-14, K-1809, TCGS-1043 and ICGV-00351 have shown low incidence in second and third week after sowing. Thirty-seven (37) genotypes recorded lower incidence of thrips than general mean (23.96%).

Rating of groundnut genotypes against thrips incidence

Low incidence (1 to 10%)

IVK-I-2007-16, K-1814, K-1789, K-9, K-1811,K-1809, TCGS-1114, TCGS-1137, TCGS-1218, TCGS-1274, TCGS-1278, TCGS-894, TCGS-1043, ICGV-08204, ICGV-06039, ICGV-07045, ICGV-00351, ICGV-07022, ICGV-07234, ICGV-87846, ICGV-07230, ISK-I-2011-14 and ISK-I-2011-16.

Moderate incidence (11 to 20%)

K-8, K-1809 and ICGV-07227

Moderately severe incidence (21 to 30%)

ISK-I-2011-2, ISK-I-2011-15, ISK-I-2011-28, ISK-I-2011-29, Abhaya, ICGV-06040, ICGV-07059, ICGV-94358, ICGV-06040, K-1787, K-8, Vemana, K-1815, K-1813, Kadiri Harithandra, TCGS-1045, TCGS-1115, TCGS-1156 and TCGS-1270.

Severe incidence (> 30%)

K-1282, Anantha, K-5, JL-24, K-4, TCGS-1146, TCGS-991, Rohini. Greeshma, ICGV-08204, ICGV-00350, ICGV-91184, ICGV-06045, ICGV-07101, ICGV-93261, ICGV-07356, ICGV-07053, ISK-I-2011-1, ISK-I-2011-9, ISK-I-2011-10, ISK-I-2011-13, K-6 and Narayani.

The present investigations revealed that the entries viz., IVK-I-2007-I-16, K-1814, K-1789, K-9, K-1811, TCGS-1114, TCGS-1137, TCGS-1218, TCGS-1274, TCGS-1043, ICGV-07045, ICGV-06039, ICGV-07045, ICGV-00351, ICGV-07234, ICGV-87846, ISK-I-2011-16 and ISK-I-2011-14 have high leaf and stem trichomes, more leaf thickness, dark green leaf foliages, high phenols (Phenols estimation was done as per the method suggested by Malick and Singh, 1980) (how was this determined?) and high chlorophyll content. Some of the genotypes had the characteristic features of wavy margin leaves and down ward folding of the leaves, which contribute to the restriction of thrips movement. These genotypes could be used as source of resistance to thrips in groundnut. Earlier Upadhyay et al. (2005), Holbrook and Dong (2005) and John et al. (2006, 2007) reported maximum frequency distribution for leaf colour and leaf size in groundnut. Amin (1985) found that resistance was associated with dark green leaf colour in groundnut. In the present study, 29 genotypes had dark green foliage colour (39.18%). TCGS-1043 had high leaf and stem trichomes, which contributed resistance to thrips. Similar results were reported by Dwivedi et al. (1993) on close association between resistance to thrips and dark green leaf colour, leaf wax and hairy (Trichomes) characters in peanut cultivar ICGV-86031. Linch and Stalker (1997) reported antibiosis as a basis of resistance to thrips in wild *Arachis* species and interspecific hybrids.

Dwivedi et al. (1996) reported higher pod yield in ICGV-86388 (2.04 t/ha) than JL-24 (1.68 t/ha) and found to be moderately resistant to *Thrips palmi*. Nugrahaeni et al. (1997) reported that, ICGV cultivars 90265, 91167 and 91176 exhibited moderate resistances to thrips (*Scirtothrips dorsalis, Caliothrips indicus* and *Frankliniella schultzei*), showing relatively low percentage of leaf damage at 28 and 42 DAS. Pod yield of most genotypes was higher than that of Mahesa. ICGV 90226 gave the highest average pod yield (2.05 t ha^{-1}), followed by ICGV 90227 and ICGV 90228 (1.8 t ha^{-1}), Mahesa was ranked as the best cultivar for seed appearance and uniformity.

The studies concluded that the use of cultivars with resistance to thrips is one of the most promising alternative control measures since it is economically and environmentally safe and can be easily integrated with other control measures. Thrips resistance will reduce the damage due to viral diseases caused by tospoviruses (PBND) and tobacco streak virus (PSND). The information obtained from the studies provides guidelines for further selection of promising lines and helps breeders to formulate appropriate breeding strategies and also these resistant sources can be used as donors in the breeding programs. Host plant resistance offers a primary strategy for thrips management and also an important component of integrated pest management.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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Contribution of some ornamental plants to the socio-economic development of urban household in Akure metropolis

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This study examined the ornamental plant nursery business in Nigeria, using Akure Metropolis, Ondo State as a case study. The study specifically identified the factors affecting ornamental plant nursery operations and income generated and challenges of ornamental plant nursery business in the state. For the study ornamental nursery operators/owners households were surveyed across the study area and interviewed via the use of the questionnaire. Descriptive and the regression analysis were the tools used in analysing the study data gathered. The study results showed that ornamental plant nursery operators are aging. Inadequate land and pest attack was indicated as a major constraint to ornamental plant nursery production. The study therefore recommends the education of youths and others alike to appreciate ornamental plant nursery business considering the business profitability.

Key word: Ornamental, nursery, landscaping, plant, nursery.

INTRODUCTION

The sustainability of the environment depends on the ways and manners in which all natural resources and artificial resources are being utilized. Global warming and ozone layer depletion is now a global issue of great concern because the effect on human lives is enormous which require an urgent attention in order to avert present and future problems that may arise (Walker and Steffen, 1997).

Ornamental plants are attractive plants use for decorative purposes. These include any plant cultured, and tamed to serve a particular function such as shade, windbreak, and beautifying places. In recent years, the growing of ornamental plants has increased across the country as a common strategy of attraction to control the unused available and marginal land, which serves as a dumping ground for refuse and some unwanted materials. Nigeria being one of the developing nation, ornamentals has gained recognition through the development of mega cities as millennium goal initiative to beautify the environment (Oseni, 2004)

Urban forestry is the act of planting trees in the cities either for recreational purposes or avenue purposes to improve the environment (NBS/CBN, 2006). In urban environment, ornamental plant functions frequently in relation to human environment. They are usually selected, planted and nurtured by people with specific

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intention either to provide shading or by government as avenue on a drive way. Many urban dwellers also generate money from the sale of these ornamental plants. The functional benefits provided by these trees depend on structural attributes thereby improving the climatic nature of the environment (Eyffe, 2001).

An unplanned environment looks ugly, unhealthy and undesirable (Oloyede, 2008). The state of the Nigeria environment has become precarious due to the problems associated with deforestation, soil degrading, desertification, massive land and coastal erosion, loss of tree cover and bio-diversity, the drying up of rivers and lake, situation of water bodies and flooding. These problems have all contributed to accentuate climate change and a host of other environmental phenomenons. We are then faced with the challenges of promotions of massive and large afforestation/reforestation and landscaping in general (Is-haq et al., 2008).

Ornamental plants are therefore used for decorative purposes in landscaping; they beautify the home and places such as street road, round about etc. Aesthetically, plant can become a piece of living sculpture when placed against a plain wall or fence, they create an interesting shadow pattern of branches and leave plant can be used as background for other planting. They provide suitable environment for birds and other wildlife. The effect of Ozone layer depletion may expose the earth to harmful, high energy and high frequency ultraviolet radiation and can result to skin cancer, sunburn, damage to plant and reduction of plankton population in the oceans. The harmful effect of ozone layer depletion can be reduced drastically through planting ornamental plants in the urban areas. This will in no small way help in absorbing carbon (iv) oxide and use it to manufacture their food (photosynthesis) which will have hitherto escaped to the atmosphere and cause damage to this layer (Oyin, 2010). Therefore this work examined the contributions of ornamental plants to the socio-economic development of urban household in Akure metropolis.

MATERIALS AND METHODS

The study area

The study area- Akure is one of the second generation State capitals and a rapidly growing medium sized urban center in Nigeria. It is located around latitude 7° 15’ North of the equator and 5° 14’ East, at an approximate altitude of 370 m above the sea level. It has a population of 190,000 (1991 census) and rose from a rural town to one of the country’s medium sized urban centers with an estimated population of 241,000 by 2003 using 2% yearly increase (Fadamiro and Atolage, 2005). The rapidity of its development within the last twenty-five years stemmed from the political status of the town which was initially a provisional headquarter and later a state capital thus serving as the seat of both the local and state governments since 1976. This accounted for the influx of people to the city for employment and other related activities. It is thus expected that the environmental situation would be critical in terms of the ability to meet up with the sporadic development devoid of adequate planning and monitoring (Fadamiro and Atolagbe, 2005).

Data collection

The primary data were collected on the contribution of ornamental plants to the socio-economic development of urban household in Akure metropolis using semi-structured questionnaire. Simple random sampling techniques were used in the study. 200 questionnaires were administered to 200 household heads that were randomly selected with the study area.

Data analysis

The data obtained was collated and subjected to descriptive statistics - frequency and percentage distribution to illustrate the contribution of ornamental plants to the socio-economic development of urban household in Akure metropolis.

RESULTS

Table 1 shows that those interviewed falls between age 20 and 60 above with age bracket 20-30 having the highest percentage of 66% and age group 60 and above with the lowest percentage of 10% (Table 1). 59.3% of the respondents were single and only 10% are divorced with the married family with 30.7 % (Table 3). Table 4 shows the educational status of respondents with 60% having possessed tertiary education. Table 5 shows that respondent interviewed were engaged in daily work ranging from civil servant with the highest population with 51.3% and horticulturist with the lowest of 11.3%. Table 6 shows percentage of people that use ornamental plant within the metropolis. 76% of those interviewed uses ornamental plant in one form or the other in their daily activity. Table 7 shows various way in which ornamental plants is being used. The highest level of usage is for medical purpose with 38% and recreational activities with the lowest value of 12%. Table 8 shows the rate of sales of ornamental plant as it was reported by the respondent, with yes having 70% and No, 30% of the respondent. It was recorded that its sales is an established factor in the metropolis as it shows 70% of sales. The sales per year as was given by the respondent within the metropolis shows that the highest percentage is found to be 5000 with 44% and between 5000 and 10000 with the lowest of 16% (Table 9). Table 10 shows the regression relationship between sales and annual income. The ANOVA show that there is significant ($p \leq 0.05$) difference between the two factors. Challenges faced by the respondent has shown that questionnaire ranges from 52 to 10%. Land space has the highest value and water with lowest value. Examples of ornamental plant species encountered in the study area are as follows, Duranta rapens, Izora spp., Tresenae spp., Hibiscus spp., Achalipha spp., Pinus spp., Calitrix spp., Queen of philipines, Gardenea spp., Ashoka spp., Fiucss spp., Benjamnae spp., Bongovillia, Stick match, Eucalyptus spp., Taxilalium spp., Culius spp., Crotons, Roses, Queen of the nught, West Indian fumor and Olianda.

Table 1. Age distribution.

Age distribution	Frequency	Percentage
20-30	99	66.0
41-50	18	12.0
51-60	18	12.0
>60	15	10.0
Total	150	100.0

Source: Field survey (2011).

Table 2. Genders.

Gender	Frequency	Percentage
Male	43	86.0
Female	7	14.0
Total	50	100.0

Source: Field survey (2011).

Table 3. Marital Status of the respondents.

Status	Frequency	Percentage (%)
Single	89	59.3
Married	46	30.7
Divorce	15	10.0
Total	150	100.0

Source: Field survey (2011).

Table 4. Educational background of the respondents.

Education	Frequency	Percentage
Non formal	3	6.0
Primary	5	10.0
Secondary	12	24.0
Tertiary	30	60.0
Total	50	100.0

Source: Field survey (2011).

Table 5. Occupation of respondents.

Occupation	Frequency	Percentage
Horticulurist	17	11.3
Civil servant	77	51.3
Trader	56	37.3
Total	150	100.0

Source: Field survey (2011).

Table 6. Usage of ornamental plant.

Usage	Frequency	Percentage (%)
Yes	114	76.0
No	36	24.0
Total	**150**	**100.0**

Source: Field survey (2011).

Table 7. Purpose of ornamental plant.

Purpose	Frequency	Percentage (%)
Medicinal	57	38.0
Beautification	55	36.7
Recreational	18	12.0
Environmental	20	13.3
Total	**150**	**100.0**

Source: Field survey (2011).

Table 8. Sales of ornamental plant.

Sales	Frequency	Percentage
Yes	35	70.0
No	15	30.0
Total	**50**	**100.0**

Source: Field survey (2011).

DISCUSSION

The socio-economic characteristics of the ornamental plant nursery operation to the well being of the inhabitants of Akure metropolis was analyzed using data collected from the field. It was revealed in Table 1 that most of the ornamental plants nursery operator respondents' were within age range bracket of 21 to 60 years. This age bracket composed of youths and few adults. This implies that ornamental plants nursery business in the study area can be greatly improved upon, since it is concentrated mostly in the hands of young and agile individuals which may be as a result of fresh graduate coming into the labour market of the state with little or no available job opportunity. Table 2 also indicates that most of the ornamental plants nursery operator respondents 86.0% were males. The large male female margin of respondents shows that ornamental plants production business is not popular among the women folks in the study area. This may be due to the high labour requirements for ornamental plants nursery operations. Also those involved are majorly single non married portion of the populace as shown in Table 3, as this is a growing industry in Nigeria. More than half of the respondents have had tertiary education (Table 4) from post-secondary institutions like the polytechnics, colleges of education and the universities, indicating that

Table 9. Sales of ornamental plant per year.

Sales per year(₦)	Frequency	Percentage
<5000	22	44.0
5000-10000	8	16.0
11000-15000	9	18.0
16000 -20000	11	22.0
Total	**50**	**100.0**

Source: Field survey (2011).

Table 10. Regression table.

Model	Sum of squares	Df	Mean square	F	Sig.
Regression	61.581	1	61.581	76.180	0.000[a]
Residual	36.376	45	0.808		
Total	97.957	46			

Source: Field survey (2011).

Table 11. Challenges facing ornamental plantation.

Challenges	Frequency	Percentage (%)
Pest attack	19	38.0
Land space	26	52.0
Water	5	10.0
Total	50	100.0

Source: Field survey (2011).

corroborated the age of those involved in the business, ornamental plants nursery operations in the study area have acquired reasonable formal educational background that could enable them introduce improvements into their ornamental plants nursery business. This level of education is far above the primary school education status in Nigeria.

The high literacy level of the respondents could affect their choice of inputs and the utilization of existing inputs and also their willingness to adopt improved technologies.This is supported by the report of Fakayode et al. (2008*).* Table 5 shows the degree of involvement of respondent on daily basis. The survey work shows that the largest numbers of the populace were civil servant and those involve in horticultural work are the least. The involvement of people in this business is still on the increase and with the age range involved, there is possibility of future improvement on the involvement in this business. This point can be buttress with Table 6 as the number of ornamental use is very high. This high utilization of ornamental plant either for beautification, recreational, income generation or for medicinal purpose gives a clear picture of what the future holds for ornamental plant within the metropolis as reported in Table 7. Among all the various use of ornamental plant, beautification and medicinal application is of great importance to people. among all the ornamental plant used either for beautification or medicinal plant, following species are very common within the state; Yellow fiscus , Green bush, Red acalypha, crotin, Ixora double and single. The income derived from ornamental plants which serve as one the source of socio-economic determination as shown in Table 8 reveals that the bulk of the sales ranges between 5000 and 18000, which is still relatively low. Regression analysis was carried out to determine the influence of hypothesized factors including quantity sold X1 on the volume of sales of ornamental plants in the study area as shown in Table 10. The regression analysis was significance for annual income and sales which means that sales of ornamental plant as the tendency to increase the income of those involve in the business. This is supported with the R^2 value which is about 62.9%. The linear function met the lead equations' criteria and was therefore chosen as the lead equation. The equation is presented as Y = M0.729 + 0.35.

Challenges

Table 11 indicates the frequency distributions of constraints to ornamental plants nursery activities in the study area. The table shows that the most prevalent limitation to ornamental plants nursing business is the operators' inability to access adequate land necessary to capitalize their farms. This problem as reported by the farmers has particularly relegated the production of ornamental plants to mere small garden. This report is similar to report given by Bankole (2002) as most of the land involves in the production are leased with very high levy on them which may serve as a limiting factor to income generation. Also insect attack, though not too much is also a factor as most of the ornamental plant are not indigenous, and this factor has brought about low adaptability and high insect attack on their growth.

Conclusion

In conclusion ornamental plants nursery occupation is profitable and inadequate funding was indicated as a major constraint to ornamental plant nursery production. The study results shows that ornamental plant nursery operators were on the increase, even if the involvement are still more within the 20 to 30 years of age of the respondent and labour were revealed to significantly determine receipts from ornamental plants nursery operation in the study area. The result also indicates that ornamental plants nursery occupation is profitable. Inadequate land was indicated as a major constraint to ornamental plant nursery production. Based on the study findings therefore there is a need for all stake holders in the ornamental plants nursery industry to seek out waysof providing adequate land especially to boost ornamental plant production in the study area. In this vein ornamental plant nursery operators can be mobilized into viable cooperatives so that they can gain from the use of pooled resources and finances in cooperatives. There is also the need to educate youths and others alike as regards the gains derivable from ornamental plant nursery production business especially considering its viability and profitability. Lastly, the consumption of ornamental plants for beautification should be encouraged as this would widen the market scope for the ornamental agriculture thereby encouraging participation in the ornamental business.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Field experimentation based simulation of yield response of maize crop to deficit irrigation using AquaCrop model, Arba Minch, Ethiopia

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This experiment was conducted during February to June 2012 in Demonstration farm of Arba Minch University located in the central rift valley of Ethiopia. The aim was to investigate the effects of different levels of deficit irrigation imposed at different growth stages of maize (BH-140) crop on its development, grain yield and water use efficiency. AquaCrop model was calibrated and validated using field experimentation data. The crop water requirement of maize for full irrigation application was calculated using CropWat 8.0. The water application levels considered were 100% of crop evapotranspiration (ETc), 75%ETc, 50%ETc and 25%ETc. based on these irrigation levels and four growth stages of maize crop, ten treatments were arranged. These treatments were replicated three times. Data collected during the experiment were: crop biomass, soil moisture content, irrigation depths and final yield. The result showed that the highest yield was found in treatment six, T6 (8842 Kg/ha) which was subjected to water deficit during mid- and maturity-stages; whereas minimum yield of about 5264 kg/ha was obtained under T8 which was irrigated imposed to deficit during the whole growing season except during the initial stage. The highest (2.11 kg/m^3) and lowest (0.93 kg/m^3) water use efficiency was recorded under T8 and T4. Generally, water deficit of 50%ETc during third and fourth growth stages had no significant effect on the grain yield of maize and it is worthwhile to save irrigation water during these growth stages. The model performed well in simulating the growth of aboveground biomass, grain yield, and canopy cover (CC) for most of the treatments but it was less satisfactory in simulating the growth performance of treatments under prolonged water-deficit. The fact that the AquaCrop model is easy to use, requires less input data, and its sufficient degree of simulation accuracy make it a valuable tool for estimating crop productivity under deficit irrigation, and on-farm water management for improving the efficiency of water use in agriculture.

Key words: Deficit irrigation, growth stage, maize, crop water productivity, AquaCrop.

INTRODUCTION

Globally, irrigated agriculture is the dominate user of fresh water. Water is becoming scarce and hence irrigation water supplies are decreasing in many areas of the world. Climate change predictions of increase in

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temperature and decrease in rainfall mean water will become increasingly scarce.

Generally, Ethiopia is considered as water abundant country. However, water availability for crop production is highly erratic both in space and time. Where in some areas, there is substantial rainfall and surface runoff during some months of the year while in others; there are high dry spell periods (Awulachew et al., 2007). This calls for storage of excess rainfall and runoff that can be utilized during the dry season. Efforts to ensure food self-sufficiency at house-hold level requires efficient use of the stored water and appropriate water application technologies that can be adopted for small-scale irrigation development. The traditional irrigation development paradigm is aiming at supplying sufficient water to crops to avoid water stress during the whole growing stage, so as to achieve maximum yields (Doorenbos and Pruit, 1992). However, the limitations in water availability oblige to adopt alternative irrigation schedules with different frequencies of irrigation to cope with the water scarcity. Because of water availability constraints in most areas of the world, the above paradigm is changing (English et al., 2002) and quite often, the allocation of irrigation water to field is below maximum crop water requirement for maximum yield (Lorite et al., 2007).

In order to optimize crop yields and water use efficiency in irrigated environments, irrigations should be timed in a way that non-productive soil water evapotranspiration and drainage losses are minimized, and possible inevitable water deficits coincide with least sensitive growth period. Therefore, it is critical that conservative irrigation water management practices has to be implemented in order to optimize crop yield by employing deficit irrigation principles that provide a means of conserving irrigation water while maintaining reasonable yield level. Deficit irrigation scheduling practice is the technique of withholding, or reducing the amount of water applied per irrigation at some stages of the crop growth with the aim of saving water, labor, and in some cases energy. This practice does lead to some degree of moisture stress on the crop and reduction in crop yield (Smith and Munoz, 2002). However, when the moisture stress is not severe, the adverse effect on crop yield is minimal and there can be an appreciable increase in crop water use efficiency especially when there is reduction in water losses due to evaporation, deep percolation and runoff (Panda et al., 2004). Furthermore, it is important to determine the crop water production functions that relate crop yield to evapotranspiration (crop yield response to different amounts of irrigation water applied) which shed light on physiological and agronomic response of crops to different levels of water applications (Kipkorir et al., 2001).

Ethiopia is among the major maize producers in Sub Saharan African countries, where smallholder farmers dominate the major share of production. Though maize is widely grown in Ethiopia, only three regional states contribute to 94% of the total annual production. These regions are Oromia, Amhara and Southern Nations, Nationalities, and People's Region (SNNP). According to a five years (2003/2004 - 2007/2008) Central Statics Agency of Ethiopia (CSAE) data, the share of Oromia region was on the average, 60% of the total maize production in the country. This was followed by Amhara region with 21.67% and SNNP region with 12.55%.

Traditionally, maize is consumed in many different food types such as Fososiye, Kurfufa, Kita, Injera, Genfo, and also consumed in the form of homemade drinks such as Bordie and Tella. Its straw is also used for animal feed. Despite its importance, the productivity remains poor with a national average yield of 1.5 tons ha^{-1} (CSAE, 2009).

In recent years, studies that have been conducted on crop yield response to water stress and water use efficiency have shown that deficit irrigation can increase crop yield by improving soil water conditions and their WUE significantly (Doorenbos and Kassam, 1979).

Some of these studies have used crop production functions to determine the irrigation level that maximizes economic return. On the other hand, simulation models are attractive tools to develop irrigation strategies under water deficit conditions, and to obtain reliable yield estimates for field crops that can be expected under various environmental conditions. Some of the models are intended to provide guidelines to mainly a practitioner type of end-user such as people working for extension services, governmental agencies, and various kinds of farmers associations. With good models, realistic estimations of crop yield can be simulated for various environmental conditions. The models are valuable for out-scaling the experimental findings to new environments. Therefore, use of simulation models could help in evaluating the interaction between numerous factors that affect plant growth.

The main objective of this study was therefore, to investigate the effects of different levels of deficit irrigation imposed at different growth stages of maize crop on its development, grain yield and water use efficiency. The specific objectives of the study were:

i. To evaluate the effects of different irrigation water application levels on crops yield and water use efficiency at different crop growth stages.
ii. To calibrate and validate the AquaCrop model using the data generated during the experiment and evaluate its applicability for deficit irrigation management.

MATERIALS AND METHODS

Description of the study area

The field experiment was conducted in the south western zone of SNNP regional state at the Demo-farm of Arba Minch located 500 km south of Addis Ababa during the period of February to June,

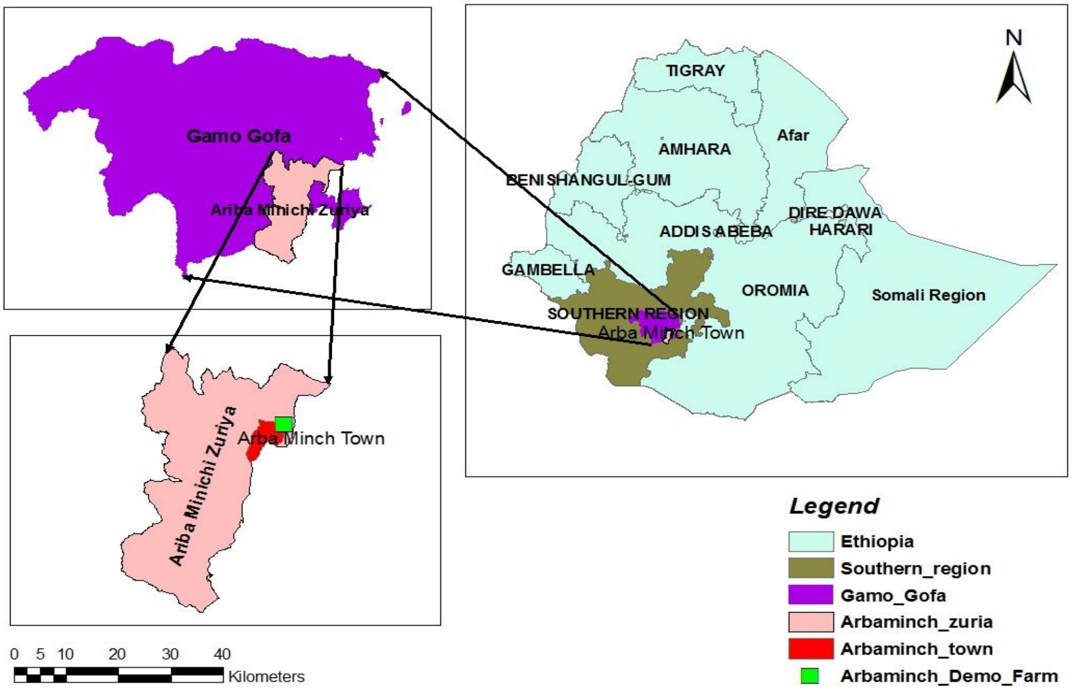

Figure 1. Location map of the study area.

2012. Arba Minch University (AMU) demonstration site was set as a practical illustration for irrigation and drainage related teaching and research purposes right after the establishment of the Arba Minch Water Technology Institute (AWTI) in 1986.

The study area is situated at 37° 34‘ E longitude and 6° 04‘ N latitude, and at an altitude of 1203 m. a.s.l (Figure 1). Mean annual rainfall of the study area is about 750 mm. Average maximum and minimum temperature is about 13 and 29.6°C, respectively. The rainfall distribution has a bimodal nature with the first and second rainfall during February to April and June to September, respectively. The soil of the study area is characterized as clay textured with average filed capacity and permanent wilting point of 34.2 and 18.7%, respectively (Table 1).

Soil characteristics of the study area

Soil samples from the study area were collected from each horizon up to 120 cm depth to characterize the soil in terms of physical characteristics such as textural class (soil texture), EC, pH, organic matter, and the average bulk density. The above mentioned soil parameters were analyzed at in the soil laboratory of AMU. Using Hydrometer method and USDA soil textural triangle, the texture of each 30 cm layer was determined as shown in the Table 1 for the total depth of 120 cm and the texture of the whole profile was clay soil. The experimental site had average field capacity (FC) of 34.25% and average permanent welting point (PWP) 18.7% with the average total available water (TAW) 15.5% in volume percentage (Seyoum, 2006).

The soil pH was determined in 1:2.5 soil: water suspension ratio by potentiometric method using glass electrode. The pH of soils was alkaline ranged from 8.1 to 8.3 with an average of 8.2 and it does not show significant difference throughout the profile.

Electrical conductivity was determined in 1:5 soil: water ratio extract using cell electrode and expressed as dS m^{-1} and appropriate temperature conversion factors for correcting conductivity data to standard temperature of 25°C were used. Measured soil salinity was low as indicated by electrical conductivity (EC) values throughout the profile which ranged from 0.058 to 0.060 ds m^{-1}. The highest EC (0.060 dS/m) was recorded in the lower horizon of the soil profile and lowest in the second from the bottom (60 - 90 cm) horizon of the soil profile.

Experimental design

The experiment was conducted in an intensively cultivated area of Arba Minch University demonstration site. It was designed to expose maize crop (BH-140) to water deficit during one or more of its growing stages. The treatments were watered at the levels of: 100, 75, 50 and 25%ETc to that of the total crop water requirement during four growing stages of the selected crop by considering four growing stages of the crop (Allen et al., 1998) there were ten treatments as indicated in Table 2.

In order to illustrate the impacts of water deficit on yield and some agronomic characteristics of maize, a study was conducted as randomized complete blocks design (RCBD) and three replications to yield a total of 30 experimental plots. The size of each experimental plot was 5 × 4 m. The space between plots and replications were 1.50 and 2 m, respectively. The BH-140 hybrid of maize was selected for the study and it was planted with 40 cm between plant and 80 cm raw spacing. This crop variety was selected for its good adaptability and most usable in the study area. The growing season of the crop was mainly divided into four major growth periods: initial, development, flowering and maturity stages based.

Each plot had five furrows for irrigation water application and five planting rows. The furrows were regularly maintained to sustain their water storage capacities over the season. These treatments were arranged in a way that a single treatment was not subjected to

Table 1. soil physical and chemical properties for the experimental site.

Soil depth (cm)	Type of analysis										
	Bulk density (gm/cm^3)	EC (ds/m)	pH	% Sand	% silt	% Clay	Texture	Organic Matter %	FC Vol. %	PWP Vol. %	TAW Vol. %
0 - 30	1.2	0.059	8.3	20.7	12.0	67.3	Clay	13.0	39.3	21.3	18.0
30 - 60	1.2	0.059	8.1	14.0	34.7	51.3	Clay	13.9	34.7	19.7	15.0
60 - 90	1.3	0.058	8.3	16.7	26.0	57.3	Clay	12.6	31.6	17.0	14.6
90 - 120	1.1	0.060	8.1	20.7	20.0	59.3	Clay	12.4	31.4	16.8	14.6
Average	1.2	0.059	8.2	18.0	23.2	58.8	Clay	13.0	34.25	18.7	15.55

Table 2. Total number of treatment combinations over crop growing stages.

Treatment	Crop growing stages/Level of water application in %			
	1	2	3	4
T1	100	100	100	100
T2	100	75	75	75
T3	100	100	75	75
T4	100	100	100	75
T5	100	50	50	50
T6	100	100	50	50
T7	100	100	100	50
T8	100	25	25	25
T9	100	100	25	25
T10	100	100	100	25

one level of deficit for the whole growing stage with the exception of control one, T1.

Crop water requirements and irrigation scheduling

The daily crop water requirements were calculated by multiplying the reference evapotranspiration values with the maize crop coefficients (0.3, 0.5, 1.2 and 0.5) initial, development, flowering and maturity stages, respectively given by Allen et al. (1998). The amount of irrigation water required at 10 days interval, number of irrigation events is summarized in Table 3. Fixed interval (every ten days) and variable depth (refill to field capacity) irrigation scheduling technique was selected. Optimal or ‘‘no stress’’ irrigation was calculated using the FAO CROPWAT program as the net amount of irrigation required to refill the soil moisture deficit with weekly application of irrigation water. The depth applied to other treatments was taken simply as percentage of the optimal irrigation at specific growth stage or throughout the growing season.

Agronomic practices and water application

Land preparations was done using labor forces for seedbed preparation and the experiment was conducted during the dry season using irrigation water only (no rainfed) in which shelters were used to exclude rain. Maize (BH-140) cultivar was sown by hand at the end of January and harvested at the end of June of the same year. The 90% seedling emergence was observed about 7 days later. After germination and establishment, thinning was carried out to maintain the spacing between plants to be 40 cm. 12 kg/ha DAP (diammonium phosphate) was applied during sowing period where as 10 kg/ha urea was applied twice during vegetative stage and at the beginning of flowering stage, respectively.

First, the required crop water was calculated using CROPWAT 8.0 computer programme (Allen et al., 1998) on daily basis. Calculations of water and irrigation requirements were done using inputs of climatic, crop and soil data, as well as irrigation and rain data. Daily reference evapotranspiration was calculated from max- and min- temperature, humidity, sunshine/radiation, and wind-speed data, according to the FAO Penman-Monteith method (FAO, 1998). After determining the total irrigation water requirement, the different water application levels (Table 2) to induce water deficits were quantified. Accordingly, the corresponding irrigation amount has supplied to each experimental plot using calibrated siphon tubes through furrow irrigation method and appropriate flow control equipment was used. Water was carefully controlled to avoid the flow of water into water deficit plots. Since the furrows are close ended all water flowing into the furrows were infiltrated over the entire length, that is, there was no runoff. The fact that the furrows are short, the stream size is large and the cut-off time is short, no significant deep percolation will be expected. Soil moisture was determined using gravimetric method by taking soil samples from effective root zone of the crop two days before and after irrigation. To maintain the capacity of furrows constant throughout the growing season, maintenances were done every time before irrigation.

Plots which are to be subjected to water deficit during particular growth stage according to schedule were deprived of irrigation water application and also protected from possible supply of water through rainfall using plastic shelters. The shelters were designed in such a way that they can easily be rolled-up when there is no

Table 3. Amount of irrigation water required for maize in 10 days interval (mm).

	Treatment									
Date	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**T9**	**T10**
10-Feb	61.1	61.1	61.1	61.1	61.1	61.1	61.1	61.1	61.1	61.1
20-Feb	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7	30.7
2-Mar	30.4	22.8	30.4	30.4	15.2	30.4	30.4	7.6	30.4	30.4
12-Mar	36.6	27.5	36.6	36.6	18.3	36.6	36.6	9.2	36.6	36.6
22-Mar	55.5	41.6	55.5	55.5	27.8	55.5	55.5	13.9	55.5	55.5
1-Apr	63.7	47.8	63.7	63.7	31.9	63.7	63.7	15.9	63.7	63.7
11-Apr	68.3	51.2	51.2	68.3	34.2	34.2	68.3	17.1	17.1	68.3
21-Apr	60.1	45.1	45.1	60.1	30.1	30.1	60.1	15.0	15.0	60.1
1-May	55.7	41.8	41.8	55.7	27.9	27.9	55.7	13.9	13.9	55.7
11-May	60.7	45.5	45.5	60.7	30.4	30.4	60.7	15.2	15.2	60.7
21-May	66.1	49.6	49.6	66.1	33.1	33.1	66.1	16.5	16.5	66.1
31-May	61.0	45.8	45.8	45.8	30.5	30.5	30.5	15.3	15.3	15.3
10-Jun	42.6	32.0	32.0	21.3	21.3	21.3	10.7	10.7	10.7	10.7
20-Jun	27.6	20.7	20.7	13.8	13.8	13.8	13.8	6.9	6.9	6.9
26-Jun	0	0	0	0	0	0	0	0	0	0
Total	720.1	563.0	609.6	687.3	406.0	499.1	654.5	248.9	388.5	621.7

rainfall and unrolled when rainfall occurs and during night. At the end of each irrigation application or before the next irrigation leaf area and aboveground biomass were collected by removing one plant per plot.

Crop water productivity

Crop water productivity (WP) or irrigation water use efficiency (IWUE), as reviewed by Molden (2003), is a key term in the evaluation of deficit irrigation (DI) strategies. The water productivity with dimensions of kg/m^3 is defined as the ratio of the mass of grain yield (Ya, kg/ha) to the volume of water consumed by the crop (Eta, mm):

$$WP = \frac{Y_a}{ET_a} \quad (1)$$

Eta refers to water lost both by soil evaporation and by crop transpiration during the crop cycle. Since there is no easy way of separating between these two processes in field experiments, they are generally combined under the term of evapotranspiration (ET) (Allen et al., 1998).

$$ET_C = I + P - D - R_O \pm \Delta S \quad (2)$$

Where I, P, and D are irrigation, precipitation, deep percolation (mm) respectively; Ro is runoff (mm); ΔS is the change in soil moisture storage between soil moisture measurements (mm).

Crop parameters and measurements

The days from sowing to emergence, maximum canopy cover, start of senescence, and physiological maturity, as well as maximum rooting depth were recorded in the field. The base and upper temperatures were assumed to be 10 and 30°C, respectively. Root observation was done in the field at about maximum canopy cover and at maturity from all plots. Leaf length, L (cm) and leaf width, W (cm) of plants from each treatment was measured using tape meter at 10-day intervals throughout the growing season.

The total leaf area A (cm^2) for maize leaves was therefore obtained with the relationship (Kang et al., 2003):

$$A = 0.759 \sum_{i=1}^{m} L_i \times W_i \quad (3)$$

The LAI was obtained by the ratio of total leaf area of per unit ground area:

$$LAI = \frac{\text{Measured leaf area per plant}\,(cm^2)}{100 \times 100\, cm^2} \times \frac{\text{number of plants}}{m^2} \quad (4)$$

AquaCrop simulates transpiration in terms of canopy cover (CC) of the crop, but often experimental studies measure LAI but not canopy cover. Therefore, canopy cover was estimated from leaf area index based on Hsiao et al. (2009).

$$CC = 1.005 \times \left[1 - \exp(-0.6\,LAI)\right]^{1.2} \quad (5)$$

Where CC (%) is canopy cover and LAI is leaf area index.

An empirical relationship between CC and LAI of maize was obtained by regression, plus slight adjustments at the extreme low and high end of CC values.

Data collection and analysis

All relevant data including weather conditions, soil and crop characteristics (such as open air dried aboveground biomass and yield, leaf area), and amount and timing of irrigation have been collected from the experimental plots and analysis was made to identify optimal deficit irrigation management practices based on crop yield responses and water use efficiency. For this purpose JMP5, GenStat 12th Edition softwares were used. Weight of seeds of each plot from the three middle furrows was recorded. One plant per plot was uprooted before the next irrigation and dried in open air and weighed after chopping it into pieces.

The open air dried grain yield and above ground dry biomass weight was measured at 13% moisture content. The data collected were subjected to descriptive statistical analysis and ANOVA test to see the effects of different treatments on the yield and water use efficiency. The results are presented in the form of tables and figures.

Model performance evaluation

The performance of the model was evaluated using the following statistical parameters of the root mean square error (RMSE) calculated as:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(O_i - S_i)^2} \quad (6)$$

And the model efficiency (ME) (Nash and Sutcliffe, 1970) is calculated as:

$$ME = 1 - \frac{\sum_{i=1}^{N}(O_i - S_i)^2}{\sum_{i=1}^{N}(O_i - \bar{O}_i)^2} \quad (7)$$

Where Si and Oi are the simulated and observed (measured) values as samples taken along the season (e.g., biomass and CC), or at the end of the season (e.g., grain yield), N is the number of observations, and $\bar{O}_i$ is the mean value of O_i. ME ranges from negative infinity to Positive 1; the closer to 1, the more robust the model.

The RMSE in Equation 6 represents a measure of the overall, or mean, deviation between observed and simulated values, that is, a synthetic indicator of the absolute model uncertainty. In fact, it takes the same units of the variable being simulated, and therefore the closer the value is to zero, the better the model simulation performance.

Sensitivity analysis

Before applying a model, it is necessary to have some familiarity with its behavior and sensitivity to input parameters. Sensitivity analysis helps to recognize the parameters that have significant impact on model output.

To assess the robustness of the AquaCrop model for maize crop under Arbaminch condition and the required quality of the input data, a sensitivity analysis was worked out by altering inputs and by keeping some inputs constant such as normalized water productivity (WP* = 32 for C4 crops), Temperature (base temperature = 10 and upper temperature = 30). The inputs for sensitivity analysis for this research were agronomic data, soil, meteorology, and irrigation management data. In order to compare the model outputs, the inputs were changed by trial and error in each step. After changing the values of input parameters, the model outputs were compared with the observed data. The results showed that the most sensitive agronomic parameter in AquaCrop model were time to senescence, reference harvest index (HIo), canopy development, canopy decline. However, the model showed less sensitive to time of seed emergence, length of flowering period, days to flowering. The difference in simulated above ground biomass and grain yield was used for the assessment. In general, the most sensitive parameters were those which are cultivar specific parameters (with white cell box) and less sensitive parameters are those with silver cell box in the model.

RESULTS AND DISCUSSION

Yield, biomass, and water use efficiency

The result in Table 4 indicated that yield of maize was significantly ($p < 0.05$) affected by the deficit irrigation. The highest yield was found in T6 (8.842 t/ha) which was subjected to water deficit during mid and maturity-stages whereas minimum yield of maize was obtained under T8 (5.264 t/ha) which was deficit during the whole growing season except during the initial stage.

According to the result shown in Table 4 both T2, T3, T6, and T7 are within the yielding potential of the hybrid (BH-140) maize crop yield collected from the research center which is 7.5 to 8.5 t/ha, and the remaining treatment were also in the range of yield collected from the farmer which is 4.7 to 6.0 t/ha (source; Bako Agricultral Mechanization Research Center).

There was significant different between the yield of T6 (8.842 t/ha) and T8 (5.264 t/ha) which was giving 25%Etc during development-, middle-, and late/maturity-stages of the crop growing season. According to the result obtained, giving 25%ETc during development-, middle-, and late/maturity-stages of the crop growing season has affected the yield of maize more as compared to other treatments. Giving 50%ETc of crop water requirement during middle- and maturity-stages were better than giving 100%ETc of crop water requirement throughout the growing season.

On the other hand, ANOVA showed that irrigation water use efficiency (IWUE) was significantly different. Thus, T8 (2.11 kg/m^3) and T4 (0.93 kg/m^3) had the highest and the lowest irrigation water use efficiency, respectively. This result elaborated that applying 25%ETc of crop water requirement during development-, mid-, and late /maturity-stages of the crop growing season has better water use efficiency than applying optimal irrigation with (100%ETc) crop water requirement.

As indicated in Table 4, T6 had the highest and T8 the lowest yield. From the treatments, highest amount of water was saved in T8 (65%) and 5% of water was saved in T4 taking into account T1 as a control (crop water requirement base). The amount of water saved in T6 was 31% which is higher than the other six treatments (T1, T2, T3, T4, T7, and T10). When the treatments are compared in terms of yield reduction/increase, T6 had (-23%) which shows there is no yield reduction rather 23%

Table 4. The amount of water saved and yield reduction.

Treatment	Irrigation (m^3/ha)	Yield (kg/ha)	IWUE (kg/m^3)	Water saved (%)	Yield Reduction (%)	Above ground dry biomass (t/ha)	HI (-)
T1	7201	7212	1.01	0	0	13.385	0.539
T2	5630	7576	1.35	22	-5	11.827	0.641
T3	6096	8088	1.33	15	-12	12.202	0.663
T4	6873	6418	0.93	5	11	12.723	0.504
T5	4060	6189	1.52	44	14	10.394	0.595
T6	4991	8842	1.77	31	-23	10.484	0.843
T7	6545	8369	1.28	9	-16	11.675	0.717
T8	2489	5264	2.11	65	27	8.862	0.594
T9	388.5	5929	1.53	46	18	9.327	0.636
T10	621.7	6736	1.08	14	7	10.290	0.655

yield increase compare to the control treatment (T1) and T8 (27%) the highest yield reduction since T1 is considered as control.

The grain yield and aboveground dry-biomass of the maize plant is presented in Table 4. ANOVA test showed that there is a significant difference between treatments in terms of grain yield and total aboveground dry-biomass. It shows that there is no significant difference between Treatments T1, T3, T4, and T7 in terms of aboveground dry-biomass.

The harvest index (HI) which refers to the percentage dry matter allocated to grain yield, increasing with increasing magnitude of deficit from all except under T6. The lowest HI is 0.504 and the highest is 0.84. These values are relatively higher than the values of 0.31 - 0.55 reported by Farre and Faci (2009) as cited by Mekonen (2011).

Simulation using AquaCrop model

Model calibration and validation

The model has been calibrated based on the measured crop data of all the treatments. The main calibration parameters for CC include the canopy growth coefficient (CGC), the canopy decline coefficient (CDC), water stress (P_{upper}, P_{lower} and the shape factor) affecting leaf expansion and early senescence. Canopy cover per seedling was estimated based on the general knowledge of the crop characteristics by specifying row spacing and plant spacing. Then, simulation was done for the above crop phenologies and the results were compared with the measured values.

In the model, initial canopy cover (CCo) was estimated based on the data from agronomic practice from row planting, row spacing (0.80 m) and plant spacing (0.40 m). Hence, the estimated initial canopy cover (CCo) for the given maize crop has been found 0.16% (3.1 plants/m^2 or 31, 250 plants/ha).

To estimate the canopy expansion rate, phonological data (listed in Table 5) such as dates to emergence, maximum canopy cover, senescence and maturity were used. The model resulted fast canopy expansion and moderate canopy decline. The canopy growth coefficient (CGC) and canopy decline coefficient (CDC) were 1.46%/°C/day and 0.114% /°C/day, respectively.

The crop parameters used for calibrating the model are presented in Tables 5 and 6. Table 5 shows maize phenological development. Table 6 shows the different crop parameters and the values used for calibrating the model. Stress parameters such as canopy expansion and canopy senescence coefficients were adjusted and re-adjusted to simulate the measured canopy cover.

The simulated above ground dry biomass agreed well with the observed biomass (Figure 3). There was strong relationship between the observed and simulated biomass (R^2 > 0.85). Table 7 shows a deviation of the simulated grain yield and above ground dry biomass from their corresponding observed data. The deviation of the simulated above ground dry biomass from the observed data for both T5 (69.23%) and T8 (84.39%) shows there was over estimated of above ground dry biomass by the model. Whereas the deviations of the simulated grain yield from the observed data for both T5 (-35.72%) and T8 (-94.96%) shows there was under estimation of grain yield of maize crop by the model. Although not largely different, the aboveground dry biomass was better simulated by the model when compared with the grain yield which is in line with Araya (2010b).

Both grain yield and above ground dry biomass were adequately simulated by the model. The simulated grain yield (Figure 4) and above ground dry biomass (Figure 5) agreed well with their observed grain yield and above ground dry biomass except for both T5 and T8 which was consecutively subjected to water deficit from development to maturity stages. There was strong relationship between the observed and simulated above

Table 5. Phenological observations of Maize crop (BH 140) from the study area (maximum rooting depth in 1.80 m).

Growth parameter	Days
Sowing to emergence	7
Sowing to flowering	68
Sowing to start of senescence	110
Sowing to max canopy cover	68
Sowing to max rooting depth	110
Sowing to harvesting	147

Table 6. Crop data input used in AquaCrop to simulate maize.

Description	Value	Units	Interpretation
Canopy cover per seedling at 90% emergence (CCo)	0.16	%	Increase in CC relative to existing CC. (3.1 cm^2 per plant)
Canopy growth coefficient (CGC)	1.46	%/°C/day	Increase in CC relative to existing CC per GDD
Maximum canopy cover (CCx)	90	%	well covered
Maximum crop coefficient	1.25	-	At max canopy
Canopy decline coefficient (CDC) at senescence	1.14	%/°C/day	Decrease in CC relative to CCx per GDD
Water productivity	32	g/m^2	Biomass per m^2
Upper threshold for canopy expansion	0.20	-	Leaf growth stop completely at this P value
lower threshold for canopy expansion (P_{lower})	0.55	-	Above this leaf growth is inhibited
Leaf expansion stress coefficient curve shape	3.1	-	
Upper threshold for stomatal closure	0.55	-	Moderately tolerant to water stress but above this stomata begins to close
Stomata stress coefficient curve shape	3.1	-	
Canopy senescence stress coefficient (Pupper)	0.55	-	Above this canopy senescence begins
Senescence stress coefficient curve shape	3.1	-	
Reference harvest index (HIo)	70	-	Common for good condition
Coefficient, HI increased by inhibition of leaf growth at flowering	0.85	-	Upper threshold for increase in HI due to inhibition of leaf growth
Coefficient, HI increased due to inhibition of leaf growth before flowering	12	%	Maximum HI increased by inhibition of leaf growth before flowering
Coefficient, HI decreased due to water stress affecting stomata closure during yield formation	5	-	Moderate
Coefficient, HI increased due to water stress affecting leaf expansion during yield formation	2	-	Moderate

As shown in Figure 2 the simulated and observed canopy cover was well correlated with strong relationship ($R^2 > 0.80$).

ground biomass and grain yield ($R^2 > 0.91$).

Model performance evaluation

The model efficiency (ME) and root mean square of error (RMSE) was used to evaluate the model performance. These parameters showed good to moderate performance for above ground dry biomass (ME = 0.99, RMSE = 0.81 t/ha) and grain yield (ME = 0.97, RMSE = 1.25 t/ha). Model efficiency and mean square error for aboveground dry biomass was done by removing the two most outliers (T5 and T8). According to the validation results, the calculated ME were close to one that is the more the robust the model. Also, moderate RMSE values indicate the good performance of the model.

Conclusions

The advantage of deficit irrigation lies in saving water and

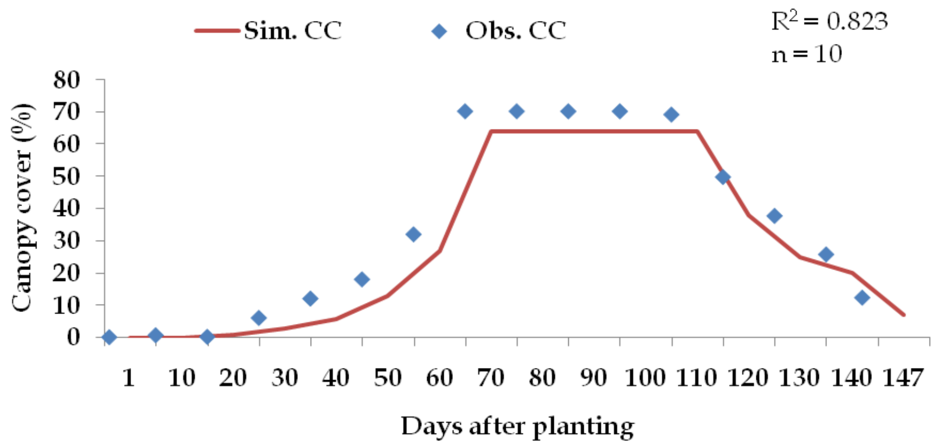

Figure 2. Simulated and observed canopy cover.

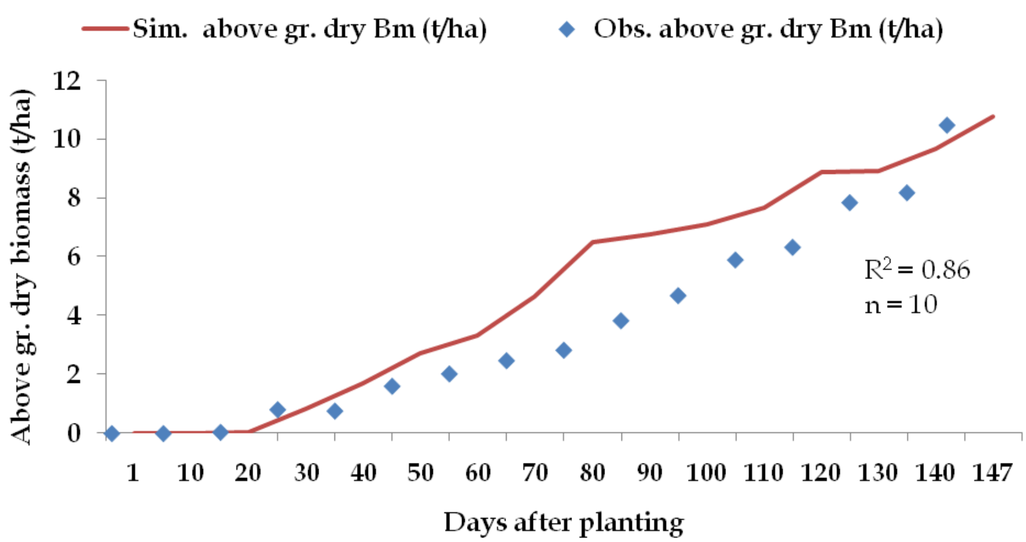

Figure 3. Simulated and observed above ground dry biomass.

Table 7. Simulated and observed grain yield and above ground dry biomass of treatments and % of deviations from observed.

Treatment	Yield			Above ground dry biomass		
	Observed (t/ha)	Simulated (t/ha)	Dev. (%)	Observed (t/ha)	Simulated (t/ha)	Dev. (%)
T1	7.21	7.61	5.23	13.39	14.85	9.87
T2	7.58	8.27	8.39	11.83	12.51	5.46
T3	8.09	9.27	12.75	12.20	12.96	5.85
T4	6.42	7.61	15.66	12.72	13.85	8.14
T5	6.19	4.56	-35.72	10.39	33.78	69.23
T6	8.84	10.27	13.90	10.48	10.78	2.75
T7	8.37	8.34	-0.35	11.68	11.99	2.63
T8	5.26	2.70	-94.96	8.86	56.76	84.39
T9	5.93	6.42	7.65	9.33	9.99	6.64
T10	6.74	7.61	11.48	10.29	10.74	4.19

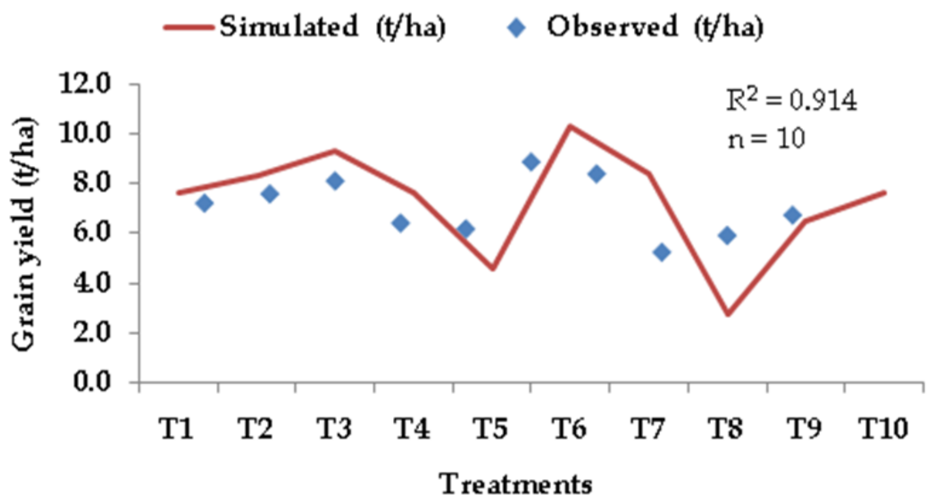

Figure 4. Comparison of simulated and observed grain yield of each treatment.

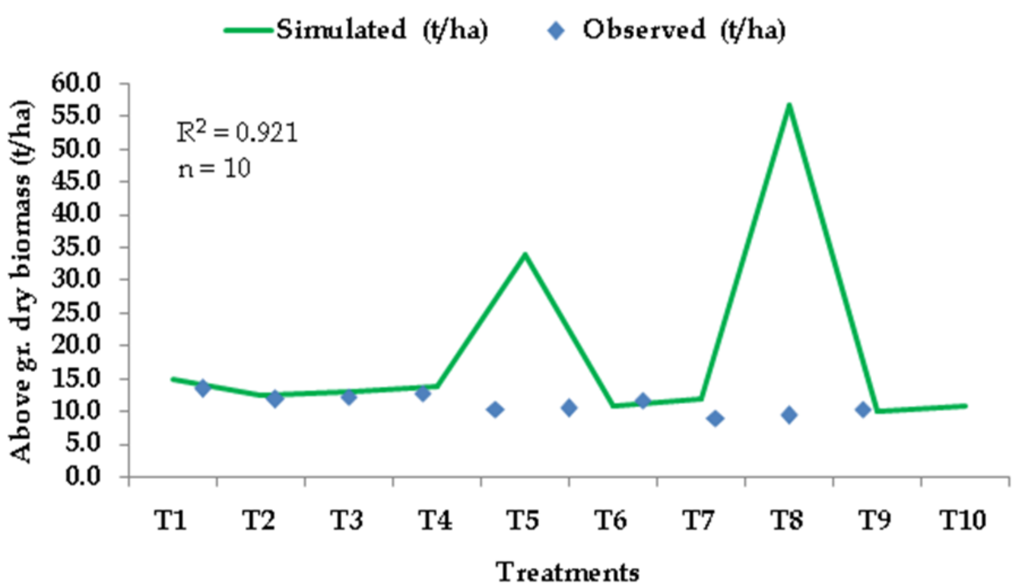

Figure 5. Comparison of simulated and observed above ground dry biomass of each treatment.

increase water productivity while maintaining optimum yield as close to fully irrigated farm (Mekonen, 2011). From the results of the experiment, continuously applied 25% of the total crop water requirement showed more yield reduction. On the other hand, slightly deficit treatments had less yield reductions. However, even 50%ETc water application throughout the growing season except the first stage had significant yield reduction. This indicates that prolonged water deficit below 50% of crop water requirement could significantly affect the yield.

There was no yield reduction observed under treatments which was irrigated 50%ETc during third and forth growth stage, followed by treatments irrigated 75%ETc during first, second, and third growth stages and plot irrigated 25% of crop water requirement only during the last stage. This indicates that water deficit at flowering and harvesting stages up to 50%Etc and only 25%ETc at harvesting stage have not significantly affected the yield. That means with this application, water and other irrigation expenses can be saved. By doing so more land can be irrigated with the saved water to enhance more production.

Generally, full irrigation has not significantly improved the grain and dray biomass yield when compared with their corresponding deficit irrigation treatment. In line with Nagaz et al. (2008) as cited in Araya 2010a obtained the highest yield and biomass at full irrigation (100%ETc) but was not significantly higher than the treatment with mild water stress (above 50%Etc at third and fourth growing stages). Hence, it is possible to generalize that the maize (BH-140) cultivar in our study site has showed positive response to mild water stress condition.

Besides to this, the most sensitive stage of any crop must be investigated to reduce sever yield reduction effects. The knowledge of the most sensitive stages of any crop to water deficit is crucial to manage and apply deficit irrigation technologies. Identifying sensitive growth stages of a particular cultivar under local conditions of climate and soil fertility allows irrigation scheduling for both maximum crop yield and most efficient use of scarce water resources. Hence, we found the most sensitive stage was during the third stage if we irrigate below 50%Etc.

In general, IWUE has increased with decreasing water application which, however is also related to decreased grain yield and hence may not be desirable from the farmers' perspective. Other agricultural inputs need to be appropriately used to enhance productivity by maintaining improved IWUE.

AquaCrop model's calibration and validation is necessary for each crop and in every climate. The results of this research showed that this model is capable of simulating above ground biomass, canopy cover, and grain yield of maize for full supplied irrigation and treatments with some water deficit; but under sever water deficit (25%ETc of full irrigation), and prolonged 50% water stress, the model performed less satisfactorily. According to the validation or model evaluation results, the calculated RMSE and ME values were 0.81 t/ha and 0.99 for grain yield; and 1.25 t/ha and 0.97 for above ground dry biomass, respectively.

RECOMMENDATIONS

The highest yield was found from T6 (8.84 t ha^{-1}) by giving 50% of crop water requirement during the third growth stage which is still better than giving 100% of crop water requirement (full irrigation) throughout the growing season. Therefore, we can recommend that this application of irrigation water (100, 100, 50 and 50%) is best for Arba Minch condition.

AquaCrop version 3.1 has adequately simulated the above ground dry biomass, grain yield, HI, and canopy cover of maize under various irrigation water conditions. There was over estimation of aboveground dry biomass and under estimated of grain yield of maize crop by the model for treatment consequently subjected to water deficit (T5) and for the severely deficit treatment (T8). From this we can recommend that, AquaCrop model is less satisfactory simulating treatments with sever or prolonged water deficit below 50%ETc.

Assuming that water is scarce and land is not scarce, the model has indicated the possibility of obtaining more grain and biomass from relatively larger maize crop by applying less water. This result may contribute to food security improvement through increasing crop yields especially in water deficit areas.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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Abbreviations: °C, Degree celsius; **AMU**, Arba Minch University; **BH**, Bako Hybrid; **CC**, Canopy Cover; **CSA**, Central Statics Agency of Ethiopia; **dS m^{-1}**, deci-Siemen per meter; **EC**, electrical conductivity; **Etc**, crop evapotranspiration; **FAO**, Food and Agriculture Organization; **GDD**, growing degree days; **Kg/ha**, Kilogram per hectare; **kg/m^3**, kilogram per meter cube; **LAI**, Leaf Area Index; **SNNP**, Southern Nations, Nationalities, and People's Region; **t/ha**, tones per hectare; **T1, T2,…, T10**, Treatment one, Treatment two,…, Treatment ten; **USDA**, United States Department of Agriculture.

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Aggregation and organic matter content in different tillage systems for sugarcane

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Monitoring the physical quality of Cerrado soils under intensive sugarcane production requires sustainable forms of soil use and management. Thus, the objective of this research was to evaluate the aggregation and organic matter content in soil planted with sugarcane under different tillage systems. The experiment was conducted at the Jalles Machado Sugarcane Mill, in the city of Goianésia – Goiás State, Brazil. The statistical design was a randomized block with four replications. The following treatments were evaluated: 1. Moldboard plow + harrow (AA + G); 2. Ripper + harrow (SS + G); 3. Direct furrowing (SD); 4. Ripper + direct furrowing (SS + SD); 5. Stubble thrasher + ripper (DS + SS); 6. Stubble thrasher + harrow + moldboard plow + harrow (DS + GAAG), for the soil layers of 0-0.2; 0.2-0.4 and 0.4-0.6 m depth. The highest soil organic matter (SOM) levels, geometric mean diameter (GMD) values and distribution of aggregates between 4-2 mm were found in the 0-0.2 m layer for the SD and SS + SD treatment. There was a positive correlation between the SOM and GMD values. SD, SS + SD and DS + GAAG systems showed higher soil aggregate classes between 4-2 mm when compared to DS + SS in the 0.2-0.4 m layer. There was also an increase in the <0.25 mm class for AA + G. The AA + G + and DS + GAAG conventional systems had higher sugarcane yields, but these results were statistically similar to the conservation cropping system.

Key words: Soil management, aggregates, Brazilian Cerrado, ratoon.

INTRODUCTION

The intense soil preparation with the use of plows, heavy harrows, rippers and deep furrowing for planting sugarcane are soil impacting practices that directly affect soil structure and the stability of aggregates (Souza and Alves, 2003). Consequently, in recent years, we have started to question the tillage for sugarcane production looking for management alternatives that prioritize minimum soil tilling.

According to Hamza and Anderson (2005), among the soil management components, preparation may influence the attributes of soil physical quality parameters the most, as they act directly on its structure. The fact is that when tillage is not performed with the right technologies for each soil class, the soil physical properties are altered, including aggregation processes (Castro Filho et al., 1998; Choudhurya et al., 2014), soil compaction

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Table 1. Chemical characterization of soil for the second ratoon crop, Jalles Machado Sugar Refining Mill, Goianésia-Goiás, Brazil, 2012.

Soil layer (m)	pH	Ca^{+2}	Mg^{+2}	Al^{+3}	P	K^{+}	H + Al^{+3}	V	O.M.
		$cmol_cdm^{-3}$			mg dm^{-3}		$cmol_cdm^{-3}$	%	g kg^{-1}
0.0-0.2	6.02	1.40	0.78	0.04	3.26	52.00	2.22	50.70	23.80
0.2-0.4	5.21	2.30	0.32	0.24	2.24	24.70	2.70	49.80	16.70
0.4-0.6	5.21	0.35	0.24	0.17	0.48	19.08	2.30	21.50	13.90

pH in H_2O; Ca^{+2}, Mg^{+2} and Al^{+3} in KCl (1 mol L^{-1}); P and K^+ in HCl (0.05 mol L^{-1}) + H_2SO_4 (0.0125 mol L^{-1}); H + Al in Buffer (SMP at pH 7.0); Base saturation (V); O.M: Organic matter (Colorimetric Method). Embrapa (2009). The Ca^{+2}, Mg^{+2} and Al^{+3} in $cmol_cdm^{-3}$; P and K^+ in mg dm^{-3}; H+Al in $cmol_cdm^{-3}$.

(Bangita and Rajashekhar Rao, 2012), pore size distribution, and consequently, the water availability to the crop (Aina, 1979).

The physical state of the soil aggregation has to be well observed when analyzing physical quality (Aratani et al., 2009). However, it is important to consider the soil organic matter levels, which is the main soil formation and stabilization agent (Wendling et al., 2005). Studies conducted in recent years, which explore the relationship between aggregates and soil organic matter, mineral fraction, soil fauna, roots and environmental variables, show that these are the factors which favor the formation of soil aggregates (Salton et al., 2008).

The average aggregate size and the proportion of aggregates are used as stability indices (Reinert and Reichert, 2006), where the microaggregates are more stable and the macroaggregates are more susceptible to changes with the use of agricultural management practices (Pagliarini et al., 2012). According to Almeida et al. (2009), the adoption of soil management systems that provide the addition of a large amount of residues in the soil favors a high energy and matter flow, consequently, tending to form larger aggregates, thus contributing to the soil quality increase process.

Understanding and quantifying the impacts caused by different soil tillage systems on physical quality are fundamental in the development of sustainable agricultural systems (Tormena et al., 2004).

The long-term effect of soil preparation systems on the formation of soil aggregates is not well documented for the Cerrado region. Therefore, the objective of this research was to evaluate the aggregation and organic matter content of an Dystrophic Yellow Red Latosol for sugarcane cultivated under different soil tillage systems.

MATERIALS AND METHODS

Area characterization

The experiment was conducted in a sugarcane field at the Jalles Machado sugarcane mill, in the city of Goianésia – Goiás State, Brazil, located at the coordinates 15°10'02 "south latitude and 49°15'12" west longitude. The climate in the region is classified as Aw type (Megathermal) or Tropical savanna climate, with dry winters and rainy summers, according to the Köppen classification. The altitude is approximately 640 m and average annual rainfall is 1600 mm. The soil was classified as Dystrophic Yellow Red Latosol according to Brazilian System of Soil Classification (Embrapa, 2013). The particle size analysis of the soil showed 432; 450 and 452 g kg^{-1} of clay in the 0-0.2; 0.2-0.4 and 0.4-0.6 m layers, respectively (Embrapa, 2009). Chemical analysis of the soil is presented in Table 1.

Historically, the area was used for grain production (soybeans, corn and sorghum) until the 2003 agricultural year when sugarcane cultivation began. The experiment was established on a sugarcane plantation at the time of soil preparation for the 2009/2010 planting season. The evaluation occurred in the 2011/2012 season.

The experimental units were 19.5 m wide × 50.0 m long, consisting of 13 lines of sugarcane spaced at 1.5 m. The total area of the plots was 975.0 m^2. This study evaluates five central lines, 30.0 m in length each, with a total area of 225.0 m^2. The experimental design was a randomized block design (RBD) with 6 × 3 factorial split-plot (tillage × soil layers). Treatments consisted of tillage systems used in soil preparation as following: 1. Moldboard + harrow (AA + G); 2. Ripper + harrow (SS + G); 3.Desiccation + Direct furrowing (SD); 4.Ripper + Direct furrowing (SS + SD); 5.Stubble thrasher + Ripper (DS + SS); 6. Stubble thrasher + harrow + Moldboard + harrow (DS + GAAG), for the soil layers of 0-0.2; 0.2-0.4 and 0.4-0.6 m depth in four replications (Table 2).

The aim of this experiment was to evaluate the geometric mean diameter (GMD) of the aggregates and the soil organic matter (SOM) in soil layer (0-0.2, 0.2-0.4 and 0.4-0.6). Distribution of aggregate size classes (4-2, 2-1, 1-0.5, 0.5-0.25 and <0.25 mm) was evaluated in a 5 × 6 factorial (tillage × classes aggregates), individually for each soil layer (0-0.2 and 0.2-0.4 m). The experiment began in March 2009 by liming the soil with dolomitic limestone at a dose of 1.5 t ha^{-1}. Gypsum was applied at the soil surface at a dose of 800 kg ha^{-1}.

Manual planting of sugarcane was performed with furrowing (average depth of 0.35 to 0.4 m), placing 18 buds per m^{-2} of the CTC 02 variety. Fertilization with 250 kg ha^{-1} of Monoammonium Phosphate (MAP), equivalent to 120 kg ha^{-1} of P_2O_5 and 27 kg ha^{-1} of nitrogen ($N\text{-}NH_4^+$), was undertakn at planting. Cover fertilization of the crop was done in September 2009 with liquid formulation N-P-K of 05-00-13 + 0.3% zinc + 0.3% Boron. The fertilization for ratoon cane (2010/2011 and 2011/2012 crop seasons) was performed according to the requirements of the plant and estimated productivity by surface application of 90 kg ha^{-1} N, 30 kg ha^{-1} P_2O_5 and 110 kg ha^{-1} of K_2O in both seasons.

Disturbed samples were collected in the 0-0.2, 0.2-0.4 and 0.4-0.6 m layers. Soil sampling was collected with a hoe and spade, opening furrows with dimensions of approximately 0.1 × 0.5 ×0.2 m.

Variables and statistical analysis

The stability of the aggregates was determined via wet sieving

Table 2. Different tillage systems and soil layers in ratoon cane cultivation in the Cerrado region, 2009, in Goianésia, Goiás State, Brazil.

Treatments	Operations in soil tillage systems
AA+G	Moldboard (soil layer of 0.35 to 0.4 m) and harrow (soil layer of 0.15 to 0.2 m)
SS+G	Ripper (soil layer of 0.4 m) and harrow (soil layer of 0.15 to 0.2m)
SD	Desiccation (Glyphosate and 2.4 D, doses of 3.0 and 2.0 L ha^{-1}, respectively). Direct furrowing (soil layer of 0.3 to 0.4 m)
SS+SD	Ripper (soil layer of 0.4 m) and direct furrowing (soil layer of 0.3 to 0.4 m)
DS+SS	Stubble thrasher (soil layer of 0.0 to 0.2 m) and ripper (soil layer of 0.4 m)
DS+GAAG	Stubble thrasher (soil layer of 0.0 to 0.2 m), harrow (soil layer of 0.15 to 0.2 m), moldboard (soil layer of 0.35 to 0.4 m) and harrow (soil layer of 0.15 to 0.2 m)

according to Embrapa (1997), where aggregates of 2-4 mm in size were agitated in the Yoder machine (Yoder, 1936) in conjunction with sieves with 1, 0.5 and 0.25 mm mesh openings [GMD in Equation (1) (Mazurak, 1950],. The distribution of the aggregates into classes was calculated for 4-2, 2-1, 1-0.5, 0.5-0.25 and <0.25 mm. SOM levels were determined by the method of dichromate oxidation and spectrophotometric reading, according to Embrapa (2009).

$$\boldsymbol{GMD} = \boldsymbol{exp}\ \frac{\sum_{i=1}^{n} \mathbf{w}i\ \mathbf{ln x}i}{\sum_{i=1}^{n} \mathbf{w}i} \quad (1)$$

In = geometric mean diameter (GMD); W*i* = mass of aggregates in size class with mean diameter x*i;* Σ_1^n =1; wi = total mass of the sample

The harvest of sugarcane by hand and without prior burning was carried out taking into consideration a useful area of five central lines and a plot area of 40 m long with 300 m^2 of total area. Subsequently, the sugarcane was weighed with a scale attached to a loader and later the data were extrapolated to hectare. The average yield was estimated in tons of sugarcane culms per hectare.

Statistical analysis of data was performed by analysis of variance (F test) and when significant, comparisons of means were made by Tukey test (P <0.05) (Ferreira, 2008) and variables were correlated by the Pearson linear correlation test (Sigma-plot In. USA).

RESULTS AND DISCUSSION

The GMD showed a significant interaction between tillage systems and soil layers (P <0.05). In the 0.0-0.2 m layer higher values of GMD were observed for direct furrowing (SD) and ripper + direct furrowing (SS + SD), being 17.83 and 16.36% higher compared to the average of other soil preparation systems (Figure 1). These results may be related to low tillage in these soil conservation systems and higher amount of SOM (Figure 2) which comes from the sugarcane crop remains from previous seasons on the soil surface. Similar results were found by Aratani et al. (2009) in red Latosol while comparing irrigated tillage, no-tillage and conventional tillage.

According to Salton et al. (2008), the management systems that provide larger aggregates are desirable as they conserve soil structure without major changes when subjected to external forces, such as animal trampling, mechanized operations and provide greater resistance to erosion loss.

The use of light harrow and moldboard in soil tillage promoted lower aggregate stability in the 0.0-0.2 m layer. The use of the stubble thrasher to eliminate old ratoons also removed the topsoil layer in a very destructive operation; consequently, the physical disruption of aggregates was inevitable. Fontes et al. (1995) stated that changes in soil physical properties, such as in Latosol, especially in the layer richer in organic matter, may be caused by the mechanical breakdown of aggregates by revolving the soil in the initial soil preparation before planting.

Higher SOM content was observed in the 0.0-0.2 m (23.8 g kg^{-1}) layer compared to the 0.2-0.4 and 0.4-0.6 m layers with average levels of 16.7 and 13.9 g kg^{-1}, respectively (Figure 2).

The SD and SS + SD systems showed higher SOM levels. These results can be justified by the non-incorporation of crop residues before planting. According to Stone and Silveira (2001), in conservation cropping systems where the soil remains covered with plant material, a strong presence of organic matter is expected in the soil surface layer, providing intense biological activity, resulting in products which play a role in the formation and stabilization of aggregates.

The SOM and GMD values were significantly correlated (r = 0.64), as shown in Figure 3. According to Wendling et al. (2012) one of the main soil particle cementing agents is the organic matter, and it is likely that part of the variation in the aggregate size and aggregation index is attributed to the SOM content variation.

Castro Filho et al. (1998) studying the stability of aggregates and their relation to organic carbon in Latosol under different tillage systems, confirmed increased soil particle aggregation in areas with higher concentrations of organic matter. Wendling et al. (2005) also observed positive correlations between soil organic carbon and aggregate stability index in a Latosol when evaluating tillage systems and stubble.

A significant interaction was found between the distribution of aggregates in classes and soil preparation systems (P <0.05). According to Salton et al. (2008) soil management systems, by influencing the soil matter and

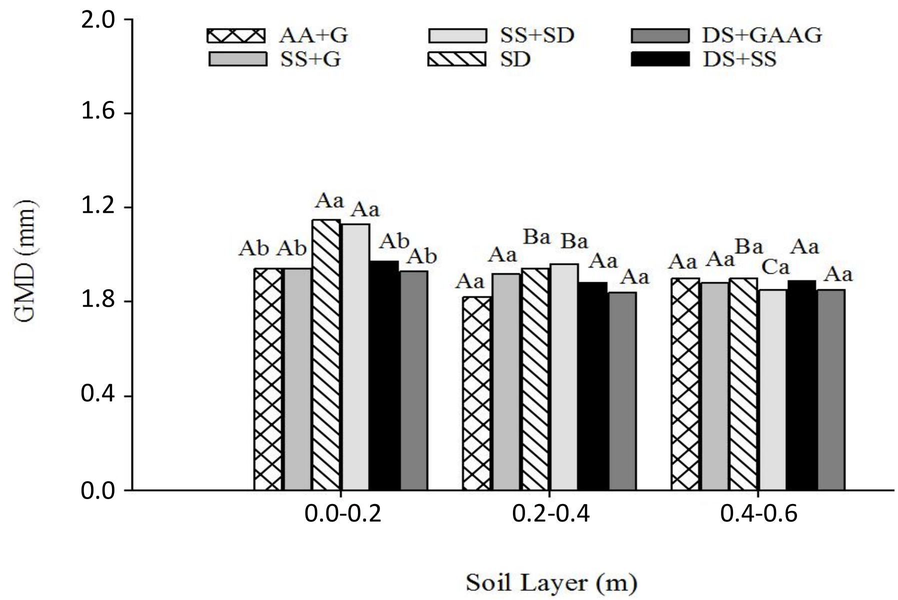

Figure 1. Geometric mean diameter (GMD) in mm in different tillage systems and cultivation layers of ratoon cane in the Cerrado region, 2012. Means followed by distinct lowercase letters differ between soil preparation systems and uppercase letters differ between layers, by the Tukey test (P <0.05).

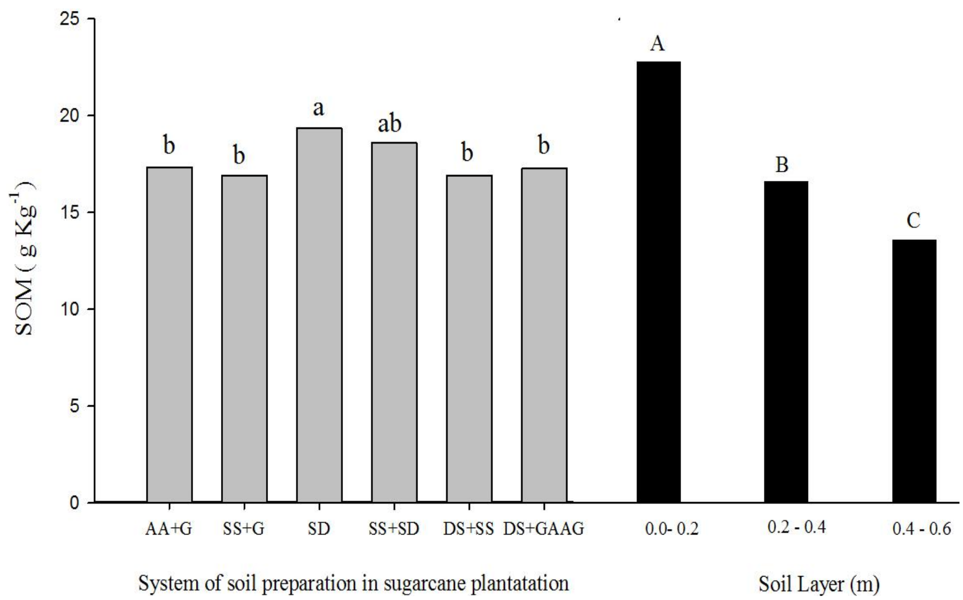

Figure 2. Soil organic matter content in various soil preparation systems and layers in ratoon cane cultivation in the Cerrado region, 2012. Means followed by lowercase letters (tillage) and uppercase (layers) differ by Tukey test (P <0.05).

energy flow intensities and dynamics, result in different degrees of soil mass organization in aggregates.

In the 0-0.2 m layer aggregate classes between 4-2 mm predominated in SD and SS + SD systems, with fractions of 37.26 and 39.59%, respectively (Figure 4). Therefore, the minimum soil tillage coupled with biological activities of roots and the sugarcane biomass, must have contributed to the highest percentages in this classes. According to Almeida et al. (2009), systems that provide the addition of a large amount of plant residues favor a high energy and matter flow, therefore, tending to form classes of larger aggregates contributing to a higher

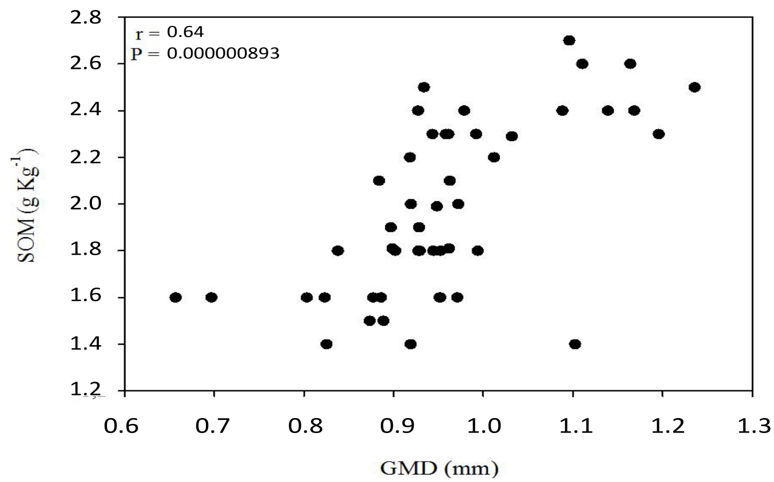

Figure 3. Pearson correlation: Geometric mean diameter - GMD (mm) and soil organic matter – SOM (g K^{-1}) in different tillage systems and soil layers in ratoon cane cultivation in the Cerrado region, 2012.

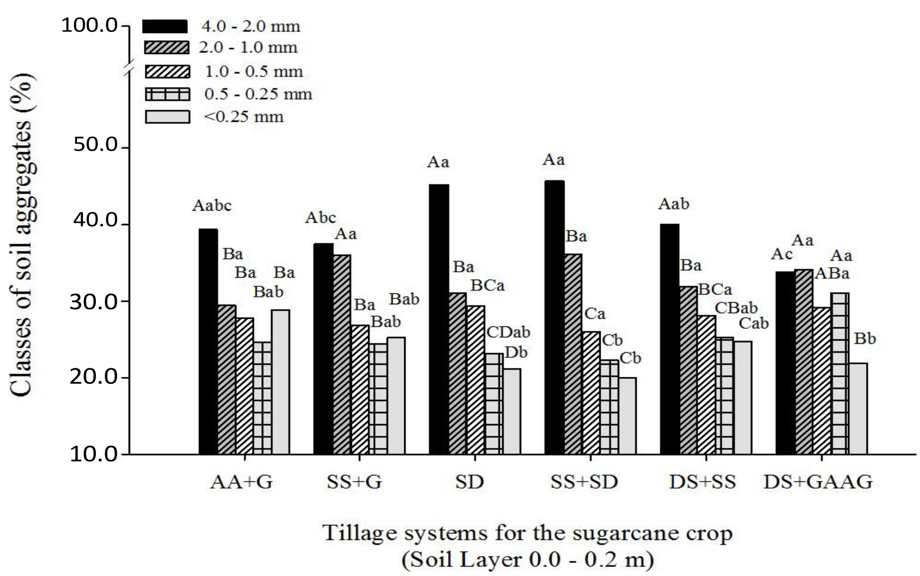

Figure 4. Distribution of aggregate classes in different tillage systems in the 0 - 0.2 m soil layers in sugarcane cultivation in the Cerrado region, 2012.

soil quality.

Conventional systems with ripper + harrow (SS + G) and stubble thrasher + harrow + moldboard plow + harrow (DS + GAAG) had lower percentages of aggregate classes between 4-2 mm (22.89 %). According to Salton et al. (2008) the macroaggregates formed by physical processes through mechanical operations of machinery and equipment or animal treading, may not be stable. However, the greater stability of aggregates is provided by cementing agents linked to biological aspects, such as microbial activity, exudate release by roots, root growth and functioning tissue growth and death, among others.

In the 0.2-0.4 m layer, SD, SS + SD and DS + GAAG systems showed higher values for aggregate classes between 4-2 mm in relation to stubble trasher + ripper (DS + SS). There was a sharp increase in the <0.25 mm class of aggregates for the tillage system which uses moldboard plow + harrow (AA + G), as observed in Figure 5.

Beutler et al. (2001), when comparing conservation and conventional systems in dystrophic red Latosol in the mountains of Minas Gerais, found that direct seeding showed a higher percentage of aggregates for the class

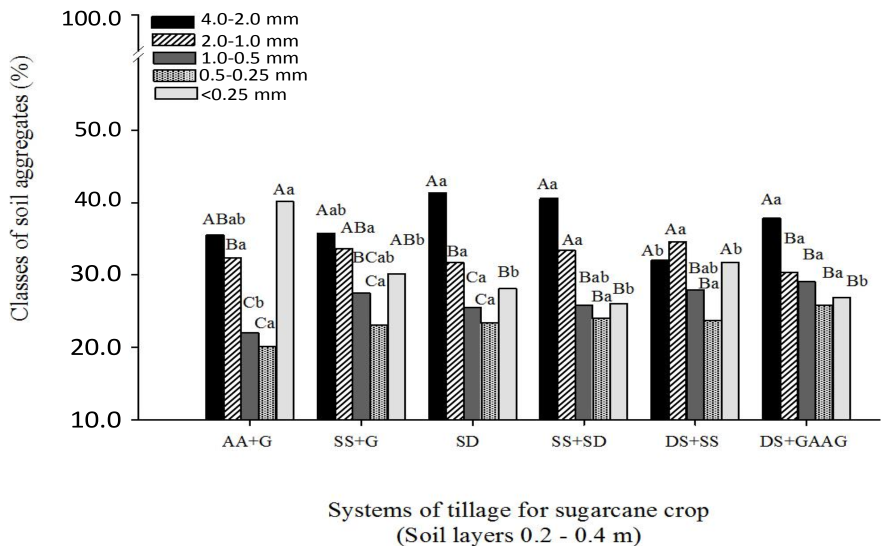

Figure 5. Distribution of aggregate classes in different tillage systems in the 0.2 - 0.4 m layer of ratoon cane cultivation in the Cerrado region in 2012.

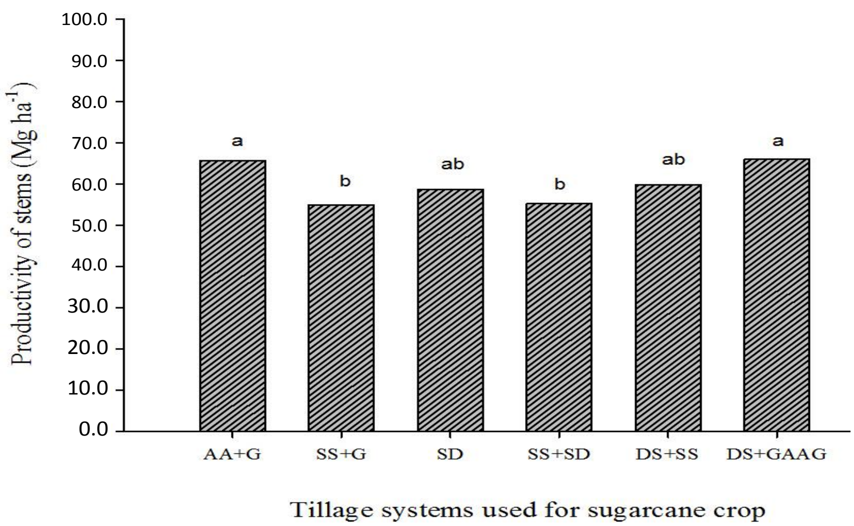

Figure 6. Productivity of culms in different tillage systems in sugarcane in the second year.

over 2 mm, lower for the 2 and 1 mm classes and higher GMD in the surface soil aggregates.

Almeida et al. (2009), in dystrophic red Latosol in the State of São Paulo, in a sugarcane cultivation area during the first year, found predominance of aggregates in the larger diameter classes.

According to Mendes et al. (2003) a sharp increase in the amounts of microaggregates in soils under conventional tillage is a consequence of macroaggregate breakdown, due to the constant mechanical cultivation and the operational features of plows. These authors also stated that the conventional tillage decreases the stability of macroaggregates, making them more susceptible to breakage when submitted to a wet separation process.

The yield of culms for the second ratoon was influenced by different tillage systems ($P < 0.05$). The AA + G and DS+ GAAG systems had higher yields, 65.77 and 65.97 Mg ha^{-1}, respectively, but with no statistically significant difference for SD and DS + SS (Figure 6).

Similar results were found by Domingues (2012) in the same environment of research. However André (2009) found higher sugarcane yields in conventional tillage in relation to other systems, however, also without statistical significance for the minimum tillage + harrow + no-tillage.

The (SS + SD) minimum tillage system showed lower productivity compared to the conventional system (DS + GAAG). This lower productivity can be attributed to the use of the subsoiler, as occurred in SS + G. The deep decompacting operation with the subsoiler can cause negative sugarcane growth effects, due to the formation of large soil clods; this interferes with the stalk contact with the soil, reducing the budding and the initial emission of roots. However, as the OSM levels of the SS + SD system were statistically identical to those of the DS + GAAG, it is expected that over the ratoon sugarcane years, the yields become equivalent.

The fact that the conservation system (SD) presents productivity statistically similar to conventional systems (AA + G and DS + GAAG) was beneficial for the sugarcane production due to lower production costs that these systems provide: As energy (diesel oil), labor, depreciation of agricultural machinery, among others. The advantages of SD in relation to soil quality should also be emphasized, such as higher SOM (Almeida et al., 2014) and GMD values and the prevalence of classes with larger aggregates.

Conclusions

The direct furrowing system and ripper + direct furrowing show higher geometric mean diameter values and bigger aggregate classes (4-2 mm) in the 0-0.2 m layer in the second ratoon cane, positively correlated with the soil organic matter level.

The use of direct furrowing shows greater soil organic matter conservation and improved soil physical quality, besides productivities similar to conventional systems using the moldboard plows and harrows. It is thus recommended that farmers adopt minimum tillage systems in agriculture, such as these that associate productivity and soil quality.

Conflict of Interest

The authors have not declared any conflict of interest.

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Crambe meal in diets supplemented with enzyme complex solid state fermentation (SSF) for Nile tilapia

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Nile tilapia performance fed with diets containing crambe meal supplied with enzyme complex SSF was evaluated. With initial average weight ranging between 1.133g ± 0.105, 280 Nile tilapias were randomized into seven treatments, with four replicates and 10 fish per tank, totaling 28 experimental units. The temperature-controlled recirculation system had 30 L per tank, with individual water supply and aeration. The physico-chemical parameters of the water (temperature, dissolved oxygen, ammonia and pH) were monitored periodically. The fish went through an adaptation period of one week prior to starting the trial. The treatments consisted of a control diet and others diets containing three levels of inclusion of crambe meal, being replaced in their proper proportion, the protein soya by the protein ingredient evaluated (5, 10 and 20%) with 500 ppm of enzyme complex SSF or not. The isoproteic diets (360 g.kg^{-1}) contained the same amount of the ingredients, changing only the levels of inclusion of soya meal, crambe meal and inert. Fish were fed *ad libitum* four times per day. At 56 days, the tilapia performance was evaluated. The physic and chemistry parameters of water were within of the levels recommended for the species during all experimental time There was statistical difference for final weight, weight gain and feed conversion. It is concluded that the inclusion of up to 10% crambe meal supplemented with 500 ppm of enzyme complex SSF provides better performance and higher nitrogen retention for Nile tilapia.

Key words: Additives, *Crambe abyssinica,* fish nutrition, fish performance, *Oreochromis niloticus.*

INTRODUCTION

In Brazil, the main raw material for production of oil is soy, responsible for over 70% of the biodiesel produced in the country. In this sense, there is a search for new oilseeds non-edible to biodiesel production within the international quality standards. Cultures little known in Brazil, such as crambe (*Crambe abyssinica*) and Jatropha (*Jatropha curcas*), appear as interesting alternatives for biodiesel production (Roscoe et al., 2007).

Recently, the interest in commercial cultivation of crambe is growing in several countries, including United States, Canada, Germany and Netherland. The planting of crambe in the Brazil reached over 10000 ha in 2009,

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being this oilseed used for culture rotation in grain production systems (Ferreira and Silva, 2011). Liu et al. (1993) reported that the mains attractive for crambe production are: (a) Domestic source of erucic acid that may be used in additives of rubber, plastic, coatings and lubricants; (b) promise alternative for biodiesel production; (c) Byproduct with higher nutritional value that may be used in animal nutrition; (d) alternative culture as a income source for farmers.

For animal feed, the economic viability of crambe depends of possibilities and limitations of this byproduct, because it has also in its composition some antinutritional factors. This product contains up to 10% of glucosinolate and hydrolases enzymes (TGSase), which limit the ingestion and affect directly the animal performance (Daxenbichler et al., 1968). With this, the crambe needs to pass by treatment for reduction of TGASase and glucosinolate levels. Some methods are used, as: Heat (Pereira et al., 1981), processing with chemistry additives, irradiation (Lessman and McCaslin, 1987) and water extraction after TGSase inactivation (Mustakas et al., 1976).

The presence of glucosinolates in diets for non-ruminants may cause tissue alterations, health problems and reduce intake (Kloss et al., 1994). Lesions in certain tissues (Van Etten et al., 1969) and high mortality (Tookey et al., 1980) were observed in rats that consumed diets containing high concentrations of glucosinolates. Broilers can be fed diets containing up to 50 g crambe meal.kg^{-1} diet with no adverse effects on gain and health (Ledoux et al., 1999).

Reducing the antinutritional factors, the crambe may be an alternative ingredient with high nutritional value for formulation of fish extruded diets, since the high temperature involved in this process reduces the levels of glucosinolate and inactive the enzymes that release toxic products. In rapeseed meal, Huang et al. (1995) observed that the glucosinolate levels decreased in the extrusion process. However, how is not possible to remove all antinutritional factors present in crambe, probably its participation will be limited in diet formulation for fish.

Therefore, the replacement of soya meal by crambe meal in extruded diets supplied with enzyme complex SSF on performance and body composition of Nile tilapia was evaluated.

MATERIALS AND METHODS

The trial was conducted during the period of 56 days at the Laboratory of Aquatic Ecology and Fish Nutrition, Department of Animal Science, Federal University of Jequitinhonha and Mucuri (UFVJM). This lab is equipped with recirculating water system, which is endowed with biofilter, individual aeration and thermostat for temperature control. The temperature was controlled with a thermostat and measured, daily, at 8 am and 5 pm with thermometer of mercury bulb. The photoperiod used was of 12 h of light controlled by electronic timer and total ammonia measured weekly. For dissolved oxygen and pH were used oximeter (YSI 55) and pH meter (Quimis Q400H), respectively, being mensured directly every seven tanks, one repetition of each treatment. In these same tanks were collected samples of 20 ml of water each for total ammonia analysis according Koroleff (1976). The tanks were cleaned by siphoning each two days, being removed the faeces and others possible decanted materials. After all analyzes of water quality, averages and standard deviations for each treatment were obtained.

It was used 280 Nile tilapia (*Oreochomis niloticus*) fingerlings with average initial weight of 1.133 ± 0.105 g distributed in a completely randomized design with seven treatments, four replicates and 10 fish by experimental unit.

The fingerlings were fed *ad libitum*, divided into four meal daily (8 am, 11 am, 2 pm and 5 pm), during every experimental time. For maximum intake without leftover, the ration were given in little amount until satiety. The extruded diets (Table 1) were processed in Animal Science Department of Federal University of Viçosa (UFV) using an extruder machine model Inbramaq MX40.

The enzyme complex SSF (Allzyme SSF, Alltech Inc.) was incorporated by jelly top coat. In the Lab, 42 g jelly was dissolved in 600 ml of boiling water. After the jelly to cool, but in liquid state, enzyme complex SSF previously weighed was added and mixed. In the bucket, eight kilogram of the diet was mixed with the enzymes jelly solution. The diet was spread on trays and dried overnight in a cool area with the help of fans.

The following performance parameters were evaluated: initial weight, final weight, weight gain (WG), feed conversion ratio (FCR), survival (SOB) and chemical body composition (dry matter, crude protein, ether extract, calcium and phosphorus).

All fish in experimental unit were weighed at the beginning and end of the trial to determination of weight gain. For body composition analysis, every tilapias of each treatment were desensitization with eugenol, slaughtered and frozen in freezer (-18°C) at end of the trial.

The diets and fish samples were sent at the Animal Nutrition Lab of Animal Science Department (LNA/DZO/UFVJM) for analysis, being used procedures described by Silva and Queiroz (2002).

For evaluation of treatments, the averages were compared by Duncan's Test at 0.05. Through the F Test at 0.05 were mensured the enzyme effects between the treatments with the same level of replacement of protein from soya meal by protein of crambe meal (50, 100 and 200g.kg^{-1}). The statistics analysis was done using the SAS (2002).

RESULTS AND DISCUSSION

The recirculation system maintained the water quality into of accepted levels during all experimental time. It was observed average values of 28.35±0.43°C to temperature; 6.64±0.41 to pH; 5.59±0.39 ppm to dissolved oxygen and 0.05±0.006 mg.L^{-1} to total ammonia. Significant difference ($p<0.05$) was observed for final weight, weight gain and feed conversion (Table 2). In general, it was verified that the gradual addition of crambe meal worsened the performance of tilapia. However, by including the enzyme complex SSF, there was an improvement in performance parameters, mainly in feed conversion.

Significant difference ($p<0.05$) was observed only for phosphorus retention in relation to body composition analysis (Table 3). There was improvement in the body phosphorus retention by adding the enzyme complex in

Table 1. Composition of experimental diets.

Ingredients (g.kg^{-1})	Replacement levels with or not SSF (g.kg^{-1})						
	0	50	100	200	50SSF	100SSF	200SSF
Soya meal	612.1	562.1	512.1	412.1	562.1	512.1	412.1
Crambe meal	0	67.4	134.8	269.5	67.4	134.8	269.5
Corn	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Rice meal	124.6	124.6	124.6	124.6	124.6	124.6	124.6
Gluten 60	101.3	101.3	101.3	101.3	101.3	101.3	101.3
Fish meal 60%	15.1	15.1	15.1	15.1	15.1	15.1	15.1
Dicalcium phosphate	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Limestone	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Mix mineral vitaminic[1]	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Vitamin C	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0
SSF[2]	0	0	0	0	0.5	0.5	0.5
Inert (Caulin)	70.0	52.6	34.8	0.5	52.1	34.3	0
BHT	0.2	0.2	0.2	0.02	0.2	0.2	0.2
Calculated[(3)] and analysed[(4)] composition							
Dry matter (g/kg)[(3)]	897.1	898.2	899.3	901.6	898.2	899.3	901.6
Dry matter (g/kg)[(4)]	881.2	890.9	874.4	884.7	881.4	875.9	888.3
Crude protein (g/kg)[(3)]	360.0	360.0	360.0	360.0	360.0	360.0	360.0
Crude protein (g/kg)[(4)]	359.0	354.3	353.1	359.7	354.3	351.6	352.9
Digestible energy (kcal/kg)[(3)]	3200	3239	3279	3356	3239	3279	3356
Crude fiber (g/kg)[(3)]	38.3	54.2	70.1	101.8	54.2	70.1	101.8
Etereo extract (g/kg)[(3)]	33.2	33.5	33.7	34.1	33.5	33.7	34.1
Total calcium (g/kg)[(3)]	10.0	10.7	11.4	12.7	10.7	11.4	12.7
Total calcium (g/kg)[(4)]	9.4	9.6	9.8	1.1	1.0	1.1	1.2
Total fósforo (g/kg)[(3)]	10.0	10.3	10.6	11.2	10.3	10.6	11.2
Total fósforo (g/kg)[(4)]	10.6	10.8	10.9	10.9	10.7	10.8	10.8
Total lysine (g/kg)[(3)]	19.0	17.6	16.2	13.4	17.6	16.2	13.4
Starch (g/kg)[(3)]	200.0	203.3	206.8	213.4	203.3	206.8	213.4
Linoleic acid (g/kg)[(3)]	16.5	16.2	15.8	15.1	16.2	15.8	15.1

[(1)] Composition per kg of product: 1,200,000 IU of Vitamin A; 200,000 IU of Vitamin D_3; 1,200 mg of Vitamin E; 2,400 mg of Vitamin K_3; 4,800 mg of Vitamin B_1; 4,800 mg of Vitamin B_2; 4,800 mg of Vitamin B_6; 4,800 mg of Vitamin B_{12}; 48 g of Vitamin C; 1200 mg of folic acid; 12,000 mg of pantothenic acid; 48 mg of biotin; 108 g of choline chloride; 24,000 mg of niacin; 50,000 mg of Fe; 3,000 mg of Cu; 20,000 mg of Mn; 30,000 mg of Zn; 100 mg of I; 10 mg of Co; 100 mg of Se. [(2)] Allzyme SSF, Alltech Inc. - Minimum levels of guaranteed enzyme activity: α-amylase, 30 AU/g; β-glucanase, 200 IU/g; cellulase, 40 IU/g; fungal protease, 700 IU/g; pectinase, 4000 IU/g; phytase, 300 IU/g; xylanase, 100 IU/g.
[(3)] Values based on the coefficient of digestibility of the ingredients according to Furuya et al. (1996), Furuya et al. (2000), Bomfim et al. (2008), Botaro et al. (2007); Gonçalves et al. (2009); Lanna et al.(2004); Furuya et al. (2004), Furuya et al. (2006), Takishita et al. (2009) and Bomfim et al. (2010); Rostagno et al. (2011).

Table 2. Nile tilapia performance fed with diets contained crambe meal and enzyme complex SSF.

Parameters	Replacement levels with or not SSF (g.kg^{-1})							CV (%)
	0	50	100	200	50+SSF	100+SSF	200+SSF	
Initial weight (g)	1.124	1.139	1.124	1.149	1.137	1.134	1.125	10.485
Final weight (g)	40.15^{a}	40.20^{a}	38.89^{ab}	34.74^{b}	42.31^{a}	42.17^{a}	38.01^{ab}	7.083
Weight gain (g)[1]	39.02^{a}	39.06^{a}	37.77^{ab}	33.59^{b}	41.18^{a}	41.04^{a}	36.89^{ab}	7.380
FCR (g.g^{-1})[1,2,3]	1.112^{b}	1.115^{bB}	1.122^{bB}	1.365^{dB}	1.020^{aA}	1.035^{aA}	1.180^{cA}	2.310
Survival (%)	92.5	92.5	85.0	92.5	95.0	92.5	95.0	8.793

[1]Average following per same lowercase are similar by Duncan's Test ($p<0.05$); [2] Average following per same letters are similar by F test ($p<0.05$); [3]Feed conversion.

Table 3. Body analysis of Nile tilapia performance fed with diets contained crambe meal and enzyme complex SSF.

Parameters ($g.kg^{-1}$)	Replacement levels with or not SSF ($g.kg^{-1}$)							CV (%)
	0	50	100	200	50+SSF	100+SSF	200+SSF	
Dry matter	188.3	193.2	188.9	190.4	193.4	192.9	190.1	9.685
Crude protein	712.9	718.4	711.2	701.9	720.6	728.9	711.7	7.684
Ether extract	203.1	224.5	213.0	206.3	222.9	226.6	219.3	9.326
Calcium	22.35	22.55	22.54	21.89	22.87	23.89	22.76	7.215
Phosphorus	22.18[a]	22.60[aA]	23.10[aA]	22.17[aA]	23.76[abB]	25.89[bB]	24.02[bB]	8.179

[1]Average following per same lowercase are similar by Duncan's Test ($p<0.05$); [2] Average following per same letters are similar by F test ($p<0.05$).

the diet, become more evident when comparing within the same level of substitution.

For Nile tilapia, Kubtiza (2000) recommend that the range of thermal comfort of the species should be of 26 to 30°C for temperature, 6 to 8.5 for pH, dissolved oxygen above of 4 $mg.L^{-1}$ and total ammonia under of 0.2 $mg.L^{-1}$, which are according with the results of this study.

The final weight and weight gain were influenced by the inclusion of crambe meal and enzyme supplementation.

It is observed that the replacement of 20% from soybean meal protein to meal crambe protein had the worst weight gain. Although the replacement has been made regarding the crude protein, the levels of the other nutrients were also altered, modifying qualitatively the diet. The inclusion of crambe meal in the diet increased the amount of fiber, which may have promoted low retention time of feed in the digestive tract. Moreover, although the protein level being the same for all treatments, there was a gradual decrease in the levels of lysine, limiting amino acid directly related to protein deposition. Unlike the present study, Pretto et al. (2014) observed no difference in the performance of silver catfish (*Rhamdia quelen*) fed with diets containing up to 20% of replacement of crude protein from soya meal by crude protein crambe meal in nature or chemically treated. However, the authors corrected the synthetic amino acid levels in the formulation of diets, which may have "masked" the effect of crambe meal on the silver catfish performance.

Other authors studied alternatives of vegetables origin contained glucosinolate for feeding of fish. Working with Nile tilapia (*Oreochromis niloticus*), Santos et al. (2009) concluded that there was no loss in performance and chemical composition of the fillet to replace 25% of soy protein by protein turnip (*Brassica rapa*). With the same fish species, Soares et al. (2001) verified that canola meal can be included to 35.40% (replacing 48.17% protein from soybean meal) in the diet without loss in performance. In pacus (*Piaractus mesopotamicus*), the addition of up to 19% of canola meal in the diet did not affect performance. Already in piavuçu (*Leporinus macrocephalus*), the maximum level of substitution was 11.19% for the same ingredient, without affecting performance (Gonçalves et al., 2002).

The plants belonging to the family of cruciferous vegetables such as radish, crambe, canola and rapeseed have in their composition the glucosinolates, which when intact, are not toxic to fish. However, the products of its hydrolysis by the action of the enzyme myrosinase or tioglicosidase may be detrimental to performance and health of this group of animals (Bell, 1993). More than 90% of the glucosinolates can be converted into epigoitrin (epi -PG) during the metabolism. In the seed, epi - PG is biologically separate of the enzyme thioglucosidase (TGSase). A reaction between the enzyme and epigoitrin can occur if the seed is crushed, if germinated, or when plant tissues are softened (Tookey et al., 1980). However, Oginsky et al. (1965) and Tani et al. (1974) reported that some intestinal bacteria (e.g., Enterobacter cloacae) are capable of displaying TGSase activity. The intake epi-PG and its subsequent hydrolysis can lead to the formation of a toxic product called aglucagon in digestive tract of animals. Thus, the nutritional value of crambe depends on the relative toxicity of epi - PG intact and product levels aglucon present. These products are toxic and have a bitter taste which makes it unpalatable meal.

The feed conversion also was influenced by treatments. It was observed that, in general way, there is a tendency of worsening in feed conversion with the inclusion of crambe meal in diet. However, the addition of enzyme complex SSF in diet improved the feed conversion up to 10% of replacement of soya meal protein by crambe meal protein. The fish fed with diets contained 10% of replacement and enzyme complex improved the feed conversion in 7.43 and 8.41%, when compared at control and the same level of replacement, respectively.

Enzyme action arising from the complex SSF probably provided greater amount of nutrients and reduced the effects of anti-nutritional factors. In a study testing inclusion levels of the same enzyme complex in diets for Nile tilapia, Moura et al. (2012) observed that there was increases in levels of sucrose, glucose and fructose in the chyme of this species, indicating that occurred an greater bioavailability of nutrients, positively influencing the performance. This is clearly evident when comparing the same inclusion levels of crambe meal with enzyme supplementation. Thus, it was observed an improvement in feed conversion of 9.31, 8.41 and 15.68% for the replacement levels of 50, 100 and 200, respectively.

For body analysis, the inclusion of enzyme complex SSF improved only the phosphorus retention. The phytase from enzyme complex acted on the phytate present in vegetable ingredients of the diet, releasing phosphorus that was unavailable. The diet with 10% of replacement plus SSF increased the body phosphorus level in 12% when compared the treatment with 10% of replacement. Similar results were verified by Bock et al. (2007) that found higher amount of phosphorus and calcium in the body composition when tilapias were fed with diets contained phytase. These same authors also mentioned that the use of phytase in diets for Nile tilapia in growth phase can reduce levels of inclusion of inorganic phosphorus in feed and minimize environmental impacts. Using phytase in diets, Furuya et al. (2005) observed that tilapias improved the deposition of phosphorus on bone and weight gain in 13.15 and 39.9%, respectively.

Therefore, it is concluded that the inclusion of enzyme complex SSF (solid state fermentation) improves the feed conversion and phosphorus retention in Nile tilapias fed with diets containing up to 10% of replacement of crude protein from soya meal to crude protein of crambe meal.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Stability analysis in Wheat: An application of additive main effects and multiplicative interaction

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Genotype-environment interaction and stability performance were investigated on morphological, yield and yield attributing traits in three environments. The AMMI analysis showed that maturity, morphological, yield, and yield attributing traits were highly influenced by genotype, environment and genotype-environment (GE) interaction. Environment had the largest contribution to the total sum of squares indicating that the environments (location and season) selected for this study were highly diverse, and this was consequently the main effect contributing most variation for these traits. The Additive Main Effects and Multiplicative Interaction (AMMI) biplot for yield clearly indicated that the Genotypes G2, G4 and G3 showed higher yield above the grand mean yield but it is less stable than G1 which was closed to zero of Interactive Principal Component Analaysis (IPCA) score with low yield. Distribution of genotypes in the AMMI II biplot revealed that G1 scattered close to the origin and this indicated that this genotype showed minimal interaction with environments. On the other hand, genotypes G2, G3, G4, and G7 were located away from the origin, hence were more responsive to different environmental conditions and are considered as specifically adapted genotypes. The high yielding environments classified according to the AMMI 1 model is E2, while the lower yielding environments are E1 and E3. All the genotypes (with IPCA 1 "+") except G1 were categorized under favorable environments with above-average means, whereas genotype G1 which lies on the origin of biplot contributed lowest to the GE interaction. The lowest yielding environment (E3) had the minimum IPCA 1 and led to zero interaction, whereas the low and high yielding environments, that is, E2 (with IPCA 1 "+") and E1 (with IPCA 1 "-"), tended to contribute highest to the GE interaction.

Key words: Adaptability, stability analysis, multiplicative interaction, wheat.

INTRODUCTION

Wheat (*Triticum aestivum* L. em Thell.) is the most important staple food of about two billion people (36% of the world population). Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally (Breiman and Graur, 1995). Because of its high economic value and place among the food crops, it is also known as "The King of Cereals". Wheat is basically a crop of temperate zone, but on account of its genetic diversity, it has extended its frontiers and has become adapted to nearly all the climates of the world

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(Khan et al., 2012). It is grown in diverse agro-climatic conditions ranging from 110° to 350°N from 720° to 920°E and from almost sea level to very high altitudes. Major wheat producing states in India lie between 20° to 32°N.

Stability of performance of genotypes will be of special importance in Jammu and Kashmir where environmental conditions vary considerably and the means of modifying the environment are inadequate. Hence, the development of high yielding genotypes and information on multi location performance are of paramount importance in Jammu and Kashmir where environments vary greatly within short distances.

Multivariate techniques are widely applied in stability analysis to provide further information on real multivariate response of genotypes to environments. Among the multivariate analysis techniques, the AMMI model is the powerful method in assessing GxE interaction and stability/ adaptation of genotypes from multi-environment trials. The advantages of the AMMI model or its variants are that, they use overall fitting, impose no restrictions on the multiplicative terms and result in least square fit (Freeman, 1990). Within limits, any model may be expected to fit the data from which it was derived. However, the AMMI model has a good chance of being able to predict for new sites and new years, thus contributing a real advance (Gauch, 1988). Gauch and Zobel (1996) showed that AMMI1 with IPCA1 and AMMI2 with IPCA1 and IPCA2 are usually selected and the graphical representation of axes, either as IPCA1 or IPCA2 against main effects or IPCA1 against IPCA2 is generally informative.

In any breeding program it is necessary to screen and identify phenotypically stable genotypes, which could perform more or less uniformly under different environmental conditions. The AMMI model (Gauch and Zobel, 1997) is more efficient in determining the most stable and high yielding genotypes in multi-environment trials compared to earlier procedures (Eberhart and Russell, 1966). Biplot analysis is possibly the most powerful interpretive tool for AMMI models. Biplots are graphs where aspects of both genotypes and environments are plotted on the same axes so that interrelationships can be visualized. The AMMI biplot where the main effects (genotype mean and environment mean) in X axis and IPCA1 scores for both genotypes and environments are plotted in Y axis. The effectiveness of AMMI procedure has been clearly demonstrated (Crossa et al., 1990; and Tarakanovas and Ruzgas, 2006).

The main objectives of the present investigation are to identify high yielding stable genotype and to determine the areas where these genotypes would be adapted and produce economically competitive yields.

MATERIAL AND METHODS

The present investigation was carried out during *rabi* season of 2012-2013 at three locations. The basic material for the present investigation comprised of 10 genotypes of wheat (*Triticum aestivum* L.) are designated as G1 (SKW-848), G2 (SKW-489), G3 (SKW-490), G4 (SKW-514), G5 (SKW-515), G6 (SKW-517), G7 (SKW-519), G8 (SKW-527), G9 (SKW-530), and G10 (SKW-531) and environments as E1 (Experimental Farm of the Division of Plant Breeding and Genetics, SKUAST-K-expand it, Shalimar, Srinagar), E2 (Mountain Field Crop Research Centre, Khudwani) and E3 (Regional Research Station, Wadura, Sopore). Observations were recorded on five randomly selected competitive plants of each genotype in every replication for morphological, yield and yield attributing traits whereas, in the case of maturity traits (days to 50% flowering and maturity), the data were recorded on the whole plot basis. Mean values for all the characters except maturity traits (where median values were used) were worked out for statistical and biometrical analysis. The experiment was laid out in a completely randomized block design with 3 replications at each location. The experimental plot comprised of 3 rows each of 1 meter length with a spacing of 25 × 10 cm. Recommended agronomic practices were followed to raise a good crop at all the three locations. Based on the performance of the cultivars three random environments, phenotypic stability was worked out by following models (i) the AMMI model of Gauch and Zobel (1988), and (ii) the linear model of Eberhart and Russel (1966).

RESULTS AND DISCUSSION

The results of AMMI analysis for maturity, morphological, yield and yield attributing traits in wheat (*T. aestivum* L.) for the 10 genotypes and 3 environments are presented in Table 1. The AMMI analysis of data revealed that the environment, genotype, and GE interaction were highly significant (P< 0.01). The large Mean square of environments indicated that the environments were diverse. The large differences among environmental means caused most of the variation in studied traits. In the present investigation, the AMMI analysis showed that maturity, morphological, yield, and yield attributing traits were highly influenced by genotype, environment and GE interaction. Other studies have reported similar observations in wheat (Hintsa et al., 2011). Environment had the largest contribution to the total sum of squares indicating that the environments (location and season) selected for this study were highly diverse, and this was consequently the main effect contributing most variation for these traits. The environment differences in terms of key climate attributes (temperatures and rainfall distribution), altitude and soil fertility affected the performance of wheat genotypes, justifying the need to identify high yielding genotypes that are stable in a wide range of environments, or to breed for wheat cultivars specifically adapted to specific environments. The magnitude of variation due to environments on the traits was large thereby causing genotypic response to diverse environments and suggesting the presence of mega-environments where best performing genotypes could be selected more efficiently. Similar findings were also reported by Tarakanovas and Ruzgas (2006) on the additive main effect and multiplicative interaction analysis studies of wheat varieties.

Table 1. AMMI Analysis of variance for maturity, morphological, yield and yield attributing traits in Wheat (*Triticum aestivum* L.)

Source of variation	Df	Mean sum of squares											
		Days to 50% heading	**Days to 100% heading**	**Days to maturity**	**Plant height (cm)**	**Tillers plant^{-1}**	**Spike length (cm)**	**Spikes spikelet^{-1}**	**Seeds spike^{-1}**	**100 seed weight (g)**	**Grain Yield plant^{-1} (g)**	**Biological yield plant^{-1} (g)**	**Harvest Index (%)**
Genotypes	9	1.88**	3.19**	1.56**	0.60**	1.01**	0.89**	1.15**	0.67**	0.11**	1.85**	0.82**	10.69**
Environments	2	143.63**	140.70*	365.64**	41.42**	422.53*	173.49*	1.56**	181.74**	20.13**	30.77*	634.67**	71.52**
Replications within environments	6	7.92*	7.87**	14.48**	1.82*	2.19**	2.30**	7.82**	1.95*	0.62*	0.78*	2.92**	8.15**
Genotype x Environment	18	1.45*	1.08**	2.73**	0.68*	0.89**	0.45*	0.39*	0.40*	0.03**	0.39*	1.08*	2.13**
Error	54	1.48	1.26	2.28	0.97	0.81	0.27	0.68	0.42	0.13	0.61	0.71	4.46
Total	89	5.14	5.00	11.29	1.84	10.41	4.40	1.17	4.62	0.59	1.38	15.19	6.37

*,** Significant at 5 and 1% levels, respectively.

In Figure 1 the IPCA 1 scores for both the genotypes (G) and the environments (E) were plotted against the mean grain yield per plant for the genotypes and the environments, respectively. From the biplot, environments are distributed from lower yielding environments (IPCA 1 "+") to the high yielding environments (with IPCA 1 "-"). The high yielding environments classified according to the AMMI 1 model is E2, while the lower yielding environments are E1 and E3. All the genotypes (with IPCA 1 "+") except G1 were categorized under favourable environments with above-average means, whereas genotype G1 which lies on the origin of biplot contributed lowest to the GE interaction. The lowest yielding environment (E3) had the minimum IPCA 1 and led to zero interaction, whereas the low and high yielding environments, that is, E2 (with IPCA 1 "+") and E1 (with IPCA 1 "-"), tended to contribute highest to GE environment.

Since IPCA 2 scores also play a significant role in explaining the GEI, the IPCA 1 scores were plotted against the IPCA 2 scores to further explore adaptation (Figure 2). The genotype G1 lies near the origin and hence showed stability and wide adaptability. On the other hand, genotypes G1, G2, G3, G4, and G7 were located away from the origin, hence were more responsive to different environmental conditions and are considered as specifically adapted genotypes. The genotype which was located near the origin was less responsive than the faraway genotype from the origin. In addition, the lines connecting the genotypes *viz*., G7 to the biplot origin measure genotype differences from the grand mean, and genotypes with long vectors were assigned as either the best or the poorest performers in the environment. With respect to the contribution of testing locations to the GE interaction, environment E3 had least contribution as it was located closest to the origin on the biplot, while the environment E2 showed the highest contribution followed by E1.

The graph for biological yield (Figure 3) showed that genotype G1 was the most stable as it was located near the origin of the biplot, while rest of the genotypes fall in the favorable environment (with IPCA 1 "+"). All the environments exhibited negative IPCA 1 value and among them E3 showed the minimum IPCA 1 value and led to zero interaction, while the environments E2 and E1 (with IPCA 1 "-") contributed maximum towards GE interaction. The AMMI 2 biplot (Figure 4) generated using the first two principal component scores showed that E3 is identified as stable environment as its IPCA2 score and vector is near to the source (zero). G1 was different from the other genotypes as it was located far apart from the other genotypes in the biplot, while rest of the genotypes formed a single group showing similar

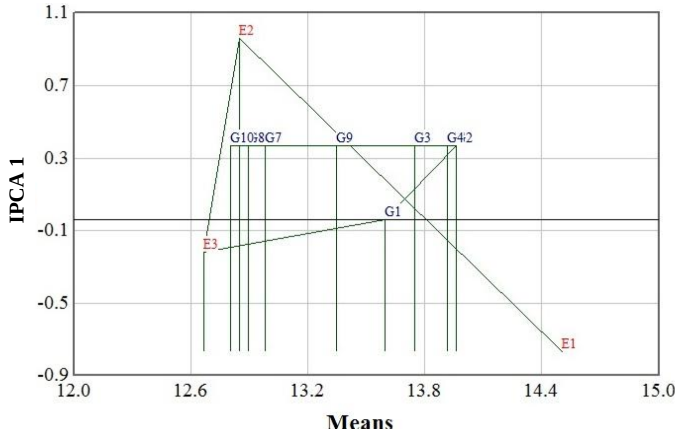

Figure 1. Biplot of the first AMMI interaction (IPCA 1) score (Y-axis) plotted against mean grain yield per plant (X-axis) for 10 wheat genotypes.

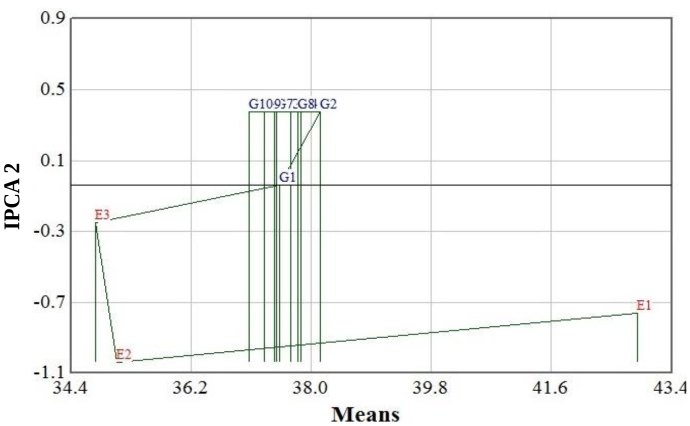

Figure 2. Biplot of the first AMMI interaction (IPCA 2) score (Y-axis) plotted against AMMI interaction (IPCA 1) score (X-axis) for 10 wheat genotypes and 3 environments.

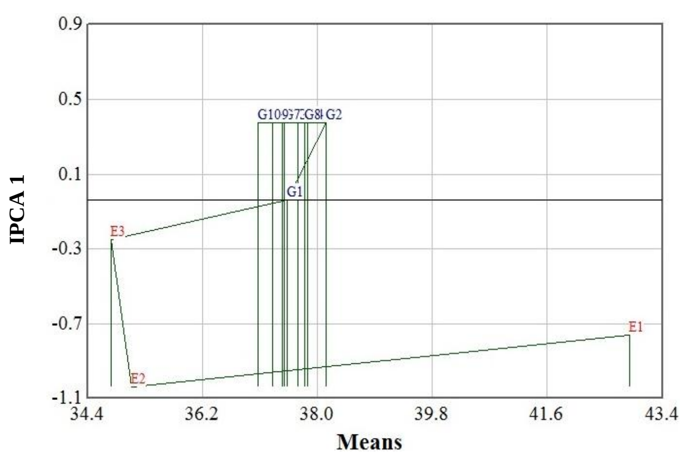

Figure 3. Biplot of the first AMMI interaction (IPCA 1) score (Y-axis) plotted against mean biological yield (g) (X-axis) for 10 wheat genotypes.

performance in favorable environment.

As displayed in Figure 5 of the AMMI biplot for harvest index, it is obvious that G1 was the most stable genotype as it lies near the origin of the biplot, while a negative interaction was observed for rest of the genotypes (with IPCA 1 "-") at environment E1 (with IPCA 1 "+"). The results also revealed that all these environments contributed equally towards GE interaction as indicated by their long distance from the origin of the biplot. The AMMI 2 (Figure 6) also indicated the relationship among the wheat genotypes. G1 was different from other genotypes as it was located far apart from other genotypes in the biplot, while rest of the genotypes showed similar performances for harvest index as they were grouped in one cluster in E3 environment which were positioned close to the origin of the biplot and hence their stability in performance across environments. The biplot also showed that E1 was the most discriminating environment for the genotypes as indicated by the longest distance between its marker and the origin, however, E3 is identified as stable environment as its IPCA1 score and vector is near to the source (zero). The IPCA scores of a genotype in the AMMI analysis were reported by Gauch and Zobel (1966) and Purchase (1997) as indication of the stability of a genotype across environments. Closer the IPCA scores are to zero, more stable ae the genotypes across their testing environments (Purchase, 1997). These results are also similar to those obtained by Castillo et al. (2012) and Kaya et al. (2002). When environmental differences are large as that in Jammu and Kashmir, it may be expected that the interaction of GxE will also be higher. As a result, one cultivar may have the highest yield in some environments while a second cultivar may excel in others. Hence, it is important to know the magnitude of the interactions in the selection of genotypes across several environments besides calculating the average performance of the genotypes under evaluation (Gauch and Zobel, 1997).

The GGE biplot aims to use the "which-won-where" pattern to facilitate identification of the most responsive genotypes (Yan et al., 2000). In this study, the most responsive genotype was G1. Interestingly, this genotype demonstrated either higher (sometimes the highest) or lower values compared to the other genotypes in all the environments within the sector in which they fall (Yan, 2002). Other vertex genotypes including G8, G7 and G3 which expressed highly responsive behavior but they did not fall under any of the test environments, indicating that they were not highly stable genotypes in any of the three environments. The test environments appeared in three sectors of the polygon view, a sign of cross-over of GEI effects, suggesting the presence of three possible mega-environments under Jammu and Kashmir conditions (elaborate). Mega-environments help plant breeders to select high yielding genotypes for a specific environment, making better use of GEI (Jandong et al., 2011). The other importance of mega- environments is that

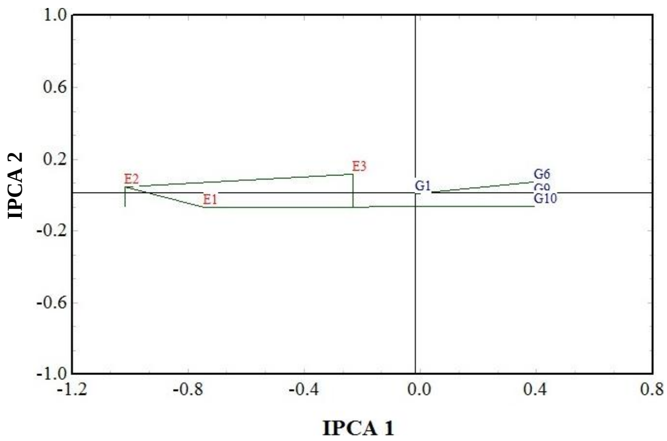

Figure 4. Biplot of the first AMMI interaction (IPCA 2) score (Y-axis) plotted against AMMI interaction (IPCA 1) score (X-axis) for 10 wheat genotypes and 3 environments.

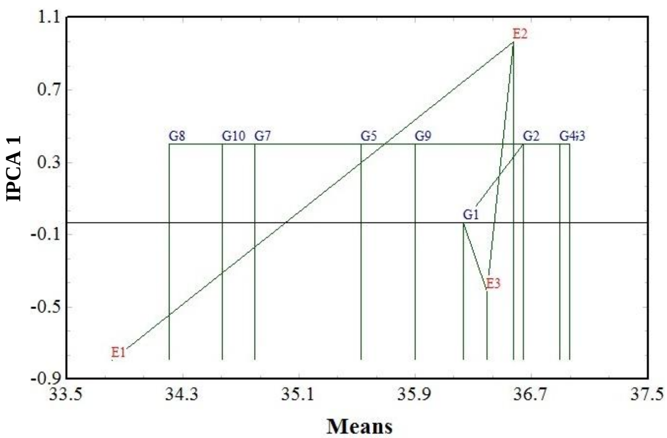

Figure 5. Biplot of the first AMMI interaction (IPCA 1) score (Y-axis) plotted against mean harvest index (%) (X-axis) for 10 wheat genotypes.

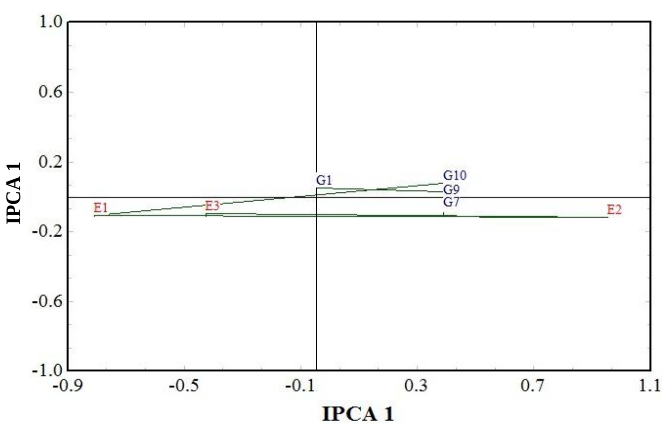

Figure 6. Biplot of the first AMMI interaction (IPCA 2) score (Y-axis) plotted against AMMI interaction (IPCA 1) score (X-axis) for 10 wheat genotypes and 3 environments.

genotypes may be evaluated in a few representative environments, which will provide informative data representing GEI trials across a much larger number of environments.

Conclusion

Genotypes G2, G4 and G3 showed yield above the grand mean yield but it is less stable than G1 which was closed to the zero of IPCA score with low yield. Distribution of genotypes in the AMMI II biplot revealed that G1 scattered close to the origin and this indicated that this genotype showed minimal interaction with environments. On the other hand, genotypes G2, G3, G4, and G7 were located away from the origin, hence were more responsive to environment change and are considered as specifically adapted genotypes.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Oviposition strategy of *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) in relation to conspecific infestation

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Experiments were carried out to investigate the egg-laying behaviour of the maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) in uninfested and previously infested (termed conditioned here) maize grains. The number of offspring produced and preferred grain type of the weevil were examined under laboratory conditions, along with the effect of the presence of egg plugs on the oviposition site selection. The number of progeny produced was higher in conditioned maize. The highest and lowest number of adults emerged from conditioned and uninfested maize, respectively. *S. zeamais* individuals were significantly more attracted to conditioned grains compared to uninfested grains. *S. zeamais* females laid more eggs on host grains already bearing conspecific eggs (that is, conditioned) compared to clean grains (that is, uninfested). The number of eggs per grain showed a contagious distribution because females laid additional eggs on grains already infested with more than one egg. The results of this study indicate the possible role of the aggregation pheromone, intraspecific competition and egg marking in the observed egg-laying behaviour pattern of this pest species.

Key words: Maize weevil, egg, aggregation pheromone, oviposition behaviour, host marker.

INTRODUCTION

In some stored agricultural products, adult female insect pests must select suitable grain on which to place their eggs because the larvae are not able to migrate to alternative grain sources. Consequently, insect larvae that develop and feed on the grain kernels of stored agricultural products are subjected to unique evolutionary problems. Adult females are able to vary their fitness according to whether they (1) space eggs out and minimise competition between larvae, or (2) lay eggs at random and risk losses in both the quantity and quality of offspring (Giga and Smith, 1985). The critical question is whether females are able to detect eggs that are already present within the seeds of host products.

For emerging larvae to receive an adequate food

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supply, several seed-oriented beetle species (Bruchidae) avoid ovipositing on host seeds that already bear conspecific eggs. For instance, *Callosobruchus* spp. use oviposition marker pheromones to regulate the distribution of eggs on seeds, to prevent the overcrowding of eggs on a few seeds, which would lead to intraspecific competition (Messina and Renwick, 1985a, b; Messina et al., 1987; Credland and Wright, 1990; MBata, 1992). In contrast, *Sitophilus* spp. eggs laid on the grains of stored agricultural products exhibit both random and aggregated distributions (Smith, 1986; Nardon et al., 1988). Fava and Springhetti (1991) and Fava and Burlando (1995) observed that the females of the granary weevil, *Sitophilus granarius* L., lay more than one egg on the same grain, leaving other grains untouched. The authors concluded that the grain was not marked with pheromones during egg deposition because females did not appear to distinguish between infested and uninfested grains. Moreover, the egg distribution of the rice weevil, *Sitophilus oryzae* L., on grains fits the negative binomial distribution well, which is characterised by the fact that most egg plug distributions are underdispersed compared to the Poisson distribution (Holloway, 1984; Nardon et al., 1988). These examples show that different weevil species exhibit various oviposition strategies. Consequently, there is debate as to whether the genus *Sitophilus* oviposits at random or contagiously.

Thus, we investigated the egg-laying behaviour of *S. zeamais*, in an environment containing both uninfested maize and maize previously infested by *S. zeamais*. This study specifically aimed to determine (1) how adults distributed eggs between uninfested and infested (termed conditioned here) maize kernels, (2) the number of eggs laid and (3) the number of offspring produced in the two kernel types.

MATERIALS AND METHODS

Grain and insects

Maize weevils were reared on shelled maize (*Zea mays* L.) for several generations under laboratory conditions. All insects (4-8 weeks old) were obtained from cultures maintained in the laboratory in darkened incubators at 30 ± 2°C and 65 ± 5% relative humidity. Maize grains of the variety “Plata” were used, and the grains were equilibrated to a moisture content of 12 to 13% at 30°C for insect rearing and use in the tests. All experiments were carried out in a dark room that was maintained at 30 ± 2°C and 65 ± 5% relative humidity.

Conditioned maize

The term “conditioned” is used here to refer to maize grains infested with stored-product insects (Mignon et al., 1996). Conditioned grains were obtained by placing approximately 150 unsexed *S. zeamais* adults in one-litre glass jars filled with 500 g of maize grains (approximately 1500 to 1600 grain kernels). After 14 to 21 days, the adults were removed and the maize was used for the experiments.

Egg plug identification

Sitophilus zeamais females deposit single eggs in holes bored into the grain, and seal each hole with a gelatinous egg plug. The egg plugs may be stained (cherry red) with acid fuchsin (Figure 1). The method used to stain the egg plugs was adapted from that of Holloway (1985). In brief, this method involves soaking grains for 1 to 2 min in warm water (25 to 30°C), followed by immersion for 1 to 2 min in an acid fuchsinic solution (0.5 g/L of water). The grains are finally rinsed with water to eliminate excess staining solution, and are then dried at room temperature. The egg plugs appear cherry red in colour when observed under a binocular microscope. We assumed that each plug covered just one egg and that the washing of kernels did not remove aggregation pheromone residues on infested kernels, if present.

Recording system

A Sterilin square box with 100 mm side exits was used (Bibby Sterilin Ltd, Stone, Staffs, UK). The box contains 25 square wells with 20 mm sides. One female of *S. zeamais* individuals from the laboratory cultures was placed in a well with three maize grains. The box was placed in a small dark room lit by a red light, not visible for insects (Chapman, 1998). In this room, a camera (Video-Flex, by Ken-a-vision, Raytown Road, Kansas City, Missouri, USA) connected to a video tape recorder (Panasonic, NV-SD430EG) was used to record insect displacement (Figure 2). Recordings took place between 08 and 09 am. After 6 h, the recording was stopped, and the displacement sequences were viewed on a colour monitor (JVC, TM1500PS). After each 5 min interval, we raised the grain on which the female is located.

Experimental procedures

Experiment 1: Progeny production in conditioned maize grains

This experiment was used to determine the number of progeny produced by the maize weevil on the two grain types (uninfested and conditioned). Seventeen male/female pairs were placed in 95 × 25 mm glass tubes containing 50 uninfested grains. A similar number of pairs were placed in identical tubes on the equivalent number of conditioned grains. Each tube was covered with a perforated plastic cap and kept in the dark room. The tubes were left undisturbed for 1 week, and then the adults were removed. The tubes were kept for 7 weeks, and then the emerged adults were sieved out and counted to provide a measure of productivity (number of emergent offspring). Productivity provides a reliable index of the number of eggs laid if there is no density-dependent mortality. This issue was not considered to be important in the present experiment; however, it was assessed because a large number of grains (50) were available for oviposition by each female over a relatively short period of 1 week. All of the grains used in this experiment were kept in a freezer at –20°C for 1 week to kill any larvae and other organisms that might have been present. The grains were then transferred to and maintained in the rearing chamber for 36 h to obtain water content equilibrium before being used for the experiment.

Experiment 2: Influence of conditioned maize on the selection of grains

We placed 150 uninfected and 150 conditioned grains (42.2 to 45.3 g) side by side at a single-kernel thickness in a plastic tray (200 ×150 × 40 mm). Thirty unsexed *S. zeamais* adults were deposited at the centre of the tray. The tray was covered with a lid. After 1, 3

Figure 1. Egg plugs identification: (a) non colored grains, (b) grains colored with an acid fuschinic solution, (c) gelatinous egg plug (cherry red).

Figure 2. Device use to record the selection of grain hosts by the maize weevil female: (a) red light, (b) box containing insects and grains to be filmed, (c) camera (d) video recorder and (e) monitor.

and 6 h, the number of adults in each batch of grains was recorded (visually). Adults are mobile; thus, we assumed that 6 h is sufficient to judge grain preference. Ten replicates were made on 10 separate trays. The number of insects per grain type reflected the host selection preference of *S. zeamais*. The same procedure was repeated with two batches of uninfested grains to confirm that insect movement and distribution was not random.

Experiment 3: Selection of grain-hosts

The selection of grain-hosts by the maize weevil female was investigated under conditions containing one uninfested maize grain, one conditioned maize grain without egg and one conditioned maize grain of varying egg density (1, 2-3, 4 and 5 or more eggs/grain). The three different grains were exposed to an adult female weevil, which had been randomly selected from the laboratory cultures in a well. The insect displacement sequences were obtained by observing 6 h video recordings of the well, using the method described in Recording system. Eighteen to 24 replicates were performed for each egg density. The grain-host selection preference of *S. zeamais* was reflected in the number of times that the female was found on each type of grain.

Experiment 4: Effect of the presence of egg plugs on oviposition behaviour

Conditioned maize grains of varying egg density (0, 1, 2, 3 and 4 eggs/grain) were selected. At each density, five conditioned grains were mixed with five uninfested grains and placed on a Petri dish (55 mm ∅). The uninfested grains were stained with acid fuchsin to avoid bias, because the conditioned grains had been stained. Both grain types were marked using two different coloured dots made with an "Artline 725" permanent marker. Adult weevils were selected randomly from the laboratory culture, and the sexes were

Table 1. Mean number ± standard deviation of progeny produced by male/female pairs of the maize weevil, when exposed, for 1 week, to 50 uninfested maize grains and 50 conditioned maize grains.

Number of progeny produced	Type of grain	
	Uninfested grain	Conditioned grain
	10.77^{b} ± 6.60	17.47^{a} ± 8.03

Values with the same letter are not significantly different, Tukey's HSD test, P < 0.05. Means were the result of 17 replications.

Table 2. Mean number ± standard deviation of individuals found on each type of grain when placing 30 *Sitophilus zeamais* adults in a tray containing 2 different batches of uninfested grains vs. conditioned grains and uninfested grains vs. uninfested grains after 1, 3 and 6 h.

Duration (in hours)	*Grain type selected by weevils*			
	Uninfested grain vs. Conditioned grain		Uninfested grain vs. Uninfested grain	
	Uninfested grain	Conditioned grain	Batch 1	Batch 2
1	13.00^{c} ± 1.94	17.00^{a} ± 1.94	14.70^{abc} ± 1.25	15.30^{abc} ± 1.25
3	13.20^{bc} ± 1.81	16.80^{ab} ± 1.81	14.50^{abc} ± 2.01	15.50^{abc} ± 2.01
6	12.90^{c} ± 2.92	17.10^{a} ± 2.92	15.30^{abc} ± 3.71	14.70^{abc} ± 3.71

Values with the same letter are not significantly different, Tukey's HSD test, P < 0.05. Means were the result of 10 replications.

separated based on the dimorphic rostrum characteristics (Halstead, 1963) and were presumed fertile. Ten *S. zeamais* adults (five females and five males) were added to the grains and the Petri dishes were placed in the dark room under controlled laboratory conditions (see Grain and Insects section). Nine replicates were performed at each egg density. After 3 days, the adults were removed and the grains were stained again with acid fuchsin. Then, the number of egg plugs was counted for the two grain types. The average number of eggs laid on the conditioned grains was obtained after subtracting the number of eggs found from the number of eggs initially present.

Statistical analysis

Data were subjected to analysis of variance (ANOVA), followed by Tukey's HSD multiple comparison test at α = 0.05 when differences were detected in ANOVA, using the computer software SYSTAT. The square root and the angular transformation were used when variances were nonhomogeneous to correct for heterogeneity of variance prior to analysis (Dagnelie, 1986). However, the untransformed data are presented in the tables.

RESULTS

Progeny production on conditioned grains

The number of progeny produced was higher in previously conditioned maize. Significant differences (P = 0.004 < 0.05; F = 9.34; DF = 1) were observed in the means of adults present on conditioned and uninfested maize. The highest and lowest number of adults emerged on conditioned and uninfested maize (Table 1). Assuming that the number of emergent offspring represents a reliable index of eggs laid, this result implies that more eggs were laid on conditioned maize compared to uninfested maize.

Influence of conditioned maize on *S. zeamais* host selection

Significantly, more *S. zeamais* adults were found on conditioned maize. The two-way ANOVA did not indicate any significant difference in the distribution of adult weevils at different observation times (P = 1 > 0.05; F = 0.001; DF = 3). In addition, a similar number of weevils were attracted to the two grain types in all three test periods. Adult weevil distributions differed on conditioned vs. uninfested grain (P = 0.0001 < 0.001; F = 13.35; DF = 2) (Table 2). More adults were present on conditioned grains. Adult distribution was similar when given the choice of 2 batches of uninfested grains (Table 2). Thus, we confirmed that insect movement was not random on conditioned vs. uninfested grains. Conditioned grains seemed to have an attractant effect on the maize weevil.

Selection of grain-hosts by *S. zeamais*

During the 6 h of recording, females were found at least 30 times on the conditioned grain carrying eggs, irrespective of the number of eggs. Females were also found on the other two grain types (uninfested and conditioned grain without eggs), averaging 12 to 18 times (Table 3). The two-way ANOVA (after the angular transformation of the data) showed significant differences (P = 0.0001; F = 28.65; DF = 2) between the two grain types. In contrast, there was no significant difference in

Table 3. Mean number ± standard deviation of *Sitophilus zeamais* female locations when exposed to one uninfested maize grain and two conditioned maize grains over a 6-h period.

Number of eggs/conditioned grain	Type of grain		
	Uninfested grain	*Conditioned grain*	
		Without eggs	Carrying eggs
1	$13.58^{b} \pm 11.42$	$17.50^{b} \pm 15.45$	$34.21^{a} \pm 17.21$
2-3	$11.52^{b} \pm 10.27$	$18.76^{b} \pm 15.55$	$30.86^{a} \pm 15.64$
4	$15.84^{b} \pm 16.17$	$12.79^{b} \pm 12.58$	$33.37^{a} \pm 16.72$
5+	$14.39^{b} \pm 11.15$	$15.56^{b} \pm 12.03$	$30.50^{a} \pm 19.68$

Values with the same letter are not significantly different, Tukey's HSD test, P < 0.05. Means were the result of 18-24 (females) replications.

Table 4. Mean number ± standard deviation of eggs laid by *Sitophilus zeamais*, when presented with five uninfested grains mixed with five grains containing different numbers of egg plugs in a Petri dish after a 3-day oviposition period.

Number of eggs/conditioned grain	Type of grain	
	Uninfested grain	Conditioned grain
0	$0.89^{a} \pm 0.35$	$1.33^{a} \pm 0.50$
1	$0.89^{a} \pm 0.31$	$1.67^{a} \pm 0.62$
2	$1.22^{a} \pm 0.32$	$4.11^{b} \pm 0.48$
3	$1.00^{a} \pm 0.24$	$3.67^{b} \pm 0.88$
4	$1.00^{a} \pm 0.78$	$4.44^{b} \pm 1.31$

Values with the same letter are not significantly different, Tukey's HSD test, P < 0.05. Means were the result of 9 replications.

the number of eggs carried by grains (P = 0.985; F = 0.01; DF = 2) and in the interaction of grain type-egg density (P = 0.816; F = 0.39; DF = 4). Thus, maize grains carrying eggs may attract female maize weevils.

Effect of the presence of egg plugs on *S. zeamais* oviposition behaviour

Females appeared to lay their eggs preferentially on conditioned grains (Table 3). The number of egg plugs on maize grains increased in relation to the number of previously deposited eggs. Gravid females oviposited more than 80% of eggs on grains containing two or more egg plugs. The two-way ANOVA showed significant differences (P = 0.0001; F = 26.543; DF = 1) between the two grain types and a significant difference among egg density levels (P = 0.031; F = 2.813; DF = 4) (Table 4). Conditioned grain may be preferred because of the density of eggs. The presence of a previously deposited egg may serve as a key attractant.

DISCUSSION

This study demonstrated that *S. zeamais* adults are able to differentiate between conditioned and uninfested maize during grain-host selection and egg-distribution on grain under laboratory conditions. Grains already conditioned by conspecific adults attracted subsequent maize weevils. More individuals emerged from conditioned maize because females laid more eggs on this grain type compared to uninfested maize. A similar phenomenon was observed by Longstaff (1981) which showed that *S. zeamais* clumps its eggs. This behaviour can be explained by the fact that egg aggregations occur because females prefer to oviposit on large grains. Yet, Stejskal and Kucerova (1996) showed that the oviposition preference for larger kernels is not constant, but is density dependent. For example, a decrease in egg aggregation occurs as the number of grains available for oviposition increases. In this study, grains were sorted, initially by both sieving and then visually, to avoid cracked grains, which attract maize weevils (Walgenbach et al., 1987), and to obtain uniformity in the shape and size of the grains. However, some conditioned kernels might have been slightly damaged or food odours may have attracted the adults.

Moreover, we found that *S. zeamais* females not only distinguish between conditioned and clean seeds, but also assess egg load quantitatively. Maize weevil females are able to recognise the presence of eggs and preferentially oviposit on grains with high egg density. The ability of females to perceive differences in egg density implies that relevant cues only exist after each preceding oviposition. A chemical basis of host recognition should be related to the aggregation pheromone (Walgenbach et al., 1983; Schmuff et al., 1984; Phillips et al., 1985; Walgenbach et al., 1987) called (4S,5R)-sitophinone (Walgenbach and Burkholder, 1986). Walgenbach et al. (1983) showed that when feeding on hosts, males produce an aggregation pheromone that attracts both sexes and causes "aggregation at optimum locations" where feeding, mating and oviposition might take place.

The aggregation pheromone also causes a larger number of individuals to gather locally, altering the microclimate, which would benefit the individual that released the pheromone (Plarre, 1998). Rising humidity and temperature have been recorded in aggregation hotspots formed by stored-product beetles and weevils (Longstaff, 1981; Sinha, 1984). It is likely that the conditioned grain in this experiment was contaminated with aggregation pheromone produced by male weevils. However, the deposition of eggs in the centre of an aggregation might endanger offspring, due to the presence of feeding adults. Mated females must strike a balance between favourable humidity and temperature conditions versus security for offspring, when selecting oviposition sites. According to Plarre (1998), the optimal location is on the periphery of hotspots. This phenomenon may explain why grain samples taken from the area surrounding a baited trap contained more weevil progeny than grain samples taken from the area surrounding unbaited traps (Plarre, 1996).

Preferred oviposition on grains already containing eggs was not expected, because studies with other insects that have confined larval stages (tephrids, bruchids, etc.) indicate that females should avoid competition and place eggs on grains that are uninfested (Messina and Renwick, 1985a, b). Previous works have shown that, as well as reducing the survival of larvae to maturity; larval competition also negatively influences the fecundity of surviving adults (Colegrave, 1993). In addition, larval competition does not influence adult fecundity, independent of its effect on adult weight (Credland et al., 1986; Colegrave, 1993). Consequently, our results raise two fundamental questions: how does this oviposition behaviour confer a fitness advantage; and how is it adaptive for the females that choose to cluster eggs in a stored grain environment.

If the tendency to clump eggs within grain does not depend on the experimental conditions, this type of oviposition strategy could be related to a certain adaptive mechanism. The presence of ovicide and cannibalistic behaviour represent two possible selective strategies. In general, weevil larvae are not able to migrate between grains and larval competition is assumed to be very high in a host grain containing multiple larvae. Either the *Sitophilus* female should (1) attempt to reduce individual competition faced by its offspring by killing eggs that are already present (ovicidal strategy), or (2) a larva within a grain should destroy other larvae (attack strategy) to maximise its expected fitness (Smith and Lessells, 1985). Regarding weevil behaviour, the hypothesis of the attack strategy is supported by the fact that larval cannibalism, which is known to enhance adult fecundity and generate nutritional benefit (Alabi et al., 2008; Alabi et al., 2009; Alabi, 2010; Via, 1999), seems to be controlled genetically (Stevens, 1989). However, there are no published estimates of ovicide and larvicide in *Sitophilus* species. Furthermore studies about cannibalism and fecundity may help provide explanations for the results reported in this paper. The results of this study provide baseline information from which further research on cannibalism and fecundity of pest insect species inhabiting stored agricultural products may be investigated.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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