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Full Length Research Paper

Does benzyladenine application increase soybean productivity?

Larissa Pacheco Borges, Hilton Dion Torres Junior, Tárik Galvão Neves, Clair Kássio Lamberty Cruvinel, Priscilla Gomes de Freitas Santos and Fábio Santos Matos*

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Although soybean flowers are produced abundantly, a large number of flowers and young pods abort naturally. Abortion reduction may result in an increased number of pods, thus leading to a growth in grain yield. The objective of this study was to evaluate the effect of benzyladenine application on soybean pod abortion and, consequently, to increase the productivity of soybean cultivation. The soil of the experimental area is classified as oxisol. After soil analysis, fertilization and pH correction were performed according to technical recommendations for cultivation. Pioneer 98Y12 RR soybean was sown by mid-November, during the rainy season. Benzyladenine application at the end of flowering, with pods of about 1.5 cm length, provided a significant increase in productivity of the species for all used concentrations, with the treatment of 300 mg L^{-1} corresponding to the highest increase, around 11%. The increase in productivity was determined by the higher number of total pods fixed to the plants by reason of abortion reduction in the three canopy positions. Other factors that contributed to the increased productivity were the higher number of seeds per plant, higher weight and seed diameter. Benzyladenine application is a promising practice for getting high productivity in the cultivation of soybean.

Key words: Growth regulator, abortion, grain yield.

INTRODUCTION

The growing global demand for food**,** especially in the light of the population growth, has intensified the search for a fair balance between increased food production and environmental, economic and social questions.

Fao (2009) estimates that, for the first half of the 21st century, the global demand for food will grow about 70%, a problem connected with intense competition for arable lands between food crops, energy crops and other industrial purposes. The most dynamic products of Brazilian agribusiness should be cotton, soybeans, chicken meat, sugar, maize and cellulose (Ojima, 2011). Among agricultural products, soybean has a significant importance for supplying the growing world population with food.

Soybean (*Glycine max* (L.) Merr.) is one of the most widely grown and consumed oilseeds in the world. The large growth of soybean production can be attributed to various factors, with special mention of: High protein content (around 40%) of excellent quality, both for human and animal feeding; high oil content of the seeds (around 20%), which can be used for various purposes, especially for human feeding and biofuel production (Lazzarotto and

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Hirakuri, 2010).

Brazil has one of the world's largest areas of arable land, with capacity to expand the cultivation of this oilseed to meet the demand for food and biofuel (Yu et al., 2013). However, the expansion of the planted area has been facing challenges, as the deadlock of environmental questions involving deforestation and its impact on environment, like greenhouse gas emission and biodiversity loss (Lazzarotto and Hirakuri, 2010). The growth of soybean production will occur depending on higher grain yield of the crop, and researches will need to be developed to adopt new management practices that guarantee higher productivity.

Studies indicate that soybean grain yield is more decisively determined by the number of pods than by other components of production (Yashima et al., 2005). The amount of flowers that give rise to the pods until reaching maturity is a key factor for getting high yields. Although soybean flowers are produced abundantly, a large number of flowers and young pods abort naturally (Nonokawa et al., 2012). Some researches show that, in normal conditions, the abscission of the reproductive structures of soybean can vary between 20 and 82% of the total number of flowers produced (Crosby et al., 1981; Carlson et al., 1987; Yashima et al., 2005; Peterson et al., 2005).

The mechanisms responsible for flower and pod fixing are not completely established. According to Dario et al. (2005), the application of growth regulators could raise productivity above levels established until now. Researches point out the use of plant growth regulators to reduce pod abortion (Crosby et al., 1981; Nonokawa et al., 2012; Passos et al., 2011). In soybean cultivation, there seems to be a link between exogenous benzyladenine and reduction of flower and pod abortion (Crosby et al., 1981; Carlson et al., 1987; Nagel et al., 2001; Yashima et al., 2005; Nonokawa et al., 2012; Passos et al., 2011).

Abortion prevention may result in an increased number of pods and seeds, thus leading to a growth in grain productivity (Nonokawa et al., 2012). Therefore, studies to increase soybean productivity have deserved much attention of researchers in recent years, in order to meet the predictable growing world demand for the grain. Aiming at raising pod percentage through abortion reduction and, consequently, at increasing the per hectare productivity of soybean, this study's objective is to evaluate the morpho-physiological effect of benzyladenine application on soybean pod abortion and, consequently, to increase its productivity.

MATERIALS AND METHODS

Experimental design

The research was carried out in the Panorama farm, located in the municipality of Ipameri, State of Goiás (Lat. 17° 67' 90'' S, Long. 48° 19' 59'' W, Elevation 805 m). This region has an Aw climate, according to Köppen classification, characterized as a tropical wet climate with rainy summers and dry winters. The soil of the experimental area is classified as Oxisol.

After soil analysis, pH correction and fertilization were performed according to technical re-commendations for cultivation (Prochnow et al., 2010). 120 kg ha^{-1} broadcast potassium chloride (KCl) were used 10 days before sowing and fertilization was performed at the time of sowing with application of 350 kg ha^{-1} of the 04-30-10 formula. Pioneer 98Y12 RR soybean was sown on November 23, 2012.

Initially, a benzyladenine stock solution was prepared by weighing 2000 mg benzyladenine and dissolved in distilled water with 8 ml NaOH 1 N solution, and then the volume was completed with 50 ml distilled water. From the dilution of the obtained solution, soybean plants received the following treatments: 0, 100, 200, 300 and 400 mg L^{-1} benzyladenine. The experiment was conducted in a randomized block design, with application in R_3 phase, broth volume of 200 L ha^{-1} and five replications. We attempted maximum uniformity in the application, by spraying benzyladenine on the leaves and flowers; to this end, we used a dosing valve coupled to a backpack sprayer. 90 plants were grown in an experimental plot of 3 × 2 m, with 0.5 spacing between the rows and 10 plants per linear meter.

The following variables were analyzed: Stomatal density, specific leaf area, length and width of leaves, number of pods in upper, middle and lower canopy and total leaf nitrogen concentrations were measured when the pods were fully developed and grains were perceptible to the touch with 10% grain fill, corresponding to $R_{5.1}$ stage.

Pod abortion

To analyze pod abortion, we counted the number of pods in the three canopy positions (lower, middle and upper) of soybean plants in the reproductive $R_{5.1}$ phase and at harvest maturation point, which corresponds to the reproductive R_9 phase. The counting difference in these two phases corresponded to the number of aborted pods in the lower, middle and upper third.

Stomatal density determination

Replicas of the adaxial and abaxial leaf surfaces were removed with colorless nail polish in the region of the middle third of previously dehydrated leaves. Stomata in the replicas were counted with the help of an optical microscope equipped with a camera lucida. Stomatal density was determined by counting the stomata located in an area of 1 mm^2, giving the number of stomata/area (Jadrná et al., 2009). Five replicas of the adaxial surface and five replicas of the abaxial surface of each replication were analyzed to determine stomatal density.

Specific leaf area (SLA)

To get the specific leaf area, we removed six leaf disks of 12 mm diameter from fully-expanded leaves which were dried in a greenhouse at 70°C for 72 h to determine dry weight. SLA was obtained through the equation proposed by Radford (2013).

Leaf area (LA)

Leaf area was determined following the equation proposed by Adami et al. (2008). For this purpose, we used an mm-graduated tape to obtain length and width of the leaves.

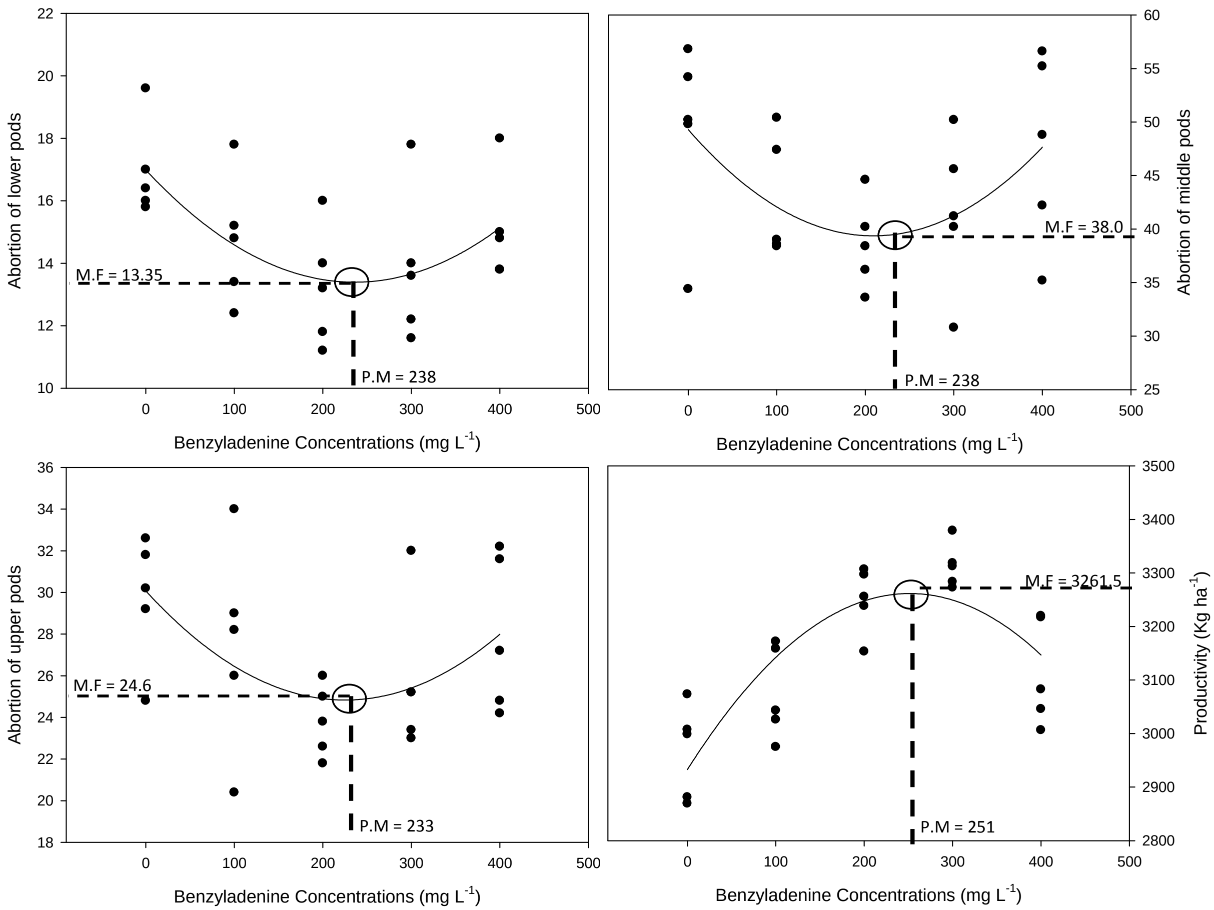

Figure 1. Regression equations for pod abortion of the lower third ($Y = 16.9874 – 0.0305x + 0.000064x^2$, $R^2 = 0.98^{**}$), pod abortion of the middle third ($Y = 49.2949 - 0.0950x + 0.0002x^2$, $R^2 = 0.97^*$), pod abortion of the upper third ($Y = 30.0766 - 0.0466x + 0.0001x^2$, $R^2 = 0.96^*$) and productivity per hectare ($Y = 2932.7643 + 2.6152x – 0.0052x^2$, $R^2 = 0.99^{**}$) of soybean plants treated with different doses of benzyladenine.

Nitrogen concentration

Samples of fully expanded leaves were collected and total N concentration was determined following Cataldo et al. (1975).

Productive variables

Number of seeds per plant, 100 seed weight, seed diameter and productivity were measured in the reproductive R_9 phase. 100 seed weight and productivity were adjusted to 13% moisture.

Experimental design and statistical procedures

Analyses of variance were processed following the randomized block design with five treatments, five replications and plot with 90 plants. Data were submitted to regression analysis using SISVAR 5.3 software (Ferreira, 2011).

RESULTS

The data obtained were adjusted using the quadratic regression model (Figure 1). Results show that benzyladenine application at the end of flowering, with pods of up to 1.5 cm length, provided a significant increase in the productivity of the species for all concentrations used, with a peak for the concentration of 251 mg L^{-1}, which corresponds to the highest gain in productivity around 11%. Abortion reduction was proportionally higher in the lower and middle third of the plants. The lower third featured a reduction of 21.3% of pod abortion at a concentration of 238 mg L^{-1} compared to control, resulting in an increase of 3.6 pods per plant. In the middle and upper third of the canopy, the reduction of pod abortion provided an increase of 22.8% (11.3 pods per plant) and 18.0% (5.4 pods per plant) respectively. The peak corresponding to the benzyladenine concentrations in the middle and upper third were 238 and 233 mg L^{-1}, respectively.

Data relating to 100 seed weight, seed diameter and number of seeds per plant were adjusted using the quadratic regression model (Figure 2). The results represented by the 100 seed weight show that there was

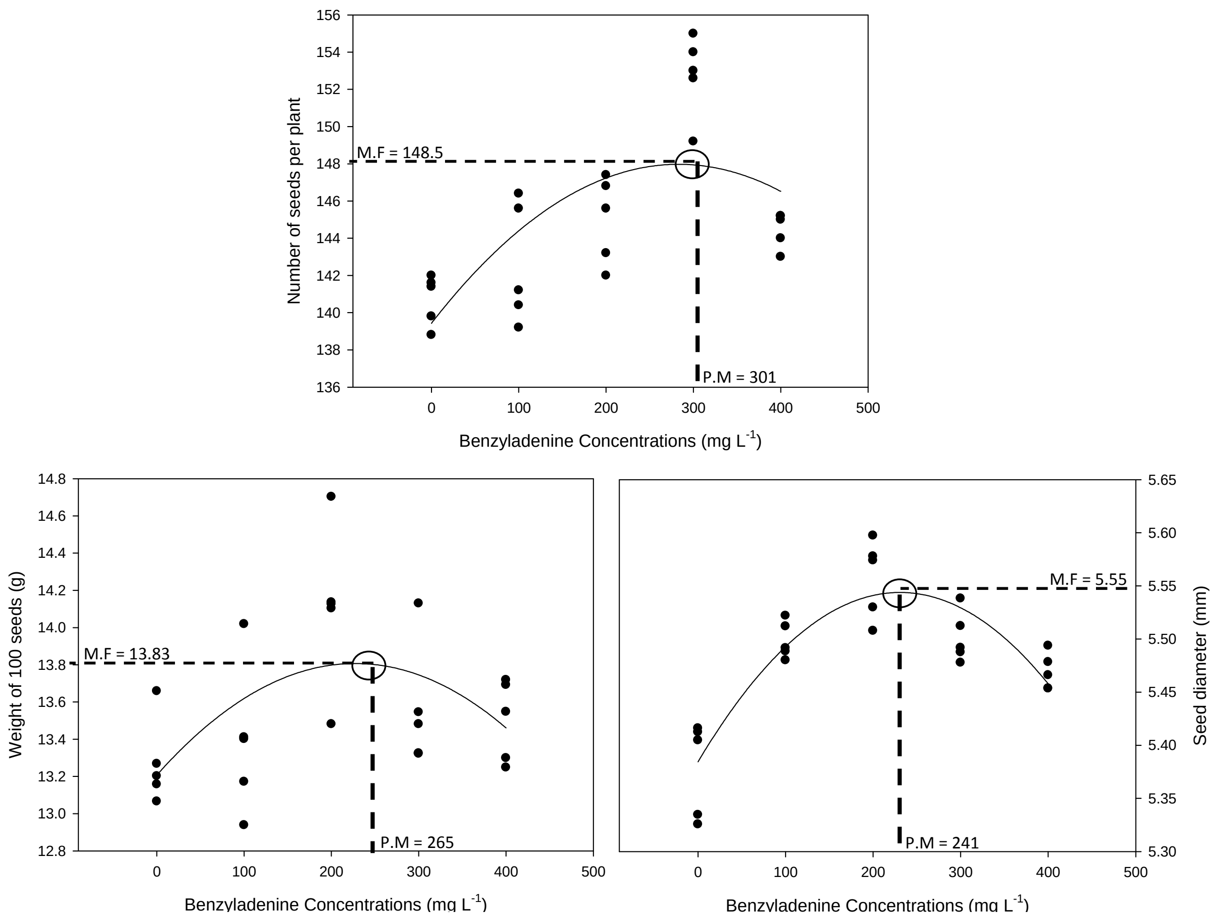

Figure 2. Regression equations for 100 seed weight ($Y = 13.2073 + 0.0053x - 0.000011x^2$, $R^2 = 0.99$*), seed diameter ($Y = 5.3845 + 0.0014x - 0.0000029x^2$, $R^2 = 0.99$**), and number of seeds per plant ($Y = 139.4286 + 0.0603x - 0.0001x^2$, $R^2 = 0.99$**) of soybean plants treated with different doses of benzyladenine.

a significant increase at all concentrations used in relation to control, presenting a peak corresponding to a concentration of 265 mg L^{-1} with a 5% increase in the seed weight. As for the seed diameter and number of seeds per plant, peaks were verified with concentrations of 241 and 301 mg L^{-1}, with contributions of 3 and 7% respectively, decreasing at higher doses.

The unit and specific leaf area and the number of stomata of the leaf adaxial and abaxial surfaces were described by quadratic models show in Figure 3. Variations in leaf expansion were also found with the increase in benzyladenine concentrations up to the dose of 220 mg L^{-1}, with maximum gain of 4%, decreasing at higher concentrations. Specific leaf area showed significant differences with the various benzyladenine concentrations, the highest result being found for the dose of 250 mg L^{-1}, with average variation of 9% in relation to control. The number of stomata of the adaxial and abaxial surfaces presented significant variation with benzyladenine application. On average, this variable showed an increase of 16 and 32%, when the control was compared with the corresponding peak at 325 and 227 mg L^{-1}, respectively.

DISCUSSION

Responses to benzyladenine application strongly show the importance of cytokinins to soybean, for influencing pod fixing and seed development and, consequently, raising the crop yield.

Levels of endogenous cytokinins in the xylem of soybean are high at the beginning of anthesis and decrease with the progress of flowering (Carlson et al., 1987). Low availability of cytokinin associated with intense competition for nutrients and assimilates between developing fruits and vegetative organs limits the production potential of seeds in the cultivation of soybean and promotes an intense abortion of the reproductive structures. We suggest that benzyladenine application raises the endogenous hormone levels in the plant, increasing the drain strength. Strengthening the drain intensifies the unloading of assimilates, influencing directly the photosynthesis balance, which results in a

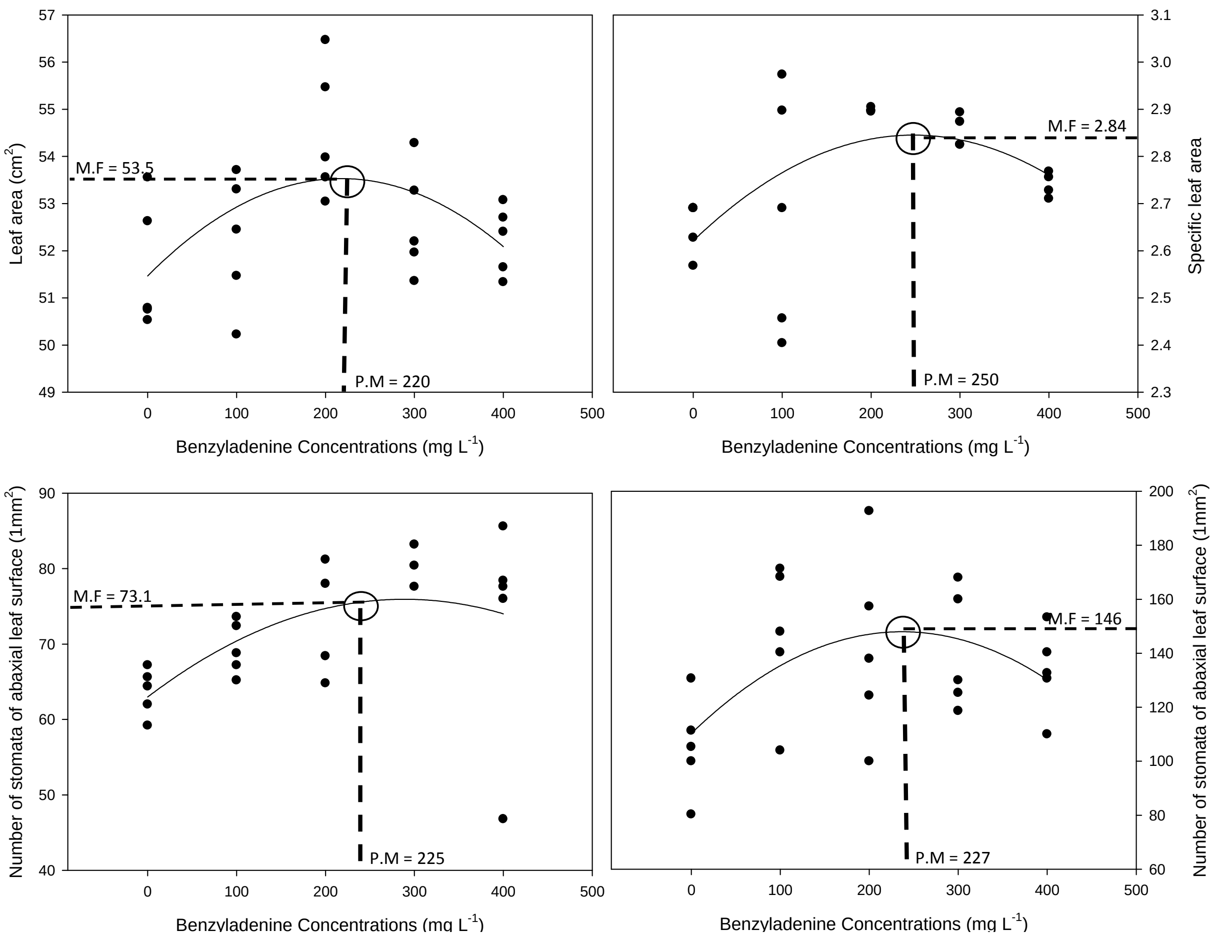

Figure 3. Regression equations for leaf area ($Y = 51.4672 + 0.0189x - 0.000043x^2$, $R^2 = 0.99^*$), specific leaf area ($Y = 2.6212 + 0.0018x - 0.0000036x^2$, $R^2 = 0.99^*$), number of stomata of the adaxial leaf surface ($Y = 62.9821 + 0.0898x - 0.0002x^2$, $R^2 = 0.98^*$) and number of stomata of the abaxial leaf surface ($Y = 110.2838 + 0.3179x - 0.0007x^2$, $R^2 = 0.95^{**}$) of soybean plants treated with different doses of benzyladenine.

higher production of assimilates.

The increased drain strength of the reproductive organs and the larger translocation of assimilates to these organs explain, at least in part, the higher 100 seed weight in plants treated with benzyladenine in relation to control. Similar results have been found by other authors using synthetic cytokinins in soybean plants (Carlson et al., 1987; Passos et al, 2011).

Benzyladenine resulted in significant gains in the number of pods fixed to the plants, with increases mainly in the pods located in the lower and middle third of the canopy. During the vegetative growth of soybean plants, stem tips and roots are normally the main drains; seeds and fruits become the dominant drains during the reproductive development, in particular for adjacent or close leaves. We may induce that the ability of benzyladenine to regulate the balance of power between sources and drains may have provided a higher mobilization of assimilates for the lower pods, reducing the amount of assimilates in direction of the roots, resulting in a higher fixing of pods in the lower and middle third of soybean plants. An experiment carried out by Nagel et al. (2001) showed that plants treated with benzyladenine use to have a less developed root system, for he noted a more visible withering in the heat of the day when compared with control plants.

The increase of the productivity of soybean plants treated with benzyladenine is in part explained by morpho-anatomical changes in the leaf, like expansion of leaf area; increase of the specific leaf area and of the number of stomata per leaf. The larger leaf area and consequent lower leaf thickness may have contributed to optimizing the interception of the light that reaches and crosses the interior of the canopy, increasing the amount of photosynthetically active radiation able to reach the lower strata of the soybean plant. The higher transmittance allowed the realization of more photosynthesis at canopy level, with direct effect on the production of photoassimilates. Of course, all these factors contributed to the optimization of photosynthesis, resulting in a significant increase in the number of pods and seeds, and consequently in productivity.

Benzyladenine application at the end of the flowering of soybean plants is a promising production technology, since it significantly increased the productivity.

Conclusion

1. Benzyladenine application reduced pod abortion in the lower, middle and upper third of the canopy of soybean plants.
2. Soybean plants treated with benzyladenine showed higher yields than control plants.
3. The highest productivity was obtained in soybean plants treated with a concentration of 300 mg L^{-1}.
4. Benzyladenine application at the end of the flowering phase is a promising management practice for soybean cultivation.

Conflict of Interest

The authors have not declared any conflict of interests.

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Full Length Research Paper

Certification rules for the fruit agri-business

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Orcharding is an activity with a high multiplier effect on income and it represents one of the main alternatives for the generation of employment in the development of agribusiness in Brazil. Certification aims to raise the standards of quality, adding value to the product and may contribute to competitiveness in the fruit industry as it is an important requirement for entry the international market. This paper conducts a systematic review of the scientific literature about the trade requirements and procedures required for the export of fruit, mapping the intellectual production developed over the last ten years. The universe of data collection comprised databases (SciELO, Scopus and Science Direct), Brazilian journals and conference proceedings in the area, following a standard literature search for systematic coherent keywords. The results show that the consumer is more aware about the whole supply chain and that the certification produces benefits not only related to the production process but also associated to environmental and social sustainability.

Key words: Certification, fruit and literature review.

INTRODUCTION

Brazil is the third largest producer of fruit worldwide after China and India, however in terms of tropical fruits Brazil ranks first (Kist, 2012). Orcharding is an activity that has a considerable positive effect on the Brazilian economy, through employment generation, as well as being a driving force behind its agribusiness development. More specifically, the orcharding pole of Petrolina-Juazeiro located in northeastern Brazil serves as an example of the capacity for growth and development of the orcharding in general (Buainain and Batalha, 2007).

In recent years, consumer confidence in food safety regarding perishables, such as fruits, has been shaken a few times. In contrast, many countries that import products together with key actors in the supply chain use global strategies to repair people's confidence in the safety of their food through the adoption of specific programs to ensure control, standardization and traceability throughout the food production chain. According to Spers (2003), food security, under the qualitative approach, is capable of ensuring that the consumers will purchase high-quality products guaranteeing their safety. This productive approach, that places a priority on a certification process that helps market quality and safety, has grown in importance, together with new manufacturing processes as well as new trends in consumer behavior.

Certification systems largely focus on the supply chain of fruit. There are implications in different parts of the chain, on both the supply and production demands, and in particular the certification focuses on activities from

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Table 1. Planning methodological.

Steps of the systematic literature review	Strategy adopted
1. Identify the databases to be queried and set keywords	The survey was conducted on the world wide web (internet) and included the databases (SciELO, Scopus and Science Direct), Brazilian magazines in the agricultural area and conference proceedings (lectures/publications), with a standard literature search using the keywords: "certification" "fruit production", "fruit exportation", "traceability", “quality certification".
2. Selection of publications	Studies published from 2001 to 2011 were considered that address the issue of Certification of food products
3. Data analysis	The information of the works were organized and tabulated so it was possible to develop comparisons and analyses
4. Synthesize the data	From the data analysis it was possible to prepare a systematic summary.
5. Conclusion	From the summary it was possible to understand the importance of certification in the supply chain of fruit

production planning to post-harvest. Nassar (2003) highlights the propagation of certification systems used as an instrument that provides standardization and procedures that enable quality control to ensure a set of attributes. In this case, the certification system serves as a tool to remove or classify companies and products. On the demand side, certification systems establish certain required features for a product, serving to unify standards and increase overall market efficiency.

It appears that private certifications are increasingly being used in all phases of the supply chain in order to exert control over the entire production process in order to limit the risk associated with various activities during production, from harvest through final transport, by various actors in the supply chain to ensure consistent, safe quality products (Jaffee and Masakure, 2005; Humphrey, 2008; Vagneron et al., 2009). In Tennent and Lockie’s view (2012), these certifications play an increasing role in determining access to the market and can be considered as an opportunity for small farmers to update their productive systems in the scope of Good Agricultural Practices (Asfaw et al., 2010), mainly in fresh fruit and vegetable markets (Unnevehr, 2000; Garcia and Poole, 2004).

Henson and Humphrey (2010) emphasize that the current proliferation of private certification sets new challenges for farmers and operators in the food chain, especially those located in developing countries, such as Brazil.

The objective of this study is to carry out a systematic review of scientific literature about the commercial and procedural requirements of fruit exportation, understanding which agents are involved in a certification process in the orcharding sector and how its quality standards add value to the product while also intensifying competetiveness in the fruit industry.

RESEARCH METHOD

The research method used was a systematic review of literature adapted from Kitchenham (2004) and Sampaio and Mancini (2007) (Table 1).

RESULTS AND DISCUSSION

The results were grouped according to the subjects of the works analyzed.

System of certification

According to Nassar (2003), certification is the defining of the attributes of a product, process or service and ensuring that they fit into pre-defined guidelines. On the supply side, certification is an instrument to provide standards and procedures that are intended to enable companies to manage their attributes and ensure access to the markets. From the perspective of the customer, certification is designed to inform and ensure the recommended attributes, related to quality and safety, for the product. Certification becomes important when (self-regulated) standardization becomes insufficient to meet the needs of those involved in the processes of production and commercialization.

According to Lazzarotto (2003) certification is stimulated in a market where there are consumers who recognize that a certified product is a product with attributes of a different quality and who are willing to pay a little more for these products. In markets where there are consumers willing to pay for that distinctive quality, certification should be available only through institutional determinations. Thus, understanding consumer behavior is important for the survival and competitiveness of companies and certifiers certified. Following this reasoning, Lourenzani et al. (2006) believes that certification is just one important necessary step for the producer who can offer their products in domestic and international markets differentiated by the fact that the consumer recognizes a differential in the certificate to offset the higher purchasing price.

The certifications facilitate access to new markets, improved product quality, and add value to encourage forms of cooperation between producers and agribusinesses (Giovannucci and Ponte, 2005). Certification is a way to differentiate the product without the huge investment that the formation of a brand requires. At the same time, a certified product is, from the standpoint of industrial processing and modification, identical to similar non-certified like products. In other words, the certification adds value without changing the product (Nassar, 2003).

Jahn et al. (2004) point out that the differences among certification processes are in the concept of quality, in the presence or absence of protectionist elements and depth of coverage in relation to the productive chain. The authors believe that in practice the development of the certification system is still in its early stages. The functions performed by the certification process are of market character (adjustments made for the goods to meet market demands) and commercial (market information or market communications with the market) character (Gomes et al., 2006).

Certification has important consequences for the fruit industry in Brazil because it guarantees access to export markets. It guarantees the quality and traceability, allowing producers of fruits from Brazil to reach new markets, without, however, guaranteeing higher prices (Dorr, 2008).

However, Humphrey (2008) highlights the challenges to deploy and maintain these licenses/certifications include technical requirements (e.g., infrastructure and equipment for health/hygiene and safety, and using the right chemicals in the right amounts) to maintain records.

Models of fruit certification

Certification involves the existence of standards, certification bodies and accreditation bodies. In order to operationalize the process, there should be a regulatory agency that sets the norms and a coordinator agent, responsible for the coordination and certification process (Lazzarotto, 2003). In private certifications, trust in the brand represents a contract between the company and the consumer, whose renewal depends on an accurate strategy for quality management that surpasses the limits of the company and expands to its suppliers and distributors (Scare and Matinelli, 2001).

Among the certification mechanisms involving public and private agencies for regulation and monitoring, the best known is Integrated Fruit Production – IFP, a voluntary program. The system of integrated fruit production (IFP) emerged in Europe in the 70s, with a view to using self-sustainable production systems that provide protection and integrated management of plants, with the goal of quality production and environmental sustainability. The precursors of this system were Germany, Switzerland and Spain, where they replaced the traditional production techniques with this system, reducing production costs and environmental damage, and improving product quality (Andrigueto and Kososki, 2005). The IFP is defined by the International Organization for Biological and Integrated Control of Noxious Animals and Plants (IOBC) as: "System to produce high quality fruit based on the principles of environmental sustainability, food security and economic viability by using techniques not harmful to the environment and human health" (Andrigueto and Kososki, 2002).

The four pillars that support Integrated Fruit Production (IFP) are: Organization of the productive base, sustainability of the system, monitoring of processes and information. The purpose of this system is to produce high quality food, while depending on the use of techniques that take into account the environmental impacts on the soil, water and production (plant). During the evaluation of the quality of products, the system considers physical, chemical and biological characteristics of local natural resources in the processes involved in the production chain. The IFP and the implementation in the production process of so-called Good Agricultural Practices (GAP)1 promote the standardization of production processes in order to ensure product quality to meet international requirements (Fonseca et al., 2010).

Integrated production activities in Brazil began in 1998/99 with a free membership program for producers and packers, under the overall coordination of the Ministry of Agriculture, Livestock and Food Supply - MAPA. Its regulation achieved a legal milestone in 2001 with the publication of its basic guidelines in the Official Gazette of the Government of Brazil. Among the goals achieved with this system of production, there is emphasis on production tracking, which gives the farmer a certification seal, and the exporter, a quality fruit (Andrigueto and Kososki, 2005). The IFP was renamed Integrated Production (IP) and is currently valid for all agribusiness chains, and it is responsible for providing the specific standards for each crop (Brazil, 2012). Integrated Production should still be applied holistically, because it is based on rules that take into account the features of each ecosystem and considers welfare as well as the conscious exploitation of natural resources. It is a system in which its basic unit is centered on the

[1] Good Agricultural Practices (GAP) refers to the practice and procedures established for the primary production to control hazards, productivity and quality. The practices and procedures are based on the application of technologies developed for the control of the possible dangers and potential for product quality and productivity in the field (Manual of Good Agricultural Practices and HACCP, 2004).

whole farm system and its application on individual parts of the operation that are not compatible with the holistic vision (Embrapa Meio Ambiente, 2012).

Among the private certification schemes, there are the initiatives of supermarket chains. An internationally recognized model, which like IFP is a voluntary program, is provided only to those who fall within pre-established norms. The EurepGAP / GlobalGAP frequently mentioned in the area of certification, was created by an association of European supermarkets. Launched in 1997 by the Euro-Retailer Produce Working Group (EUREP), EurepGAP/GlobalGAP corresponds to a frame of reference of good agricultural practices, which aims to serve the interests of consumers, in terms of food safety, animal welfare, environmental protection and health, as well as safety and well-being of the worker (EUREPGAP, 2004). Consists of a set of normative documents, which include the General Regulations Integrated Farm Assurance, the document GLOBALGAP Control Points and Compliance Criteria and the GLOBALGAP Checklists (GlobalGAP, 2013). To obtain EurepGAP certification an audit is performed by auditors of unbiased companies. They are skilled enough to act professionally while checking whether the standards established by the Protocol are being met in every respect (Pessoa et al., 2002).

According to Cavicchioli et al. (2005), the EurepGAP is the most common seal found in Europe and it is accepted by about 30 retailers representing 34% of the European market. Gomes et al. (2006) point out that European countries were pioneers in the search for agricultural certification due to the internationally recognized tradition of valuing and seeking food production quality. The Europeans were the first to have products with certificates attesting to the quality of its products as superior to other similar and also attest to the origin. The European retail sector plays a key role in assembling and organizing marketing alliances that aim to ensure the quality of production processes and agricultural products (Carfantan and Brum, 2006). Thus, the network of retailers in Europe was the initial driving force for what was already becoming an issue for their customers. For this reason, the development of a certification standard with more general acceptance was also the interest of producers. EUREPGAP focused on Good Agricultural Practices - GAP, highlighting the importance of Integrated Production and of working conditions of agricultural laborers (Berger, 2009).

Due to the wide acceptance of the EurepGAP concept from producers worldwide, at the end of 2007 it was decided to change the brand to GLOBALGAP.GLOBALGAP is now a private organization that sets voluntary standards for the certification of agricultural products around the world, whose secretariat is based in Germany. Their goal is to establish standards of Good Agricultural Practice (GAP) that include different requirements for the several products, adaptable to agriculture worldwide. GLOBALGAP has volunteer members who are divided into three groups: Producers, suppliers or retailers, and distributors (Berger, 2009). The Global GAP is a need to maintain access to export markets, investments, and these investments are likely to generate substantial profits. The same has been gaining global importance, becoming indispensable, especially for exporters who supply the European market (Henson et al., 2011). EurepGAP also establishes requirements to ensure the conservation and welfare of the people who are involved in food production, stimulated also by the use of Hazard Analysis and Critical Control Points - HACCP. The main points of control are: Storage and maintenance of records; traceability; seedlings and varieties; seed stocks; history and site management; soil and substrate management; use of fertilizers; irrigation; crop protection; harvesting; post-treatment harvesting, pollution and waste management; recycling and reuse; health, safety and welfare of workers, environmental issues; customer service and complaints (Cavicchioli et al., 2005).

The Control Points and Compliance Criteria (CPCC) assessed as critical of the level of service in the early stage of EurepGAP certification are: Fertilization, crop protection, waste management and pollution, recycling and reuse, health, safety and welfare workers and environmental issues (Paulino and Jacometi, 2006). In addition, the EurepGAP protocol consists of a set of basic requirements of good agricultural practices that correspond to global standards of food safety, environmental preservation, health and safety and animal welfare (Cafartan and Brum, 2006). EurepGAP certification can be given to a producer or a group of producers (belonging or not to an association or cooperative). A version of this protocol, published in March 2001, defines essential elements for the development of best practices for the global production of vegetable and fruit products. These guidelines define the minimum acceptable standard to guide groups of European producers (Pessoa et al., 2002).

Another seal, considered voluntary, that can be cited is Tesco Nature's Choice (TNC). This is a private process of certification of suppliers used exclusively by the British retailer Tesco. More stringent than the EurepGAP, the Code of Practice Tesco Nature's Choice was created by the technical staff of Tesco, with requirements aimed at product quality, the use of best management practices for products and processes, protection of the environment, as well as improving the welfare of rural workers and biodiversity. To get the seal, you must be a supplier of Tesco, and all those interested in supplying the network had to be certified by January 2006 (Cavicchioli et al., 2005). In TNC certification the products are marketed only in its own stores, making the seal highly restrictive.

In addition to voluntary certification, the main requirement for the United States to permit imports is the Department of Agriculture (USDA) pre-shipment seal of the Animal and Plants Health Inspection Service (APHIS) which is a certificate that includes health and phytosanitary and animal health regulations, presenting specifications for each fruit and vegetable (Assis, 2009).

The APHIS seal uses several methods to protect their producers and consumers against the introduction of diseases, plant and animals pests that might limit or jeopardize food production. It is based on a strategy to safeguard human animal and plants health, making a secure ecosystem, providing safe agricultural trade, and reducing loss of natural resources (APHIS, 2011). For the issue of USDA-APHIS, there must be monitoring by a representative of the USDA itself, funded by producers, which significantly burdens the export process.

According to Trienekens and Zuurbier (2008), voluntary certifications have become almost a mandatory requirement for access to markets, especially those in developed countries. Companies that focus on the international market are faced with the need to certify their product and process for different voluntary standards. Companies need to demonstrate greater control in the production, trade and distribution of food to ensure quality and traceability of their product and remain competitive in the market. Thus, standards can act as reducing trade barriers by reducing the information asymmetry between buyers and producers, providing greater confidence between the parties to the transaction.

Some studies have shown the impact of certifications for exports of products in some countries. A study of fruit growers in Thailand showed that the costs of implementation are still major barriers to farmers adopting the GlobalGAP. However, the main determinants for farmers to acquire and maintain the standards are: Establishment size, capital, access to information and external assistance (Kersting and Wollni, 2012). Maertens et al. (2012) conducted a study on the inclusion / exclusion of smallholders in export horticulture chains of high standards in Africa. They concluded that there are still differences, because in some countries the rules led to increased exclusion of small farmers, while other exports of high standards are largely made by small farmers. A common strategy used to increase the participation of small farmers in the export of high value chain is to promote the certification of private standards through development with the goal of helping small farmers to acquire a certificate (Asfaw et al., 2010). In the center-south of Chile's GlobalGAP certifications and Tesco are the most used by producers of fresh fruit exporting to world markets (Barrena et al., 2013). The GlobalGAP certification of small farmers contributes to improved quality, increased sales volumes and higher for the production of fruit or vegetables, respectively, Chile, Kenya and Madagascar (net income Handschuch et al., 2013; Asfaw et al., 2009; Subervie and Vagneron, 2013).

Dorr (2009) presents a comparative analysis of certification systems that exist in the fruit industry in Brazil and the results showed that EurepGAP / GlobalGAP and Integrated Fruit Production (IFP) are similar certification systems. However, they differ with respect to the number of requirements and their distribution over various stages (e.g. production, post-harvest). In both systems, much attention is given to labor and environmental conditions, as well as ensuring a minimum price for farmers. Most of the requirements of EurepGAP / GlobalGAP are included in the IFP, but there are differences with regard to their level of importance and distribution over several stages. Moreover, it was found that farmers with certification EurepGAP/ GlobalGAP use accounting provided by the IFP, although EurepGAP / GlobalGAP itself does not require any accountability. This means that the certification process with EurepGAP / GlobalGAP is easier and faster when the farmer has already implemented the IFP. Andrigueto and Kososki (2005) argue that the IFP is placed at the apex of the pyramid as the most evolved strategic level in organization, technology, management and other components. These aspects are embedded in a context where the levels for innovation and competitiveness are stratified by levels of development.

Table 2 shows a summary of the main characteristics of the certification models found in the literature. Considering the pyramid of the organization, technology, management and production quality, proposed by Andrigueto and Kososki (2005), Good Agriculture Practices - GAP represent all models of certification for the first step towards certification and standardization, quality and preservation of environmental resources in the productive system.

Role of certification in the fruit production chain

The requirement of certification in relation to the inputs of a supply chain can lead to further integration of their links, improving coordination, information flow and adaptation to the demands. This process aims at a more efficient management and operates in the improvement of coordination mechanisms, both upstream and downstream in the supply chain. In this sense, quality programs in the chain of food production have been adopted, reflecting the international requirements, resulting in the adoption of certification seals proving the quality, health and safety of imported products, as happens today with mainly fruit for to the markets of the United States and European Union (Assis, 2009). According to Lazzarotto (2003), the benefits generated by the adherence to the certification are reflected throughout the production chain as there is a reduction in informational asymmetry so all parties obtain unbiased information about product quality. These standards certifications, led by retailers, offering a new form of governance in the value chain in the global food system, but in doing so they reinforce the oligopolistic structure of the food system, where power is concentrated in a few actors

Table 2. Comparative analysis of the main models for the certification of fruit.

Model	Features	Coordinating agent	Applications
IFP	Voluntary accession. It is premised on the Good Agriculture Practices - GAP. It has 115 requirements divided into mandatory, recommended, prohibited and permitted with restrictions. Certificate valid for 12 months, but monitoring occurs three times a year	Public agencies	Specific Standards for culture.
EurepGAP/ GLOBALGAP	Voluntary accession. It has 214 requirements, obligations classified as major, minor obligations and recommendations. Certificate valid for 12 months, but monitoring occurs twice a year. It is based on Good Agriculture Practices - GAP. A necessary requirement to export fruit to the European continent	Network of retailers in Europe	Applies to all cultures of fruits.
TNC	Voluntary accession. Premised on Good Agriculture Practices – GAP. It includes the requirements of EurepGAP, but there is a greater emphasis regarding food safety and the environment. Restricted to registered suppliers of Tesco	Network British retailer (Tesco)	Applies to all cultures of fruits.
APHIS	Mandatory requirement from the United States to permit imports of the United States Department of Agriculture (USDA) regulations includes sanitary, phytosanitary and animal health, with every fruit and vegetable for some specific standards and is premised onGood Agriculture Practices - GAP	Public agencies	Applies to all cultures of fruits.

who define the rules of the game. Moreover, the governance structure is from the top down, where producers have little decision-making power in the process, creates dependencies between producers and retailers (Tennent and Lockie, 2012).

Some authors emphasize the role that the retail sector plays in the food chain in relation to obtaining certification seals. Trienekens and Zuurbier (2008) pointed out that large retail companies have the power to put pressure on their suppliers to comply with all the public and private norms. By taking on the coordination of food supply chains, European Union retailers pursue a goal of standardization and differentiation. It makes unique products available to the consumer that combine market differential with food security and even deal with social issues. Control devices, used by the various segments of the production chain, become validated by certification systems and interdependent entities, sometimes by groups of consumers that drive retailers to look for a different quality from its suppliers (Cafartan and Brum, 2006).

The ability to add value to a product through the legitimacy of some aspects and definitions of quality leads to the need for certification. Thus it is important to know the institutions that organize and control both the quality criteria and the certification mechanisms. The importance of the certification also appears strongly in the food chain. Food quality is not only related to physical properties but also to social aspects involved in the production system, which may add economic value to the product. In this context, the enhancement of quality in the market is provided by the process of certification (Renard, 2005).

Santos et al. (2005) identified the roles and the impact of private certification adopted by large supermarket chains in Brazil and the coordination chain management of fruits. They concluded that the management of the supply chain is mainly with regard to technical assistance, monitoring and quality control. However, the certification of fruit by supermarket chains seems to be influencing some of the coordination chains of fruit in Brazil. However, the connection between them and the producer is still weak and for the most part they are characterized by partnerships without a long established formal contract.

Souza and Amato Neto (2009) pointed out the relationships between producers and intermediaries in the chain. They observed that the intermediaries are concerned with the requirements of their main customer, the retailer. Information is transferred in respect of certificates and what changes should be made to suit them. For this reason, many intermediaries put some of their staff inside the packing house at times of harvest in order to verify that quality standards are met. In addition, information is transferred about the varieties in demand and problems regarding the quality standards of the fruit until it reach its destination. Some intermediaries highlight the difficulty in educating the producers about the importance of adherence to the certificates. They contend that the certificates do not necessarily represent increased sales or better prices; therefore it is difficult to convince producers of their importance.

The occurrence of postharvest diseases is one of the most disturbing factors in the production chain of fruit, accounting for a large part of the volume losses of the fruit products during storage and marketing (Kluge et al., 2002). All protocols require that certifications be made in pest control during the post-harvest and storage, however, did not specify techniques for specific controls of fungi and pests during post harvest storage and transportation. Initiatives used to improve quality in post-harvest treatments are in control of fungi, pests and rot. We will highlight this work, prevention and control in mango and grape fruits exported throughout the San Francisco Valley, these measures are not specifically required by any of the certificates, however, may contribute to the fulfillment of the requirement for the control pests and fungi during post-harvest. In the case of the sleeve, there is a treatment to control fungi, suitable for the sleeve destined for Europe and Canada. It is used to avoid problems with rot. The treatment is done by keeping the fruit immersed in water at 52°C for 5 min. The control of temperature and immersion time must be extremely rigorous because if these variables are outside the control range there may be irreversible damage to the product. In addition, there is the hydrothermal treatment (hot water dip), this treatment applied to the sleeve for the United States, Japan and Chile, consists of immersing the fruit in a "hot" water (46.1°C) solution for 75 to 90 min depending on the weight of the sleeve. Immediately after the end of this time, the sleeve is immersed in "cold" water at 21°C. So it is taken to the "clean zone", an area free of insects, especially the fruit fly (EMBRAPA, 2004). In the case of the grape, the main problems are in the post-harvest dehydration, desgrane and rot that can be mitigated by proper and careful handling of the fruit (Kluge et al., 2002). The rapid cooling of the temperature of the grape is one of the recommended techniques to reduce problems during storage and transportation of this product. In the São Francisco Valley this treatment is performed by controlled cooling air flow. The process must be performed under ideal temperature and humidity for the preservation of grape and requires 8 to 14 h to complete. For seedless cultivars, the cooling temperature and storage should be 0°C, while the cultivars seeds can be cooled and stored at 2°C. In both cases, the recommended relative humidity values range between 85 and 95%. Lower values predispose the grape to water loss while values above 95% favor the development of microorganisms (EMBRAPA, 2010). Another way to prevent fungus and rot is through packaging, blister packs of generators of SO_2, consisting of sodium metabisulfite or potassium can be placed on the packaging of grapes, the goal is to minimize the development of some post-harvest rots. The proportion of sodium metabisulfite or potassium used in the boxes is 1.5 g per 1 kg of grapes ((EMBRAPA, 2010). Studies prove that grapes subjected to the action of SO_2 generator showed smaller loss of weight, the lowest rate of detached and damaged berries, and better quality of stem (Castro et al., 2003;. Lichter et al., 2008; Neves et al., 2008; Zutahy et al., 2008). Speaking with three large producers of the São Francisco, they demonstrated the use of these techniques, in addition to monitoring temperature and relative humidity inside the refrigerated containers throughout the transport time. Producers confirmed that certification protocols help in pest control, however, certificates could standardize these procedures to standardize preventive actions to fungi, pests and diseases during the post-harvest, particularly for long distance travel.

Modern orcharding should be able to produce healthy and quality products in accordance with the requirements of environmental sustainability, food security and economic viability, using technologies which are not harmful to the environment and human health. In this context, the conformity of the fruit is a market requirement. The market demands commercial characteristics of quality and safety through legislation, ensuring the control and traceability for the process of the supply chain of fruit. In addition, there is a unique opportunity for social gain arising from the adoption of systems that create "cleaner" production, which ensure a higher quality of life for each link in the chain of production, and this is currently a latent concern of consumers. The adjustment to the requirements of certification requires understanding of the role to be played by all segments and links that operate in the production chain, and their interrelationships, for traceability procedures and the production of a safe and quality fruit (Chaves et al., 2010).

One can expect that the differentiation of markets and therefore the differentiation of quality standards, certification systems and labels encourage companies and brands to build supply chains that are based on quality assurance. In other words, quality assurance can provide benefits for businesses to add value to their products throughout the supply chain.

Conclusion

Some issues stand out in the analysis which helps to understand the role of certification in fruit growing. The first considers the growing interest of consumers to guarantee traceability and healthy products without waste from production systems that are environmentally and socially correct. The consumer, who was once regarded a passive agent in the production chain now becomes active, exposing their expectations and desires to the whole chain. Faced with a global market, increasingly dynamic demands coupled with an increasingly aware global population, certification protocols such as EUREPGAP / GLOBALGAP, IFP and TNC, are indicators with visual identity, recognized internationally, which ensure the production within the demands of Good Agricultural Practices (GAP) required by consumers. The second refers to certification as a factor which can increase competitiveness of companies giving product differentiation by adding value and therefore increasing international trade. The competitive environment for most companies is responsible for the rapid and dynamic changes that occur in it, requiring constant strategies and operations to enhance their competitiveness in the market. The third issue assesses the importance of certification for the production chain of fruit. It has intensified due to increased requirements of the leading importers of fruits in the world as it pertains to food safety, from the plantation to the end consumer. The major retailers are becoming the coordinators of this chain, absorbing consumer and customer demands for food safety. Moreover, the retailers are driving the suppliers to comply with the requirements regarding Good Agricultural Practices (GAP), environmental sustainability and social systems of production in which they participate. Thus, the certification results in benefits not only related to the production process but also associated to the social aspects.

Despite the managerial implications for certification organizations in the fruit industry to produce products that meet the requirements for certification protocols, investments are needed in strategic planning. Other aspects comprise identification, monitoring and control of critical success factors for service to CPCC (control Points and Compliance Criteria), and technological development, with improved production techniques and specialized training of manual labor. Another issue comprises the adoption of performance measurement practices to assist the process of continuous improvement. These practices can detect what is happening with the performance of businesses and the actions that should be taken. Thus, the measurement of performance can become a vital aspect for the efficiency of the companies that make up the supply chain of fruit.

Conflict of Interest

The authors have not declared any conflict of interests.

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Full Length Research Paper

Production of bioethanol from varieties of dates of poor quality

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Algeria is one of the important date-producing countries with a yearly production of about 850,000 tons. The number of date palms is more than 18 million palm trees with more than one thousand varieties, however only 30% of this product is of good quality, and the rest is consumed locally or directly fed to the cattle. This study aims at transforming low quality types of dates using technical biotechnology (fermentation) into bioethanol. Our research shows that the average rate of ethanol production is 350 ml per kilogram of dates, thereby achieving a profit margin up to 2.9 € per kilogram, not to mention the byproducts of fermentation: The nuclei of dates, fibers etc. The application of this study allows the exploitation and marketing of poor quality date and a thus taking large profit that helps promote date palm trees cultivation and the production of all its types.

Key words: Fermentation, bioethanol, anaerobic, biomass, palm tree, dates, El-ouel.

INTRODUCTION

In Algeria, the number of date palms is over 18 million with a number of varieties that exceeds one thousand varieties (Document, 2012; Website of the FAO, 2012). The State of El Oued is considered among the most important States of Algeria producers of dates with a rate of 29.54% of the national production; the phoenicicole potential of this State has a significant increase with a number nearing 3.4 million date palms for an area of over 32562 ha, producing about 212 thousand tons, including 31,330 thousand tons of Deglet Nour, considered as the best variety of commercial dates (Document, 2013a). The dates of low market values represent approximately 50% of the total production of dates; these dates can be used as raw material for the production of various products such as flours dates, syrups, creams and jams date, alcohol, vinegar, citric acid, yeast, cattle feed and other products (Amallal and Chibane, 2008; Messaid, 2008; Siboukeur et al., 2001; Ould et al., 2006; Acourène and Tama, 2001; Acourene et al., 2008). For example, in Iraq, wort dates is the main feedstock for ethanol production (Mohammed and Al-Abid 2006).

The work done in this study, aims at valorizing four varieties of dates (Ghars, Tinissine, Taquermeste and Boucheire) in a bid to obtaining a widely used product. It is precisely the bioethanol prepared at the laboratory by the fermentation of the most of the varieties of dates and the optimization of parameters of the alcoholic fermentation of the most of dates.

Choice of varieties

Targeting a comparative study of the different varieties of must yield of bioethanol, the following four varieties were

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Figure 1. Photo of dates variety Ghars.

Figure 2. Photo of dates variety Tinissine.

Figure 3. Photo of dates variety Taquermest.

chosen: Ghars, Tinissine, Taquermeste and Boucheire (Figures 1 to 4). We opted for this choice for two basis: Their abundance and availability in considerable quantities in the region of El Oued.

Figure 4. Photo of dates variety Boucheire.

The region of El Oued

The State of El Oued is located in the south-east of Algeria, with an area of 44586.80 Km^2 (Document, 2013b). Its borders are: From the North- east with the State of Tebessa and Khenchela, from the North-West with the State of Biskra, from the West with the State of Djelfa, from the South and West with the State of Ouargla and from the East with Tunisia. The State has four main population centers: Souf region, Erg, Oued, Righ and depression regions (Figure 5).

MATERIALS AND METHODS

Physico-chemical characterization of the raw material

We determined the physical characteristics that are: Color, consistency, weight of the date, weight of the pulp, the pulp / report date, weight of the core, length and width of the date. The chemical characteristics are determined: The rates of sugars (total sugars, reducing sugars and sucrose)

Physical analysis

1. The color was visually appreciated;
2. Consistency: by touch;
3. The size is determined by means of a vernier caliber;
4. The weights are determined directly using an analytical balance.

Chemical analysis

Determination of reducing sugars: Determining the reducing sugars is performed by the method of phenol / sulfuric acid: The carbohydrates in sulfuric acid medium and at hot are dehydrated into furfural derivatives which readily combine with phenol and give a salmon-pink color (glucose provides the hydroxyfurfural). The absorbance is read at a wavelength of 490 nm. The color is permanent (Dobois et al., 1956; Audigie et al., 1983).

The determination of total sugars: An acidic medium allows the hydrolysis of sucrose into reducing sugars, the analysis is easier

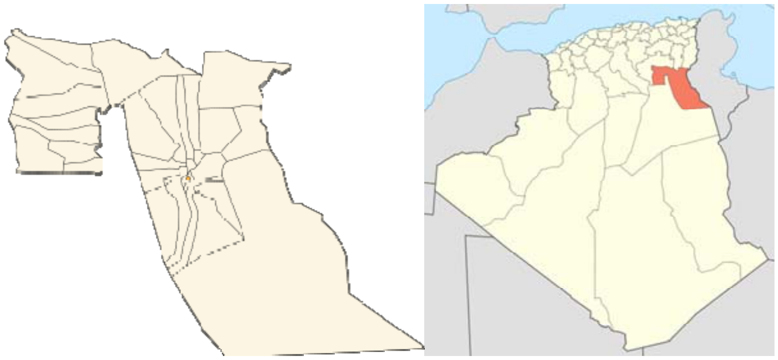

Figure 5. Geographic situation and the card of the state of El Oued.

(the determination of reducing sugars). The result obtained represents the amount of reducing sugars already present as well as sugars obtained by hydrolysis of sucrose, so we can know the amount of total sugars (Audigie et al., 1983).

The sucrose content: The sucrose content is obtained by the difference between the total sugar content and the content of reducing sugars present in the sample.

Production of ethanol by fermentation of dates

First of all we can mention that the whole study was prepared in the laboratory. The production of ethanol from dates is based on the following steps: The preparation of most of dates, the process of alcoholic fermentation, the distillation and rectification.

Preparation of must

The most is a sweet liquid taken from the prepared dates which must be washed to get rid of dust and to reduce their microbial loads, then they are pitted. The most of dates is obtained by maceration of pitted dates in warm water 70 to 80°C. The quantity is determined by1000 g of date pitted for each 3000 mml distilled water with continuous stirring of the mixture for 5 h to avoid sedimentation of date and maintaining the homogeneity of mixture at all points. Finally the solution is filtered through a fabric of fibers between the dates and the must (Boulal et al., 2010; Kaidi and Touzi, 2001).

Process of alcoholic fermentation

The must already prepared is directly used for the anaerobic fermentation with the baker's yeast Saccharomyces servisiae developed in a medium enriched with inorganic salts (ammonium sulfate, ammonium phosphate). The Must and the yeast are put in the fermentor. The fermentor (which is a recipient made of glass with holes above through which we can add the electrodes of pH meter ; also it has a valve used as an exit for gases). In order to keep the temperature constant at 32°C the fermentor is immersed in a water bath, with a pH adjusted between 4.2 and 5.4; the amount of yeast used is 3 g for 3 L of must, fermentation lasts 72 h.

Distillation and rectification

At the end of fermentation, the date wine is obtained; it must be filtered using a tissue to separate fibers from yeast. To extract ethanol, the filtered wine is distilled at a temperature of about 79°C. The rectification of the crude alcohol requires a second distillation of the order of 78°C (we mention that the distillation was done with a simple mounting).

RESULTS AND DISCUSSION

Physical analysis

Table 1 lists the physical characteristics of the four cultivars studied:

Chemical analysis

The sugar content of the four varieties is shown in Table 2. It may be noted that the date of Ghars variety is sweeter with a total sugar content of 88.52%, other varieties have close levels of reducing sugars, the varieties Boucheire and Ghars are rich in sucrose with a sucrose levels respectively 5.13 and 5.04%. However the other two varieties (Tinissine and Taquermeste) have low levels of sucrose 0.85 to 1.14%. High levels of sugars facilitate the fermentation of musts of dates and thus help obtaining bioethanol. Our results of physicochemical analysis are similar and close to those dates studied previously (Amallal and Chibane, 2008; Cheikh, 1994; Dowson and Aten, 1963; Hamdoud, 1994; Khali et al., 2007; Munier, 1973; Ould, 2001; Riviere, 1975).

Yield bioethanol

After distillation and rectification we obtained the results in Table 3. Our results are comparable to the results of Touzi who came to the production of ethyl alcohol in the laboratory with a yield of 87%.

Dates variety of Ghars is largely consumable. Its price in the Algerian market is between 50 and 100DA or between 0.47 and 0.95€. The prices of the other varieties in the Algerian market do not exceed 25DA (0.23€). The cost of ethanol production from dates is about 60DA

Table 1. Physical characteristics of dates studied.

Parameter	Variety			
	Ghars	**Tinissine**	**Taquermeste**	**Boucheire**
Color	Brown	Black	Black	Amber-Black
consistencies	Soft	Soft	Soft	Soft Half
Weight date (g)	12.68	8.18	12.48	8.27
Pulp weight (g)	11.6	6.75	11.25	6.44
Report pulp / date (%)	91.48	82.52	90.14	77.87
Core weight (g)	1.08	1.43	1.23	1.83
Length date (cm)	4.45	3.7	2.4	3.85
Width date (Cm)	2.0	1.55	2.5	1.2

Table 2. Levels of sugars studied dates.

Variety	Sugar content (%)		
	Total sugars	**Reducing sugars**	**Sucrose**
Ghars	88.52	83.1	5.13
Tinissine	77.6	76.7	0.85
Taquermeste	79.9	78.7	1.14
Boucheire	73.21	78.51	5.04

Table 3. Bioethanol yield for 1kg of pitted date.

Variety	Ghars	Tinissine	Taquermeste	Boucheire
Volume of ethanol (ml) in for 1 kg of date	624	242	333	475

(0.57€) per 1kg of date (electricity, reagents, raw material, labor etc). The average yield of the three varieties (Tinissine, Taquermeste and Boucheire) is 350 ml of ethanol per 1 kg of these varieties, the price of ethanol 95° in the world market is 10.6 € (1113DA) (website servilab, 2013), so the price of 1 kg of these dates when converted into bioethanol is about 3.71€ instead of 0.23€ without transformation. It means a profit of about 2.91€ per 1 kg of this variety of dates.

Conclusion

Wastes from dates varieties: Tinissine, Taquermeste and Boucheire grown in the region of Oued Souf can be converted into bioethanol by fermentation. We arrived at an average rate of ethanol production of about 350 ml per kilogram of dates, taking into consideration the price of these varieties in the market, the cost of processing and the price of ethanol (we can reach a margin up to 2.9 € per kg), regardless the byproducts of fermentation process: nuclei dates, fibers, etc. The application of this study allows the exploitation and marketing of dates of poor quality and thus taking large profits that helps promote date palm cultivation and production of all types. In addition to all that, the bio ethanol could be used as a bio-fuel because of its characteristics as a green energy.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Bioefficacy of products derived from *Milletia ferruginea* (Hochst) baker against the bean bruchid, *Zabrotes subfasciatus* (bruchidae: coleoptera) in stored beans in Ethiopia

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Petroleum ether, acetone and water extracts, and fresh seed powder of *Milletia ferruginea* (Hochst) Baker (Leguminaceae) were evaluated as grain protectant against bean bruchid, *Zabrotes subfasciatus* (Boheman) in the laboratory at an ambient temperature of 28±1°C and 70% RH in a 12 h light: dark regime at the concentrations of 1, 2 and 3 ml in the case of extracts and at the rates of 5, 10 and 15 w/w in the case of seed powder. Adult mortality, F_1 progeny emergence, oviposition inhibition, insect damage and viability index of haricot bean seeds were the parameters measured. The results obtained showed that water and acetone extracts of *M. ferruginea* gave 100% mortality of the adult *Z. subfasciatus* 24 h after treatment application at the rates of 2 and 3 ml. *M. ferruginea* powder provided good protection of haricot bean seeds by reducing *Z. subfasciatus* oviposition rate, F_1 progeny emergence and seed infestation. The seed powder treatment did not show any adverse effects on the germination capacity of haricot bean seeds. This study revealed that *M. ferruginea* can be used as a botanical insecticide to protect haricot bean seeds against *Z. subfasciatus* in storage.

Key words: Botanicals, *Milletia ferruginea, Zabrotes subfasciatus*, toxicity, storage pest.

INTRODUCTION

The haricot bean, *Phaseolus vulgaris* L. (Fabaceae) is extensively grown in the lowland and medium altitude areas of Ethiopia ranging from 700 to 2000 m above sea level (Tsedeke and Ampofo, 1996). In the past, *P. vulgaris* was mainly grown by private peasant holdings under rainfed conditions. However, currently this trend has changed and big State farms and private investors are involved in the production of the crop both for domestic consumption and export market under rainfed and irrigated conditions (Shaun and Elly, 2008). *P. vulgar* is served as an important protein supplement to the cereal based Ethiopian diet. It is also a very important export commodity for the country valued at over 40 million USD annually (Shaun and Elly, 2008). Production

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varies from region to region (Ferris and Kaganzi, 2008). For example, the Oromia and the Southern Nations Nationalities region produce 70 and 60 thousand tonnes per year, respectively which is 85% of the total production.

The production of *P. vulgaris* in Ethiopia is constrained by a number of biotic and abiotic factors both under field and storage conditions (Tsedeke and Ampofo, 1996). However, pre and post harvest insect damage are the most important constraints resulting in 40 to 50% average grain losses (Tsedeke and Ampofo, 1996). *P. vulgaris* normally stored for 3-6 months in Ethiopia either to look for a better price and/or for home consumption. In the store a number of insect pests are damaging *P. vulgaris*. Among the various storage insect pests of haricot bean, *Zabrotes subfasciatus* is the most important causing over 25% losses (Tsedeke and Ampofo, 1996).

For decades, pest control strategy in developing countries has depended heavily on the use of synthetic pesticides (Tsedeke and Ampofo, 1996). Although synthetic pesticides are known to have undoubted benefits, their adoption rate and use for insect pest control in grain storage has remained remarkably low in the resource-poor farming environments of Africa including Ethiopia (Tsedeke and Ampofo, 1996). The subsistence nature of agriculture in developing countries in general and Ethiopia in particular coupled with high cost, poor information and erratic supply of synthetic pesticides accounted for farmers' reluctance to use pesticides (Tembo and Murfitt, 1995; Ogendo, 2000). Recent information about the penetration of synthetic insecticides into the stored seed and reduce the germination capacity of the seed worsen the situation (El Sheamy et al., 1988; Lalah and Wadinga, 1996). However, oils and crude powders of several plant species have been proved to have no adverse effects on the germination of maize, sorghum, pigeonpea and green gram which initiated scientists to look for botanical pesticides which are environmentally friendly (Pandey et al., 1986; Kasa and Tadese, 1995; Obeng, 1995; Saxena, 1983). *Milletia ferruginea* is one of such environmentally friendly botanical plant used for the control of stored product insect pests (Jiliani and Saxena 1988).Hence, the present study investigated the effect of seed powder and different extracts of *M. ferruginea* on the control of *Z. subfasciatus* in haricot bean seeds under storage conditions.

MATERIALS AND METHODS

Description of *M. ferruginea* and preparation of its products

M. ferruginea is a large shady tree which grows up to a length of 35 m. It is endemic to Ethiopia and widely grown at the elevation ranging from 1000 to 2500 m above sea level. There are two subspecies known to occur in Ethiopia: M.f. *ferruginea* and M. f. *darasana*. *M. f. ferruginea* is confined to the northern part of Ethiopia, while *M. f. darasana* occurs in southern region, particularly Sidamo. *M. furruginea* from central and western Ethiopia show mixture of the two species (Azene et al., 1993). *M. ferruginea* in Ethiopia is used for fish poisoning where mature pod and seed are ground to fine powder and spread over the surface of water (Siegenthaler, 1980). Furthermore, the tree is extensively used as shade for coffee in Eastern Ethiopia (Teketay and Tegineh, 1991). Seeds of *M. furruginea* were collected from matured trees in Addis Ababa and dried under shade at the room temperature of 24±1°C. Dried seeds were ground into fine powder using mortar and pestle and the powder was passed through a 25 mm-mesh sieve to obtain a fine dust.

Mass rearing of test insects

Heavily infested *P. vulgaris* seeds (over 60% infestation) were collected from the farmers' stores in the central rift valley areas of Ethiopia and stored in the laboratory for 3-6 days for the emergence of *Z. subfasciatus* adults. Two hundred unsexed adults of *Z. subfasciatus* were drawn from the stored haricot bean and reared in a 1 L jar containing 500 g of disinfested haricot bean seeds as described by Haines (1991). The top of each rearing jar was covered with nylon mesh and fastened tightly with rubber bands, and the insects were allowed to lay eggs for seven days. After seven days all adults were removed and the jars were left in the laboratory for 34 days for the emergence of F_2 generation adults which were used for the experiment. After 34 days the emerging adults of *Z. subfasciatus* were monitored and transferred to separate jars according to their age. The rearing of test insects was done in the laboratory at the ambient temperature of 28±1°C and 70% relative humidity and at 12 h light: dark condition. Seeds of susceptible haricot bean variety, "HAL-5" were obtained from Melkassa Agricultural Research Center (MARC) of Ethiopia and used for the experiment.

Disinfesting of test haricot bean seeds

Following the procedures of Lima et al. (2004) haricot bean seeds were placed in plastic bags and kept in a freezer at -5°C for one month to make them free of possible internal infestation prior to their use for various bioassays. To maintain the moisture content of the seeds to normal level, the seeds were kept in the laboratory for six days prior to the experiments.

Seed viability index

Seed powder of *M. ferruginea* at the rates of 5, 10 and 15 w/w and pirimiphos-methyl at the rates of 0.125 and 0.25 g per 250 g of haricot bean seed were used for the seed viability study which was expressed as the percent germination. Seed viability index study was conducted 90 days after treatment application by taking 25 seeds each from treated, untreated (non-infested) and infested seeds. Seeds were kept separately on a moistened filter paper (Whatman No.1) in petri dishes and arranged in a completely randomized design (CRD) in four replications. The petridishes were kept in an incubator at 25°C and at L 12: D 12 conditions. The number of germinated and un-germinated seeds in each petridish were counted after seven days.

Toxicity of *M. ferruginea* seed powder to Z. *subfasciatus*

After disinfestation, 250 g haricot bean seeds having a moisture

Table 1. Percent weight loss caused by *Z. subfasciatus* on haricot bean seeds treated with different concentrations of *M. ferruginea* seed powder at different exposure time

Treatments	Concentration (g/ 250 g bean seeds)	Exposure time (days)		
		30	60	90
Mf	5	0.11	0.17	0.33
Mf	10	0.08	0.11	0.19
Mf	15	0.0	0.0	0.0
PM	0.125	0.0	0.0	0.0
PM	0.25	0.0	0.0	0.0
C	0.0	2.17	3.80	5.40

Mf = *M. ferruginea* seed powder, PM = Pirimiphos-methyl, C = Control.

content of 10.4% were placed in 1 liter volume glass jars and treated with three rates of *M. ferruginea* (5, 10 and 15 w/w) seed powder. The treatments were thoroughly admixed with haricot bean seeds for five minutes for uniform coating. Twenty 10-day old adults of *Z. subfasciatus* (10 males and 10 females) were introduced into each jar. The glass jars were covered with nylon mesh to allow ventilation, prevent entrance and escape of insects after introduction. An untreated seeds and pirimiphos methyl treated seeds at the recommended rate of 4 ppm were used for comparison. Mortality was observed 24 and 48 h. after treatment application and the experiment was arranged in a completely randomized design in four replications.

Adult emergence, percent insect damage and oviposition rate

Following the methods of Lima et al. (2004) adults of *Z. subfasciatus* were placed in 1 L empty jars for 24 h before their release into jars containing treated and untreated haricot bean seeds. The experiment was conducted in a controlled chamber of 30°C and 40 to 50% RH. One week latter 100 treated seeds were sampled and number of eggs laid on the treated haricot bean seeds was counted. After count the adult insects were discarded. As soon as the "exit holes" were externally visible, observations were made every other day for F_2 progeny adults emergence for one month. Emerged adults were counted and removed during observation. Percent weight loss was determined by the count and weigh method as recommended by Adams and Schlten (1978).

Preparation of extracts

M. ferruginea seeds were air dried and milled into fine powder to pass through 0.5 mm mesh and extracted using water, petroleum ether and acetone in a soxhlet apparatus for 49 h or more. Before collecting the extract, excess solvents (water, petroleum ether and acetone) were evaporated and concentrated into a small volume. Then the concentrate was dissolved in 100 ml of distilled water and ready for the experiment. The extracts were kept under liquid nitrogen in a cold room until use.

Z. subfasciatus bioassay

Filtrates of *M. ferruginea* extracts at the rates of 1, 2 and 3 ml were applied to Whatman No.1 9cm diameter filter paper in a petridish. In the case of petroleum ether and acetone, the treated filter papers were exposed to open air to allow the solvent evaporate for 30 min. After evaporation 1 ml of distilled water was applied to the treated filter paper to moisten the petridish. Then 10 *Z. subfasciatus* adults were introduced into each petridish. Mortality was recorded 24, 48, 72 and 96 h after treatment application. The different solvents were used as a control and the experiment was designed in a completely randomized design (CRD) in three replications.

Data analysis

All the data collected were normalized using logarithmic and square root transformations (Gomez and Gomez, 1984) before analysis. Significant means ($p<0.05$) were separated using Tukey's studentized range test (HSD) (Scheiner and Guvevitch, 1993; SAS Institute Inc., 1995).

RESULTS

Effect of different treatments on haricot bean seed damage due to *Z. fasciatus*

Results of percent grain loss due to *Z. subfasciatus* 90 days after storage are presented in Table 1. The results obtained showed that all the treatments significantly ($P< 0.05$) reduced weight loss due to *Z. subfasciatus* compared to the untreated check. Seeds treated with pirimiphos-methyl and *M. ferruginea* at the rate of 15 g showed no grain losses due to *Z. subfasciatus*, while the untreated grains suffered 5.4% grain losses for similar period of storage. The table further explicitly indicated that as the concentration of *M. furrignea* increase, the amount of losses due to *Z. subfasciatus* reduced by over 40%.

Effect of *M. ferruginea* seed powder on the mortality rate of *Z. subfasciatus*

The effect of *M. ferruginea* seed powder on the mortality

Table 2. Mean percent mortality of Z*. subfasciatus* exposed to different concentration of *M. ferruginea* seed powder.

Treatments	Concentration(g)	Mean % mortality ±SE at:	
		24 h	48 h
Mf	5	20.00 ± 0.58[c]	75.00 ± 0.8[b]
Mf	10	78.35 ± 0.88[b]	100 ± 0.0[a]
Mf	15	96.65 ± 0.33[a]	100 ± 0.0[a]
PM	0.125	100.00 ± 0.00[a]	
PM	0.25	100.00 ± 0.00[a]	-
C	0.0	0.00 ± 0.00[d]	-0.00 ± 0.00[c]

Mf = *M. ferruginea* seed powder, PM = Pirimiphos-methyl, C = Control, **-** = All *Z. subfasciatus* died, Means within a column followed by the same letter(s) are not different at 5%level (HSD).

Table 3. Mean number of eggs laid by Z*. subfasciatus* on 100 haricot bean seeds treated with different concentration of *M. ferruginea* seed powder for a week.

Treatments	Concentration (g)	Mean number of eggs ± SE
Mf	5	6.22 ± 0.98[c]
Mf	10	2.22 ± 0.32[b]
Mf	15	0.00 ± 0.00[a]
PM	0.125	0.00 ± 0.00[a]
PM	0.25	0.00 ± 0.00[d]
C	0.0	65.6 ± 14.98[d]

Mf = *M. ferruginea* seed powder, PM = Pirimiphos-methyl, C = Control, Means within a column followed by the same letter(s) are not different at 5% level (HSD).

of adult *Z. subfasciatus* is presented in Table 2. Results showed that mortality of Z*. subfasciatus* was significantly high (P < 0.05) on haricot bean seeds treated with *M. ferruginea* seed powder at the rate of 15 /250 g and pirimiphos-methyl at both concentration 24 h after treatment. High mortality rate of *Z. subfasciatus* was also recorded on haricot bean seeds treated with 10 g *M. ferruginea* 24 h after treatment.

Effect of *M. ferruginea* seed powder on oviposition of *Z. subfasciatus*

The effect of different treatments on the oviposition capacity of *Z. subfasciatus* is presented in Tables 3 and 4. There was significant (p<0.05) reduction in the number of eggs laid by of *Z. subfasciatus* treated with different products of *M. ferruginea*. No egg was laid by Z*. subfasciatus* in haricot bean seeds treated with 15 g of *M. ferruginea* seed powder. Table 4 shows the number of eggs laid by *Z. subfasciatus* after 30, 60, and 90 days after treatment. No eggs were also deposited on the seeds treated with pirimiphos-methyl. The number of laid eggs significantly (p = 0.009) increased with the increase in storage time after treatment.

Effect of *M. ferruginea* seed powder on F_1 progeny of *Z. subfasciatus*

The effect of *M. ferruginea* seed powder on F_1 progeny of *Z. subfasciatus* 30 days after treatment is presented in Table 5. All treatments markedly (p< 0.05) inhibited development of larvae or pupae of *Z. subfasciatus* as indicated by the low F_1 progeny emergence compared to the control. No F_1 emergence was recorded from pirimiphos-methyl treated haricot bean seeds in all the storage periods. The different concentrations of *M. ferruginea* powder except 15 g were not as effective as pirimiphos-methyl in terms of reducing the number of F_1 progeny.

Effect of *M. ferruginea* extracts on mortality of adult *Z. subfasciatus*

Results of mortality rate of *Z. subfasciatus* adults due to different treatments are presented in Table 6. Water extract of *M. ferruginea* seed showed significantly high (p< 0.05) mortality rate of *Z. subfasciatus* at all levels of application (1, 2 and 3 ml/filter paper) 24 h after treatment. Acetone extract of *M. ferruginea* seed induced

Table 4. Mean number of eggs laid by females of *Z. subfasciatus* on 100 seeds treated with different concentration of of *M. ferruginea* seed powder at different exposure times.

Treatments	Concentration g/250 g bean seeds	Time (day)	Mean number of eggs ± SE
	5	30	4.00 ± 0.58[b]
Mf		60	5.00 ± 1.15[b]
		90	9.67 ± 0.88[b]
	10	30	1.67 ± 0.33[b]
Mf		60	1.85 ± 0.42[b]
		90	3.33 ± 0.33[a]
	15	30	0.00 ± 0.00[a]
Mf		60	0.00 ± 0.00[a]
		90	0.00 ± 0.00[a]
	0.125	30	0.00 ± 0.00[a]
PM		60	0.00 ± 0.00[a]
		90	0.00 ± 0.00[a]
	0.25	30	0.00 ± 0.00[a]
PM		60	0.00 ± 0.00[a]
		90	0.00 ± 0.00[a]
	0.0	30	32.00 ± 2.31[c]
C		60	48.67 ± 4.13[d]
		90	93.33 ± 6.67[e]

Mf = *M. ferruginea* seed powder, PM = Pirimiphos-methyl, C = Control, Means within a column for each concentration followed by the same letter(s) are not different at 5% level (HSD).

Table 5. Mean number of Z. *subfasciatus* F_1 progeny emerged 30 days after *M. ferruginea* seed powder application.

Treatments	Concentration (g/250 g bean seeds)	Mean number of F_1 progeny ± SE
Mf	5	8.89 ± 1.16[c]
Mf	10	3.00 ± 0.41[b]
Mf	15	0.00 ± 0.[a]
PM	0.125	0.00 ± 0.00[a]
PM	0.25	0.00 ± 0.00[a]
C	0.0	62.11 ± 2.82[d]

Mf = *M. ferruginea* seed powder, PM = Pirimiphos-methyl, C = Control, Means within a column followed by the same letter(s) are not different at 5% level (HSD).

significant mortality of *Z. subfasciatus* 24 h after treatment at the rates of 2 and 3 ml. However, petroleum-ether extract of *M. ferruginea* significantly ($p < 0.05$) gave high mortality at all levels 48 h after treatment. Acetone, petroleum-ether and distilled water did not cause mortality to *Z. subfasciatus*.

Effect of different treatments on germination

The effect of *M. ferruginea* on the viability of haricot bean seeds is shown in Figure 1.There was no significant difference ($p > 0.05$) in the germination of haricot bean seeds treated with different concentrations of

Table 6. Mean percent cumulative mortality of *Z. subfasciatus* adults exposed to different extracts of *M. ferruginea* at different concentrations.

Treatments	Concentration(ml)	Hours after treatment application			
		24	48	72	96
Water extract	1	95.0±0.10^{a}	99.6± 0.1^{a}	100± 0.0 ^{a}	-
	2	100.0±0.0^{a}	-	-	-
	3	100.0± 0.0^{a}	-	-	-
Acetone extract	1	85.0± 1.0^{a}	96.6± 0.8^{a}	100±0.0^{a}	-
	2	96.6± 0.7^{a}	98.3± 0.2^{a}	100± 0.0^{a}	-
	3	100.0± 0.0^{a}	-	-	-
Petroleum ether extract	1	65.0± 5.0^{b}	75.0± 1.5^{b}	90.0± 1.7^{a}	100± 0.0^{a}
	2	73.5± 3.5^{b}	95.0± 3.4^{a}	100± 0.0^{a}	100± 0.0^{a}
	3	80.0± 1.0^{b}	86.6±0.8^{a}	100± 0.0^{a}	-
Water	1	0.0± 0.0^{c}	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}
	2	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}	0.0± 0.0^{b}
	3	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}	0.0± 0.0^{a}
Acetone	1	0.0± 0.0^{c}	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}
	2	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}	0.0± 0.0^{b}
	3	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}	0.0± 0.0^{a}
Petroleum ether	1	0.0± 0.0^{c}	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}
	2	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}	0.0± 0.0^{b}
	3	0.0± 0.0^{c}	0.0± 0.0^{b}	0.0± 0.0^{b}	0.0± 0.0^{a}

- = 100% mortality already attained at the immediate earlier exposure time, Means within a column for similar concentration followed by the same letter(s) are not different at 5% level (HSD).

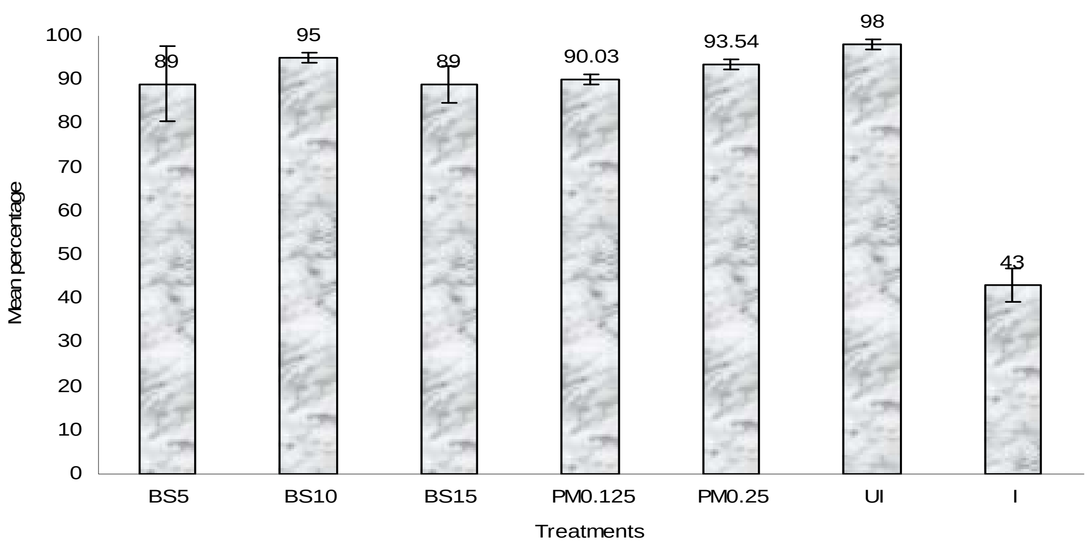

Figure 1. Effect of *M. ferruginea* seed powder on percent germination of haricot bean seeds. BS5 = Birbira seed (Mf) (5 g), PM 0.125 = Pirimiphos-methyl (0.125 g), BS10 = Birbira seed (Mf) (10 g), PM0.25 = Pirimiphos-methyl (0.25 g),BS15 = Birbira seed (Mf) (15 g),UI = Uninfested haricot bean seeds, I = Infested haricot bean seeds, Mf = *M. ferruginea.*

M. ferruginea and pirimiphos-methyl. However, the germination percentage of the treated haricot bean seeds were significantly ($p< 0.05$) higher than the germination percentage of the untreated haricot bean seeds.

DISCUSSION

Results of the present study indicated that all tested concentrations (5, 10 and 15 g) of *M. ferruginea* seed powder were comparable with primiphos-methyl in controlling *Z. subfasciatus* irrespective of exposure time. The seed powder highly reduced the number of F_1 progeny emergence, oviposition of *Z. subfasciatus* and percent weight loss. All concentrations of *M. ferruginea* seed powder extracts (acetone and water) caused very high mortality of *Z. subfasciatus* 24 h after treatment. *M. ferruginea* water extract gave more adult mortality of *Z. subfasciatus* may be because of the presence of more water soluble chemical substance in *M. ferruginea* seed powder (Bekele et al., 2005). Similar result was reported by Bekele (2002) on toxicity of *M. ferruginea* against *Sitophilus zeamais* (Motsch). Rotenone is one of the dominant chemical substance found in the seed and stem bark of *M. ferruginea* and is a well known botanical insecticide with a rat oral of LD50 = 132-1500 mg/kg through contact and stomach poisoning (Saxena, 1983; Bekele, 2002). It is also highly toxic to fish and soluble in polar solvents (Bekele, 2002). Bayeh and Tadesse (2000) reported that *M. ferruginea* and *Azadirachta indica* were able to effectively control *Callosobruchus chinensis* on faba bean by partially or completely preventing egg-laying. Tebkew and Mekasha (2002) tested *M. ferruginea* against *C. chinensis* in chickpea for six months in the laboratory. In a recent laboratory and field based study by Bekele et al. (2005), it was also investigated that all concentration levels of *M. ferruginea* seed extract filtered with cheesecloth caused very high mortality of all the termite castes comparable to Chlorpyrifos.

In general, the powder of *M. ferruginea* gave better protection at all storage periods after treatment application as compared to the check. The over-all results showed that pirimiphos-methyl can protect haricot bean seeds from *Z. subfasciatus* infestation for two to four months as less than one egg per female was laid in all storage intervals. Similarly, number of eggs laid by the female on *M. ferruginea* seed powder treated beans (that is, 10 and 15 g seed powder) was not significantly ($p>0.05$) different from pirimiphos-methyl treated seeds for all storage intervals. The reduced oviposition might be due to the reduction in egg production or inhibition of egg laying. This is in agreement with Ofuya (1990) who reported that weakening of adults by plant powder may cause insects to lay fewer eggs than normal. Bekele (2002) observed reduced F_1 progeny emergence by *S. zeamais* in maize mixed with *M. ferruginea* seed powder.

M. ferruginea seed powder used as a grain protectant for the control of *Z. subfasciatus* had no effect on the germination of haricot bean seeds. Kasa and Tadesse (1995) investigated the use of crude powders of 17 botanical plants for the control of *S. zeamais* on sorghum and indicated that the botanicals had no effect on seed germination. Similarly, Pandy et al. (1986) reported that petroleum-ether extracts of *Lantana camara* and four other plant species had no adverse effects on the germination of *Vigna radiata* (L.) Wilcz. Onu and Aliyu (1995) reported that pepper powder was effective in reducing oviposition and damage of *C. maculates* without impairing the seed quality and viability.

In conclusion, seed powder and extracts of *M. ferruginea* can be recommended for the control of *Z. subfasciatus* on stored haricot bean seed. However, some aspects such as its effect on human being, on natural enemies existing in storage ecosystem and cost-benefit analysis need to be investigated before the wide application of this research outcome.

Conflict of Interest

The authors have not declared any conflict of interest.

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Full Length Research Paper

Genotype by environment interactions and phenotypic stability analysis for yield and yield components in parental lines of pearl millet *(Pennisetum glaucum* [L.] R. Br)

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Twenty-four parental lines of pearl millet and a seed parent (ZATIB) as check were evaluated in five different locations in northern Nigeria to determine their yield levels and stability across the environments. Identification of stable parental line(s) will improve the performance of resulting pearl millet hybrids. Location and genotype effects were highly significant (P<0.05) for all the parameters sampled while interaction between locations and genotypes were significant (P<0.05) for stand count, days to 50% flowering, downy mildew score, panicle length and grain yield (kg ha^{-1}). Estimates of environmental index showed that Samaru was the best performing environment while Bagauda and Panda were the poorest grain yielding environments. Most of the lines were adapted to high rainfall environment of Samaru while others showed specific adaptation to low rainfall locations; indicating the possibility of developing specific lines adapted to low and high rainfall areas. Mean grain yield ranged from 504.8 (kg ha^{-1}) for G3 (20A-2) to 1920 (kg ha^{-1}) for G24 (75B-3). G10, G14 and G15 were found suitable for favorable conditions with predictable performance as they gave high mean grain yield along with above average responsiveness (bi>1) and non-significant deviation from regression line while G13, G17 and G18 were considered suitable for poor environments. Regression coefficient and deviation from regression indicated that G23 and G24 (75A-3 and 75B-3) and ZATIB were most stable in performance across the test environments.

Key words: Genotype by environment interaction, pearl millet, parental lines, stability, yield components.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* [L.] R. Br) is an important cereal crop common in the arid and semi-arid tropical areas of the Indian sub-continent and Africa (Yadav et al., 2001). It is cultivated mainly as a grain crop across a wide range of environments around the sub-saharan Africa. In Nigeria, pearl millet is usually grown under traditional farming system, where the rainfall is between 200 to 800 mm and average yield of about 200 kg/ha (Ndjeunga et al., 2010). The main production constraints of this crop in Nigeria is unpredictable and

Table 1. Description of testing locations.

Location	Agro-ecological zone	Annual rainfall* (mm)	Soil type	Global position		
				Latitude	Longitude	Altitude (m.a.s.l)
Samaru	Northern Guinea	1050	Clay loam	11° 18'N	07° 61'E	691.7
Panda	Sudan	670	Sandy loam	11° 60'N	09° 04'E	454.1
Bagauda	Sudan	800	Loamy	11° 56'N	8° 40'E	498.7
Babura	Sahel	550	Sandy	12° 78'N	9° 00'E	387.7
Minjibir	Sudan	650	Sandy loam	12° 13'N	8° 69'E	416.1

*Long term average, m.a.s.l= meter above sea level.

variable weather conditions, low soil fertility, fragile environment, use of landraces, poor crop establishment and less availability of inputs.

Genotype-Environment (GE) interaction is extremely important in the development and evaluation of plant varieties, because they reduce the genotypic stability values under diverse environments (Hebert et al., 1995). Crop production is the function of genotype, environment and their interaction (GEI). Significant GEI results in changing behavior of the genotypes across different environment or changes in relative ranking of the genotypes (Crossa, 1990). A significant GxE interaction for a quantitative trait such as grain yield can seriously limit the efforts of selecting superior genotypes for improved cultivar development (Kang and Gorman, 1989). Understanding the relationship among yield testing locations is important if plant breeders and agronomists are to target germplasm better adapted to different production environments (Trethowan et al., 2001).

It has been observed that single crossed hybrids generally give 20 to 30% more grains than open pollinated varieties (OPV) under normal conditions (Rai et al., 2006). However, hybrids may not express its full potentials in the presence of limited environmental resources. Under these circumstances parental lines with a stable performance across changing environments, even with modest yield, are considered more relevant than high yielding lines with inconsistent performance across unpredictable crop season (Yadav and Weltzien, 2000; Ceccarelli, 1994; Joshi, 1998). Information on yield performance and stability over variable environments of pearl millet parental lines developed jointly by Lake Chad Research Institute (LCRI) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) during 1997 to 1999 has not been ascertained. Knowledge of the variability for different characters present in pearl millet parental lines is important for successful pearl millet hybrid development. A stable genotype possesses an unchanged or least changed performance regardless of any variation of the environmental conditions (Rahman et al., 2010). Several stability analyses have been proposed to determine linear relationship between genotypic performance and the environment. Eberhart and Russell (1966) proposed a method in which the environmental index is the mean performance of all the entries in an environment. A desirable genotype is one with high mean value, with regression coefficient of 1.0 and deviation from regression is 0. Such a genotype would have increased performance as the productivity of the environment improves. Tollenaar and Lee (2002) reported that high yielding maize hybrids can differ in yield stability and that yield stability and high grain yield are not mutually exclusive.

Based on the availability of a commercially exploitable cytoplasmic-nuclear male-sterility (CMS) system LCRI, Maiduguri along with ICRISAT embarked on pioneer research of developing commercial pearl millet hybrids using indigenous germplasm and converted lines. This study was therefore, designed to examine the yield levels and stability in performance of pearl millet parental lines with a seed parent across different locations in northern Nigeria.

MATERIALS AND METHODS

The study was conducted during the 2000 rainy season at five different locations comprising of Samaru, Panda, Bagauda, Babura and Minjibir. These locations represent the diverse agro-ecologies of the major pearl millet growing regions of northern Nigeria (Table 1). Twenty-four pearl millet parental lines developed jointly by LCRI, Maiduguri and ICRISAT, Kano along with one seed parent (ZATIB) used as check were laid out in randomized complete block design (RCBD) with 3 replications. The experimental unit was a four-row plot of 5 m long, spaced at 0.75 m apart and intra row spacing of 0.5 m. Inorganic fertilizer (NPK 15:15:15) was applied as a basal dose @ 300 kg ha^{-1}. Crops were thinned down to two plants per stand two weeks after crop emergence. It was top dressed with urea three weeks post crop emergence @ 100 kg ha^{-1}.

Data were collected from two middle rows for stand count, days to 50% flowering, downy mildew score, *Striga* count, plant height, panicle length, head weight and grain yield following the recommendation of International Board for Plant Genetic Resources (IBPGR) and ICRISAT

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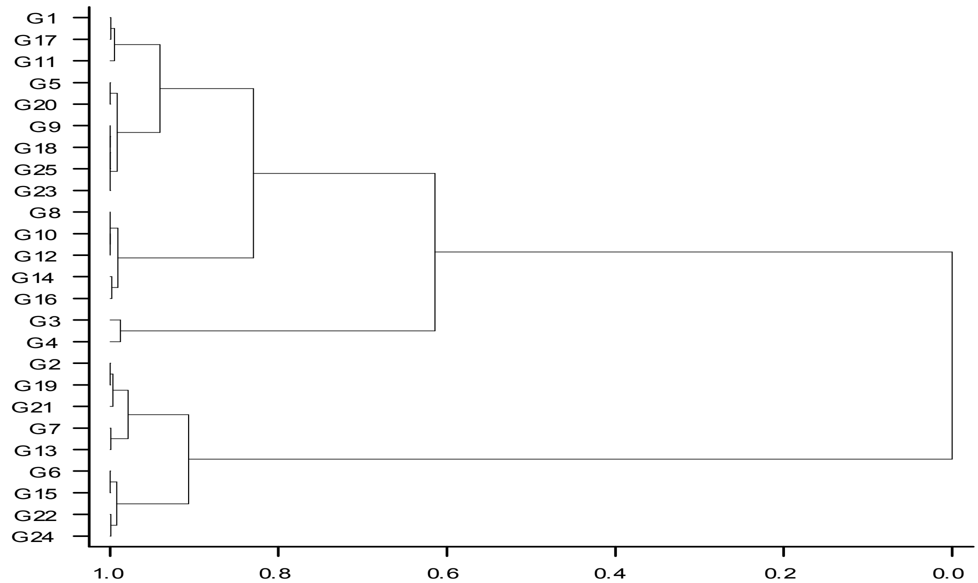

Figure 1. Dendrogram showing clustering pattern of 25 parental lines of pearl millet.

descriptor list for pearl millet (IBPGR/ICRISAT, 1993). Stability parameters were calculated according to Eberhart and Russell (1966) model. Data analysis were performed using GENSTAT, 2009 edition. Means procedure in the GENSTAT program with the option Duncan (for Duncan's multiple range test) was used in separating the means of the main effects. Cluster analysis of grain yield data was used to group the parental lines. The similarity between two lines was expressed as the squared Euclidean distance. An agglomerative hierarchical procedure with an incremental sum of squares grouping strategy known as Ward's method (Ward, 1963) was employed for the purpose of grouping genotypes. To adjust for the differences in yield levels between different locations, data for each environment were standardized to a mean of zero and standardized deviation of one as suggested by Fox and Rosielle (1982).

RESULTS AND DISCUSSION

The mean square values for stand count, days to 50% flowering, downy mildew score, *striga* count, plant height, panicle length, head weight and grain yield (kg ha^{-1}) are presented in Table 2. There was highly significant (P>0.01) component of variation across locations and genotypes for all the parameters sampled indicating that the locations and genotypes were inherently variable justifying their selections for this study.

The interaction between locations and genotypes were significant for stand count, days to 50% flowering, downy mildew score, panicle length and grain yield suggesting that these parameters were considerably influenced by the environmental variations across the five locations. On the other hand locations by genotype interaction was non-significant for *striga* count, plant height, and head weight indicating that these parameters were stable across the environments. The presence of significant location by genotype interaction showed the inconsistency of performance of pearl millet parental lines across the test environments. A similar result was reported by Abebe et al. (1984) on sorghum, Khalil et al. (2010) on maize hybrids and Lothrop (1989) on maize. Baradwaj et al. (2001) stated that the significant differences among crop genotypes for grain yield indicated the necessity to group them into clusters to identify the nature of the groupings. Figure 1 is the dendrogram showing clustering pattern of pearl millet parental lines. Although, the maintainer B-lines and male sterile A-lines possess similar genetic background since they were developed from NCD2; they did not display a particular order of clustering across the three main groups formed. However, different A-lines and B-lines showed greater affinity with each other irrespective of their selection. There were instances where A/B counterparts clustered. The difference in clustering pattern among the parental lines was an indication of the variability that exists in pearl millet being predominantly cross pollinated crop.

As shown in Table 3, partitioning of genotype by environment into linear and non-linear portions for grain yield indicated that both were vital. Genotype by environment (linear) and pooled deviations were significant when tested against pooled mean square revealing that both linear and non-linear components accounted for genotype by environment interaction. The large significant genotype by environment variance suggests that the component was most important in contributing to differences in performance of genotypes across the test environments. The relatively large proportion of environment variance when compared with genotype as main effect suggests the large influence of environment on yield performance of pearl millet lines in northern Nigeria. These findings were in accordance with Kang (2002).

The estimates of environmental index (Table 4) showed

Table 3. Combined analysis of variance for grain yield in pearl millet lines used to estimate stability parameters.

Source	Df	Mean square
Genotype (G)	24	15.296**
Environment (Env) + GxEnv.	100	29.13**
Environment (Linear)	1	18.267**
GxEnv. (Linear)	24	1.062**
Pooled deviation	75	9.801**
Pooled error	250	45.5

** Significant when tested against pooled mean square at P < 0.01.

Table 4. Estimates of environmental index.

Environment	Mean grain yield (kg ha^{-1})	Environmental index (I_i)
Babura	1440.77	0.212
Minjibir	1504.4	0.276
Panda	784.88	-0.444
Bagauda	752.79	-0.476
Samaru	1669.11	0.432
SE±		0.146

that Samaru location was the best performing environment, Minjibir and Babura were medium performing while Bagauda and Panda were the poorest grain yielding environments. This variations in the environmental index showed that the performance of the genotypes varied from location to location. Samaru location was therefore the most favorable environment for realizing the yield potential of the pearl millet parental lines with the location possessing favorable environmental resources in terms of higher and longer rainfall duration as well as better soil variables. Although most genotypes were adapted to high rainfall environment of Samaru, some genotypes demonstrated specific adaptation to low rainfall locations suggesting that rainfall distribution during growing season was the determining factors for the performance of pearl millet genotype and confers either broad or specific adaptation to such locations.

According to Ghaderi et al. (1980), analysis of variance procedure is useful for estimating the magnitude of genotype by environment interaction but fails to provide more information on the contribution of individual genotypes and environment to genotype by environment interactions. To address the problem, different stability parametric procedures were employed in this study to evaluate and describe pearl millet parental lines performance and their result presented in Table 5. The individual location grain yield, mean grain yield of the genotypes across the five locations, regression coefficient and deviation from regression indicated that mean grain yield across the five locations ranged from 504.8 (kg ha^{-1}) for G3 (20A-2) to 1920 (kg ha^{-1}) for G24 (75B-3). The top five higher mean values for grain yield in descending order are G24, G21, G19, G16 and G20 with mean grain yield ranging from 1920 (kg ha^{-1}) to 1483.4 (kg ha^{-1}). These five parental lines consistently produced highest grain yield in low rainfall locations of Babura and Minjibir than in high rainfall regions. A-lines parents generally produced lower mean grain yield than their B-lines counterpart. Samaru location produced the highest overall mean grain yield of 1669.1 (kg ha^{-1}) which differed significantly from the rest locations. However, the lower rainfall locations of Babura and Minjibir produced similar mean grain yield but significantly higher than Panda and Bagauda with higher rainfall occurence. The variation in yield among parental lines across the testing location confirm the presence of genotype by environment interaction and for high yield potential indicating that specific breeding programmes are necessary for effective development of stable pearl millet parental lines in a diverse environmental conditions of northern Nigeria. This is similar to the report of Rathore and Gupta (1994) who stated that crossover interaction is substantial evidence in favor of breeding specific adaptation.

Parental lines with superior performance in drier areas is an indication of the presence of stress tolerant potentials among the lines while on the other hand those with better performance in wetter regions have specific adaptation to favorable environment. Stability of genotypes and their performance over a set of diverse environments is of considerable importance to agronomists and plant breeders. Newly developed cultivars are usually evaluated across different environments in order to elucidate the pattern and the magnitude of genotype by environment interactions. If the interaction is present particularly for trait of interest, then it can reduce the correlation between phenotypic and genotypic values and will ultimately reduce progress from selection (Kang and Gorman, 1989). On the other hand, if the genotype by environment interaction is not prominent, a single genotype can be recommended for a wider geographical area. This approach will not only lead to increased productivity, but can also considerably reduce the input cost by developing a single variety for a wider agro-ecological zone.

Understanding the relationship among yield testing locations is important if plant breeders are to target germplasm better adapted to different production environments or regions (Trethowan et al., 2001). Two stability parameters consisting of regression coefficient “bi” and deviation from regression “S^2di” were used to evaluate some parental lines as shown in Table 5. A genotype with a unit value for regression coefficient and minimum deviation from regression is considered to be stable (Eberhart and Russell, 1966). Several of the genotypes had a significant deviation from linear regression implying that these genotypes were unstable

Table 5. Mean grain yield (kg ha^{-1}), regression coefficients (bi) and deviation mean square (S^2di) of 25 pearl millet parental lines tested across five environments.

Code	Parental lines	Babura	Minjibir	Panda	Bagauda	Samaru	Mean grain yield	bi	S^2di
G1	6A-2	313	399	203	258	1419	518.2	0.932	23.2**
G2	6B-2	1202	2136	856	721	1849	1352.6	1.188	6.7
G3	20A-2	578	220	263	200	1264	504.8	0.956	24.5**
G4	20B-2	1160	621	564	472	1162	795.8	0.746	2.7
G5	21A-1	1160	2082	424	998	1565	1235	1.169	14.0*
G6	21B-1	1720	1205	999	1101	2075	1420	1.011	10.1*
G7	23A-1	1037	1324	597	968	1929	1171	0.999	6.8*
G8	23B-1	618	714	361	443	1729	773	0.675	1.5
G9	24A-1	1283	1502	702	501	1508	1099.2	1.300	4.2
G10	24B-1	1913	1414	704	539	1729	1259.8	1.319	0.6
G11	25A-1	1732	1510	599	740	1352	1186.6	1.209	3.5
G12	25B-1	1238	758	306	535	1729	913.2	1.080	4.1*
G13	37A-1	1325	1485	771	1063	1907	1310.2	0.565	3.7
G14	37B-1	1877	1725	559	735	1685	1316.2	1.363	1.1
G15	47A-3	1082	1588	1036	480	2062	1249.6	1.150	5.9
G16	47B-3	1873	2297	1099	650	1641	1512	1.263	10.3*
G17	51A-4	1914	1917	1086	878	1397	1438.4	0.873	4.9
G18	51B-4	1455	1802	814	1287	1508	1373.2	0.609	1.6
G19	60A-2	2075	2492	1300	1088	1840	1759	0.896	19.6**
G20	60B-2	1529	2217	1056	1041	1574	1483.4	0.459	29.2**
G21	66A-2	2609	2328	1623	949	1796	1861	1.185	15.1*
G22	66B-2	963	717	753	407	2017	971.4	0.810	7.1
G23	75A-3	1311	962	546	469	1490	955.6	1.051	0.05
G24	75B-3	2363	2321	1372	1549	1995	1920	1.022	0.03
G25	ZATIB	1743	1876	1030	747	1507	1380.6	1.006	0.2
CV%							34.75		
Mean							1230.39		
SE±							0.022		

*,**Significant at 5 and 1% levels of probability respectively; suitable for optimum environment bi=1, suitable for favorable environment bi>1, suitable for poor environment bi<1.

across the environments. Parental lines G10, G14 and G15 were found suitable for favorable conditions with predictable performance as they showed high mean grain yield along with above average responsiveness (bi>1) and non-significant deviation from regression line. Genotypes G13, G17 and G18 were considered suitable for poor environments with predictable performance as they exhibited high performance for grain yield along with below average responsiveness (bi<1) and non-significant deviation from regression line. Other high yielding lines (G19 and G20) have regression coefficient of less than one, they are suitable to poor environments because of their unpredictable performance due to their significant deviation from regression line. All the top five yielders demonstrated significant mean square from linear regression except G24 (75B-3) that displayed high mean value, regression coefficient value of near unit (1.022) and deviation from regression of approximately zero (0.31), indicating that the genotype is stable, widely adapted and therefore would increase performance as the productivity of environment improves. G23 (75A-3) showed regression coefficient of 1.051 (close to unit) and deviation from regression of 0.05 revealing that the genotype is stable. G23 and G24 are A/B counterparts (75A-3 and 75B-3) possessing wide adaptation with stable performance across the test environments. The two lines can be utilized as parental lines for the development of single cross hybrids in view of their stability and high mean values. This finding is in agreement with Ezeaku and Angarawai (2006), who found that pearl millet hybrid produced with 75A-3/75B-3 possessed superior grain yield. The report of Angarawai et al. (2004) revealed that male sterile line (75A-3) produced high grain yield and was one of the lines least affected by downy mildew.

ZATIB (check) showed regression coefficient value of

Table 6. Mean values for yield and yield components of 25 pearl millet parental lines across five locations.

Traits	Babura	Minjibir	Panda	Bagauda	Samaru	CV(%)
Stand count	17.9^{a}	20.0^{b}	16.2^{c}	13.4^{d}	12.1^{d}	26.77
50% flowering (days)	52^{e}	60^{c}	67^{a}	66^{b}	54^{d}	6.14
Downy mildew score	1.29^{b}	1.72^{a}	1.22^{b}	1.05^{c}	1.64^{a}	28.52
Striga count	1.20^{a}	1^{b}	1^{b}	1^{b}	1^{b}	15.03
Plant height (cm)	176.52b^{c}	196.60^{ab}	164.17^{c}	173.57^{bc}	216.77^{a}	38.85
Panicle length (cm)	32.2^{b}	31.92^{b}	33.45^{b}	32.52^{b}	36.32^{a}	18.42
Head weight (kg ha^{-1})	2216.8^{c}	2597.5^{b}	1207.4^{d}	1158.2^{d}	2951.5^{a}	33.99
Grain yield (kg ha^{-1})	1440.77^{b}	1504.4^{b}	784.88^{c}	752.79^{c}	1669.11^{a}	35.57

Mean values having similar letter(s) are not significantly different at 5% level of probability according to Duncan Multiple Range Test.

1.006, which is closer to unity and deviation from regression of near zero (0.2). Considering the criteria of stability, ZATIB showed stability in yield across the five locations when compared to the rest of the genotypes. Tollenaar and Lee (2002) reported that high yielding maize hybrids can differ in yield stability and that yield stability and high grain yield are not mutually exclusive. Regression coefficient for grain yield across locations ranged from 0.456 to 1.362. The result further showed that 14 out of 25 pearl millet parental lines gave regression coefficient values greater than one, indicating that these lines responded to favorable environment and can produce higher yields when provided with suitable environments. On the other hand, the rest 11 lines with regression coefficient less than one responded to all environments and possess wider adaptation to varying environmental conditions. Tollenaar and Lee (2002) reported significant differences among high yielding maize hybrids for their yield stability. Gama and Hallauer (1980) detected significant hybrid x environment interaction for maize hybrids while some were reported to be stable when both stability parameters were considered. Kang and Gorman (1989) and Vulchinokova (1990) also reported significant GxE interactions for different traits of maize.

The values of yield and yield components across test locations are shown in Table 6. The result showed significant differences in response of these characters to changes in environments. Plant height, panicle length, head weight and grain yield were prominently expressed in Samaru location with the values significantly higher in this location than other locations. The rest characters varied across the locations. The differential response of various characters sampled to changing environmental conditions was also manifested in the significant genotype x environment interactions as observed earlier in this study. The lowest coefficient of variation (CV%) was observed for days to 50% flowering (6.14%), *striga* count (15.03%), panicle length (18.42%) indicating the highest precision by which they were measured and also suggest less influence by environments compared to other traits. The highest CV% was recorded for plant height (38.85%), an indication of less precision by which it was recorded as well as higher influence by the environmental variations.

Conflict of Interest

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

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Full Length Research Paper

Gross margin analysis of rubber based cropping systems in Nigeria

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The study aims at determining the economic impact of the rubber based cropping system introduced to rubber farmers in Nigeria by Rubber Research Institute of Nigeria under the sponsorship of the Common Fund for Commodity (CFC) project in Nigeria coded CFC-IRSG 21. Thirty three farmers were randomly selected in five states in Nigeria (Edo, Delta, Ogun, Kaduna and Akwa Ibom) using interview schedule. The profitability of rubber based cropping systems on farmers' farms in the five states was determined using gross margin analysis. The study revealed that rubber based cropping systems in the study area were profitable with positive gross margins for all the identified cropping systems in the study area. Furthermore, the study revealed that a gross margin of ₦178, 000/ha and return on investment of ₦4.79 was the highest for the two cropping system identified in Edo state. A gross margin of ₦331, 000/ha and return on investment of ₦7.76 per Naira was the highest for the three cropping system adopted in Delta state. For the four crop combination in Ogun state, a gross margin of ₦181,000 and return on investment of ₦6.32 per Naira was the highest. In Akwa Ibom state, a gross margin of ₦402, 100 and return on investment of ₦8.05 per Naira was the highest for the three crop combination. For the four crop combination in Kaduna state, gross margin of ₦ 488,000 was the highest. The study however, concluded that cassava featured more in the intercropped combination and it gave higher gross returns in the rubber based cropping systems in Nigeria compared with other crops across the states.

Key words: Gross margin, profitability, rubber, intercropping, cropping systems.

INTRODUCTION

Rubber industry in Nigeria suffered significant decline by almost 50% in the past two decades (NRAN, 2014). Some of the reasons for the decline include; demand for large expanse of land and almost 70% of the vast inter-row spaces are underutilized. Secondly, long gestation period of the crop (about 5 to 7 years), a period during which the rubber plantation cannot be tapped for latex and hence no income accrued from the huge capital investment and maintenance of the plantation. This situation has remained a disincentive to rubber farmers and has made rubber enterprise unattractive, especially to small-scaled farmers in Nigeria.

One possible approach that may assist smallholder rubber farmers is to create a source of income capable of back rolling the cost of plantation maintenance, take care of his family food needs and other personal expenses.

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Table 1. Distribution of selected farmers by state.

State	Respondents
Delta	5
Edo	6
Ogun	9
Akwa Ibom	7
Kaduna	6
Total	**33**

Hence, a timely adoption of appropriate plantation management practices that is capable of utilizing the under-utilized land resources and increases the revenue base of the enterprises is important to the attainment of the drive for increase rubber production in Nigeria.

Intercropping of rubber with arable crops has been found to be beneficial to the growth of rubber and capable of improving the economy of the rubber enterprise thereby reducing the need for subsidies and credit to rubber farmers (Zainol et al., 1993, Haliru et al., 2014). Many researchers have demonstrated that intercropping of rubber with arable crop is advantageous in boosting yield crops (Masea and Cramp, 1995). It has also been reported that intercropping of rubber increase the rate of growth of rubber thereby reducing the gestation period of rubber (Esekhade and Idoko, 2009). Rubber Research Institute of Nigeria through the project 'Promote economically viable small holding rubber production in West Africa' funded by the Common Fund for Commodity (CFC) and the International Rubber Study Group (IRSG) have encouraged several farmers in Nigeria to go into rubber farming and intercropped their plantations with arable and bi-annual crops during the immature phase. Surveys have established, however, that rubber smallholders are practising intercropping (Mesike et al., 2009; Uzokwe U.N., 2009). The component food crops recommended to smallholder farmers as intercrop with rubber in Nigeria are maize, soybean, pepper, cowpea, tomato, yam, or cassava (Rosyid et al, 2008). This system has been reported to improve the soil (Masea and Cramp, 1995), enhance the growth rates of rubber (Abdul Razak and Barizan, 2001), increase land productivity, and reduce cost of plantation management by ensuring early income generation to farmer during the period of immaturity (Abraham, 1980; Zainol et al., 1993). Despite these positive benefits of rubber based intercropping system, there are still pockets of scepticism by some farmers in adopting this technology. Hence, there is need for a research to quantify in monetary terms, the derivable gains in adopting the system. Hence, this study was carried out to determine the actual economic benefit of different arable crops and their combinations as intercrop with rubber in Nigeria.

MATERIALS AND METHODS

The study was conducted in 5 states in Nigeria which include; Delta, Edo, Ogun, Akwa Ibom and Kaduna state. Rubber plantations were established using the doubled row planting system at a spacing of 2.5 x 2.5 m and 10 m avenue between each double row of rubber. The component crops were planted in the inter rows at a spacing of at least 1.0 m away from the rubber. Component crop spacing was the recommended spacing for each crop. Based on soil test results, fertilizer were applied (uniform broadcast) at the rate of 19.0, 60.0, 36.0 and 5.0 kg ha^{-1} N, P_2O_5, K_2O and MgO; using urea, single super phosphate, muriate of potash and magnesium sulphate as sources respectively. The fertilizers were divided into two equal doses and applied at planting and 3 months after planting. All farmers were encouraged to observe all agronomic protocols up to harvesting, processing and marketing. Data were generated using the primary data collected through personal interview schedule and structured questionnaires administered to the beneficiaries of CFC-IRSG 21 project in Nigeria. Altogether, 33 respondents were randomly selected across the states (Table 1). The major economic activity of the respondents is farming. The major crops cultivated are rubber, cassava, yam, maize, plantain, cassava, pineapple, watermelon, cocoyam and different types of vegetables. A whole farm budgetary technique was used to assess the profitability of rubber-based cropping systems among the beneficiaries of the project. The farmers made use of traditional farm implements like hoes, cutlasses with negligible depreciation. The profitability of the farm was determined using gross margin analysis as follows:

Gross Margin = Total Revenue – Total Variable cost

Where Total Revenue (TR), TR= $P_iQ_i + P_nQ_n$, P_i = Price of rubber (₦), Q_i= Output of rubber (Kg), P_n = Price of crop (n) intercropped with rubber (₦), Q_n= Output of crop (n) intercropped with rubber (Kg)

Variable costs include cost of labour, fertilizer, chemicals and other variable inputs. Returns per Naira (₦) invested (RI) was computed as RI= Gross Returns/TVC. The higher the value of RI the more profitable is the cropping system.

RESULTS AND DISCUSSION

The total variable cost per hectare for each cropping system is shown in Table 2. There are many intercropped combinations with rubber but the major crops intercropped with rubber include cassava, yam, maize, plantain, pineapple, watermelon, melon and millet. Labour costs incurred by farmers for the cropping systems were due to land preparation, planting, weeding,

Table 2. Total variable cost and relative input cost per hectare.

State	Cropping systems	Labour cost	fertilizer	Planting material	Chemicals	Total variable cost
Edo	Rubber/cassava/yam/maize	30,000	15,000	20,000	2,000	67,000
	Rubber/cassava/plantain/maize	20,000	15,000	10,000	2,000	47,000
Delta	Rubber/cassava	20,000	15,000	2,000	2,000	39,000
	Rubber/cassava/plantain/pineapple	20,000	15,000	12,000	2,000	49,000
	Rubber/cassava/maize	20,000	15,000	6,000	2,000	43,000
Ogun	Rubber/maize	10,000	15,000	6,000	2,000	33,000
	Rubber/maize/watermelon	10,000	15,000	8,000	2,000	34,000
	Rubber/plantain	20,000	15,000	20,000	2,000	57,000
	Rubber/cassava	30,000	15,000	5,000	2,000	52,000
Akwa Ibom	Rubber/cassava/Telfera/cocoyam	30,000	15,000	10,000	2,000	57,000
	Rubber/cassava/okro	30,000	15,000	7,000	2,000	54,000
	Rubber/cassava/Telfera	30,000	15,000	7,000	2,000	54,000
Kaduna	Rubber/cassava/yam/melon/maize/rice	25,000	15,000	20,000	2,000	62,000
	Rubber/yam/millet/maize/melon	20,000	15,000	20,000	2,000	57,000
	Rubber/maize/millet	10,000	15,000	10,000	2,000	37,000
	Rubber/yam/maize/millet	20,000	15,000	20,000	2,000	57,000
	Rubber/maize/millet/bitter leaf/pepper	15,000	15,000	10,000	2,000	42,000
	Rubber/cassava/maize/bitter leaf/pepper	25,000	15,000	10,000	2,000	52,000

Table 3. Gross returns per hectare of rubber-based cropping system in Edo state.

Cropping system	Crops	Output(kg/Ha)	Average market price (₦/kg)	Total revenue (₦)
	Rubber	-	145	-
	Cassava	10,000	15	150,000
Rubber-cassava-yam-maize	Yam	5,000	10	50,000
	Maize	500	50	25,000
	Gross returns			**225,000**
	Rubber	-	145	-
	Cassava	10,000	15	150,000
Rubber/cassava/plantain/maize	Plantain	5,000	10	50,000
	Maize	500	50	25,000
	Gross returns			**225,000**

fertilizer applications and harvesting. Labour cost was the highest variable cost incurred and it accounted for over 40% of the total variable cost in Edo, Delta, Akwa Ibom and Kaduna states. The farmers used 2 to 4 L of herbicides per hectare with an average of 3 L per hectare. The cost of herbicides used was estimated at ₦3, 000 per hectare. The price of 1 bag of fertilizer ranged from ₦4, 500 to ₦5, 500 for 50 kg bag with an average of ₦5, 000 per bag. Fertilizer cost was about ₦15, 000 per hectare.

Farm returns for the rubber based cropping system in each state are shown in Tables 3 to 7. The gross returns were calculated by multiplying the total quantity of the outputs by the average market price prevailing at the period. The study revealed that cassava has the highest return per hectare when compared with other crops that were intercropped with rubber in Edo, Delta and Ogun states. However, coco yam and maize have the highest return in Akwa Ibom and Kaduna respectively. Data in Table 3 shows that the two cropping systems adopted by farmers in Edo state recorded gross returns of ₦225,000 per hectare. In Table 4, the combination of rubber-cassava-plantain-pineapple intercropping gave the highest gross returns of ₦380,000 per hectare in Delta state when compared to other cropping systems adopted in the state. In ogun state, rubber-maize-water melon

Table 4. Gross returns per hectare of rubber-based cropping system in Delta state.

Cropping system	Crops	Output(kg/Ha)	Average market price (₦/kg)	Total revenue (₦)
Rubber/cassava	Rubber	-	145	-
	Cassava	10,000	20	200,000
	Gross return			**200,000**
Rubber/cassava/plantain/pineapple	Rubber	-	145	-
	Cassava	10,000	25	250,000
	Plantain	5,000	10	50,000
	Pineapple	1,000	80	80,000
	Gross return			**380,000**
Rubber/cassava/maize	Rubber	**-**	**145**	**-**
	Cassava	9,000	13	117,000
	Maize	2,000	25	50,000
	Gross return			**167,000**

Table 5. Gross returns per hectare of rubber-based cropping system in Ogun state.

Cropping system	Crops	Output(kg/Ha)	Average market price (₦/kg)	Total revenue (₦)
Rubber/maize	Rubber	-	145	-
	Maize	3,000	40	120,000
	Gross return			**120,00**
Rubber/maize/watermelon	Rubber	-	145	-
	Maize	2,600	37	96,200
	Watermelon	2,600	46	119,600
	Gross return			**215,800**
Rubber/plantain	Rubber	**-**	**145**	**-**
	Plantain	3,000	40	120,000
	Gross return			**120,000**
Rubber/cassava	Rubber	-	145	-
	Cassava	7,000	20	140,000
	Gross return			**140,000**

cropping system gave the highest gross returns of ₦215,800 per hectare when compared to other cropping systems in the area (Table 5). From the results in Table 6 and 7, rubber-cassava-telfera-cocoyam and rubber-cassava-yam-melon-maize-rice cropping system have the highest gross return of ₦459,000 and ₦550,000 per hectare respectively in Akwa Ibom and Kaduna state when compared with other cropping system in the states.

Table 8 shows that farmers make positive Gross Margin for the various types of cropping systems in the study area. For the cropping system used in Edo state, the combination of rubber-cassava-plantain-maize cropping system consistently gave higher gross margin (₦178, 000/ha) and return on investment of ₦4.79 than the combination of rubber-cassava-yam-maize. The value of the return on investment indicated that for every ₦1 invested in the cropping combination, there was a return of ₦4.79. For Delta state, the intercropping of rubber-cassava-plantain-pineapple gave the highest gross margin (₦331, 000/ha) and return on investment (₦7.76) in the three cropping system used by the farmers. For the cropping combination in Ogun state, the intercropping of rubber-maize-watermelon consistently gave the highest gross margin of ₦181,000 and return on investment of ₦6.32. For the cropping combination used in Akwa Ibom state, the intercropping of rubber/cassava/telfera/

Table 6. Gross returns per hectare of rubber-based cropping system in Akwa Ibom state.

Cropping system	Crops	Output (kg/Ha)	Average market price (₦/kg)	Total revenue (₦)
	Rubber	-	145	-
	Cassava	112,200	15	168,000
Rubber/cassava/Telfera/cocoyam	Telfera	8,000	12.50	100,000
	Cocoyam	14,700	13	191,000
	Gross return			**459,000**
	Rubber	-	145	-
Rubber/cassava/okro	Cassava	11,000	15	165,000
	Okro	500	60	30,000
	Gross return			**195,000**
	Rubber	**-**	**145**	**-**
Rubber/cassava/Telfera	Cassava	11,000	15	165,000
	Telfera	8,000	12.50	100,000
	Gross return			**265,000**

Table 7. Gross returns per hectare of rubber-based cropping system in Kaduna state.

Cropping system	Crops	Output(kg/Ha)	Average market price (₦/kg)	Total revenue (₦)
	Rubber	-	145	-
	Cassava	3,000	50	150,000
	Yam	1,000	50	50,000
Rubber/cassava/yam/melon/maize/rice	melon	500	50	25,000
	Maize	5,000	60	300,000
	Rice	500	50	25,000
	Gross return			**550,000**
	Rubber	-	145	-
	Yam	1000	50	50,000
Rubber/yam/millet/maize/melon	millet	1,500	50	75,000
	Maize	5,000	60	300,000
	Melon	1500	50	75,000
	Gross return			**500,000**
	Rubber	**-**	145	**-**
Rubber/maize/millet	Maize	4,000	50	200,000
	Millet	2,500	50	125,000
	Gross return			**325,000**
	Rubber	-	145	-
	Yam	1,000	50	50,000
Rubber/yam/maize/millet	Maize	5,000	60	300,000
	Millet	2,000	50	100,000
	Gross return			**450,000**
	Rubber	-	145	-
Rubber/maize/millet/bitter leaf/pepper	Maize	4500	50	225,000
	Millet	2,000	50	100,000

Table 7. Contd.

	Biter leaf	500	90	45,000
	Pepper	500	80	40,000
	Gross Return			**410,000**
Rubber/cassava/maize/biter leaf/pepper	Rubber	-	145	-
	cassava	3,000	50	150,000
	Maize	4,000	50	200,000
	Bitter leaf	500	80	40,000
	Pepper	500	100	50,000
	Gross return			**440,000**

Table 8. Gross Margins and Returns per Naira invested per hectare of rubber-based cropping system.

States	Cropping system	GR (₦/ha)	TVC (₦/ha)	GM (₦/ha)	RI (₦/ha)
Edo	Rubber/cassava/yam/maize	225,000	67,000	158,000	3.36
	Rubber/cassava/plantain/maize	225,000	47,000	178,000	4.79
Delta	Rubber/cassava	200,000	39,000	161,000	5.13
	Rubber/cassava/plantain/pineapple	380,000	49,000	331,000	7.76
	Rubber/cassava/maize	167,000	43,000	124,000	3.88
Ogun	Rubber/maize	120,000	33,000	87,000	3.64
	Rubber/maize/watermelon	215,000	34,000	181,000	6.32
	Rubber/plantain	120,000	57,000	63,000	2.11
	Rubber/cassava	140,000	52,000	88,000	2.69
Akwa Ibom	Rubber/cassava/telfera/cocoyam	459,100	57,000	402,100	8.05
	Rubber/cassava/okro	195,000	54,000	141,000	3.61
	Rubber/cassava/telfera	265,000	54,000	211,000	4.91
Kaduna	Rubber/cassava/yam/melon/maize/rice	550,000	62,000	488,000	8.87
	Rubber/yam/millet/maize/melon	500,000	57,000	443,000	8.77
	Rubber/maize/millet	325,000	37,000	288,000	8.78
	Rubber/yam/maize/millet	450,000	57,000	393,000	7.89
	Rubber/maize/millet/bitter leaf/pepper	410,000	42,000	368,000	9.76
	Rubber/cassava/maize/bitter leaf/pepper	440,000	52,000	388,000	8.46

cocoyam also consistently gave the highest gross margin of ₦402,100 and return on investment of ₦8.05. For the cropping combination used in Kaduna state, the intercropping of rubber-cassava-yam-melon-maize-rice have the highest gross margin of ₦488,000. However, the return on investment of ₦8.87 for cassava-yam-melon-maize-rice intercrop was not the highest in Kaduna state because of high labour cost recorded in the crop combination. However, the highest return on investment in Kaduna state was obtained from intercropped rubber-maize-millet-bitter leaf-pepper (₦9.76).

CONCLUSION AND RECOMMENDATIONS

The study shows that farmers in the study area used different crops like cassava, yam, maize, plantain, pineapple, millet, leafy and fruity vegetables for intercropping with rubber. The farmers made positive returns on capital invested for different combination of cropping systems used in the study area. Generally, cassava featured more in the intercropped combination and it gave higher gross returns in the rubber based cropping systems in Nigeria compared with other crops across the states. In Edo and Delta State, cropping systems involving cassava and plantain gave the highest gross returns while in Ogun state it was maize and water melon. In Kaduna state, it was the cassava, yam, melon, maize while in Akwa Ibom it was cassava, telfria and cocoyam combinations.

Conflict of Interest

The authors have not declared any conflict of interest.

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Review

Effect of iron on yield, quality and nutrient uptake of chickpea (*Cicer arietinum* L.)

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The role of micronutrients in crops is well known in the present context. Research already proved the micronutrient deficiency in various crops as well as in the human beings and which results as drastic reduction in crop yield. Chickpea (*Cicer arietinum* L.) is an important grain legume crop in the World, and being a rich and cheap source of protein can help people to improve the nutritional quality of their diets. It is also the premier food legume crop in India, ranks first among all pulse crops. Iron (Fe) play vital role in several enzymatic reactions and metabolism in plants. A little amount of Fe enhanced the chickpea yield and quality. Application of Fe fertilizer for crop production also reduces the malnourishment in human and animals. At present, more emphasis is on biofortification aspect through agronomic as well as breeding techniques. Application of Fe fertilizers in chickpea crop production may be a better sustainable option to overcome these problems in the future. This review article described the Fe role in yield, quality and nutrient uptake by chickpea.

Key words: Chickpea, micronutrient, Nutrient management.

INTRODUCTION

The word' micronutrient' represent some essential nutrients that are required in very small quantities for the growth of plants and microorganisms. Essential micronutrients for plant growth are iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo), nickel (Ni) and chlorine (Cl). Amongst these eight micronutrients, the content of Fe in soil as well as in plants is the highest than even P and S contents (Tisdale et al., 1985). It plays a crucial role in enzyme like cytochrome oxidase, catalase and peroxidase. Although most of the Fe on the earth crust is in the form of Fe^{3+}, the Fe^{2+} form is physiologically more significant for plants. This form is relatively soluble, but is readily oxidized to Fe^{3+}, which then precipitates. The major natural source Fe are hematite (Fe_2O_3), goethite (FeOOH), magnetite (Fe_3O_4), pyrite (FeS_2) and olivine [(Mg, Fe)$_2$ SiO_4] . The total contents in the surface of soil is 4000 to 2,73,000 ppm whereas Fe available content in surface soil is 0.36

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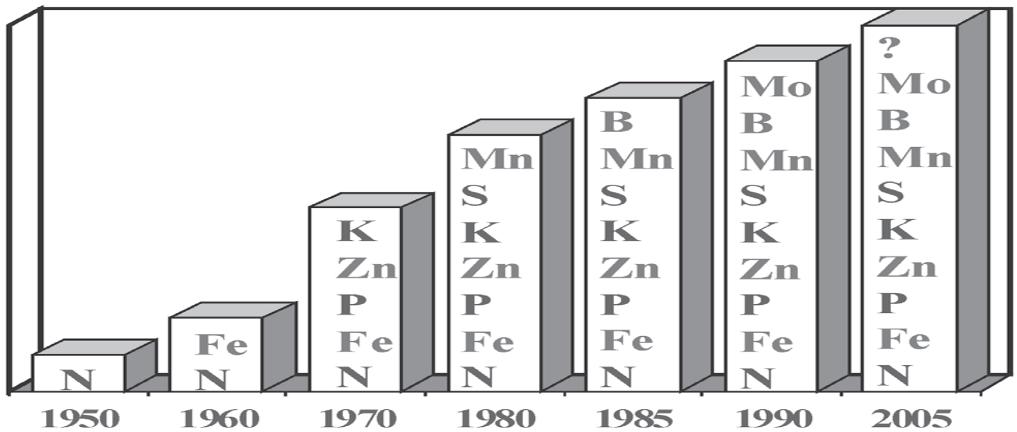

Figure 1. Progressive expansion in occurrence of nutrient deficiencies (Katyal and Rattan, 1995).

Table 1. Extent of micronutrient deficiencies in soils of various states (Singh, 2009).

Name of State	Percent sample deficient (PSD)			
	Zn	**Cu**	**Fe**	**Mn**
Andhra Pradesh	49	< 1	3	1
Assam	34	< 1	2	-
Bihar	54	3	6	2
Gujarat	24	4	8	4
Haryana	61	2	20	4
Himachal Pradesh	42	0	27	5
Karnataka	73	5	35	17
Kerala	34	31	< 1	0
Madhya Pradesh	44	< 1	7	1
Maharashtra	86	1	24	0
Meghalaya	57	2	0	-3
Orissa	54	<1	0	0
Punjab	48	<1	14	2
Tamil Nadu	58	6	17	6
Uttar Pradesh	46	1	6	3
West Bengal	36	<1	0	3
All States	48	3	12	5

to 174 ppm DTPA-$CaCl_2$ extractable. Its deficiency is a limiting factor for plant growth and affected crop yield adversely (Kobayashi and Nishizawa, 2012). Symptoms include leaves turning yellow or brown in the margins between the veins which may remain green, while young leaves may appear to be bleached. It is present at high quantities in soils, but its availability to plants is usually very low, and therefore Fe deficiency is a common problem (Nozoye et al., 2011). The Fe deficiency in soil was reported in early sixties (Katyal and Rattan, 1995); and found in most of the state of India (Figure 1 and Table 1). Excessive application of Zn, Mn and Cu induces Fe deficiency in crops. The rood exudates enhanced the mobilization of *in situ* Fe for plant uptake (Xiong et al., 2013; Ueno et al., 2007).

Chickpea (*Cicer arietinum* L.) is an important pulse crop in India. It significantly contributed in protein requirement of poor peoples. It is a highly nutritious pulse and places third in the importance list of the food legumes that are cultivated throughout the world. It contains 25% proteins, which is the maximum provided by any pulse and 60% carbohydrates (Singh et al., 1993). India is the largest producer of this pulse contributing to around 70% of the world's total production. Fe plays the crucial role in enhancing crop yield. This review paper described the role of Fe in chickpea production.

Effect of iron on growth attributes

Bhanavase et al. (1994) reported that the soil application of ferrous sulphate at 25 kg ha^{-1} to soybean crop increased nodulation, nodules dry weight per plant and dry matter accumulation as compared to control. Mundra and Bhati (1994) conducted a field experiment in loamy sand soil and they concluded that the application of Fe through ferrous sulphate at 10 kg ha^{-1} significantly increased the number of branches per plant, dry matter accumulation per plant and nodules per plant in cowpea over control. Shukla and Shukla (1994) at Allahabad, India applied 25 and 50 kg $FeSO_4$ ha^{-1} to chickpea crop which resulted in increased number of nodules per plant, dry weight of root nodules, leg haemoglobin content of root nodules and rate of N_2 fixation as compared to control treatment. Singh et al. (1998) working on mung bean under clay loam soil of Kanpur found that the plant height, branches per plant, dry matter partitioned by stem and leaves as well as the total dry weight. Mung bean did not differ with soil applied 15 kg $FeSO_4$ ha^{-1} and foliar applied $FeSO_4$ (0.5%) compared to control treatment at 40 day after sowing. Mahriya and Meena (1999) conducted a field trial at Jobner (Rajasthan), and they concluded that all the growth characters *viz.*, plant height, number of branches per plant, dry matter production per meter row length were increased with the application of 4 kg Fe ha^{-1} in cowpea.

Balachander et al. (2003) reported that the application of Fe at 2 kg ha^{-1} through ferrous sulphate significantly increased the number and weight of nodules, biomass production, plant height and grain yield of black gram over control. Thapu et al. (2003) concluded that the application of micronutrients like Fe (as ferrous sulphate at 0.4%), Mn, Cu, Zn significantly increased the growth characters in pea. Kumawat et al. (2006) conducted an experiment at Bikaner in mung bean and reported that the application of 25 kg $FeSO_4$ ha^{-1} gave the higher chlorophyll content in leaves, shoot weight and root nodules weight over control. Nenova (2006) revealed that pea plants were supplied with different amount of Fe, ranging from complete deficient to toxicity, higher plant growth, chlorophyll and carotenoid content and chlorophyll fluorescence parameters were recorded at 7 days intervals from day 20 to day 91. Sahu et al. (2008) reported that the application of $FeSO_4$ at 2 kg ha^{-1} significantly increased the growth characters over control in chickpea. Kumar et al. (2009) conducted an experiment at Kanpur and reported that the branches per plant, number of pods per plant, number of grains per pod and test weight significantly increased with levels of Fe up to 10 kg Fe ha^{-1} over control in chickpea.

Effect of Iron on yield and yield attributes

Singh and Varun (1989) conducted a pot experiment on alluvial sandy loam soil with cowpea and concluded that the application of 0 to 20 mg kg^{-1} Fe increased the yield components. Gawad et al. (1991) reported that the application of 25 or 50 mg kg^{-1} Fe as ferrous sulphate along with 15.5, 31.0 or 46.5 kg P_2O_5 feddon^{-1} significantly increased the yield attributes in chickpea crop. Mundra and Bhati (1991) reported that the application of 20 kg $FeSO_4$ along with *Rhizobium* inoculation increased the seed yield in cowpea over control. Kumpawat and Manohar (1994) reported that the application of 20 kg $FeSO_4$ ha^{-1} significantly increased the dry weight of nodules, seed protein content and seed yield increased over control in gram. Kumpawat and Manohar (1994) reported that the seed yield of gram was increased by the application of 30 kg P_2O_5 ha^{-1} and 20 kg $FeSO_4$ ha^{-1} along with seed inoculation over control. Singh et al. (1995) observed that the application of Fe at 5 kg ha^{-1} increased seed yield of french bean by 26% over control. Sakal et al. (1996) opined that the application of 1% ferrous sulphate + 0.2% citric acid solution as foliar spray increased grain yield of black gram and chickpea over control.

Singh et al. (1998) reported that the soil application of 15 kg $FeSO_4$ ha^{-1} significantly increased grain and straw yield of mung bean by 9.78 and 11.81% over 0.1% $FeSO_4$ foliar treated plots. Further yield attributes were also increased significantly with 15 kg $FeSO_4$ ha^{-1} over foliar applied $FeSO_4$ and control treatment. Sawires (2001) reported that the seed yield of gram was increased by the application of 20 kg $FeSO_4$ ha^{-1} along with seed inoculation over control. Gupta et al. (2002) conducted a field experiment at Kota (Rajasthan) and results revealed that the application of Fe either through soil (2.2 and 5.0 mg kg^{-1}) or foliar (0.5% $FeSO_4$ two spray) increased grain yield of mung bean over control. Yadav et al. (2002) reported that the seed and stover yield of mung bean significantly increased with the application of 4 kg Fe ha^{-1} over control. Balachander et al. (2003) reported that the application of Fe at 2 kg ha^{-1} through ferrous sulphate significantly increased the number and weight of nodules, biomass production, plant height and grain yield of black gram over control. Thapu et al. (2003) observed that the application of micronutrients like Fe (as $FeSO_4$ at 0.4%), Mn, Cu, Zn significantly increased the grain yield in pea. Salam et al. (2004) conducted a field experiment at Raipur, Chhatisgarh and concluded that the seed yield of urdbean under application of $FeSO_4$ at 2-20 kg Fe ha^{-1} was maximum over control. Mevada et al. (2005) conducted a field experiment on sandy loam soil to study the effect the application of micronutrients (Zn, B, Mo, Fe) on the performance of urdbean and reported that the maximum grain yield (1180 kg ha^{-1}) was obtained under the application of chelated Fe (1 kg ha^{-1}) over control (924 kg ha^{-1}). Kumawat et al. (2006) observed that the soil application of Fe at 25 kg $FeSO_4$ ha^{-1} recorded significantly higher seed and straw yield of summer mung bean as compared to control. Sahu et al. (2008) reported that the application of $FeSO_4$ at 2 kg ha^{-1} along with biofertilizer inoculation gave the highest grain yield (1473 kg ha^{-1}) and straw yield (1423 kg ha^{-1}) as compared to control in chickpea.

Kumar et al. (2009) conducted an experiment at Kanpur and results revealed that the application of 10 kg Fe ha^{-1} enhanced the grain yield of chickpea by 17.3% over control. Similar trend in straw yield response was also recorded. Sharma et al. (2010) reported that the application of chelated Fe (1 or 2 kg ha^{-1}), all the yield contributing characteristics *viz.*, number of pods per plant, number of seeds per pod and 100 seeds weight were significantly increased in pigeon pea crop.

Effect of iron on nutrient content, uptake and quality

Mundra and Bhati (1991) conducted a field experiment at Jobner (Rajasthan), revealed that the application of 10 and 20 kg $FeSO_4$ ha^{-1} significantly reduce P and Mn concentration in seed and its uptake but increased the uptake of N and Fe compared to control. Singh and Tiwari (1992) reported that the concentration and plant uptake of Zn were increased by Zn application while plant concentration of P, Fe and Cu were generally decreased due to Zn application in chickpea crop. Patel et al. (1993) conducted a field trial on calcareous soils of Gujarat revealed that foliar spray of one per cent $FeSO_4$ + 0.1 per cent citric acid and 2 per cent ferric citrate solution significantly increased concentration of Fe in groundnut leaves by 160.78 and 166.00% at 60 days of crop over control. Both the treatments were at per in their effect and significantly reduces the concentrations of P at all stages of crop growth. Whereas, in another experiment results revealed the foliar spray of 3% $FeSO_4$ to groundnut increased uptake of N, K, and Fe as compared to foliar spray of 0.5, 1.0 and 2.0% $FeSO_4$ and soil applied $FeSO_4$ at 25 and 50 kg ha^{-1} (Pande et al., 1993). Kumpawat and Manohar (1994) reported that the seed protein content of gram was increased by the application of 30 kg P_2O_5 ha^{-1} and 20 kg $FeSO_4$ ha^{-1} along with seed inoculation over control. Shukla and Shukla (1994) observed that increase in Fe and P concentration in seeds of chickpea with increasing levels of $FeSO_4$ up to 50 kg ha^{-1} over control. Singh et al. (1995) reported that the uptake of N by French bean crop increased with increasing application of Fe up to 5 kg ha^{-1} but uptake of P remained unaffected.

Mahriya and Meena (1999) conducted a field trial at Jobner (Rajasthan), and they concluded that all the growth characters as well as protein content in seed were increased with the application of 4 kg Fe ha^{-1} in cowpea. Yadav et al. (2002) reported that the protein content in seeds increased significantly with application of 30 kg P_2O_5 ha^{-1} and 4 kg Fe ha^{-1} over their lower levels in mung bean. The Fe content and uptake in seed and stover increased significantly with the application of 6 kg Fe ha^{-1} but decreased the content and uptake of phosphorus. Kumawat et al. (2006) observed that the application of 25 kg $FeSO_4$ ha^{-1} to summer mung bean increased the activities of the catalase, guaiacol peroxidase synthesis of chlorophyll and active Fe content of green leaves over lower doses of $FeSO_4$ and controlled treatment. While on calcareous soils of western Rajasthan, Kumawat et al. (2006) noted that soil application of 25 kg $FeSO_4$ ha^{-1} significantly increased Fe concentration in green leaves of mung bean as compared to control, further N, P, K and S uptake by grain and straw also increased due to 25 kg $FeSO_4$ ha^{-1} compared to control. Sahu et al. (2008) reported that the application of $FeSO_4$ at 2 kg ha^{-1} along with biofertilizer inoculation gave the highest grain yield (1473 kg ha^{-1}) and nutrient uptake with *Rhizobium* + PSB inoculation compared to control in chickpea. Kumar et al. (2009) reported that the uptake of P and Fe by grain and straw increased significantly by application of varying levels of P and Fe up to 50 kg P_2O_5 and 10 kg Fe ha^{-1} over control in chickpea. Sharma et al. (2010) reported that the application of chelated Fe (1 or 2 kg ha^{-1}), all the yield contributing characteristics as well as protein content in seed were significantly increased in pigeon pea crop.

Conclusions

Chickpea is one of the leading pulse crop of India, contributing larger portion of dietary protein. But last few years, use of Fe fertilizers showed the higher yield. Application of Fe fertilizer enhanced the quality as well as chickpea yield. Spread the awareness of Fe fertilizer use in crop production by government and non government organizations (NGOs), a potential strategy to enhance the crop yield. More initiative should be taken by research institute, so that Fe plays a vital role in sustainable chickpea production in future.

Conflict of Interest

The authors have not declared any conflict of interest.

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Stability and regression analysis in elite genotypes of sugarcane (*Saccharum* spp hybrid complex)

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Experiments were conducted during 2012-2013 with eight sugarcane genotypes along with four commercial checks to study the phenotypic stability and regression of cane yield, and its components under four environments. The G × E component of variation was significant for single cane weight, number of millable canes, commercial cane sugar percent, cane yield and sugar yield. The genotypes SNK 07680 and SNK 07337 was found stable for cane yield (132.60 and 105.66 t ha^{-1} respectively), sugar yield (14.44 and 12.70 t ha^{-1}) its component characters such as sucrose (16.81 and 16.31% respectively), whereas SNK 07680 found stable for CCS (11.98%). Genotype SNK 07658 showed adoptability to unfavorable environment for single cane weight, number of millable canes and sucrose as evident by its deviation from regression and regression coefficient. Regression analysis concluded that 81.13% of total cane yield was contributed by single cane weight and number of millable canes.

Key words: Sugarcane, stability, G × E interaction, sucrose %.

INTRODUCTION

Sugarcane (*Saccharum* spp hybrid complex) is one of the most important agro-industrial crop grown in subtropical and tropical parts of the world especially in India. India is the second largest producer of sugarcane next to Brazil. Generally sugarcane is a vegetatively cultivated crop with wide adoptability and diversity. In subtropical India particularly in peninsular zone variation in climatic conditions are wide during the period of its growth and maturity stage. Sugarcane breeding is highly complex because it is highly heterozygous in nature, combined with higher polyploidy (2n=80-120). In multi location trial over the years for yield, sugarcane breeders are aware about the differences of cultivar for yield and quality which varies from location to location. This raises a question that, do we require different cultivar for different environment or should we select specific cultivar for particular environment. Further the ranks of the genotypes vary from one location to another location, indicating a strong genotype × environment interaction. Phenotypically stable genotypes with good cane yield potential under vast array of environmental conditions are of great importance because sugarcane is grown by farmers of all the regions. Different biometrical methods have been used for genotype x environment interaction in crop plants by several workers the important ones being Finlay and Wilkinson (1963), Eberhart and Russel (1963) and Perkinson and Jinks (1968). Most of them give information about the genotype, constitution and role of

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environment. Therefore it is necessary to evaluate the genotype x environment interaction for yield and quality parameters in sugarcane.

Stability for cane yield and its parameters has been a neglected research and very limited number of literatures has been reported so far in sugarcane, particularly in the peninsular India (Comprising Parts of Karnataka, Maharashtra, and Tamil Nadu) sufficient information regarding the stability of cane yield parameters are the bottle neck in sugarcane which otherwise could be used in further breeding progamms for crop improvement. Keeping these above factors in view, an investigation was planned to evaluate and screen out the elite sugarcane genotypes along with commercially accepted varieties over environments and to select the genotypes on the basis of stability parameters for yield and its important component characters. Although stability analysis provides a clear picture of the stability of genotype, but it cannot construct a prediction equation for cane and sugar yield using its components. Considering this point of view, the multiple linear regression analysis was also done.

MATERIALS AND METHODS

The materials for the present investigation comprises of 12 genotypes of sugarcane viz., SNK 07337, SNK 07344, SNK 07360, SNK 07342, SNK 07658, SN K 07680, SNK 071013 and SNK 071138 including with four checks *viz.,* Co 94012, Co 86032, Co 92005 and CoM0265. The experiment was carried out at four diverse environments namely E1, (Agriculture research station, Sankeshwar), E2, (S. Nijalingappa Sugar Institute, Belagaum), E3, (Shegunsi, Belagaum), E4, (R&D unit, Nandi Sugars, Hosur, Bijapur), in randomized block design with 3 replications during the crop season 2012-2013. Each treatment plot comprised 6 rows of 6 m length spaced with 90 cm apart. The crop received 150:60:40 kg of NPK per hectare. The total quantity of phosphorus and potassium was applied at basal and nitrogen was split into three dose: at germination, tillering and final earthing up. All the cultural practices were adopted during the entire cropping season to ensure good crop. Observation were recorded for characters namely, cane height (m), cane girth (cm), single cane weight (kg), number of millable canes, sucrose (%), commercial cane sugar (%), cane yield (t ha^{-1}), sugar yield (t ha^{-1}). Five randomly selected canes were used to record cane height, cane girth, single cane weight, sucrose and commercial cane sugar. The data were analysed for stability parameters, *viz.,* mean (μ), regression coefficient (bi,) and deviation from regression (S^2di) using the model proposed by Eberhart and Russell (1966). The soil properties of different locations were presented in Table A and weather parameters have been presented in Table B.

RESULTS AND DISCUSSION

Stability analysis

The pooled analysis of variance (ANOVA) (Table 1) revealed that environments, genotypes, genotype × environment interaction components of variation was significant for all the characters indicating the presence of substantial amount of variation among the genotypes over environments. Genotypes also exhibited significant interaction with environments for all the traits studied which indicates that genotypes behaved differently under each environment for the expression of the characters of interest. It means the particular variety may not exhibit the same phenotypic performance under different environment or different variety may respond differently to a specific environment. Queme et al. (2005) also reported that variance due to environment, genotype and G × E interactions were highly significant for cane yield, sucrose (%) and sugar yield. Environment (linear) showed highly significant variances for all the traits, signifying unit changes in environmental index for each unit change in environmental conditions.

The G × E (linear) as well as pooled deviation mean squares were found significant for single cane weight, number of millable canes, cane yield, sucrose% and sugar yield, indicating the presence of both predictable and non predictable components. The importance of both linear and non-linear sensitivity for the expression of these traits was thus evident. However linear component was significantly higher than the non-linear portion of the G × E interaction supporting the earlier findings of Kumar et al. (2004); Tiawari et al. (2011) and Sanjeevkumar et al (2007). As linear component is higher for all the characters, performance prediction of genotypes based on these traits would be more accurate across the environments. Eberhart and Russell (1966) discussed stability of genotypes in terms of three parameters namely, genotypic mean (μ), regression or linear response (bi,) and deviation from the linearity (S^2di,). According to this model an ideally stable variety is one that confirms high mean values, unit regression or linear response and no deviations from the linearity.

The genotypes SNK 07360, SNK 071138 and CoM 0265 were unpredictable interms of their significant deviation from regression coefficient for cane height (0.187 0.239 and -0.190 respectively) and cane girth (0.392 and -0.324 respectively) whereas the rest all genotypes were predictable as they exhibited non significant deviation from regression for both the characters (Table 2). Genotypes SNK 07680 and SNK 07658 showed high mean coupled with non significant regression coefficient greater than unity for cane height and cane girth indicating these genotypes do better in favorable environment, whereas SNK 07337 exhibited high mean with non significant regression coefficient less than unity for cane girth indicating its adoptability in unfavorable environment. The genotypes SNK 07342 and SNK 071138 showed significant deviation from regression for single cane weight (-0.213) with regression coefficient more than unity indicating their unpredictability over environment. Whereas genotypes SNK 07337 and SNK 07680 were stable across the environment for single cane weight as indicated by their high mean (1.31 and 1.53 kg respectively) coupled with non significant regression coefficient close unity (1.01 and 1.02 respectively).

Table 1. Pooled analysis of variance for stability analysis (Eberhart and Russell, 1966) for cane and jaggery parameters in clonal-VII over four locations.

Source of variation	df	Cane height (cm)	Cane girth (cm)	Single cane weight (kg)	Number of millable canes (‘000/ha)	Sucrose %	CCS %	Sugar yield (t/ha)	Cane yield (t/ha)
Genotype	11	373.39**	0.101*	0.247**	14397.9**	3.94**	1.39**	16.86**	837.5**
Environment + (G × E)	36	2388.41**	0.217*	0.049	1902.2*	0.79**	2.02	3.94	321.8
Environments	3	75.48**	0.118*	0.212*	2418.3**	0.86*	6.75*	9.01*	846.5**
Genotype ×Environment (G × E)	33	2484.78**	0.125**	0.034**	1855.3**	0.78**	1.82**	3.48**	274.1**
Environments (Lin.)	1	150.97*	0.531*	0.637	7254.8**	2.57**	13.51*	27.04	2539.5**
Genotype × Environment (linear)	11	2644.80	0.014	0.017*	1960.4**	1.55**	2.38*	3.71*	307.9*
Pooled deviation	24	2231.77**	0.026	0.039**	1652.6**	0.36**	1.21	3.08**	235.8**
Pooled error	88	442.2	0.018	0.013	602.2	0.73	0.43	1.77	92.9

Stability of all the genotypes for number of millable canes is predictable except SNK 07360, SNK 07342¸ SNK 071013, SNK 071138, Co 92005 and CoM 0265 as they exhibited significant deviation from regression, whereas SNK 07658 was adoptable to unfavorable environment as indicated by its high mean with non significant regression coefficient lesser than unity. Based on stability parameters SNK 07337 and SNK 07680 were found most stable for number of millable canes. Similar results were reported for single cane weight and number of millable canes.

All the genotypes were linearly predictable for sucrose % (Table 3) because of non significant deviation from regression except SNK 071013 and SNK 071138 which recorded significant deviation from regression (1.121 and -1.400 respectively) and significant regression co efficient (1.994 and 2.213 respectively). Genotypes SNK 07337, SNK 07680, Co 94012 and Co 86032 were stable across the locations for sucrose %. SNK 07658 showed high mean with non significant deviation from regression and regression co efficient close to unity indicating its adoptability to unfavorable environment. Commercial cane sugar % (CCS %) and CCS yield being important quality (sugar yield) parameters for which genotypes like SNK 07342, SNK 07360, SNK 071013 and SNK 071138 were unpredictable as they exhibited significant deviation from the regression. Whereas SNK 07337, SNK 07680 and SNK 658 were stable and superior as compared to popular standard check Co 86032 for quality parameters. The same genotypes (SNK 07337 and SNK 07680) recorded significantly superior cane yield (111.92 and 120.41 t ha^{-1} respectively) compared to popular check Co 86032 (97.37 t ha^{-1}). These genotypes are stable across the generation for cane yield as indicated by their high mean coupled with non significant deviation from regression and regression coefficient close to unity (Table 3). In a study (Tahir et al., 2013) similar reports were made for cane yield whereas rest characters were not stable across locations.

The genotypes SNK0 7680 and SNK 07337 were stable across locations for cane yield because their high mean and also they are significantly superior (population mean) compared to commercial check Co 86032 which is most popular variety cultivated and occupied major area in peninsular India. These genotypes SNK 07680 and SNK 07337 also have commercially acceptable CCS% (11.98 and 11.31 respectively) and CCS yield (14.44 and 12.70 t ha^{-1} respectively).

Mean performance for cane and sugar yield in clonal VII

The mean data on cane yield (t ha^{-1}) and commercial cane sugar yield (CCS) (t ha^{-1}) at four locations are presented in Table 4. Out of 8 genotypes studied, SNK 07680, SNK 07337 and SNK 07658 recorded significantly maximum cane yield (t ha^{-1}) (120.41, 111.92 and 109.35 respectively) over the best available check Co 86032 (97.37).

Out of all the four locations, highest cane yield (t ha^{-1}) has been observed in ARS Sankeshwar (106.13 t ha^{-1}) followed by SNSI Belgaum and Nandi sugars Hosur (98.54 and 97.23 t ha^{-1}, respectively) and the lowest was recorded at Shegunsi (92.68 tha^{-1}). The mean cane yield (t ha^{-1}) over four environments was 98.64. Similarly

Table 2. Stability parameters for cane height, cane girth, single cane weight and number of millable canes over four locations.

Clone	Cane height (cm)			Cane girth (cm)			Single cane weight (kg)			Number of millable canes ('000/ha)		
	μ	b_i	S^2di	μ	b_i	S^2di	μ	b_i	S^2di	μ	b_i	S^2di
Snk 07337	171.86	0.99	0.007	2.66	1.01	0.009	1.31	1.01	0.009	85.44	1.08	12.021
Snk 07344	204.05	1.13	-0.011	2.24	2.23*	0.392*	1.38	1.19	-0.046	65.51	1.3	103.30*
Snk 07360	197.56	1.43	0.187*	2.88	2.11*	0.123	1.41	1.13	0.098	64.52	3.70*	117.67*
Snk 07342	186.38	1.68	-0.017	1.99	2.37*	0.383*	1.06	1.27	-0.869*	75.68	4.32*	98.67*
Snk 07658	183.81	1.04	0.015	2.56	1.39	0.044	1.53	0.98	0.023	71.47	0.96	31.04
Snk 07680	227.19	1.01	0.003	2.75	1.11	0.005	1.42	1.02	0.003	84.80	1.09	24.02
Snk 071013	204.44	-1.91*	0.075	1.89	-2.88*	0.432*	0.98	2.10*	0.034	79.72	3.59*	141.77*
Snk 071138	189.44	1.32	0.239*	1.68	-1.54	-0.324*	1.17	1.14	-0.213*	84.57	1.3	121.50*
Co 94012	198.08	1.24	0.08	2.2	1.21	0.211	1.07	1.24	0.032	94.83	2.11*	24.22
Co 86032	189.78	1.19	0.021	2.37	0.89	0.001	1.09	1.1	0.006	89.33	1.06	38.02
Co 92005	170.56	1.23	0.024	2.14	1.29	0.021	1.13	1.24	0.005	88.80	0.66	111.94**
CoM 265	215.06	-1.84*	0.190*	2.81	1.33	0.211	1.61	2.31*	0.008	64.72	1.57	24.48*
Mean	194.85			2.35			1.26			79.12		
C.D.@ 5%	11.29			0.12			0.08			9.86		
CV	5.56			4.68			9.94			11.08		

Table 3. Stability parameters for sugar yield parameters.

Clone	Sucrose %			Commercial Cane Sugar (CCS) %			CCS Yield (t/ha)			Cane Yield (t/ha)		
	μ	b_i	S^2di	μ	b_i	S^2di	μ	b_i	S^2di	μ	b_i	S^2di
Snk 07337	16.31	1.012	0.011	11.31	0.989	0.052	12.70	1.011	0.007	111.92	1.011	5.003
Snk 07344	16.24	1.093	-0.192	11.56	1.321	0.310*	10.42	1.831*	-1.041*	90.40	-1.313*	-121.61*
Snk 07360	15.93	1.312	0.124	11.36	1.421	-0.660*	10.38	1.043	0.061	90.98	1.594	82.21*
Snk 07342	16.78	1.382	-0.793	11.97	1.321	-0.105	9.61	1.612*	0.083	80.22	1.897*	90.34*
Snk 07658	15.28	0.997	0.029	10.90	1.021	0.033	11.97	1.019	0.006	109.35	0.905	5.003
Snk 07680	16.81	1.002	0.011	11.98	1.011	0.020	14.44	1.016	0.008	120.41	1.005	3.001
Snk 071013	16.58	1.994*	1.121*	11.74	0.769	0.601*	9.22	-2.210*	-1.052*	78.13	1.254*	101.18*
Snk 071138	15.13	2.123*	-1.400*	10.80	-1.830*	-4.370*	10.65	-2.650*	-1.153*	98.95	-2.344*	-91.23*
Co 94012	18.32	1.003	0.005	13.15	1.130	-0.390	13.36	1.014	0.042	101.47	1.113	8.08
Co 86032	15.89	1.029	0.011	11.24	1.020	-0.355	10.97	1.015	0.002	97.37	1.044	9.04
Co 92005	16.27	1.212	-0.027	11.64	1.933*	0.320	11.68	1.042	0.002	100.34	-1.197*	90.29*
CoM 265	16.35	1.193	0.053	11.73	1.784*	-0.286	12.26	1.234	1.133*	104.20	-1.102	10.10
Mean	16.23			11.62			11.05			98.65		
C.D. @ 5 %	0.56			0.35			2.26			11.15		
C V %	4.93			5.26			10.24			12.58		

the mean data on commercial cane sugar yield (CCS) (t ha^{-1}) for four locations indicated that, SNK 07680, and SNK 07337 recorded significantly maximum commercial cane sugar yield (t ha^{-1}) (14.44 and 12.70 respectively) over the best available check Co 86032 (10.97). Among all the four locations, highest commercial cane sugar yield (t ha^{-1}) has been observed in ARS Sankeshwar (12.75 tha^{-1}) followed by Nandi sugars Hosur and SNSI Belgaum (11.52 and 11.34 respectively) and the lowest was recorded at Shegunsi (10.28 t ha^{-1}). The mean commercial cane sugar yield (t ha^{-1}) over three environments was 11.47.

Mean performance for juice quality parameters in clonal VII

The mean data on sucrose percentual content at harvest for four locations are presented in Table 5. Out of 8 genotypes SNK 07680 and SNK 07342 recorded

Table 4. Mean performance of top productive clones along with checks for cane and sugar yield parameters over four locations.

Clone number	Cane yield (t/ha)					CCS yield (t/ha)				
	Env-1	Env-2	Env-3	Env-4	Pooled	Env-1	Env-2	Env-3	Env-4	Pooled
Snk07 337	109.57	102.7	106.21	129.23	111.92	12.82	11.01	11.5	15.48	12.70*
Snk07 344	81.4	77.7	77	125.52	90.4	9.03	9.33	9.04	14.29	10.42
Snk07 360	117.09	88	80.33	78.5	90.98	13.89	9.8	8.66	9.16	10.38
Snk07 342	90.01	71	86	73.86	80.22	12.11	8.25	8.84	9.25	9.61
Snk07 658	119.02	114.3	107.67	96.39	109.35	13.59	13.22	11.56	9.52	11.97
Snk07 680	129.57	112.7	114.67	124.74	120.41	15.95	13.5	13.6	14.71	14.44*
Snk07 1013	89	79.7	70.67	73.18	78.13	11.17	9.77	7.58	8.35	9.22
Snk07 1138	89	99.3	102	105.46	98.95	10.12	11.74	10.35	10.41	10.65
Checks										
Co 94012	90.81	110.2	101	103.85	101.47	11.76	15.18	12.69	13.81	13.36
Co 86032	124.26	92.3	85.67	87.22	97.37	14.25	10.53	9.03	10.08	10.97
Co 92005	101.33	102.5	91	106.49	100.34	12.06	12.51	10.32	11.83	11.68
CoM 0265	132.5	116.3	90	77.98	104.2	16.3	13.37	10.24	9.15	12.26
μ	106.13	97.23	92.68	98.54	98.64	12.75	11.52	10.28	11.34	11.47
C.D.@ 5%	16.23	13.85	12.22	18.58		1.96	1.87	1.6	2.3	1.14
C.D.@ 1%	22.9	19.55	17.24	26.22		2.76	2.63	2.26	3.25	1.61

Env-1 = ARS Sankeshwar, Env-2 = Nandi Sugars, Hosur,* - Significant at 5% probability level, Env-3 = Shegunsi ** - Significant a1% probability level, Env-4 = SNSI Belagum.

Table 5. Mean performance of top productive clones along with checks for juice quality parameters over four locations.

Clone number	Sucrose % at harvest					CCS % at harvest				
	Env-1	Env-2	Env-3	Env-4	Pooled	Env-1	Env-2	Env-3	Env-4	Pooled
Snk 07337	17.08	16.53	14.96	16.69	16.31	11.70	10.73	10.83	11.98	11.31
Snk 07344	16.05	16.78	16.32	15.79	16.24	11.09	12.02	11.74	11.39	11.56
Snk 07360	17.06	15.41	14.96	16.29	15.93	11.86	11.14	10.78	11.67	11.36
Snk 07342	19.27	16.17	14.14	17.53	16.78*	13.45	11.62	10.28	12.53	11.97*
Snk 07658	16.29	15.99	14.87	13.96	15.28	11.42	11.57	10.73	9.87	10.90
Snk 07680	17.63	16.74	16.40	16.47	16.81*	12.31	11.98	11.86	11.79	11.98*
Snk 071013	18.14	17.43	14.87	15.88	16.58	12.55	12.26	10.73	11.41	11.74
Snk 071138	16.17	16.32	14.18	13.86	15.13	11.37	11.81	10.15	9.87	10.80
Checks										
Co 94012	18.76	19.07	17.01	18.44	18.32	12.95	13.77	12.56	13.30	13.15
Co 86032	16.52	16.24	14.63	16.18	**15.89**	11.47	11.40	10.54	11.56	**11.24**
Co 92005	17.06	16.82	15.72	15.47	16.27	11.91	12.20	11.34	11.11	11.64
CoM 0265	17.21	15.94	15.86	16.40	16.35	12.30	11.49	11.38	11.73	11.73
Mean	**17.27**	**16.62**	**15.33**	**16.08**	**16.23**	**12.03**	**11.83**	**11.08**	**11.52**	**11.62**
C.D.@ 5%	0.92	0.84	0.83	1.16	0.73	0.63	0.68	0.64	0.86	0.55
C.D.@ 1%	1.29	1.18	1.17	1.64	1.04	0.89	0.96	0.90	1.22	0.78
CV	5.90	5.59	6.00	8.03	5.01	5.85	6.37	6.44	8.35	5.26

Env-1 = ARS Sankeshwar, Env-2 = Nandi Sugars, Hosur,* - Significant at 5% probability level, Env-3 = Shegunsi, ** - Significant a1% probability level, Env-4 = SNSI Belagum.

significantly maximum sucrose percentual content at harvest (16.81 and 16.78 respectively) compared to the best commercial check Co 86032 (15.89), whereas SNK 07337 and SNK 071013 (16.31 and 16.58) recorded sucrose per cent at harvest on par with Co 86032. Among all the four locations, highest sucrose percent at

Table 6. Multiple linear regression model to explain cane yield variation using some its related characters.

Regression parameter for cane yield	Regression coefficient (b)	Standard Error (SE)	Probability level (P-value)	Variance inflation factor (VIF)
Single cane weight (SCW)	2.75 **	0.680	000	5.42
Cane height (CH)	-0.007	0.002	0.10	4.06
Cane girth (CG)	0.122	0.318	0.47	5.45
No. millable canes (NMC)	1.423 **	0.066	000	4.20
Intercept	-12.75			
Model sig.	000			
R^2	81.13			
Adjusted R^2	76.3			
R^2 of eliminated traits	3.10			

Table 7. Multiple linear regression model to explain sugar yield variation using some its related characters.

Regression parameter for sugar yield	Regression coefficient (b)	Standard Error (SE)	Probability level (P-value)	Variance inflation factor (VIF)
CCS %	3.015 **	0.518	001	6.21
Purity % (P)	-0.007	0.007	0.21	3.87
Brix %	0.198	0.411	0.48	6.22
Juice Extract (JE)	0.047	0.077	0.27	2.88
Sucrose % (S)	1.784 **	0.101	000	3.97
Intercept	-8.99			
Model sig.	000			
R2	88.73			
Adjusted R2	84.63			
R2 of eliminated traits	2.22			

harvest has been observed in ARS Sankeshwar (17.27) followed by Nandi sugars Hosur and SNSI Belgaum (16.62 and 16.08 respectively) and the lowest was recorded at Shegunsi (15.33). The mean sucrose per cent at harvest over four environments was 16.23.

The mean data on CCS per cent at harvest for four locations are presented in Table 3. Out of 8 genotypes SNK 07680 and SNK 07342 recorded significantly maximum CCS percent at harvest (11.98 and 11.97 respectively) compared to the best commercial check Co 86032 (11.24), whereas SNK 07337 and SNK 071013 (11.31 and 11.74) recorded sucrose per cent at harvest on par with Co 86032. Among all the four locations, highest CCS percent at harvest has been observed in ARS Sankeshwar (12.03) followed by Nandi sugars Hosur and SNSI Belgaum (11.83 and 11.52 respectively) and the lowest was recorded at Shegunsi (11.08). The mean sucrose percent at harvest over four environments was 11.62.

Multiple linear regression analysis

Regression coefficients and their significance for some quantitative traits in predicting cane yield (CY) (Table 6) and sugar yield (SY) (Table 7) using full model regression, the prediction equation for cane yield and sugar yield was formulated as follows:

Cane Yield

$$= -12.75 + 2.75(SCW) - 0.007(CH) + 0.122(CG) + 1.423(NMC)$$

Sugar Yield

$$= -8.99 + 3.015(CCS\%) - 0.007(P) + 0.198(Brix\%) + 0.047(JE\%) + 1.784(S\%)$$

In addition to the high significance of the used model (P < 0.01), it successfully accounted for 81.13% of the total variation of cane yield expressed as R^2. The residuals content (18.87 %) may be attributed to unknown variation (random errors), human errors during measuring the studied traits and/or some other traits that were not in account under the present investigation. Furthermore, results showed that the single cane weight, number of millable canes, cane girth and cane height significantly contributed towards cane yield while the other traits did not (negligible contribution of 3.10). A contribution of 88.73% to sugar yield was made by CCS% alone expressed as R^2, residual was to the tune of 11.27%

which is because of the random errors, so this indicated that CCS% and Sucrose % are the important traits contributing to the sugar yield while a contribution of other traits for sugar yield was only 2.22.

On the other hand, the values of variance inflation factor (VIF) for all studied characters were less than ten for both cane and sugar yield, indicating trivial influence of multi co linearity problem. The present results ensured the goodness of fit for the proposed model of regression (Hussein et al., 2012).

The present study revealed that SNK 07680 and SNK 07337 were stable for most of the characters namely, single cane weight, number of millable canes, sucrose%, CCS yield and cane yield. Similarly SNK 07658 is stable for cane eight, CCS% and CCS yield. Overall the outstanding genotypes were SNK 07680, SNK 07337 for cane yield and sugar yield and genotype SNK 07658 for sugar yield. These genotypes were superior to other genotypes and checks by their per se performance and stability. Regression coefficients and their significance for both cane and sugar yield indicates that, SCW and NMC are major contributors for cane yield, where as Sucrose% and CCS % are major contributors for sugar yields.

Conflict of Interest

The authors have not declared any conflict of interest.

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APPENDIX

Table A. Chemical and physical properties of soil at different locations of experiments conducted.

Locations	Organic carbon (%)	Bulk density (Mgm^{-3})	Hydraulic conductivity (cm^{-1})	Water holding capacity (%)	P^H	EC (dSm^{-1})
E1	0.72	1.35	0.81	51.9	7.6	0.15
E2	0.75	1.22	0.94	51.7	7.6	0.55
E3	0.79	1.36	0.86	52.1	7.5	0.23
E4	0.69	1.20	0.79	50.3	7.7	0.30

Table B. Mean monthly meteorological data for the crop season 2012-2013 at at different locations of experiments conducted.

Month	Rain fall (mm)				Max. temperature (°C)				Min. temperature (°C)				Relative humidity (%)			
	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
February	-	8.4	-	-	30.21	30.21	33.3	34.1	13.53	15.57	21.4	11.2	61.10	69.75	79.7	69.5
March	-	-	-	-	33.35	35.03	36.6	37.3	17.45	17.32	21.4	12.4	60.96	58.42	68.2	76.4
April	-	91.4	103.2	12.0	36.00	37.93	36.86	38.5	19.20	19.86	23.3	17.6	51.00	56.6	79.1	86.1
May	-	17.4	103.3	23.2	37.29	38.83	36.5	38.1	19.90	22.83	22.1	18.2	56.96	57.5	76.8	88.5
June	46.4	142.0	41.1	27.1	31.66	32.53	29.7	34.6	19.16	20.7	20.4	17.6	61.78	59.02	87.0	88.6
July	94.8	129.4	68.1	41.5	28.77	27.93	29.1	31.9	19.09	19.93	20.1	17.6	69.95	66.69	87.7	90.7
August	93.2	102.4	185.2	36.0	29.29	29.35	28.9	31.7	18.41	19.16	19.5	17.1	70.54	69.06	88.9	91.1
September	92.6	143.4	34.5	20.0	29.03	29.03	29.4	32.0	18.33	18.66	19.9	16.5	67.35	67.47	86.8	91.2
October	88	179.8	101.0	187.8	29.16	29.16	30.7	31.4	17.93	18.51	20.0	14.8	66.54	67.53	83.5	89.9
November	12.6	-	-	22.4	28.66	27.76	28.6	30.7	16.10	16.63	18.8	13.2	60.53	64.58	77.6	89.5
December	5.4	-	-	-	29.22	44.93	29.5	31.1	15.61	17.76	17.1	10.9	61.19	90.58	78.4	82.4
January	-	-	-	-	28.32	28.38	28.9	31.0	11.35	13.22	17.6	8.9	62.35	74.22	67.9	77.3
Total	**433.2**	**814.2**	**636.4**	**370.0**												

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