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COLLEGE OF BASIC AND APPLIED SCIENCE

EFFECT OF SOIL AMENDMENT AND SEED EXTRACTION TECHNIQUES ON SEED YIELD AND QUALITY OF PEPPER (*Capsicum chinensis*) IN SOUTHERN SENEGAL

By

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DECLARATION

I hereby, declare that except for references to the work of other researchers which have been duly cited, this work is an original work and has not been submitted or presented in part or whole for any other degree.

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ABSTRACT

Vegetable production in general and pepper production in particular are of paramount importance in the economic life of rural and peri-urban farmers in Senegal. However, high input costs such as seeds and chemical fertilizers are a limitation to the sector's growth. In order to find technologies capable of producing quality seeds with cheaper inputs, this study was conducted at the Djibelor Agricultural Research Centre in the southern region of Senegal.

Six treatments T1 (NPK 300 kg/ha and urea 200 kg/ha), T2 (NPK 150 kg/ha, urea 200 kg/ha and compost 10 tons/ha), T3 (NPK 100 kg/ha, urea 200 kg/ha and compost 15 kg/ha), T4 (NPK 50 kg/ha, urea 200 kg/ha and compost 20 tons/ha), T5 (compost 25 tons/ha) and T6 (control) made from the combination of compost and chemical fertilizer were tested in a randomized complete block with four replicates. The results of this study revealed a positive effect of the combined fertilizer at different rates on pepper growth and reproduction parameters. The height of the plants, the number of branches, the thickness of the stems, the size of the fruits and the biomass were significantly increased with the mixture of compost and chemical fertilizers. In addition, these fertilizers had the effect of shortening days of the reproductive stages (50% flowering, 50% fruiting and 50% ripening) of the Big Sun pepper variety (*Capsicum chinensis*) used for this study. Also, after harvest two seed extraction techniques were used (Fresh fruit extraction and dry fruit extraction). With the two extraction techniques used, fruit drying prior to seed extraction played an important role in seed quality. The seeds from the dried fruits showed germination rates and germination vigour well above that of seeds from fresh fruits. These results suggest that the mixt of compost and low rate of chemical fertilizers in the south region of Senegal should be encouraged for use as a substitute to the high level cost of chemical fertilizers for optimum pepper fruits production. Furthermore, dried pepper berries prior to seed extraction is the best technique that maintains seed quality.

Keywords: ***Capsicum chinensis*, compost, chemical fertilizer, growth, yield, seed extraction and quality.**

DEDICATION

To the soul of my mother

Rest in the peace of Christ your Saviour.

To my father source of inspiration

To my wife Catherine

To my sisters, brothers and friends

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ABBREVIATIONS AND ACRONYMS

WACCI: West Africa Centre for Crop Improvement

ANSD: Agence National pour la Statistique et la Démographie

CEDEAO : Communauté Economique Des Etats De l’Afrique de l’Ouest

ECOWAS: Economic Community Of West Africa States

FAO: Food and Agriculture Organisation

CORAAF: Conseil de l'Afrique de l'Ouest et du Centre pour la Recherche et le Développement Agricoles

IPI : International Potash Institute

PADEN: Programme d'Aménagement et de Développement Economique des Niayes

AVRDC: Asian Vegetable Research and Development Centre

ISRA : Institut Sénégalais de Recherches Agricoles

UNEP : Union Nationale des Entrepreneurs du Paysage

IFA : International Fertiliser Industry Association

UNEP : United Nations Environnement Programme

CDH : Centre de Développement Horticole

CHAPTER ONE

1. INTRODUCTION

Peppers (*Capsicum spp*.) belong to the family of *Solanaceae* and are grown widely in various part of the world (Ashilenje, 2013). The area cultivated for the production of pepper powder reaches 2 million hectare for 3.4 million tonnes (Mt) of dry product worldwide (Sage-Palloix and Palloix, 2016; Rey, 2005). The Asian continent is the biggest producer with 2.4 Mt followed by Africa (0.62 Mt), the Americas (0.25 Mt) and Europe (0.12 Mt). The top producers in the African continent are Ghana and Ethiopia with 0.1 Mt each (Sage-Palloix and Palloix, 2016). Chili peppers are commonly used as a condiment (Alabi, 2006) and also have a wide range of uses including pharmaceutical, natural colouring agents and cosmetics, as an ornamental plant and as the active ingredient in most defence repellents (Brito-Argáez *et al.*, 2009; Palevitch and Cracker, 1995; Pérez-Gálvez *et al*., 2003). The varied uses of chili pepper fruits has made this plant economically importantis.

In Senegal, pepper is the second vegetable crop in terms of the people involved in its production. During the cold off season vegetable crop mobilizes 53,004 households in which 35.5% grows pepper while the hot off season mobilizes 29,837 with 37.3% pepper growers (ANSD, 2013).

Demand for chili pepper fruit is increasing year by year due to local population growth and increased exports. Therefore, it is urgent to increase the productivity of chili pepper to meet the increasing demand. Unfortunately, farmers involved in chili production are facing many problems. According to a survey carried out by CORAAF in 2008, the main constraints to productivity of vegetables range from inadequate access to the quality seeds and chemical fertilizers due to their high cost, the use of inappropriate production technologies, the declining soil fertility and climate change, and ultimately to the monopoly of the sector of vegetable seeds by foreign farms. The low soil fertility in sub-Saharan Africa farm has leaded to an increase of the use of inorganic fertilisers. However, the financial situation of small producers does not allow them to buy these large quantities of mineral fertilizers. Access to quality seeds and fertilizers remain definitively the two main challenges to vegetable production in Senegal. Indeed, it is recognized that quality seed would contribute up to 20 to 30% to the yield of a crop (Thompson, 1986).

Increasing of production and productivity of chili is necessary for improving the incomes of small producers and to meet the local demand. This implies a total or partial reduction of the numerous constraints that undermine the sector, particularly the high cost of quality seeds and chemical fertilizers.

Various authors have suggested technologies that can increase production or ensure quality seed production. Rahman *et al*. (2012) reported that the combination of compost and NPK played a important role in pepper growth and on reproductive parameters like; days required for first flower initiation, the number of fresh fruit, the weight of fruits, the number of seeds per fruit and the weight of 100 seed compare to the control. Abud *et al*. 2013; Dias *et al.,* 2006; Vidigal *et al*., 2009; Dos Santos *et al.*, 2016, suggested that harvesting pepper for seed should be done at physiological maturity. However there is some disagreement on period of seeds extraction after harvesting. Some authors recommended that seeds of Chilli pepper should be extracted soon after harvest. Nagaraja *et al*., (1998) and Sahoo (2014), on the other hand have reported that chili seed maintains higher germination value up to six month when retained in fruit and stored under ambient conditions before extraction.

In order to reduce the cost production of pepper, this study aims to offer to small holder farmer and seeds producers affordable production technologies that are easily applicable in the farmer's environment.

The overall objective of this study is to improve the availability of good quality pepper seeds for small scale producers. The specific objectives are to:

i) determine an optimal combination of organic and chemical fertilizers for pepper seeds production;

ii) assess the influence of extraction technique on the quality of pepper seeds; and

iii) determine the interactive effect of soil amendment and seed extraction method toward good seeds quality.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. The pepper plant

The pepper is a perennial shrub from 1 to 1.50m high, strongly branched. The stalk, with its cylindrical shape, branches easily to spread the many lateral branches and progressively becomes lignified, hence the tendency to a perennial mode (Chaux and Foury, 1994).

The root system is characterized by the presence of a main root pivoting down to 50cm deep and numerous lateral secondary roots, relatively superficial with a radius of 0.30 to 0.50cm. Pepper is a hermaphrodite plant. Their flowers appear solitary at the top of a pedicel, starting at a node of the stem. And they only stay open for two to three days. Fruits from different species of pepper vary in colour, size, form and flavour, from very hot to mild or sweetly pungent. Pepper fruits are commonly green before maturity. After maturity, fruit colour can either be red, orange, and yellow or purple (Ashil3enje, 2013).

The seed is borne on the placenta, mostly on the basal end of the fruit (McCormack, 2006). They are kidney-shaped, flat, with smooth integument and straw-yellow in colour. Their size is considered variable (Belletti and Quagliotti, 1988) according to the conditions under which they mature; the general environment of the mother plant, the position of the bay on it, their number by fruit, the time of harvest and the time of fruit extraction. One gram has about 140 to 150 (Chaux and Foury 1994; Purseglove, 1966), and can retain 50% viability for three (03) years when stored in a clean, dry, dark place (Ashworth, 1991).

Being a perennial shrub, the life of the pepper can exceed more than 10 years. However, the decline of yield over the years requires producers to renew their plantations every one, two or three years depending on the specie or variety grown. Its vegetative cycle consists of four main phases: germination and vegetative phase, flowering, fruiting and ripening.

The duration of each phase of development of pepper, mentioned above, depends on several factors such as the variety chosen, temperature and humidity. But in general, the pepper cycle (from sowing to first harvesting) lasts between 130 days to 150 days (Tokiherinionja, 2007). The flowers are usually white or occasionally tinged with purple, and are borne in the axils of the leaves or branches. Pepper is a hermaphrodite plant. Their flowers appear solitary at the top of a pedicel, starting at a node of the stem. Pepper flowers continue to open for up to 2 hours after sunrise and reopen the following days two to three days (McCormack J., 2006). The fruit of the pepper is a berry (consisting of boxes). The shape of the fruit depend highly on the variety.

2.2. Climatic and edaphic factors for pepper cultivation

Pepper is known for its great ease of adaptation. Indeed, its geographical area is between 50 ° N (Canada) and 30 ° South (South Africa). In addition, it is very common to meet it in the sub-tropical state in tropical countries. The three key ecological factors affecting production of pepper are rainfall, soil condition and temperature (Ashilenje, 2013). Pepper presents an optimum development with an altitude level of the sea at 2.000m. Cultivation of pepper in lower areas should be avoided during extremely hot periods.

Soils composed of light-draining, well-drained, silty clay-silty alluvium, rich in limestone, humus, organic matter and mineral elements, neutral pH (between 6.5 to 7); better yield at the top of the crop. However, pepper can also tolerate a wider soil pH range of 4.5 (acidic) to 8.0 (slightly alkaline).

Favourable climate for growing pepper range between 18°C and 25°C. During the growing season, hot and humid climate is required while dry wither is suitable for ripening. The temperature also affect the colour and the quality of pepper. Best fruit colour is realized at temperatures from 18°C to 24°C.

2.3. Common diseases and pests of pepper

The extent of its geographical area of cultivation to five continents, under various types of climates (temperate, Mediterranean, subtropical and tropical) and the generalization of monovarietal intensive cultivation, are two essential factors that make the cultivation of pepper a target of choice for parasites and the development of epidemics. There are several references in the literature dealing with pepper diseases (Palloix *et al.*, 1995, AVRDC 1990, Yoon *et al.*, 1989). Pepper like most crops is affected by viruses, fungi, bacteria, nematodes, insects and mites. The principal diseases and pests that cause severe damages to fruits and chili pepper seeds are as follow:

2.3.1. Insects

False codling moth: *Cryptophlebia leucotreta*

The eggs are laid on the surface of the fruits. After hatching, the caterpillars penetrate directly into the fruit, lodge in its flesh and dig galleries that cause secondary rots due to bacteria and fungi. (Collingwood *et al*., 1984).

Southern green stink bug (***Nezara viridula)***

This insect is believed to have originated in Ethiopia. Now its distribution includes the tropical and subtropical regions of Europe, Asia, Africa and the Americas (Squitier, 1997). Its bug of 15 mm of long and 8 mm wide uniform green coloration, causes by its bites a wilting of the organs attacked (Collingwood *et al*., 1984). Attached shoots usually wither or, in extreme cases, may die.

Dark sword-grass (*Agrotis ipsilon*)

Agrotis ipsilon has a very wide host range, but seedling crop plants are most seriously damaged. The caterpillars cut young transplanted pepper plants. It cuts the *stems* flush with the ground.

During the day it is found in the soil, coiled on itself at the foot of the severed plant (Collingwood *et al*., 1984).

Mediterranean fruit fly *(Ceratitis capitata*)

The Mediterranean fruit fly, *ceratitis capitata* (wiedemann), is known to be a highly polyphagous tephritid that infests more than 300 species of fruit and vegetables throughout the world Cohen and Yuval, 2000. The female lays her eggs under the epidermis of the fruit. The maggots that come out undermine the interior by feeding on the flesh. The attacked fruits rot and fall prematurely. According to a study conducted in the south region of Senegal by Tendeng *et al.,* this fruit fly is most damaged pest in pepper production.

The cotton bollworm (*Helicoverpa armigera)*

The cotton bollworm is a moth and it is one of the most destructive and widely distributed Lepidopteran pests of many important crops including pepper (Bhonwong *et al*., 2009). The caterpillars dig and empty the fruits of their contents. Their damage can cause significant losses in terms of fruit and seeds yield.

The green peach aphid (*Myzus persicae)*

Myzus persicae is a serious phytophagous pest of greenhouse and field. In addition to feeding directly on crop assimilates, this parasite also acts as a vector of virus to the infested plant (Kirchner *et al*., 2005). This specie is known to cause damages on pepper fruits (FAO, 1997). According to Collingwood *et al*., 1984; the Green peach aphid usually grow in large colonies on the underside of the leaves, on young shoots and flower buds. They can colonize a crop in a few days. They usually attack young organs. After their bites, the leaves and the growing terminal shoots are embossed, curled up and deformed, stopping growth, reducing the number and quality of the fruits. The number of fruit can be further diminished by the presence of a black fungus that develops on sugar substances secreted by aphids.

The Thrips (*Frankliniella occidentalis* and *Thrips tabaci*)

The thrips cause winding of young leaves and deformations of the terminal bud. The damage caused by *F. occidentalis* on sweet pepper is typical of thrips, including discoloration of leaves and fruit, necrosis of the attacked area, and deformation (Tommasini M.G. *et al* 2002). The trips are also considered to be the vector of tospo viruses.

2.3.3. The diseases

Damping off (*Rhizoctoni solani*).

Damping off is caused by *Rhizoctoni solani* and *Pythium* fungal species. They are ubiquitous soilborne pathogens with a broad host range (Rivera *et al*., 2013). Infected seeds fail to germinate. They become soft and brown before decaying. Seedlings develop slightly darkened water soaked spots and they die before emerging.

Bacterial wilt (*Pseudomonas solanacearum*)

Bacterial wilt is caused by *Pseudomonas solanacearum* bacteria. It is a serious soil borne disease of many economically important crops, including pepper (Momol, 2001). Once it infects a crop it is difficult to control and it leads to total crop losses.

Powdery mildew *(Leveillula taurica* Lev.*)*

The first symptoms of this disease are chlorotic spots (5 to12 mm) poorly defined on the leaves. These spots are covered at the underside of a white down and necrosis in scattered spots. This may cause a significant drop in the leaves, decrease the yield and expose the fruits to sunburn. The disease is found during the entire growing season but mainly in fairly dry weather and a temperature of 20^{o}C to 28^{o}C (Collingwood *et al*,. 1984). This disease can cause severe damage to pepper plants and the pathogen is difficult to control, since a major part of its life cycle takes place inside the leaf (Elad *et al*., 2007).

2.4. Soil fertility and pepper production

In all crop productions, crops export mineral elements, leading to a gradual depletion of nutrients in soils. Chilli pepper cultivation is very demanding in terms of soil fertility. It requires deep, well-drained, warm, nutrient-rich soil and optimum pH around 6.5 to 7 (PAPSEN, 2015). Pepper grows very well in a sandy loam soil which holds moisture fairly well with liberal supply of organic matter (Ashilenje, 2013; Udoh *et al*., 2005). One of the reason that contribute to low yield in pepper production in the Africa tropical region is the low fertility of soil (Ogunsesin and Aiyelari, 2017). Chili is a very demanding crop from a pedological point of view. Its cultivation requires a deep, well-drained soil, warm and well provided with nutrients with an optimum pH around 6.5 to 7. To obtain good yields, soil moisture must remain between 80-85% (PAPSEN, 2015).

There is a need to maintain soil nutrients necessary for good pepper growth and therefore a good harvest. Fertilisers can be made in the form of humeral (organic) or mineral (chemical) amendments or the combination of organic and mineral fertilisers.

2.4.1. Organic fertilization effect on pepper production

Organic manures have very beneficial effects on the physicochemical and biological properties of the soil; that is, its structure, drainage, aeration (gas exchange properties), its water retention and resistance to compaction (Heaton *et al*., 2010). The high particle size of the organic material plays an important role in the soil resistance to compaction by giving it some elasticity (Dragonet S. et Icard C., 2010).

Many experience conduced on pepper production using various organic manure as fertiliser showed it benefit effect on vegetative growth and fruits production. The maintenance of soil fertility is considered a prerequisite for sustainable pepper production and for increasing yield (Jablonska, 1990; Ikeh *et al* 2013). The number and mass of the fruits of pepper plants were considerably higher in plot under organic fertilisers. This high fruits production was attributed to the improvement of nutrition in the treated plants, which accelerated the growth and the accumulation of biomass of the photosynthesizing organ (Berova, 2010). Organic fertilization brings on the one hand the macro-elements (NPK) essential for the development of pepper and on the other hand it contributes to the maintenance of organic matter in the soil (Schöl, 1998). The application of organic amendments to agricultural soils may influence metal distribution in soil fractions and, in turn, can influence the availability of micronutrients (Mn, Mg, Ca, Al, Fe..) to plants (Herencia *et al*., 2008).

However the most important role of organic fertiliser in soil is certainly the contribution of organic carbon which constitutes the major effect in the short, medium and long term on the soil. The contribution of carbon has an energetic role for microorganisms (bacteria, fungi) and macrofauna, of which the earthworm is the most important actor for the good functioning of the soil (drainage, aeration, rise and concentration in mineral elements) (RMT DevAB, 2009). According to Rahman (2012) the microorganisms contained in organic matter are important biological organisms helping nature to maintain nutrients flows from one system to another and also minimize environmental degradation.

2.4.2. Mineral fertilization effect on pepper production

Mineral fertilizers are materials, either natural or manufactured (other than the liming material) (Abga, 2013; IFA-UNEP, 2000), containing nutrients essential for the normal growth and development of plants. Chili pepper is a crop that need a high amount of nutrients for its development. Inorganic fertilisers release easily their nutrients when incorporated and are generally used to allow pepper plants to have direct access to major nutrients such as nitrogen, potassium and phosphorus as well as other essential elements such as calcium (Ca), magnesium

(Mg), sulphur (S) and boron (B). Pepper plants strive well when sown in plots fertilised with inorganic fertiliser like NPK (Adeola *et al*., 2007).

According to Alhrout, 2017; high yield per hectare and greater number of fruits of pepper by plant was obtained in field under NPK fertiliser compare to plot under organic manure. He attributed the result to the important role of nitrogen on synthesis of chlorophyll, protein and enzymes which increase photosynthesis and promote vegetative growth result in increasing assimilates which express into yield. However, to see the beneficial effect of mineral fertilizers in pepper production, a certain amount of organic matter is required (Bado, 2002).

Continuous cultivation without fertilizer application leads to lower yields due to soil nutrient depletion (Segda *et al.*, 2010). Chemical fertilizers. These elements are classified into three categories: major elements (N, P, and K), secondary elements (Ca, Mg and S) and trace elements (Fe, Cu, Mo, Zn, B and Mn).

2.4.3 Organomineral effect on pepper production

In order to increase high growth and yield performance, the use of organic and chemical fertiliser in combination is suggested by various authors. The yield of dry white pepper berries was highly increased by the combination of compost and chemical fertiliser in a sandy and loam soil. This performance was attributed to the effect of the organic and chemical fertiliser on root growth that increases the surface for nutrient uptake. In fact, the increase of nutrients supply lead to a greater rate of assimilation that in turn increases root growth (Ann, 2012).

Aliyu (2000) also reported an increase in fruit yield in sweet pepper as a result of poultry manure and supplementary mineral fertilizer application in Nigeria.

Organic matter has the advantage of improving the water capacity holding while the mineral fertiliser give to plant the nutrients necessary for growth at the earlier stages soon after it application. Organic fertilisers are slow realiser of nutrients and their benefits at while the season goes. Pepper generally has an indeterminate vegetative growth and a superficial root system and as long as it has a good water regime and sufficient nutrients in the root zone, it continues to flower and grow, giving higher yield (Guohua *et al*., 2001).

2.5. Pepper production in tropical Africa

Vegetable production in general and that of pepper in particular have experienced spectacular growth in the peri-urban areas of most cities in West African countries in recent 30 years (Dugué, 2016). It has also developed in many villages, including arid Sahelian zones, as soon as surface water collection or groundwater drainage systems are put in place and allow to irrigate a few hectares. In most West African countries (Mali, Burkina Faso, Chad, Guinea, Niger and Senegal) chilli is grown alone or in combination with other vegetable or cereal crops. It is usually grown by small-scale producers in rural areas in small plots.

They first supply households and surpluses are sold on local markets (Blein *et al.*, 2008). In this sector, women are generally buyers, processors and resellers (Yaméogo *et al* 2002, AVRDC, 2008)

The production of spices in the ECOWAS zone is clearly growing. It rose from 98 150 tonnes in 1986 to 326 930 tonnes in 2006, an increase of 2.3% (Blein *et al.*, 2008). This feat is made possible thanks to several factors. According to the BAD (2016), the liberalization of input markets and the support of the horticultural sector through innovative financing contributes to the increase. Basquin *et al*., 2014 argued that the constant growth of the urban population and the emergence of a middle class have increased the demand for horticultural products such as pepper. The most popular varieties in the sub-region include among others Legon 18, Gbatakin, Bird’s eye, Safi, Cayenne, and Jaune du Burkina for hot pepper. According to a study conducted in 2013 in six countries (Burkina Faso, Benin, Togo, Niger, Gambia and Thiad), chilli varieties yields ranged from 0.14 to 21.91 tonnes per hectare, ie a sub-regional average of 6.78 tonnes per hectare (Dagnoko *et al* 2013).

Countries such as Togo, Ghana and Senegal export substantial quantities of pepper to Europe. Ghana is the fifth largest exporter of pepper to the European Union where the demand for chilli grows by 17% each year since 2000. This is made possible to the introduction of the Legon 18 chili variety (Osafo, 2013).

In Central Africa, and particularly in Cameroon, the production of pepper has become a flourishing in the locality of Foumbot thanks to the existence of a drying and molding unit of the pepper. On the other hand the demand for this product in Douala is 50 tons and 500 tons for neighboring Nigeria (FAO, 2018). The existence of these processing units has limited crop losses when large quantities are produced.

2.6. The use of pepper

Based on the shape or size of the fruit, more than 20 varieties of hot or sweet pepper are known. Depending on their use, we can classify peppers in five market categories: fresh market (whole green, red, multicolored fruits), fresh processing (sauce, dough, canning, and brine), dried spices (whole fruit and powder) industrial extracts (paprika / oleoresin, capsaicinoids and carotenoids) and ornamentals (plants and / or fruits) (Valenzuela 2011, Poulos 1994). Chili is best known for its food use. Used as a spice or food additive, chili consumption is steadily increasing worldwide (Kouassi, 2012). Its fruits are highly prized for their tangy flavor by people around the world who use it as a staple of their cooking (Kollmannsberger *et al*., 2011). Capsaicin, a lipophilic alkaloid is the main compound responsible for the hot taste or pungency of chili pepper. In Côte d'Ivoire, Ghana and most of the West African countries, pepper is an essential ingredient in culinary habits (Kouassi, 2012).

Chili is also known to be a source of vitamin A, C, B6, folic acid and beta-carotene, which are very important for human food (Saleh *et al*., 2018, Nadeem *et al*., 2011). They are considered a good source of various nutritional compounds, including carotenoids, flavonoids and essential minerals. Chili is used as medicinal plant, the fruits are used in traditional medicine for their antimicrobial properties due to the secondary metabolites they contain. It is used in various forms, the most frequent of which are enemas, followed by ingestion of decoctions, plasters and finally wound dressings (Rêgo *et al*., 2012; Kouassi *et al*., 2012).

Aqueous, ethanolic and acetal extracts of chilli varieties (Antillean, Sudanese and chinense varieties) are known to have antifungal activity on Alternaria, Fusarium, Penicillium on Alternaria, Penicillium and Aspergillus flavus, which are responsible for some diseases (Koffi *et al*, 2014).

2.7. Advantages of pepper "Big Sun" variety cropping in the south of Senegal

The Big Sun pepper variety belongs to the species *Capsicum chinense* L. It was created in Senegal by Tropicasem / Technisem. It is a very popular variety in the Caribbean and Africa.

The Big sun variety has a number of advantages that have made it a favourite variety by producers in the southern region of Senegal.

With a pendulous peduncle, the fruits are globular in shape, therefore wider than they are long. The shape and attractive colour of the fruit makes this variety ideal for the local market ant for export (TROPICASEM, 2013). Indeed, the globular form of the fruits and it pungency make this variety the favourite of women cooking in the restaurants.

The BigSun variety, like all varieties of the *Chinense* species, has a better production during the hot raining season. Their cultivation requires good brightness and high temperatures.

(TROPICASEM, 2013). These climatic conditions are met in the southern zone of the country where the rainfall is relatively abundant compared to the rest of the country.

It is a vigorous upright plant with shortened internodes at the top. The foliage is dark green. Suitable for growing in the open field, the size of plants can reach 70cm (PAPSEN, 2015).

The fruits are scented and capsaicin in the placenta is very pungent. The first fruit of the “Big Sun” variety matures approximately 90 to 100 days after transplanting.

2.8. Factors influencing seed quality

2.8.1. Fertilisation

The use of fertilisation and it management in any crop production is of crucial importance to sustain the plants establishment, the growth and a high yield (Ann, 2012). The use of compost improve the soil structure, it water capacity holding and therefor it nutrient supply to plants. The plants grown under plots with a good fertilizer management produce good yield and quality seeds.

2.8.2. The harvest stage

According to Elise *et al* (1989), the period of harvesting has a direct influence on the future quality of seeds of a given variety. Therefore, it must be made to full maturity of the fruits or seeds. During the harvest time must also be taken into account the climate condition. For example harvesting in rainy weather will be avoided.

2.6.3. Harvesting methods

Harvesting is done manually or mechanically. This is a very delicate step in the production of quality seeds and must be done in a way that preserves the integrity of the seeds. In fact, the method of harvesting must take into account several parameters such as: the importance of production, the uniformity of maturation, the blow of labour and the importance of investments for appropriate machinery. Manual harvesting is preferable for small areas and maturing varieties over time. As for mechanized harvesting, it is preferable for large areas with uniformly matured varieties. According to Govindaraj *et al*., 2017, rice seedling vigour index values are known to be significantly influenced by different harvesting and threshing methods. And the maximum vigour index was recorded in seeds harvested and threshed manually.

2.8.4. Seed extraction techniques

This is the stage of the seed production process that requires the most delicacy. In fact, improper handling can lead to a reduction in the germination capacity of seeds by mechanical injury. This will usually be referred to as wet seed extraction and threshing for dry seed. It can be done manually or mechanically depending on the volume of harvests or the means available to the seed grower. In the case of small fruits such as pepper, the crop can be mortared before separating the seeds from the pulp using water (FAO, 1978).

Seed drying conditions and conservation Seed drying aims to reduce the natural moisture of seed after extraction to a percentage that ensures their viability for a medium and long term conservation. Excess of water on seed promotes respiration during storage and decreases seed viability and shelf life. According to Raymond *et al.*, 1983, in a tropical environment, freshly harvested seeds can have water contents in the order of 18 to 35%, which must be reduced to an appropriate level depending on the type of seed storage. Drying is done naturally using solar radiation or by the use of appropriate equipment. Too high a drying temperature can kill the germ of the seed.

2.8.5. Seeds drying

The principal aim of seed drying is the reduction of their moisture content to appropriate levels for storage.

Some seed must dry to a low moisture content so they can be able to germinate. Therefor drying is part of seed maturation process. According to Harrington, 1972, for each 10°F (5.6°C) decrease in temperature, longevity doubles. However, during this process, care have to be taken in the temperature to ovoid damage to the seeds (Filho *et al* 2016). A high level of moisture content in seeds increase seed respiration and temperature in a store and can damage the seeds faculty to germinate. Furthermore high level moisture content can results to mould and insects attack and therefore to seeds damage (Rakita and McCormack J., 2014).

2.8.6. Seed storage

After drying and cleaning seeds must be kept in good conduction to maintain their viability in a short, medium or long time. So the local or container in witch seeds are to be stored must fulfil a certain conditions related mainly to the temperature and the relative humidity (Monira U.S., 2012). A local with a high level of air moisture contain and a high temperature increase seeds respiration and temperature and will be therefore an ideal factors for diseases and insects multiplication.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Experimental site

The experiment was carried out in the region of Ziguinchor in the Centre of the Senegalese Institute of Agriculture Research localised in the village of Djibelor. In this region the climate is of sub-Guinean type with two seasons. A dry season of 7 to 8 months and a rainy season of 4 to 5 months with 1200mm of average rainfall. The soils are essentially of leached ferruginous tropical type.

3.2. Experimental materials and treatments

Only one pepper variety "Big Sun" (*Capsicum chinensis*) was used as plant material for this test. Two types of fertilizer was used, a compost made of groundnut industry waste and chemical fertilizers (NPK 10-10-20 and urea 46%). Six treatments were compared for the test. An absolute control (without fertilizer), chemical fertilizers at the research recommended rate and four other treatments made of a mixtureure of compost and chemical fertiliser.

Urea was applied at two times: at flowering and at the second harvest while the other fertiliser was applied at transplanting period. The detail of the application rate, the combination proportion and the period of application are presented in Table 3.1.

Table 3.1: The different fertilizers and their rate of application

Treatments	Periods of application	Fertilizers and rate
T1	1st (at transplantation)	NPK (150kg / ha)
	2nd (at flowering)	NPK (150kg / ha)+urea 100 kg/ha
	3rd (after the second harvest)	NPK (0kg / ha)+urea 100 kg/ha
T2	1st (at transplantation)	Compost 10tons /ha + NPK 150kg / ha
	2nd application(at flowering)	Urea 100 kg/ha
	3rd (after the second harvest)	Urea 100 kg/ha
T3	1st (at transplantation)	Compost 15tons/ha + NPK 100kg/ha
	2nd (at flowering)	Urea 100 kg/ha
	3rd (after the second harvest)	Urea 100 kg/ha
T4	1st (at transplantation)	Compost 20 t/ha + NPK 50 kg/ha
	2nd (at flowering)	Urea 100 kg/ha
	3rd (after the second harvest)	Urea 100 kg/ha
T5	1st (at transplantation)	Compost 25t/ha
T6(control)		Zero fertilizer

3.3. Experimental design, nursery practices and field planting

A Randomised Complete Block Design (RCBD) was used with six treatments per block and four replicates. An elementary plot was 2.2 m long by 1 m wide. The spacing between two plots was 1m and the blocks by 2 m. This makes a total area of 14.8 m in length by 11 m width that is a surface of 162.8 m². At the beginning and at the end of the experiment, chemical analyses were performed both on the soil and on the compost. Before application of fertilizer a composed sample was taken in each block at the deep of 30 cm. At the end of the test, each plot was sampled and the following elements was determined: the organic matter, the pH, the total nitrogen, the total content of the phosphorus and the total quantity of potassium.

A nursery was made in seed tray filled with potting soil and the seedlings were transplanted to the field. The transplanting was done at the stage of 12 true leaves. Two rows of pepper were planted at the spacing of 50 cm between two hole in the same row and 60 cm between two rows. Each plot had two rows of 5 plants which gives a set of 10 plants in each elementary plot.

3.4. Seed extraction studies

Two techniques was used for the seeds extraction. The fruit harvested from the sample plants was divided in two batch. The seeds of the one batch were extracted immediately while the fruits remain wet and the fruit of the second batch was dried before extraction. The fruits was dried artificially using sun light in bulk for 15 days and the seeds being separated later by threshing.

The seed extraction with wet fruit was done by cutting and splitting the fruit longitudinally and scratching out the seeds with a small knife or a similar tool. The seed was arranged so they do not touch each other. The plate is after put in a dry, well-ventilated area away from direct sunlight for two weeks.

3.5. Data collection

3.5.1. Field data

The measurement was taken on 5 plants in each elementary plot. The following data were collected:

- **Plant height:** The sample plant height was measured every two weeks.
- **Steam diameter:** at the end of the trial the steam diameter of the sample plants was measured and the average recorded.
- **The primary and secondary branches**: the number of primary and secondary branches of the sample plant was counted at the end of the trial and the average number of the branches produced by plant was recorded.

- **Days to flowering:** when 50 percent of the plants in each treatment per replicate were in bloom, the number of days from planting until blooming was recorded and represents 50% flowering.
- **Days to fruiting:** The number of days to 50% fruiting is determined by counting the days after transplanting until 50% of the plant of a given treatment in each replicate have fruits.
- **Days to ripening:** Counting begins after transplanting until 50% of the fruits in each treatment per repetition red ripen.
- **Fruits number and fruits weight:** After each harvest, all the fruits from the sample plants were separated between marketable and unmarketable fruits. The fruits was after counted for each plot and their weight determined with a digital scale balance. At the end of the experiment all weight from the same treatment were summed and the average calculated.
- **Length and width size of the harvested fruits:** the length and the width of fruits from the sample plants were measured after each harvest using centimetre scale and the mean value was calculated and was expressed in centimetre (cm).
- **Fresh and dry biomass:** The average weight of root and shoot biomass were considered for the five freshly harvested plants per replicate and then dried in an oven at 60°C for 72 hours.

3.5.2. Laboratory data

- **Seeds weight:** the diseased, deformed or empty seed were separated from the good seeds then the weight of seeds of each treatment was determined. This weight have also been used to determine the seeds yield.
- **Percentage germination:** the germination percentage of seeds from dried and fresh fruits have been determined separately. A number of 400 seed from each treatment

repeated four time have been performed. Each seed where there has been emergence of the radicle is counted as germinated.

- **Seedling vigour:** The same number of seeds for the germination test was used for the seedling vigour. The Seedling vigour index rate was determined using this formula (Vigour index = [mean of root length (cm) + mean of shoot length (cm)] × percentage of seed germinations).

3.5. Data Analysis

Data collected from the field and laboratory experiments were subjected to analysis of variance (ANOVA) using GenStat Twelfth Edition to determine significance differences among the various fertilizer and compost treatment for all variables sored. Fisher LSD (Last Significant Difference) test was used for mean separation at probability level of 0.05.

CHAPTER FOUR

4. RESULTS

4.1. Chemical properties of compost and soil.

The compost used in this test was submitted for chemical content analysis (Table 4.1). With a pH of 8 and C/N of 9.7, this compost can be considered as a mature one. The analysis has also revealed a high level in organic matter content with 209kg/Ton. The macroelements as Nitrogen (12.55kg/Ton) Phosphorus (6.61kg/Ton) and Potassium (13.14Kg/Ton) as well as the other microelement are present in good proportions.

Table 4 1: Chemical analysis of compost

Determinations	Chemical composition
Total organic matter	209kg/Ton
Ammonia nitrogen (N-NH4 +)	0.05kg/Ton
Total nitrogen (N)	12.55kg/Ton
Phosphorus (P_2O_5)	6.61kg/Ton
Potassium (K_2O)	13.14Kg/Ton
Calcium (CaO)	27,25kg/ton
Magnesium (MgO)	6,96kg/Ton
Sodium (Na_2O)	5,79kg/Ton
Iron (Fe)	2113mg/kg
Manganese (Mn)	313mg/kg
Copper (Cu)	9mg/kg
Zinc (Zn)	81mg/kg
pH	8.0
C/N	9.7

The statistical analysis of soil pH (Table 4.2) have revelled a significant increase of the pH in the plots where compost have been applied alone (T5) and all others plots under a mixture of compost and chemical fertilizers. However, the plots und chemical fertilizers alone (T1) does not shows any significant difference compare to the control (T6) and that of the soil before fertilizers application (T0).

Table 4 2 : Soil pH as influenced by treatments

Treatments	pH
T6= control	5.60b
T5= Compost (25tons/ha)	6.20a
T4= NPK50kg/ha+urea200kg/ha+compost20tons/ha	6.02a
T3= NPK 100kg/ha+urea200kg/ha+compost15tons/ha	6.05a
T2= NPK150kg/ha +urea200kg/ha+compost10tons/ha	6.00a
T1= NPK300kg/ha+ urea 200kg/ha	5.42bc
T0=(Before fertilizers application)	5.22c
LSD (P<005)	0.37

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test

4.2. Height of pepper plants

Statistical analysis of the bi-weekly height of the big sun pepper variety showed significant differences from four (4) to 12 weeks after transplanting (Table 4.2). The plot under a mixture of compost and chemical fertilizer revealed a positive effect on plant growth. The tallest plant of pepper at 12 weeks after transplanting (35 to 36cm) was recorded in plot under a mixture of compost and chemical fertilisers followed by plant under plot fertilised by compost alone and chemical fertiliser alone. The control had the shortest plant at 12 weeks after transplanting.

Table 4 3: Biweekly height growth of pepper plants as influenced by combined fertilizers.

	Week after transplanting height (cm)					
Treatment	2	4	6	8	10	12
T6(Control)	13.34a	14.46c	15.79c	17.57d	20.38c	23.94d
T5 (Compost 25tons/ha)	14.34^{a}	18.19^{a}	22.71^{ab}	26.27^{bc}	29.03^{b}	32.86^{b}
T4(NPK 50kg/ha+urea200kg/ha+compost20tons/ha)	12.45^{a}	17.33^{ab}	24.06^{a}	29.22^{a}	32.39^{a}	36.60^{a}
T3(NPK 100kg/ha+urea200kg/ha+compost15tons/ha)	12.76^{a}	17.09^{ab}	24.20^{a}	28.98^{ab}	32.35^{a}	35.32^{ab}
T2 (NPK150kg/ha +urea 200kg/ha+compost10tons/ha)	13.49a	17.73ab	24.66a	29.79a	32.55a	35.66ab
T1(NPK300kg/ha+ urea 200kg/ha)	12.52a	15.94bc	21.52b	25.77c	28.96b	32.00c
LSD ($P<0.05$)	2.114	2.050	2.129	2.765	2.867	2.819

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test

4.3. Number of primary and secondary branches

Statistical differences were observed in the number of primary and secondary branching (Table 4.3). The plants that received a mixture of compost and chemical fertilisers (T2, T3 and T4) produced the highest number of primary branches with an average of 5 branches. The lowest number of branches was recorded with the control (T6) with a number of two primary branches per plant.

With regard to secondary ramifications, three significantly different groups stand out. The first group with the highest number of branches consist of treatments with a mixture of compost and chemical fertilisers with an average of 10 branches. The second group consist of plants from plot under chemical fertilisers alone (T1) with an average number of 6 branches per plant. However, the plant under compost only (T5) were not significantly different from under the combination fertiliser (T4 and T3). The third group consists of the plants from the control (T6) with the lowest number of branches per plant (3.9 branches).

Table 4. 4 : Number of primary and secondary branches of pepper plants as influenced by treatments

Treatment	Number of plant branching	
	Primary branching	Secondary branching
T6 = Control	2.12c	3.95c
T5 = Compost (25tons/ha)	4.77^{ab}	8.80^{ab}
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	5.65a	10.40a
T3 = NPK 100kg/ha+urea200kg/ha+compost15tons/ha	5.37a	10.30a
T2 = NPK150kg/ha +urea 200kg/ha+compost10tons/ha)	5.27a	8.57ab
T1= NPK300kg/ha+ urea 200kg/ha	3.60bc	6.90b
LSD (P≤0.05)	1.567	2.814

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test

4.4. Thickness of plant stems

The treatments were significantly different for the width of the stems (Table 4.4). Three significantly different groups appear. The widest stem diameter was obtained with the treatment where a mixture of compost and chemical fertilizer was combined at different rates. In this group the stems diameter range from 9.6 to 9.7 on average. The second group is represented by plant under organic fertiliser alone and chemical fertilisers alone with respectively 8.7 and 8.2 on average. The third group consist of the control that produces the smallest stems with an average of 5.487 mm.

Table 4. 5 : Stem diameter of pepper plant as influenced by treatments.

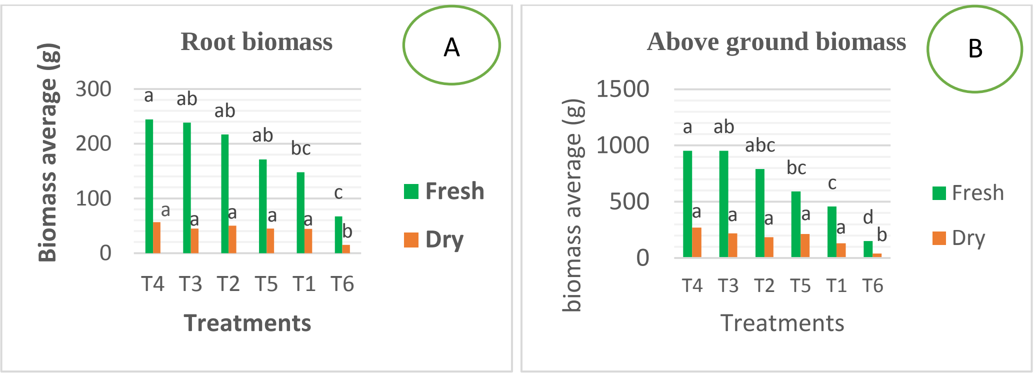
Treatments	Stem diameter (mm)
T6 = Control	5.48c
T5 = Compost (25tons/ha)	8.22b
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	9.64a
T3 = NPK 100kg/ha+urea200kg/ha+compost15tons/ha	9.78a
T2 = NPK150kg/ha +urea 200kg/ha+compost10tons/ha)	9.70^{a}
T1 = NPK300kg/ha+ urea 200kg/ha	8.74b
LSD (P≤0.05)	0.706

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according

4.5. The biomass

The treatment had significant positive effect on plant root biomass and above ground biomass respectively (Figures 4.1a & b). The treatments with a mixture of compost and chemical fertiliser (T2, T3 and T4) and organic fertilizer alone (T5) produced the highest fresh root biomass. However, the greatest fresh above biomass was obtained with plant under a mixture of compost and chemical fertiliser.

For the dry biomass, except the control (T6), all other treatments (T1 to T5) produced non-significant differences in weight for both the root and above ground biomass.



T1=NPK300kg/ha+urea200kg/ha; T2=NPK150kg/ha+urea200kg/ha+compost10tons/ha; T3=NPK 100kg/ha+urea200kg/ha+compost15tons/ha; T4= NPK 50kg/ha+urea200kg/ha+compost20tons/ha; T5= Compost (25tons/ha); T6= Control

Figure 4 1 : Pepper root biomass (A) and shoot biomass (B) as influenced by treatments

The means assigned to the same letter on bars of the same colour are not significantly different at the 5% threshold according to Fisher's test

4.6. Days to flowering, fruiting and red ripe fruits.

Days to 50% flowering, 50% fruiting and 50% ripening were significantly different (Table 4.5) among the treatments. For flowering, fruiting and ripening, two significantly different groups were observed. The control (T6) had the greatest number of days to all three reproductive stages; 58 days for 50% flowering, 67 days for 50% fruiting and 111 days for 50% ripening. All other treatments (Compost only, chemical fertiliser only and a mixture of compost and chemical fertiliser) had the effect of shortening the different reproductive stages and did not differ significantly from one another for all three stages.

Table 4. 6 : Days to 50% flowering, 50% fruiting and 50% ripening as influenced by treatments

	Development stages (days)		
Treatments	50% flowering	50% fruiting	50% red ripe
T1 = NPK300kg/ha+ urea 200kg/ha	39.25b	48.50b	73.25b
T2= NPK150kg/ha +urea 200kg/ha+compost10tons/ha)	35.75b	45.00b	78.50b
T3 = NPK 100kg/ha+urea200kg/ha+compost15tons/ha	34.25b	48.00b	85.50b
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	37.50b	47.50b	86.50b
T5=Compost (25tons/ha)	37.50b	49.00b	81.25b
T6= Control	58.50a	67.25a	111.5a
LSD (P<0.05)	7.35	7.645	16.798

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test.

4.7. Number of marketable and unmarketable fruits

The number of marketable and unmarketable fruits is highly influenced by the type of treatment used. The lowest number of marketable fruits (30.749 fruits) was recorded in the control (T6) (Table 4.6). The plot under a mix of compost and chemical fertilisers. The number of unmarketable fruit by treatment does not follow the same trend as the marketable fruit. The lowest number of unmarketable fruit (1.75 fruits) was observed in the control while the highest was obtained in plot under a mixture of compost and chemical fertiliser.

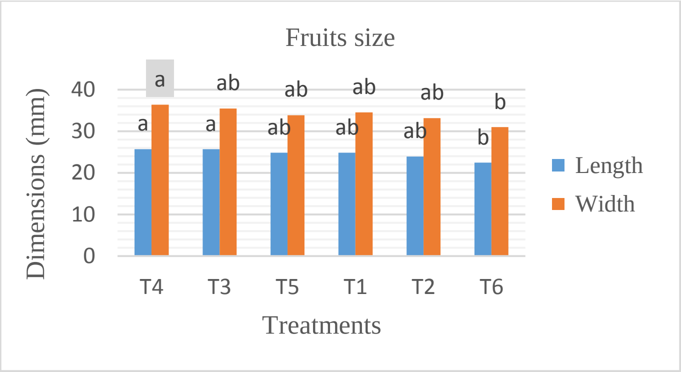
Table 4 7 : The number of marketable and unmarketable fruits as influenced by treatments

	Number of fruits	
Treatments	Marketable fruits	Unmarketable fruits
T1 = NPK300kg/ha+ urea 200kg/ha	110.75^{c}	4.25^{ab}
T2= NPK150kg/ha+urea 200kg/ha+compost10tons/ha)	181.75ab	9.00ab
T3 = NPK 100kg/ha+urea200kg/ha+compost15tons/ha	210.50a	6.75ab
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	148.75bc	11.25a
T5= Compost (25tons/ha)	114.00^{c}	8.50^{ab}
T6 = Control	30.74d	1.75b
LSD (P<0.05)	48.97	7.31

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test.

4.8. Length and width of the fruits

The result of statistical analysis of the length and width of the pepper fruits by treatment is represented in Figure 4.2. The figure shows a positive effect of the use of organic and chemical fertilizer on the size of pepper fruits. The plants from plots under chemical fertilisers alone and compost alone as well as those under a mixture of compost and chemical fertiliser produced the greatest length and width of fruits and was significantly different from the control T6.



LSD (P≤0.05) = (fruit length: 2,783); (Fruits width: 4,495)

Figure 4 2 : Length and width of pepper fruits as influenced by treatments.

The means assigned to the same letter on bars of the same colour are not significantly different at the 5% threshold according to Fisher's test.

4.9. Number of fruits by plant

The number of fruits produced by each plant is significantly influenced by the type of fertilizer used (Table 4.9). The greatest number of fruits by plant (21.05 fruits) was obtained with plant under a mixture of compost and chemical fertiliser followed by plants under compost alone (11.04) and chemical fertiliser alone. The lowest number of fruits was recorded with the control with 3.07 fruits by plants.

Table 4 8 : Number of fruits by plant as influenced by fertilizers

Treatments	Fruits by plant
T1(NPK 300kg/ha and urea 200kg/ha)	11.07c
T2 (NPK150kg/ha +urea 200kg/ha+compost10tons/ha)	18.17ab
T3 (NPK 100kg/ha+urea200kg/ha+compost15tons/ha)	21.05a
T4 (NPK 50kg/ha+urea200kg/ha+compost20tons/ha)	14.87bc
T5 (Compost 25 tons/ha)	11.40c
T6(Control)	3.07d
LSD (P<0,05)	

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test.

4.10. The fruit yield

The combination of compost and chemical fertilizer at different rates has shown significant effect on yield of pepper fruits (Table 4.6). Three statistically different group in fruit yield appear. The first group with plant under a mixture of compost and chemical fertiliser present the highest yield by plant of approximatively 6 tons/ha. The second group is composed by plants under compost alone and chemical fertiliser alone with respectively 3.24 and 3.95 tons/ha. The control (T6) with 0.653 tons/ha presented the third group with the lowest yield (0.65 tons/ha).

Table 4 9 : Pepper fruit yield as influenced by treatment.

Treatments	Fruits yield(tons/ha)
T1= NPK 300kg/ha + urea 00kg/ha	3.95b
T2= NPK150kg/ha + urea 200kg/ha+compost10tons/ha)	6.31a
T3 = NPK100kg/ha+urea200kg/ha+compost15tons/ha	6.30a
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	6.65a
T5=Compost (25tons/ha)	3.24^{b}
T6 = Control	0.65c
LSD (P<0.05)	1,743

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test.

4.11. Seed yield

The combination of organic manure (compost) and inorganic fertilizer (NPK and urea) have shown a significant effect on pepper seed yield (Table 4.9). As observed for fruit yield, the seed yield was highest on plots under a mixture of compost and chemical fertilizer with a minimum mean of 135.4 kg/ha. The plot under compost alone and chemical fertiliser alone was not statistically different from those under a mixture of compost and chemical fertiliser. The lower yield was recorded on the control with 18.4 kg/ha.

Table 4. 10: Pepper seed yield as influenced by the treatments.

Treatments	Good seed yield (kg/ha)
T1 = NPK 300kg/ha + urea 200kg/ha	91.30b
T2= NPK150kg/ha +urea 200kg/ha+compost10tons/ha)	140.10ab
T3 = NPK 100kg/ha+urea200kg/ha+compost15tons/ha	135.40ab
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	146.10a
T5=Compost (25tons/ha)	91.80b
T6 = Control	18.40^{c}
LSD (P<0.05)	53.14

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test

4.12. Bad quality seed weight

The bad seed weight (Table 4.8) didn’t follow the same tendency as the good seed. Two statistically different groups appear. On one hand the first group composed by the control with the lowest weight (0.432 g) and on the second hand composed by the rest of the treatments (T1 to T5) with the greatest weight.

Table 4. 11 : Pepper bad seeds as influenced by treatment.

Treatments	Bad seed weight (g)
T1 = NPK 300kg/ha + urea 200kg/ha	1.611a
T2= NPK150kg/ha+ urea 200kg/ha+compost10tons/ha)	2.119a
T3 = NPK 100kg/ha+urea200kg/ha+compost15tons/ha	1.694a
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	1.997a
T5=Compost (25tons/ha)	2.047a
T6 = Control	0.432b
LSD (P<0.05)	0.909

The averages assigned to the same letter in the same column are not significantly different at the5% threshold according to Fisher's test

4.13. The weight of 1000 grains

Significant differences were observed among the different treatments for 1000 seeds weight only where the pepper fruits were dried prior to extraction (Table 4.10). Treatments made of a mixture of compost and chemical fertilisers, followed by treatment with chemical fertiliser alone and compost alone gave the heaviest weight for 1000 seeds. The control T6 (no fertilizer) had the lowest weight of 0.0206 g. The seeds from fresh fruits didn’t show any significance differences among all treatments. The analysis of these results revel that an interactive effect exist between the type of fertiliser and extraction technic used. Fruit drying have a positive effect on seeds weight.

Table 4 12 : 1000 pepper seeds weight as affected by treatments and extraction techniques

	1000 seed weight (g)	
Treatments	Dry fruits	Fresh fruits
T1 (NPK 300kg/ha + 200kg/ha)	0.0386a	0.0351a
T2 (NPK150kg/ha+urea200kg/ha+compost10tons/ha)	0.0339b	0.0324a
T3 (NPK100kg/ha+urea200kg/ha+compost15tons/ha)	0.0380ab	0.0341a
T4 (NPK 50kg/ha+urea200kg/ha+compost20tons/ha)	0.0406a	0.0371a
T5 (Compost (25tons/ha)	0.0366ab	0.0567a
T6(Control)	0.0290^{c}	0.0325^{a}
LSD (<0.05)	0.0043	0.029

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test

4.14. The percentage germination of seed

The results of seeds germination percentage (Table 4.11) depend highly on the technique of seeds extraction used.

Fruits dried prior to seed extraction showed significant differences for germination percentage (The seeds from plants under a mixture of compost and fertiliser (T2, T3 and T4) and those from plants under chemical fertiliser alone (T1) was statistically similar and sowed better germination percentage. The seeds from the control and those from compost only gave the lowest germination percentage for dried fruits. However, only T1 and T3 reach the requirement for seed germination with respectively 81% and 73%.

The germination percentage of seed extracted from fresh fruit was not significantly different for all treatments. These results show a positive interaction effect between drying fruits extraction method and chemical fertiliser or a mixture of compost and chemical fertiliser that enhance seeds germination.

Table 4. 13 : Germination percentage as influenced by treatments and seed extraction techniques.

Treatments	Germination percentage (%)	
	Dry fruits	Fresh fruits
T1 = NPK 300 kg/ha + urea 200kg/ha	81.25a	67.50a
T2= NPK150kg/ha +urea 200kg/ha+compost10tons/ha)	60.25^{ab}	54.50^{a}
T3 = NPK 100kg/ha+urea200kg/ha+compost15tons/ha	73.00ab	56.00a
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	70.25^{ab}	58.00^{a}
T5=Compost (25tons/ha)	55.50bc	63.20a
T6 = Control	34.00c	63.20a
LSD (<0.05)	22.51	21.44

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test.

4.15. The seedling vigour

The seedling vigour of pepper as influenced by the type of fertilizer used on one hand and on the second hand by the technique of seed extraction have shown significant differences only where fruits was dried prior to seed extraction (Table 4.12). Furthermore, the seedling vigour of seeds extracted from dried fruits shown the greatest seedling vigour over those from fresh fruits. The seed extracted from dry fruits have shown three different groups significantly different. The first group with the greatest sidling vigour (370.1) was recorded with the seeds from plant under chemical fertilisers only (T1). The second group is composed by seeds from plant under a mixture of compost and chemical fertilisers (T2, T3 and T4). The lowest vigour index was recorded with the control (T6) with 108.1 and was statistically similar with T5.

As the weight of 1000 seeds and the germination percentage, the seedling vigour has been increased by the interactive effect of drying fruit prior to seeds extraction and the use of chemical fertiliser alone or the mixture of compost and chemical fertiliser.

Table 4 14 : Seedling vigour as influenced by treatments and seed extraction techniques.

Treatments	Seedling vigour	
	Dry fruits	Fresh fruits
T1 = NPK 300kg/ha + urea 200kg/ha	370.1^{a}	242^{a}
T2 = NPK150kg/ha +urea 200kg/ha+compost10tons/ha)	222.4^{b}	225^{a}
T3 = NPK 100kg/ha+urea200kg/ha+compost15tons/ha	244.9^{b}	197^{a}
T4 = NPK 50kg/ha+urea200kg/ha+compost20tons/ha	258.7^{b}	212^{a}
T5 = Compost (25tons/ha)	194.0^{bc}	152^{a}
T6 = Control	108.1^{c}	208^{a}
LSD (<0.05)	105.3	94.1

The averages assigned to the same letter in the same column are not significantly different at the 5% threshold according to Fisher's test

5. DISCUSION

5.1. Soil chemical properties as influenced by fertilizers

The use of compost at different rate (10 tons/ha, 15 tons/ha, 20 tons/ha and 25tons/ha) have increased the soil pH that was 5.22 at the beginning of the test to 6.0, 6.05 and 6.02 respectively. The soil pH is known to be one of the most decisive factor affecting soil ability to provide plant nutrient (Garcia -Gil *et al* 2004). The increase of soil pH might be due to the increase of organic matter in the soil that in turn have changed the initial chemical and physical properties of the soil. Similar results was found by Haute (2014), investigating the effect of compost on soil properties in Kenya. He found and increase of soil pH after compost application and attributed this phenomenon on one hand to the increase of exchangeable bases level like Ca, K and Mg and on the second hand to the reduction of the exchangeable rate of Al through Al precipitation or chelation of organic colloids. Organic manure application is known to increase soil pH of acidic soil through base-forming cations (Erhart & Hartl, 2010). Hubbard *et al.*, 2008, cited by Duong 2013, attributed the increase of soil pH following compost application to the addition of basic cation, ammonification and the production of NH_3 during the compost decomposition.

5.2. Plant growth parameters as influenced by treatments

The combination of organic manure (compost) and inorganic fertilizer (NPK and urea) gave better growth in plant height than those that received only inorganic or organic fertilizer. According to Badiane (1984), Djibelor soils are sandy with high permeability (between 3 and 11 cm / h) and have poor fertility with a marked deficiency of phosphorus, a low organic matter content. This explains the low growth observed in the plants from the control plots. This also explains the lower agronomic performance of plots that have been fertilized with mineral fertilizer or compost solely. The good development of chilli pepper in height can be explained by the advantage given both by the organic and inorganic fertilizer combination. The inorganic fertilizer provides to the plants the principal macronutrients (N, P and K) necessary for their growth in their usable form and stimulates growth in the earlier time after transplanting. On the other hand, compost supply nutrient slowly as the season goes and improve other chemical, physical and biological properties of the soil. The compost application is also known to increase soil level of other nutrients like: calcium, potassium and magnesium (Nanik *et al*., 2014). Rosen and Bierman (2005) reported that the application of compost improves soil structure and increases its water holding capacity. Pepper fertilized with inorganic fertilizer alone only provides nitrogen without significant improvement of other soil properties and may suffer nutrients deficiency as the season goes due to the sandy and high level of permeability aspect of the soil. Furthermore, the plants fertilized by combined fertilizer, i.e NPK, urea and compost [T2 (NPK 150kg/ha, urea 200kg/ha and compost 10tons/ha), T3 (NPK 100kg/ha, urea 200kg/ha+compost15tons/ha) and T4 (NPK 50kg/ha, urea 200kg/ha and compost 20tons/ha)] revealed an increase in primary branching number. However, T5 (compost 25tons/ha) was not statistically different from those that received the combined fertilizer. This increase in number of stem branching might be due to the supply of urea at the flowering time for the plant fertilized with combined fertilizer and for those treated with organic manure (T5) by the high level of phosphorus in compost. These results are in accordance with Segnou *et al*., 2013 and Islam *et al*, 2017, on pepper (*Capsicum annum* L.) who reported a greater number of branches by plant in plots fertilised by combined fertilizers.

The production of both above and underground biomass followed approximatively the same trend both for fresh and dry matter. The more important weight was recorded in plant fertilised with combination of organic and inorganic manure as a result of an increase in plant branching and stem diameter. The highest fresh and dry biomass was observed for T4. The same results was found by Ann (2012) on black pepper (*Piper Nigrum* L.) and Wang *et al* (1999) on chinensis cabbages (*B. chinensis*). They reported that the application of organic fertilizer improves soil physical properties and its water holding capacity that provide a good supply of nutrients to pepper plants. According to Arisha *et al.* (2013) and Segnou *et al.* (2013), the organic fertilizer activates soil living microflora and microfauna organisms that in turn release the micronutrients necessary for plant shoot and root growth. Atiyeh *et al*.2002, cited by Duong (2013), reported that humic substances that constitutes the major component of compost organic matter, can increase shoot biomass by simulating hormonal elongation of root and plant development.

5.3. Reproductive stages of pepper as influenced by treatments

The use of fertilizer, whether mineral (NPK), organic (compost) or the combination of the two (compost and NPK) at different rate had the effect of shortening the time to reproductive stages (50%flowering, 50%fruiting and 50%ripening) in comparison with the control. The plants from fertilized plot reached their 50% flowering before 40 days after transplanting. They also reached their 50% fruiting before 50 days after transplanting and their 50% ripening before 87 days. In opposite the plants from the control reached these three reproductive stages 58 days, 67 days and 111 days after transplanting. According to TROPICASEM (2013), the Big Sun variety reach its ripening time about 90 to 100 days after transplanting when grown in Senegal condition and fertilizer using the research recommended rate. The effect of shortening the different reproductive stages can be explained by the good establishment of plants after transplanting and the rapid uptake of the essential macronutrients (NPK) provided by the different fertilizer that accelerates their growth. These results are in agreement with findings of Abu-zahra (2012). They observed that the use of compost have accelerated the days of blooming of the pepper plant and attributed this phenomena to an increase of the temperature around plant rhizosphere due to the continued decomposition of organic manure.

5.4. Yield and yield component of pepper as influenced by treatments

The use of compost in combination with chemical fertilizer have shown a positive effect on the number of fruits by treatment, the fruits size (Figure 4.2), the fruits yield (Table 4.7) and the seed yield (Table 4.9).

The highest number of fruits by treatment was recorded with T3 (NPK 100 kg/ha, urea 100kg/ha and compost 15tons/ha) (210.5 fruits) and was statistically similar to treatments T2 (NPK 150kg/ha, urea 100kg/ha and compost 10tons/ha), T4 (NPK 50kg/ha, urea 100kg/ha and compost 20tons/ha) and T5 (compost 25kg/ha). The lowest number of fruit was recorded with the control (30.749 fruits). Furthermore, the fruits yield (kg/ha) from the plant fertilised with combined fertilizer was higher than those of control (the lowest) and those grown under chemical fertilizers (T1) and compost (T5) solely. The differences observed between these treatments might be due the greatest number of branches (Table 4.3) recorded from plant fertilised with combined treatment. On the second hand by the improvement of soil properties that increase in turn the availability of nutrient supply from compost, NPK and urea.

Segnou *et al*., (2013) and Ann (2012), in an earlier study observed greater fruit number with plants grown in plot fertilised with combined fertilizer compared to the plant from the control and those fertilised with inorganic fertilizer or compost solely. The low yield observed on plant fertilised only with compost is attributed to the low availability of nutrient and their slow release to the plant (Abu-Zahra, 2012). Similar results was found by Ayoola, 2016 who observed a low productivity in maize plants grown under plot fertilised with organic manure and attributed that to a low nutrient availability in organic manure compared to the chemical fertilizer. However, these results contradict with the earlier finding of Abu-Zahra (2012), on sweet pepper fruit number as influenced by different fertilizers. He found low and non-significant differences between fruit production from plant fertilized by combination of organic and inorganic manure compared to those under chemical fertilizer.

The seed yield follows the same trend with the other yield component. Better yield in seeds was recorded from plants grown under plot fertilised with combined compost and NPK. The highest yield was recorded with treatment T4 with 146 kg/ha and was statistically similar with T3 (135.4 kg/ha) and T2 (140.1 kg/ha) which in turn was statistically similar with plant from T5 (91.8 kg/ha) and T1 (91.3 kg/ha). The lowest yield was recorded with the control with 18.4 kg/ha. The good seed yield recorded is a result of high fruits production (Table.4.6) in plant under combined fertilisation. These results are in accordance with those of Pascual *et al*., 2010, who attributed the increase of yield to the fruit production rather to the fruit size as a result of nutrient availability to plants. Aliyu 2000, attributed this increase in yield to the improvement of the soil properties and to the supply of supplementary Nitrogen by the NPK.

5.5. Pepper seeds quality as influenced by treatments

The seeds quality of the pepper have been improved by the interactive effect of the use on one hand of a mixture of compost and chemical fertiliser as an amendment and on the other hand the fruits drying prior to seeds extraction. Among the three parameters (germination percentage, 1000 seeds weigh and seedling vigour) that was used to measure the quality of pepper seeds significant differences was record only where fruits was dried prior to seed extraction.

Concerning the weight of 1000 seed, the greatest weight was recorded with plant under a mixture of compost and chemical fertiliser (0.04061) and with plant under chemical fertiliser alone while the lowest seed weight was observed in the control (T6) with 0.02906 g. The application of chemical fertilizer was favourable for the rapid uptake of the essential macronutrient (NPK) in their usable form while compost improved soil physical properties like water holding capacity and therefore nutrient availability and their adsorption (Ann, 2012).

This favourable soil properties have ultimately improved the seed filling during seed formation and maturation stage.

The seed germination percentage and the seedling vigour follow approximately the same tendency with the weight of 1000 seeds weight. The highest germination percentage and seedling vigour was recorded with plants under chemical fertiliser alone (81.25% and 370.1) and was not significantly different from plant under a mixture of compost and chemical fertiliser According to FAO (2006), the minimum germination percentage for sweet and hot pepper seeds germination range between 70 and 80%. From this assertion, it can be affirmed that only the seeds from plant under chemical fertiliser alone (both seeds from fresh and dried fruits) and plant under a mixture of compost and chemical fertiliser (T3 and T4) have fulfil the requirement for seed germination quality.

The better germination percentage obtained from dried fruit might be due to the best conditions in which they dried. Indeed, when seed drying occur under fruit bay they slowly release their moisture content. However, the seed extracted from fresh fruits and dried soon after, may suffer from an excessive release of water in a shorter time that may harms their embryo grains. Vidigal *et al*., (2009) reported that seed extracted from pepper fruits harvested at maturity stage and stored at least for 15 days prior to the extraction, had better germination percentage and seedling vigour index compared to those extracted after a short time of storage. He attributed this observation to the involvement of the LEA-protein in physiological quality improvement of pepper seeds. The LEA (late embryogenesis abundant) is a protein known to play a role in cellular dehydration tolerance by protecting the other proteins to aggregation due to stress associated with low temperature (Hundertmark *et al*., 2008). Dos Santos *et al*. (2016) working on habanero pepper (*Capsicum chinenses*) found that seeds obtained from fruits harvested and stored up to 9 days showed a greater germination percentage.

For Da Sylva *et al*. (2018), the low germination percentage of seeds from fresh fruit may be due to the higher removal rate of water from seeds dried at higher temperature that caused damage to the seeds reducing their quality. Indeed, the extraction seeds study occur in April and the maximum monthly average in the study area is (37 °C) (ANSD, 2014).

The interactive effect of a mixture of compost and chemical fertiliser on one hand, the drying fruits prior to seed extraction have improve the quality of the seed.

CHAPTER SIX

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

This study has shown that chilli cultivation can be promoted and supported by the provision of appropriate technologies that can boost production to small producers. Indeed, the combination of compost and small rate of chemical fertiliser used as amendment have highly increase vegetative and reproductive capacities of pepper plants studied in this trial. Since organic manure is available to famers, it will be useful for famers to produce pepper at a low cost by combining organic and chemical fertiliser. The mixture of compost and chemical fertiliser in the proportion of 50 kg/ha NPK and 200 kg/ha of urea and 20 tons/ha of compost is the optimum for pepper fruits and seeds production. Furthermore, the interactive effect of this combination on one hand and fruit drying prior to seeds extraction on the other hand gave high germination rate and seedling vigour. Therefore, this result indicates that quality seeds can be produced with a mixture of compost and small rate of chemical fertiliser and rendered available with cheaper prise to small producers.

6.2. RECOMMENDATIONS

To overcome the various constraints related to the high production cost of chilli pepper among small producers; the following recommendations may be proposed:

- the mixture of compost and chemical fertilisers for soil fertilization;
- the seeds to be produced must be extracted from previously dried fruits.

REFERENCES

Abga P.T. 2013. Détermination des options de fertilisation organo-minérale et de densité de semis pour une intensification de la production du maïs dans la région de l'Est du Burkina Faso. Mémoire de Master II en Science du sol, Institut du Développement Rural (IDR), Université Polytechnique de Bobo-Dioulasso (UPB), Burkina Faso. 85 p.

Abud H.F., Araújo E.D., Araújo R.F., Araújo A.V., Pinto C.M.F. 2013. Physiological quality of ‘‘malagueta’’ and ‘‘biquinho’’ pepper seeds during ontogeny. *Pesquisa Agropecuária Brasileira*, 48(12): 1546-1554.

Abu-Zahra T. R. 2012. Vegetative, Flowering and Yield of Sweet Pepper as Influenced by Agricultural Practices. *Middle-East Journal of Science Research*, 11 (9): 1220-1225.

Adeola, R. G., Tijani-Eniola, H., and Makinde, E. A. 2011. Ameliorate the Effects of Poultry Manure and NPK Fertilizer on the Performance of Pepper relay cropped with Two Cassava Varieties. *Global Journal of Science Frontier Research*, 11(9): 7-13.

Afrakhteh S., Frahmandfar E., Hamidi A. and Ramandi HD. 2013. Evaluation of growth characteristics and seedling vigour in two cultivars of soybean dried under different Temperature and Fluidized bed dryer. *International Journal of Current Research in Biosciences and Plant Biology*, 5 (21): 2537-2544.

Alabi D. A. 2006. Effect of fertilizer phosphorus and poultry droppings treatments on growth and nutrient components of pepper (*Capsicum annum L*.). *African Journal of Biotechnology*, 5(8): 671-677.

Alhrout H. H. 2017. Response of growth and yield components of sweet pepper to tow different kinds of fertilizers under greenhouse conditions in Jordan. *Journal of Agricultural Science*, 9(10): 2065-272

Aliyu L. 2000. Effect of Organic and Mineral Fertilizers on Growth, Yield and Composition of Pepper (*Capsicum annuum* L.). *Biological Agriculture and Horticulture*, 18: 29-36.

Ann Y. C. 2012. Impact of Different Fertilization Methods on the Soil, Yield and Growth Performance of Black Pepper (*Piper Nigrum* L.) *Malaysian Journal of Soil Science*, 16: 71-87.

ANSD. 2014. Situation Economique et Sociale de la Région de Ziguinchor, édition 2014. 154p.

ANSD. 2013. Recensement Général de la Population et de l'Habitat, de l'Agriculture et de l'Elevage. Rapport définitif. Septembre 2014. pp30.

Arisha H.M.E., Gad A. A. and Younes S.E. 2003. Response of some pepper cultivars to organic and mineral nitrogen fertilisation under sandy soil cultivation. Zagazig *Journal of Agricultural Research*, 30: 1975-99.

Ashilenje D.S. 2013. Learn how to grow Peppers. First edition 2013. ISBN 978 - 9966 - 47 - 838 – 2

Ashouri, S. & Shayesteh, N. 2010. Insecticidal activities of two powdered spices, black pepper and red pepper on adults of Rhyzopertha dominica (F.) and Sitophilus granaries (L.). *Munis Entomology & Zoology*, 5 (2): 600-607.

Ashworth, S. 1991. Seed to seed. Seed Savers Exchange, Inc. Seed Saver Publications, Decorah, Iowa.

Atiyeh R. M,, Lee S,, Edwards C. A., Arancon N. Q., Metzger J. D. 2002. The influence of humic acids derived from earthworm processed organic wastes on plant growth. *Bioresource Technology*, 87: 7-14

AVRDC. 1990. Progress Report Summaries 1989. *Aisan Vegetable Research and Development Center*. Shanhua, Taiwan.

Ayoola O. T. 2016. Effect of fertilizer treatment on soil chemical properties and crop yield in a cassava-based crop system. *Journal of Applied Science Research*, 2(12): 1112-1116

Bacye B., Moreau R., Feller C. 1998. Décomposition d'une poudrette de fumier incorporée dans un sol sableux de versant et un sol argilo-limoneux de bas-fond en milieu soudano-sahélien. *Etude et Gestion des Sols*, 5 (2) : 83-92

BAD. 2016. « Nourrir l'Afrique : stratégie pour la transformation agricole de l'Afrique, 2016–2025 ».87p.

Badiane A. 1984. Etudes cartographiques et agro-pédologiques des sols de plateau de basse-Casamance. Mémoire de Stage Présenté pour la Confirmation. CRA de Djibélor. pp104.

Bado B. V. 2002. Rôle des legumineuses sur la fertilité des sols ferrugineux tropicaux des zones guinéenne et soudanienne du Burkina Faso. PhD thesis, Universtité Laval, Québec.197p.

Barbier G. 1955. Essai de définition de la fertilité de la terre. In: Économie rurale. N°23, 1955. pp. 3-6. doi : 10.3406/ecoru.1955.1359.

Basquin H., Charhon F., Cissokho M., Le Gauyer G., Rouillé d'Orfeuil H.et Vielajus J. L. 2014. « Nourrir les villes, défi de l'agriculture familiale », CFSI, Fondation de France, Roppa. 112p.

Belletti, P. and Quagliotti, L. 1988. Problems of seed production and storage of pepper. In: Proceedings of the International Symposium on Integrated Management Practices. *Asian Vegetable Research and Development Center*, Taipei, Taiwan: 28-41

Berova M., Karanatsidis G., Sapundzhieva K. and Nikolova V. 2010. Effect of organic fertilization on growth and yield of pepper plants (Capsicum annuum L.). *Folia Horticulture Annals*, 22(1): 3-7.

Bhonwong A., Stout M. J., Attajarusit J., Tantasawat P. 2009. Defensive role of tomato polyphenoloxidases against cotton bollworm (helicoverpa armigera) and beet armyworm (spodoptera exigua). *Journal of Chemical Ecology*, 35(1):28-38.

Blein R., Soulé B. G., Dupaigre B. F. et Yérima B. 2008. Les potentialités agricoles de l'Afrique de l'Ouest (CEDEAO). FARM; 116p.

Bongkyoon, K. 2004. Effect of vermicompost on growth of fall-cropping potato in vocanic ash soil. *Korean Journal of Crop Science*, 49 (4): 305-308.

Brar B. S., Singh J., Singh G., Kaur G., 2015. Effects of Long Term Application of Inorganic and Organic Fertilizers on Soil Organic Carbon and Physical Properties in Maize – Wheat Rotation. *Agronomy*, 5: 220-238.

Brito-Argáez L, Moguel-Salazar F., Zamudio F., González-Estrada T., Islas-Flores I. 2009. Characterization of a Capsicum chinense Seed Peptide Fraction with Broad Antibacterial Activity. *Asian Journal of Biochemistry*, 4: 77-87.

CEDEAO. 2008. Règlement C:REG.4/05/2008 portant harmonisation des règles régissant le contrôle de qualité, la certification et la commercialisation des semences végétales et plants dans l'espace CEDEAO. Soixantième session ordinaire du conseil des ministres. Abuja 17-18 Mai 2008. 30pp.

Chaux C.L., Foury C.L. 1994. Cultures légumières et maraichères. Tome III. Légumineuses potagères, légumes et fruits. Tec et Doc Lavoisier, Paris. 563p.

Cohen H. Yuval B. 2000. Perimeter trapping strategy to reduce Mediterranean fruit fly (*Diptera: tephritidae*) damage on different host species in Israel. *Journal of Economic Entomology*, 101(1):126-31

Collingwood E.F., Bourdouxhe l., Defrancq M. 1984. Les principaux ennemis des cultures maraichères au Sénégal. 2ème édition, 1984. 92pp.

CORAAF. 2008. Analyses du continuum de la chaîne de valeur des cultures vivrières prioritaires pour des interventions stratégiques en recherche et développement en Afrique de l'Ouest et du Centre.150p.

Da Sylva H. W., Vale L. S. R., Silva C. F., Souza R. do C., Soares R. S. 2018. Drying kinetics and physiological quality of 'Cabacinha' pepper seeds during storage. *Revista Brasileira de.Engenharia Agrícola e Ambiental*.22 (4).292-297.

Dagnoko S., Yaro-Diarisso N., Sanogo P. N., Adetula O., Dolo-Nantoumé A., Gamby-Touré K., Traoré-Théra A., Katilé S. and Diallo-Ba D. 2013. Overview of pepper (Capsicum spp.) breeding in West Africa. *African Journal of Agricultural Research*. 8(13), pp. 1108-1114.

Deblay S. 2006. Fertilisation et amendements. *Educagri éditions*, 2ème édition, Paris, 129 p

Dias DCFS, Ribeiro FP, Dias LAS, Silva DJH, Vidigal DS. 2006. Tomato seed quality harvested from different trusses. *Seed Science and Technology* .34(3):681-689

Dos Santos H. O., Dutra SMF., Pereira RW., De Oliveira Pires RM., Von Pinho É V D R., Dragonet S. et Icard C. 2010. Effet d'apport de différents amendements organiques sur les propriétés du sol - Bilan de 15 années d'essai en culture légumière à la SERAIL. Echo-MO n° 81. 4-8.

Dugué P., Kettela V., Michel I., Simon S. 2016. Diversity of innovation processes in the Niayes market gardening system (Senegal): between conventional intensification and agro-ecological transition. OpenScience – Published by ISTE Ltd. London, UK – openscience.fr. pp16.

Duong T. T. T. 2013. Compost effect on soil properties and plant growth. Soil School of Agriculture, Food and Wine. University of Adelaide. pp 92.

Elad Y., Messika Y., Brand M., David D.R. and Sztejnberg A. 2007. Effect of Colored Shade Nets on Pepper Powdery Mildew *(Leveillula taurica)*. *Phytoparasitica*, 35(3):285-299.

Elise P., Erik D., Mario A., SamChim A Tam. T.L. 1989. La culture de la

Erhart E. and Hartl W. 2010. Compost Use in Organic Farming. E. Lichtfouse (ed.), Genetic Engineering, Biofertilisation, Soil Quality and Organic Farming, Sustainable Agriculture Reviews 4, DOI 10.1007/978-90-481-8741-6_11

FAO Rome, 1983.

FAO. 1978. Situation mondiale de l'alimentation et de l'agriculture. *FAO: Collection Agriculture N° 9***.** 199p.

FAO. 1997. L'inventaire et l'importance des ennemis de 11 cultures maraîchères dans les 10 pays du RADHORT. 18p.

FAO. 2003. Gestion de la fertilité des sols pour la sécurité alimentaire en Afrique subsaharienne. FAO, Rome, Italie. 63 p.

FAO. 2004. L'état de l'insécurité alimentaire dans le monde 2004. Rome.43p.

FAO. 2006. Sécurité alimentaire et développement agricole: dossier pour un accroissement des soutiens publics.111p.

FAO. 2018. Le développement de l'horticulture urbaine et péri-urbaine en Afrique Centrale. 40p.

Filho C.P.H., Goneli A. L. D., Masetto T. E., Martins E. A.S., Oba G. C. 2016. The effect of drying temperatures and storage of seeds on the growth of soybean seedlings. *Journal of Seed Science*. 38(4): 287-295.

Garcia -Gil, J.C., Plaza, C., Senesi, N. 2014. Effects of sewage sludge amendment on humic acids and microbiological properties of a semiarid Mediterranean soil. *Biology and Fertility of Soils*. 39 (5). 320–328.

Gerson, U. 1992. Biology and control of the broad mite, *Polyphagotarsonemus latus* (Banks). 13 (3) 163–178.

Govindaraj M.; Masilamani P.; Asokan D.; Rajkumar P. and Selvaraju P. 2017. Effect of Different Harvesting and Threshing Methods on Seed Quality of Rice Varieties. International *Journal of Current Microbiology and Applied Sciences*, 6 (8): 2375-2383.

Guohua X., Wolf S. and Kafkafi U. 2001. Effect of varying nitrogen form and concentration during growing season on sweet pepper flowering and fruit yield. *Journal of. Plant Nutrition*. 24 (7): 1099 - 1116.

Harrington J. F. 1972. Seed storage and longevity. In Kozlowski, T. T., Seed Biology 3: 145-245. NY.

Haute J. V. 2014. Evaluation of the effects of compost on soil properties, performance and yield of maize and beans in Kenya. Faculteit Bio-ingenieurswetenschappen. 102p.

Heaton K., Koenig R. 2010. Solutions to soil problems. Reviewed December 2010. 2p.

Herencia F. T., Ruiz C. J., Morillo E., Melero S., Villaverde J., Maqueda C. 2008 .The effect of organic and mineral fertilization on micronutrient availability in soil. *Soil Science*: 173 (1) 69-8.

Hubbard R. K., Bosch D. D., Marshal L. K., Strickland T. C.,Rowland D., Griffin T. S., Honeycutt C. W., Albercht S. L., Sistani K. R., Torbert H. A., Wienhold B. J., Woodbury B. L., Powell J. M. 2008. Nitrogen mineralisation from broiler litter applied to south-eastern Coastal plain soil. *Journal of Soil and Water Conservation*. 63, 182-192.

Hundertmark M., and Hincha D. K. 2008. LEA (Late Embryogenesis Abundant) proteins and their encoding genes in Arabidopsis thaliana. BMC Genomics, 9:118.

IFA-UNEP, 2000. Mineral Fertilizer Use and the Environment. Fertilizer Use and the Environment by K.F. *Isherwood International Fertilizer Industry Association* Revised edition. Paris, February 2000.

Ikeh A. O., Ndaeyo N. U., Uduak I. G., Iwo G. A., Ugbe L. A., Udoh E. I. and Effiong G. 2012. Growth and yield responses of pepper (*Capsicum frutescens L.)* to varied poultry manure rates in Uyo, southeastern Nigeria s. (2012). *Journal of Agricultural and Biological Science.* 7 (9). 735-742.

IPI (International Potash Institute), **1968.** Fertilization of Protected Crops. Proceedings of the VI h Colloquium of the International Potash Institute Florence/Italy 1968. International Potash Institute CH - 3000 Berne 14/Switzerland.

Islam M., Islam M. K., Proshad R., Islam S., Islam S., Kormoker T., Masum Billah K. M. M. 2017. Effect of inorganic and organic fertilizers on soil properties with vegetative growth and yield quality of sweet pepper (*Capsicum annuum* L.) in Bangladesh. *International Journal of Agronomic and Agriculture Research*, 11(5).37-46.

Jablonska, C.R. 1990. Straw as an organic fertilizer in cultivation of vegetables. Part II. Effect of fertilization with straw on the growth of vegetable plants. *Horticulture Abstract*, 63: 244.

Jovicich, E., D.J. Cantliffe, L.S. Osborne, and P.J. Stoffella. 2004. Mite population and damage caused by broad mites ½ *Polyphagotaronemus latus* (Banks) infesting bell pepper (*Capsicum annuum L.)* at different seedling developmental stages. *Acta Horticulturae*, 659:339–344.

Kiba D. I. 2012. Diversité des modes de gestion de la fertilité des sols et leurs effets sur la qualité des sols et la production des cultures en zones urbaine, péri-urbaine et rurale au Burkina Faso. Thèse de doctorat unique, Université Polytechnique de Bobo-Dioulasso, Burkina Faso. 172 p.

Kirchner S.M., Doring T.F., Saucke H. 2005. Evidence for trichromacy in the green peach aphid, Myzus persicae (Sulz.) (Hemiptera: Aphididae). *Journal of Insect Physiology* 51; 1255–1260.

Koffi A.C., Koffi-Nevry R., Kouassi K.C., Loukou Y. G. 2014. Activité des extraits de six variétés de piment (Capsicum) utilisés en Côte d’Ivoire. *Journal of Applied Biosciences*. 82:7379 – 7388.

Kollmannsberger H, Rodríguez-Burruezo A, Nitz S, Nuez F. 2011. Volatile and capsaicinoid composition of ají (Capsicum baccatum) and rocoto (Capsicum pubescens), two Andean species of chile peppers. *Journal of Science Food and Agriculture*. 91(9):1598-611.

Konombo M. 2001. Etude de faisabilité technique et de profitabilité de la production de semences de quelques plantes potagères dans la région de Bazéga. Mémoire de fin d’étude pour l’obtention du diplôme d'ingénieur du développement rural option: agronomie. Université Polytechnique de Bobo Dioulasso (U.P.B). 126pp.

Kouassi C.K. et Koffi-Nevry R. 2012. Évaluation de la connaissance et utilisation des variétés de piment (Capsicum) cultivées en Côte d' Ivoire. *International Journal Biology Chemical Sciences* (1): 175-785.

McCormack J.H. 2004. Principles and practices of isolation distances for seed crops: an organic seed production manual for seed growers in the Mid-Atlantic and Southern U.S. Isolation distances. 21pp.

McCormack J.H. 2006. An organic seed production manual for seed growers in the mid-Atlantic and South. Pepper seed production .18pp.

Momol T., Pradhanang P., and Lopes C. A. 2001. Bacterial Wilt of Pepper. http://edis.ifas.ufl.edu. PP 189.

Monira U.S., Amin M. H. A., Aktar M. M. and Mamun M.A.A. 2012. Effect of containers on seed quality of storage soybean seed. Bangladesh *Research Publications Journal*.: 7(4) : 421-427.

Mouria B., Ouazzani-Touhami A., Douir A. 2010. Valorisation agronomique du compost et de ses extraits sur la culture de la tomate. *Revue Ivoirienne en Science et Technologie*: 16, 165 – 190.

Nadeem M., Anjum F. M., Khan M. R and Saeed M., Riaz A. 2011. Antioxidant Potential of Bell Pepper (*Capsicum annum* L.)-A Review. *Pakistan Journal of food science*, 21(1-4): 45-51.

Nagaraja A., Basavaraja P.K., Yogeesha H.S. 1998. Effect of drying methods on fruit and seed quality of chilli. International *Journal of Science, Environment and Technology*. 5(5): 3262 – 3270.

Nanik S., Zainal M., Bani S. and Marulak S. 2014. Growth and Yield of Chili Pepper as Affected by Weed Based Organic Compost and Nitrogen Fertilizer. *International Journal on Advancing Science Engineering Information Technology*. 4(2): 84-87.

Ogunsesin A. and Aiyelari E. A. 2017. Soil properties and yield of pepper (*Capsicum chinense* Jacq.) as influenced by Almond leaf-based compost and tillage in Ibadan, Nigeria. *International Research Journal of Agricultural Science and Soil Science* (ISSN: 2251-0044). 7(4). 058-067.

Osafo Ansah E. 2013. A survey on production and postharvest handling of pepper in the upper manya krobo district in the eastern region of Ghana. A thesis submitted to the school of research and graduate studies, kwame nkrumah university of science and technology, kumasi, for the award of a master of science (msc) degree in postharvest technology. pp119.

PADEN, 2013. Etudes de filières horticoles, Rapport définitif. pp54.

Palevitch, D. and Cracker, L. E. 1995. Nutritional and medical importance of red pepper (Capsicum spp.). *Journal of herbs, spices and medicinal Plants* 3:55-83.

Palloix A., Daubeze A.M., Nemouchi G., Ruffinato A. 1995. Maladies et ravageurs, les solutions apportées par la lutte génétique. PHM - *Revue Horticole*, décembre 1995-janvier 1996, n°365-366, pp 56 - 61

Pandita V. K. 2017. Advances in variety maintenance and seed production of vegetable crops *in* advances in Quality Seed Production of Vegetable Crops .CAFT, 2017-18. 49-61.

PAPSEN, 2015. Etude préliminaire sur l'horticulture dans les régions de Thiès, Diourbel et Fatick. Rapport n° 12. 177p.

Pascual I. A., Azcona I., Aguirreolea J., Morales F., Corpas F. J., Palma J. M., Rellan-Alvarez R., Sanchez-Diaz M. 2010. Growth, yield, and Fruit quality of pepper plants amended with two sanitized sewage sludges. *Joural of Agricultural Food Chemestry*. 58: 6951–6959.

Pascual I., Azcona I., Aguirreolea J., Morales F., Corpas F. J., Palma J. M., Rellan-Pérez-Gálvez, A., Martin, H. D., Sies, H. and Stahl, W. 2003. Incorporation of carotenoids from paprika oleoresin into human chylomicrons. *British Journal of Nutrition.* 89:787-793.

Poulos, J.M. 1994. Pepper breeding (Capsicum spp.): achievements, challenges and possibilities. *Plant Breeding Abstracts.* 64:143-155.

Purseglove, J.W. 1984. Tropical Crops: Dicotyledons. 1 & 2, *Longman Group*, London, 719 p.

Rahman M. A., Rahman M. M., Begum M. F., Firoz Alam M. 2012. Effect of bio compost, cow dung compost and NPK fertilizers on growth, yield and yield components of pepper. *International Journal of Biosciences* (IJB). 2(1): 51-55.

Rakita C. and McCormack J. 2014. Seed Processing and Storage: Principles and Practices.

Raymond A.T.G., 1983. Guide pour la technologie des graines de légumes.170p.

Rêgo E. R., Finger F. L. and Rêgo M., 2012. Consumption of pepper in Brazil and its implications on nutrition and health of humans and animals. In: Peppers: Nutrition, Consumption and Health. *Nova Science Publisher*. 159-170.

Rey F. 2005. Semences et Plants Bio en Languedoc-Roussillon. Bulletin Numéro 7, 2ème Semestre 2005. 24p.

Rivera M. C., Wright E. R., Fabrizio M. C., Freixá G., Cabalini R., Lopez S. E. 2013. Control of seedling damping off caused by *Rhizoctonia solani* and *Sclerotium rolfsii* using onion broths. 82: 227-234.

RMT DévAB. 2009. La fertilisation organique en Agriculture Biologique –AXE1–Agronomie – Fiche n°6. pp4.

Rosen, C.J. and Bierman, P.M. 2005. Using manure and compost as nutrient sources for fruit and vegetable crops. Univ. Minnesota Ext. Serv. M1192. 28 July 2011.

Sage-Palloix A. M. et Palloix A. 2016. Le piment : des goûts et des couleurs pour tous les amateurs d'épices. Dossier Sur la route des épices - Jardins de France 639 - Janvier-février 2016. 11-14.

Sahoo L.P. 2014. Fruit and seed development pattern and seed storability of some genotypes of chilli (*Capsicum annuum* L.). Ph.D. thesis, Department of Seed Science and Technology, Orissa University of Agriculture & Technology, Bhubaneswar, Odisha, India. pp: 225

Saleh B.K., Omer A., Teweldemedhin B. 2018. Medicinal uses and health benefits of chili pepper (Capsicum spp.): a review. *MedCrave Online Journals Food Processing and Technology*. 6(4): 325–328.

Sawadogo H. 1997. Rapport de stage sur la production et le triage des semences potagères. 12p. Nankosem 01 B.P. 6502 Ouagadougou 01- Burkina Faso.

Schöl V. L. 1998. Gérer la fertilité du sol. Agrodock 2, quatrième édition, Agromisa, Wageningen, Pays-Bas. 88 p.

Segda, Z., Mando, A., Haefele, S.M., Sedogo, M.P., Guinko, S. and Wopereis, M.C.S. 2010. Closing yield gaps through partnerships and good agronomy in Africa. Presentation at the 3rd International Rice Congress, Hanoi, Vietnam, 8–12 November.

Segnou J., Akoa A., Youmbi E et Njoya J. 2012. Effet de la fertilisation minérale et organique sur le rendement en fruits du piment (*capsicum annuum* L.; *solanaceae*) en zone forestière de basse altitude au Cameroun. *Agronomie Africaine*, 24 (3): 231 – 240.

Segnou J., Akoa A., Youmbi E. et Njoya J. 2012. Effet de la fertilisation minerale et organique sur le rendement en fruits du piment (capsicum annuum L.; solanaceae) en zone forestiere de basse altitude au cameroun. *Agronomie Africaine*, 24 (3): 231 - 240

Setyowati N., Muktamar Z., Suriyanti B., Simarmata M. 2014. Growth and yield of chili pepper as affected by weed based organic compost and nitrogen fertilizer. *International journal on advanced science engineering*, 4(2): 84-87.

Simmone, A.H., Simmone, E.H., Eitenmiller, R.R., Mill, H.A. and Green, N.R. 1997. Ascorbic acid and provitamin A content in some unusually coloured bell peppers. *Journal of Food Composition and Analysis*, 10: 299-311.

Squitier J.M. 1997. Southern green stink bug Nezara viridula (Linnaeus.) (Insecta:Hemiptera:Pentatomidae). UFIFAS Extension, Univ. Florida. EENY-016(IN142).

Stads G-J, Sène L. 2011. Recherche et innovation agricoles du secteur privé au Sénégal - Tendances récentes relatives aux ressources financières et humaines et aux politiques gouvernementales. Institut international de recherche sur les politiques alimentaires, Université Rutgers et Université McGill. p. 39

Thompson, J.R. 1986. An Introduction to Seed Technology. New York, John Wiley and Sons.

Tokiherinionja T. F. 2007. Proposition de méthodes de conservations, de conditionnements et de stockages de piments « pilo kely » dans les communes rurales de Tsivory et Mahaly. Mémoire de fin d'étude, en vue de l'obtention du Diplôme d'Ingénieur en Sciences Agronomiques Option Agriculture. 151pp.

tomate, du piment et de poivron. Agrobook ed., Agromisa, 55 p.

Tommasini M.G. and Maini S. 2002. Thrips control on protected sweet pepper crops: enhancement by means of Orius laevigatus releases in thrips and tospoviruses: proceedings of the 7th international symposium on thysanoptera (249-256p).

TROPICASEM 2013. Tropiculture N°204. Septembre 2013 édité par TROPICASEM. 8pp.

Udoh D. J., Ndon B. A., Asuquo. P. E. and Ndaeyo N. U. 2005. Crop Production Techniques for the Tropics. *Concept Publication*, Lagos, Nigeria. p. 446.

Valenzuela, H. 2011. Farm and Forestry Production and Marketing Profile for Chili Pepper (Capsicum annuum). In: Elevitch, C.R. (ed.). Specialty Crops for Pacific Island Agroforestry. Permanent Agriculture Resources (PAR), Holualoa, Hawai'i. http://agroforestry.net/scps

Vallerie M. 1969. Fertilité et fertilisation des sols tropicaux. Cours donné à l'Ecole Fédérale Supérieure d'Agriculture, République fédérale du Cameroun. 194 p.

Vidigal D.S., Dias D.C.F.S., Von Pinho E.R.V., and Dias, L.A.S. 2009. Sweet pepper seed quality and lea-protein activity in relation to fruit maturation and post-harvest storage. *Seed Science. and Technology*, 37. 192-201.

Wade I. 2003. Information et coordination dans les filières maraîchères au Sénégal. Mémoire de recherche. Montpellier (France) : Ecole Nationale Supérieure Agronomique de Montpellier et Université Montpellier 1. 85p.

Wang J. W. C., Ma K. K., Fang K. M., and Cheung C. 1999. Utilisation of manure compost for organic farming in Hong Kong. *Bioresource Technology*, 67: 43-6.

Yaméogo C.K., Karimou A.R., Kabore S., Diasso K. 2002. Les pratiques alimentaires à Ouagadougou, Burkina Faso : Céréales, légumineuses, tubercules et légumes. CNRST/CIRAD. pp. 111-132.

Yoon J. Y., Green S. K., Tschanz A. T., Tsou S. C. S., Changa L. C. 1989. Pepper improvement for tropics-problems and the AVRDC approach in tomato and pepper production in the tropics. Int. Symp. on Integrated Management Practices, pp. 86-98.

APPENDIX: ANOVA

Combined ANOVA for soil pH

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	0.10679	0.0356	0.56	
Blocs.*Units* stratum					
Treatments	6	3.29429	0.54905	8.63	<.001
Residual	18	1.14571	0.06365		
Total	27	4.54679			
s.e.				0.2523	
cv%				4.4	

Combined ANOVA for plant height at 2 weeks after transplanting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	31.803	10.601	5.39	
Blocs.*Units* stratum					
Treatments	5	10.379	2.076	1.06	0.423
Residual	15	29.513	1.968		
Total	23	71.695			
s.e.				1.403	
cv%				10.7	

Combined ANOVA for plant height at 4 weeks after transplanting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	11.723	3.908	2.11	
Blocs.*Units* stratum					
Treatments	5	37.432	7.486	4.05	0.016
Residual	15	27.74	1.849		
Total	23	76.895			
s.e.				1.360	
cv%				8.1	

Combined ANOVA for plant height at 6 weeks after transplanting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	5.685	1.895	0.95	
Blocs.*Units* stratum					
Treatments	5	221.421	44.284	22.18	<.001
Residual	15	29.945	1.996		
Total	23	257.051			
s.e.					1.413
cv%					6.4

Combined ANOVA for plant height at 8 weeks after transplanting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	4.054	1.351	0.4	
Blocs.*Units* stratum					
Treatments	5	417.401	83.48	24.8	<.001
Residual	15	50.489	3.366		
Total	23	471.943			
s.e.					1.835
cv%					7.0

Combined ANOVA for plant height at 10 weeks after transplanting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	4.105	1.368	0.38	
Blocs.*Units* stratum					
Treatments	5	436.586	87.317	24.13	<.001
Residual	15	54.274	3.618		
Total	23	494.966			
s.e.					1.902
cv%					6.5

Combined ANOVA for plant height at 12 weeks after transplanting

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	10.263	3.421	0.98	
Blocs.*Units* stratum					
Treatments	5	432.427	86.485	24.72	<.001
Residual	15	52.479	3.499		
Total	23	495.169			
s.e.					1.870
cv%					5.7

Combined ANOVA for number of primary branching

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	23.781	7.927	7.33	
Blocs.*Units* stratum					
Treatments	5	36.886	7.377	6.82	0.002
Residual	15	16.219	1.081		
Total	23	76.886			
s.e.				1.040	
cv%				23.3	

Combined ANOVA for number of secondary branching

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	46.477	15.492	4.44	
Blocs.*Units* stratum					
Treatments	5	118.062	23.612	6.77	0.002
Residual	15	52.287	3.486		
Total	23	216.827			
s.e.				1.867	
cv%				22.9	

Combined ANOVA for stem diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	1.978	0.6593	3	
Blocs.*Units* stratum					
Treatments	5	54.1728	10.8346	49.28	<.001
Residual	15	3.2979	0.2199		
Total	23	59.4488			
s.e.				0.4689	
cv%				5.5	

Combined ANOVA for root biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	1999	666	0.48	
Blocs.*Units* stratum					
Treatments	5	90873	18175	13.06	<.001
Residual	15	20874	1392		
Total	23	113747			
s.e.				37.30	
cv%				20.6	

Combined ANOVA for shoot biomass

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	61494	20498	0.79	
Blocs.*Units* stratum					
Treatments	5	1974845	394969	15.13	<.001
Residual	15	391585	26106		
Total	23	2427924			
s.e.				161.6	
cv%				24.9	

Combined ANOVA for number of fruits by plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	1.82	0.61	0.05	
Blocs.*Units* stratum					
Treatments	5	797.66	159.53	12.35	<.001
Residual	15	193.84	12.92		
Total	23	993.33			
s.e.				3.595	
cv%				27.1	

Combined ANOVA for 1000 seed weight of fresh fruits seed extraction

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	0.0006131	0.0002044	0.53	
Blocs.*Units* stratum					
Treatments	5	0.0017438	0.0003488	0.91	0.5
Residual	15	0.00574	0.0003827		
Total	23	0.0080968			
s.e.				0.01956	
cv%				51.5	

Combined ANOVA for 1000 seed weight of dry fruits seed extraction

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	7.85E-05	2.62E-05	3.2	
Blocs.*Units* stratum					
Treatments	5	3.40E-04	6.80E-05	8.32	<.001
Residual	15	1.23E-04	8.17E-06		
Total	23	5.41E-04			
s.e.				0.002859	
cv%				7.9	

Combined ANOVA for germination % of fresh fruits seed extraction

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	304.5	101.5	0.5	
Blocs.*Units* stratum					
Treatments	5	506.3	101.3	0.5	0.771
Residual	15	3035	202.3		
Total	23	3845.8			
s.e.					14.22
cv%					23.5

Combined ANOVA for germination % of dry fruits seed extraction

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	2075.1	691.7	3.1	
Blocs.*Units* stratum					
Treatments	5	5552.4	1110.5	4.98	0.007
Residual	15	3346.1	223.1		
Total	23	10973.6			
s.e.				14.94	
cv%				23.9	

Combined ANOVA for Seedling vigour of fresh fruits seed extraction

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	2001	667	0.17	
Blocs.*Units* stratum					
Treatments	5	18718	3744	0.96	0.472
Residual	15	58440	3896		
Total	23	79160			
s.e.				62.4	
cv%				30.3	

Combined ANOVA for Seedling vigour of dry fruits seed extraction

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocs stratum	3	26326	8775	1.8	
Blocs.*Units* stratum					
Treatments	5	147301	29460	6.04	0.003
Residual	15	73161	4877		
Total	23	246788			
s.e.					69.8
cv%					30