EFFECT OF PLANT SPACING AND INORGANIC FERTILIZER RATE ON TOMATO SEED PRODUCTION

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DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other University

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DEDICATION

This work is dedicated to Mrs. Agnes Wairimu Mwangi for her support, encouragement and sacrifice during research work and thesis writing

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ACRONYMS AND ABBREVIATIONS

ANOVA- Analysis of Variance

AVRDC- Asian Vegetable Research and Development Center

Ca- Calcium

CEC- Cation Exchange Capacity

EDTA- Ethylenediametetraacetic Acid

FAO- Food and Agricultural Organization of United Nations

FAOSTAT- Food and Agricultural Organization of the united nation Statistics

GOK- Government of Kenya

ISTA- International Seed Testing Agency

K- Potassium.

LSD- Least Significant Difference

Mg – Magnesium.

MoARD- Ministry of Agriculture and Rural Development.

N- Nitrogen.

pH- Potential of Hydrogen.

P - Phosphorous

RCBP- Rural and Capacity Building Project.

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ABSTRACT

Tomato (*Solanum Lycopersicum*) is rated as high market value horticultural crop in Kenya with a ready market both domestically and regionally. Moreover, tomato is among horticultural crops with great potential for improving food security and income generation among rural and urban resource poor community. Tomato seed production is becoming a major source of income for small scale farmers in Kenya. However, its productivity is low due to several factors such as, lack of use of fertilizers, poor plant stand, use of unimproved cultivars and pest and disease infestation. Nutrient management and maintenance of optimum number of plants per unit area are considered as important management tools for enhancing tomato seed production. Therefore this study was conducted to identify the optimum level of NPK (17:17:17) fertilizer and plant population that promote seed production in tomato. Field experiments using tomato cultivar Riogrande VF were conducted in October, 2015 and March, 2016 cropping seasons. The treatments consisted of three spacing; 60 cm×25 cm, 60 cm×45 cm and 60 cm×60 cm and four levels of NPK (17:17:17) fertilizers applied at : 0 $kgha^{-1}$, 200 $kgha^{-1}$, 300 $kgha^{-1}$ and 400 $kgha^{-1}$. The experimental design was complete randomized block design fitted with a split plot arrangements. The main plots were plant spacing and the subplots were fertilizer levels. Data were collected on plant height, number of leaves, number of branches, number of fruits per cluster, number of seeds per fruit, weight of 1000 seeds and seed yield per hectare. The results revealed that combination of plant spacing and NPK (17:17:17) application significantly ($P \leq 0.05$) influenced growth and seed yield of tomato. A combination of 60 cm×60 cm spacing with 400 $kgha^{-1}$ NPK (17:17:17) fertilizer resulted in the highest number of leaves (55 per plant), number of branches (13 per plant), weight of seeds per fruit (9.3 g) and seed yield per hectare (86.3 $Kgha^{-1}$). This was followed by a combination of 60 cm×60 cm spacing supplied with 300 kg ha^{-1} NPK (17:17:17), and 60 cm×45 cm sp acing supplied with 400 $kgha^{-1}$ NPK (17:17:17). A combination of 60cm×25cm spacing and 400 $kgha^{-1}$ NPK (17:17:17) fertilizer resulted in the tallest plants with low seed yield compared to all other treatments. Therefore in order to realize high seed yield in tomato, a spacing of 60 cm × 60 cm with application of 400 kg ha^{-1} NPK (17:17:17) fertilizer should be adopted. A closer spacing of 60cm× 25cm results in taller plant that could be a disadvantage in seed production due to the possibility of lodging. In addition, this spacing resulted in the use of high quantity of seeds at planting that eventually produce low seed yield per unit area, hence increasing the cost of production.

Key words: · Fertilizer Application, Plant population, Riogrande VF, seed yield, Tomato, Variety.·

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

Horticultural crops are a source of income for millions of Kenyans and it accounts for 14% of total export earnings (HCDA, 2011). Tomato (*Solanum Lycopersicum)* is rated as a high market value horticultural crop in Kenya and it has a ready market both domestically and regionally. Lemma *et al*., (2003) indicated that the total tomato seed production in Ethiopia has shown a marked increase since it has become the most profitable crop providing higher income to small scale farmers than other vegetable crops. Presently, tomato is one of the vegetables with the highest production in the world (FAO, 2005). This is because it can be grown on small scale in the kitchen garden where few plants yield fruit for the whole family and as commercial cash crop by vegetable grower (David, 2010). However, the challenges faced by farmers in tomato seeds production include: unimproved cultivars, poor plant stand, lack of use of fertilizers and other improved agricultural inputs in the management of the crop, in addition to biotic and abiotic factors (Tumwine *et al*., 2002; Waiganjo *et al*., 2006). Among notable factors that contribute to low production of tomato seeds are improper spacing and poor application of fertilizer. Abdel – Mawgoud *et al.,* (2007) reported that the two management practices which greatly influence tomato fruit yield are spacing and fertilizer application. The fertilizer does this through its ability to replenish the soil with nutrient that are lacking in the soil. Plant spacing greatly influences growth, yield and quality parameter both in fresh market and processing tomato. This is because correct spacing is crucial to ensure adequate and uniform distribution of light. Lemma *et al.*, (2003) reported that plant spacing greatly influence growth, yield and quality parameter both in fresh market and processing tomato.

1.2 STATEMENT OF THE PROBLEM

Production of tomato seed has been faced by many challenges in most countries which led to low production; among those challenges are improper fertilizer use and spacing. According to Tesfanye (2008) the plant spacing is the most important factor that affects yield and quality of tomato. Yield variation in tomato seeds may also occur due to pest and disease infestation, use of unimproved cultivars and variation in cultural practices (FAO, 2005; GOK, 2010). Low seed yield have been experienced due to these challenges, and hence many nations have been forced to import tomato seed and fruit to meet the increasing demand, which is very expensive. During seed production, it is necessary to supply the crops with adequate N. P and K. However nutrition differs among crops. Although some work has been done by Ogundare *et al*., (2015) on effect of different spacing and Urea application rate on fruit nutrient composition, growth and yield of tomato, the exact nutrition needs and appropriate spacing for the production of quality tomato seeds yield remain undefined.

1.3 JUSTIFICATION

The study of the effect of spacing at different levels of NPK fertilizer on the seed yield of tomato will help unlock the problem farmers' face in seed production. This will lead to improved seed yield among farmers which has great role in strengthening the growing and established seed companies. This will lead to creation of employment in those companies and increases in income to the farmers which will reduce poverty and improve livelihood of the farmers.

1.4. OBJECTIVE

To enhance tomato seed yield by small scale farmers in Kenya.

1.5 SPECIFIC OBJECTIVES

1) To evaluate the effect of plant spacing on growth and seed yield of tomato.

2) To assess the effect of different levels of NPK (17:17:17) fertilizer on growth and seed yield of tomato.

1.6 HYPOTHESES

1. Plant spacing has an increase effect on plant growth and seed yield of tomato.
2. Fertilizer levels of NPK (17:17:17) has an increase effect on plant growth and seed yield of tomato.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin, cultivation and benefits of tomato (*Solanum Lycopersicum*)

Tomato (*Solanum lycopersicum)* belongs to a family called solanaceae which contain many important food crops, including potato and aubegine (eggplant) (Ara, *et al*., (2007). According to Ara *et al*., (2007) the center of origin of the word tomato is considered to be Andean zone, whereas it is considered that tomato was domesticated in Mexico and that the name of tomato was derived from tomatil natiso tongue of Mexico. Tomato is regarded as fruit in some quarters and as a vegetable in others, but whichever way, tomato is a nutritious ingredient in preparations of food. According to Antonio *et al*., (2004), tomato is rich in minerals, vitamins, essential amino acids, sugar and dietary fiber. It contains high level of vitamin B and C, iron, lycopene and phosphorus. In addition, Kallo (1993) reported that tomato fruit is an essential component of human diet for the supply of vitamins, minerals, and certain types of hormones precursor in addition to protein and energy. According to Antonio *et al*., (2004), tomato not only contributes to the share of agriculture in national economy but possess a great potential and comparative advantage to compete in the liberized economy. Lemma *et al*., (2003) indicate that the total production in Ethiopia has shown a marked increase since it is the most profitable crop providing higher income to small scale farmers than other vegetable crops. Tomato can be grown for domestic use, where few plant yield fruit for the whole family and as a commercial cash crop by vegetable grower (David, 2010). Tomato seed yield is directly proportional to tomato fruit yield and the production in Kenya is still very low compared with countries like China, Japan and United State. According to (FAO, 2005), yield per hectare in Kenya is 9.9 tonnes per hectare (t ha^{-1}), 25 t ha^{-1} in China and 52.8 t ha^{-1} in Japan and United State. In addition, the world total tomato output was 77.5 million tonnes from 2.9 million hectares in 2000. Presently, tomato is one of the vegetable with the highest production in the world (FAO, 2005). Tomato is one of the most widely grown vegetable food crop not only in Kenya but other part of East Africa and whole world at large second to potato (FAO, 2005; Maerere *et al., (*2006). The crop is among the key crops in the horticultural industry in the country. Despite the fact that the Kenya tomato satisfies the internal demand and has strong export demand, there is a seasonal scarcity. However, traditionally the tomato fruit have been marketed fresh picked and is best selling fresh market vegetable crop (AVRDC, 2006,; Boriss and Brunke, 2005).

2.2 Tomato demand and production

Consumer demand for tomato all year long has increase by 30% in the past 30 years and hence there is increased demand for tomato seed. Fresh consumption per capita in the US was 12.1 lb (Lucier *et al*., 2000), to meet the growing demand for tomato seeds, application of effective technique such as plant spacing and fertilization must be in place.Farmers get lower yield mainly due to inappropriate agronomic practices and use of unimproved variety.

Improper spacing is among notable reason of low productivity of tomato seeds (lemma *et al*., 2003). The commonest practice by the resource-poor farmers in many parts of tropics, especially in Africa is the growing of two or more crop on the same piece of land simultaneously or in relay such that the period of overlapping of crop is enough to include vegetative phase. As result these farmers grow their crop at wide and random spacing because of the system of cropping. However as management practices improve and their crop soles, specific plant population would be used, this was in response to Bodunde *et al*., (1996) report that confirmed increasing economic yield of most cropping at high planting density.

In tomato production, there is huge deficit between what is supplied in the market and what is demanded ,for example while US tomato production has increased to meet demand, imported tomato still exceed domestic production, in 2003 the US imported 308,949 tons worth USD

365.5 million and only produce 175,949 tons (Cook and Calvin, 2005). This low production has been caused by the biotic and abiotic as well as cultural management practices, according to Qasem and Hill (1993) the average yield depend upon certain production factor amongst them appropriate and balance nutrition play important role. Fertilizer application is one of the most important factors for obtaining economical yield of tomato. Nitrogen and potassium play important role in the plant growth and development, tomato especially need phosphorous after transplanting. But according to Adani *et al*., (1998) the knowledge of crop response to population density provide a basis for assessing the effect of intra -specific competition. During seedling production, it is necessary to supply adequate N, P and K; however nutrition need differ among crops. Although some work has been done by (Ogundare *et al*., 2015) on effect of different spacing and urea application rate on fruit nutrient composition, growth and yield of tomato, the exact nutrition needs for the production of quality tomato seed yield remain undefined. Hence this study will investigate the effect of spacing at different level of NPK on the seed yield of tomato.

2.3 Constraints to tomato production

Kenya has a strong horticultural industry spanning over several years of experience in production of fruits, vegetables, and cut flowers for the domestic and export market (export promotion council, 2004). Tomato being a horticultural vegetable /fruit has contributed to the growth of horticultural industry. During the last two decades horticulture has emerged as major export industry and together with tourism and tea is the top three foreign exchange earner for Kenya (GOK, 2004). Horticulture occupies 14% of the horticulture surface cultivated and contributes to 23 % of the value of sector's production. However the sub-sector is faced by a number of challenges both biotic and abiotic factors (FAO, 2005; GOK, 2010). For example among the horticultural crops tomato faces a number of challenges including diseases and pests (Maerere *et al*., 2006). These yield reducing factors reduce the production of tomato seed and fruit yield. For example, in the North Rift Kenya, the area occupied by tomatoes each year is about 300ha with an average yield of about 9 to 10 tons per hectare (DAO, 1999-2005). However, the potential yield is between15 to 17 tonnes per acre and about 30 tonnes per hectare. The yield gap is attributed to a number of yield reducing factors which include biotic and abiotic. Apart from insect pests, there are diseases which significantly contribute to yield gap (Tumwine *et al*., 2002; Waiganjo *et al*., 2006).

Factors that could result in low seed yield in tomato include; unimproved cultivars, poor plant stand, lack of use of fertilizers and other improved agricultural inputs in the management of the crops among others. Adequate fertilizer and proper spacing is required for proper growth and increased yield of both the fruits and seeds of tomato (Ogundare *et al*., 2015). However, most African soil show nutrient deficient problem after only a short period of cultivation because of the nature as well as prevailing environmental conditions (Rafi, 1996). Abdel –Mawgoud *et al*., (2007) reported that the two management practices which greatly influence tomato fruit yield are spacing and fertilizer application. The fertilizer does this through its ability to replenish the soil with nutrient that are lacking in the soil. But according to lemma *et al*., (2003) plant spacing greatly influences growth, yield, and quality parameter both in fresh market and processing tomato. This is because correct spacing is crucial to ensure adequate and uniform distribution of light, Mehla *et al*., (2000) also reported the importance of plant spacing on yield and quality parameter in tomato. This is in conformity with Tasfanye (2008) who indicated that plant spacing is the most important factor that affects yield quality of fruit. However, seed yield variation in tomato may also occur due to disease infestation, use of unimproved variety and variation in cultural practices.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 SITE DESCRIPTION

Field experiments were carried out at Simlaw Research field in Thika on October, 2015 and March, 2016 cropping season during short and long rain season respectively. Thika research farm is located in Murang'a County, 5 km North of Thika town and 43 km from Nairobi city on Nairobi-Nyeri roads. It lies within coordinates 0059' south and 370, 04' East at an altitude of 1548 meters above sea level. The area receives an annual rainfall of 844.5mm with maximum of 879mm and minimum of 910 mm. The rainfall is bimodal and long rain fall between April and May while short rain fall between October and November. The mean annual temperature is 20.9℃ with maximum of 27.6^0C and minimum of 15.3^0C. The soils are well drain, deep dark reddish brown of varying texture described as Ferralsols (Farm management Handbook of Kenya Vol 2, September, 2008).

3.2 Experimental materials

A tomato variety (Riogrande VF) and Nitrogen,Phosphorous ,Potassium compound fertilizer(N-17% ,P_20_5=17%,K= 17%) were used in the study

Riogrande VF is a tomato variety with average yield from 43.1-50 tonnes per hectare. Riogrande VF is a determinate type fresh market tomato with pear shaped fruit. Fruit are medium large (80-85g) and uniform deep red colour when ripe. It mature in 80-90days after transplanting in tropical zones (RCBP, 2009)

3.3 EXPERIMENTAL DESIGN AND TREATMENTS

The field experiment was laid in complete randomized block design fitted with a split plot arrangement with three replications. The main plots consisted of plant spacing (60 cm×25 cm, 60 cm×45 cm and 60 cm×60 cm corresponding to 66667, 37037 and 27778 plants per hectare respectively) while the subplots consisted of fertilizer level (0 kgha^{-1}, 200 kgha^{-1}, 300 kgha$^{-1,}$ 400 kgha^{-1}).

3.4 FIELD EXPERIMENTS

3.4.1 Nursery operation

Raised seed bed of 5 meters length and 1 meter width was prepared. Half (1/2) kg of NPK 17:17:17 fertilizer was incorporated thoroughly into the soil in the seed bed. Furrows were at distance of 10cm across the length of the bed. The seeds were sown and the nursery bed was mulched with straw (EARO, 2009). The seed bed was watered daily during evening hours. Seedlings were transplanted 28 days after sowing when seedlings attained 2-3 true leaf stage.

3.4.2 Soil sampling and analysis

Before planting, soil analysis was done to determine the fertility level of the soil. Soil sample were picked at random at 10 sampling points at a depth of 0-30cm using soil auger then mixed to make a composite sample. Three replicates were obtained from the experimental field. The samples were air-dried, ground using a pestle and mortal and allowed to pass through a 2mm sieve. The samples were then analyzed for selected physical properties: sand, silt and clay content and texture class using standard laboratory procedure (FAO, 2008). Chemical properties analyzed were: organic carbon, total N, pH, Potassium, available phosphorous and CEC. The Walkey-Black wet combustion procedure (Nelson and Sommer, 1982) was used to determine organic carbon, while percent organic carbon was multiplied by 1.724 (The van Bemmelen Factor) to get percent organic matter. Soil pH was measured in 1:2.5 soils to water suspension by the use of glass Electrocolomel electrode (Mclean, 1962) pH meter. The macro Kjeldahl method described by Bremmer and Mulvanel (1982) was used to determine total nitrogen, While a 10 g soil sample (< 2 mm in size) was digested with a mixture of 100g Potassium Sulphate, 10g Copper Sulphate and 1g Selenium with 30mls of concentrated sulphuric acid. This was followed by distillation with 10ml boric acid (4%) and 4 drops of indicator and 15ml of 40% NaOH. It was then titrated with Ammonium Sulphate solution. Based on the relation that 14g of Nitrogen is contained in one equivalent weight of NH_3, the percentage of nitrogen in the soil was calculated. The flame photometer method was used to determine the amount of potassium with Ammonium Acetate as the extractant. The Bray-1 test method was used for the determination of available phosphorous with dilute acid fluoride as the extractant (Jackson, 1958). The exchangeable base cations (Ca, Mg, K, Na) were extracted using Ammonium acetate at pH of 7.0 .Calcium and magnesium were determined using EDTA titration method (Moss,1961) While Potassium and Sodium were determined by Flame Photometer.

Table (1): Soil physical and chemical properties.

The properties of the soil prior to planting are shown in (Table 1).The soil was Sandy loam in texture, low in organic carbon, total N, and available P. The exchangeable Ca, K and Mg were adequate according to critical levels of 3.0% OM, 0.20%, 10.0 mg kg^{-1} available P, 0.16-0.20 Cmol kg^{-1} exchangeable K, 2.0Cmol kg^{-1} exchangeable Ca and 0.4 Cmol kg^{-1} exchangeable Mg recommended for crop production in tropical zone (Ogundare *et al*., 2015)

Physical properties	**Sample Value**	**Optimum Range For Loamy soil** (Ogundare *et al.*,2015)
Sand %	71.2	70-75
Silt %	18.1	18-22.5
Clay%	10.7	8-12
Texture Class	Sandy Loam	Loam

Chemical Properties	Soil Sample Value (Concentration)	Critical level for tomato seed production. (Ogundare *et al.*,2015)
pH (water)	5.7	6.0-6.5
Organic matter,%	1.62	3
Total N,%	0.18	0.20
Available P,mg.kg^{-1}	7.30	10.0
Ca,Cmol.kg^{-1}	7.80	2.0
K,cmol.kg^{-1}	0.60	0.16-20
Mg,cmol.kg^{-1}	0.60	0.4

3.4.3 PREPARATION OF EXPERIMENTAL PLOTS AND TRANSPLANTING

The land was ploughed to the fine tilth by repeated harrowing and leveling using human labour force. Then, the layout was made and the plots were prepared. The seedlings were transplanted on 18th April 2015 in the first season and 14th August 2015`in the second season. The seedlings were transplanted to a plot measuring 3 m× 2 m at spacing of 60 cm × 25 cm, 60 cm × 45 cm, 60 cm × 60 cm to achieve plant population of 66667, 37037 and 27778 per hectare respectively. Four levels of NPK (17:17:17) fertilizer were applied at rate of (0 kg ha^{-1},200 kg ha^{-1},300 kg ha^{-1} and 400 kg ha^{-1}) during planting. All agronomic practices (Weeding was done at the 3rd week after transplanting, Watering was done on daily basis during evening hours, Staking was done at flowering stage, diseases and pest control chemicals were sprayed at interval of 7-14 days and it was done during evening hours) were applied during the growing season as per recommended by (Lemma,2001). Recommended fungicide (Ridomil and MZ63%-3.5 kgha^{-1}) to control leaf diseases and cypermethrin (100g ha^{-1}) to control insect pest, were sprayed at seven day interval from transplanting to 20 days before first harvest according to Lemma (2001).

3.4.4 Seed extraction methods

Well ripe fruits were selected and cut across and the content emptied into a bucket. The fruit content were frequently stirred at least 3 times daily to maintain uniformity of fermentation and to avoid discoloration of the seed as well as prevent fungus growth (RCBP, 2009). The process of fermentation lasted for 36 hours under room temperature (24-27°C). The seeds were repeatedly washed 3 times with tap water till the seed was free from pulps. During the process, the seeds were sinking to the bottom and clean seeds were collected after the pulp was drained off. The seeds were then spread on suitable trays and dried under the shade for about six days to bring down to moisture content of between 8-10% (RCBP, 2009)

3.5 DATA COLLECTION

Data was taken on plant height, number of leaves per plant, number of branches per plant, number of fruit per cluster per plant, seed yield per fruit and plant, weight of 1000 seeds and seed yield per hectare. For measurement of various variables, five (5) plants were randomly selected and tagged using the Simple Systematic Random Sampling Technique, as describe by Gomez and Gomez, (1984).

3.5.1 Determination of plant height.

The plant height was measured from the ground level to the highest tip for the five sampled and tagged plants. This was done using a meter ruler at interval of 7 days up to harvest maturity. The average plant height was calculated for each treatment.

3.5.2 Determination of number of leaves

The number of leaves was done by counting the number of leaves at interval of 7 days for the period of 5 consecutive weeks from the day of transplanting and average of each treatment computed

3.5.3 Determination of number of branches.

The number of primary and auxillary branches was done at physiological maturity, when all plants had ceased growth, branches of five sampled and tagged from each plots were counted and average computed

3.5.4 Determination of number of fruit per cluster

Number of fruit per cluster was done by counting the number of fruits per cluster at maturity and average of each treatment computed

3.5.5 Determination of seed yield per fruit.

Five fruits were randomly collected from each batch harvested (1^{st}, 2rd and 3^{rd} batch) crushed and seeds were extracted. The seeds were counted manually and the average numbers of seeds per fruit were expressed as number of seed per fruit.

3.5.6 Determination of 1000 seeds weight (g)

Seeds were extracted from 1^{st}, 2^{rd} and 3^{rd} batch harvested fruit. The weight of 1000 seeds was recorded from each batch per the treatment and average weight was taken at moisture content of 9 % (ISTA, 2008).

3.5.7 Determination of seed yield per hectare

Seed yield was determined by harvesting fruit from central one meter square of each plot and extracting seeds. These were put in a labeled envelop and sun dried for 48 hours and then weighed using digital weigh machine. The resulting weights in grams (g) per meter square were then scale up to tons per hectare to get seed yield per hectare.

3.6 DATA ANALYSIS

The data was subjected to analysis of variance (ANOVA) using Genstat statistical package (Genstat15th Edition) and means were compared using Fisher's protected Least Significant Difference (LSD) at $P \leq 0.05$

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 PLANT HEIGHT

The results indicated that there was a significant (P≤0.05) interaction between spacing and fe rtilizer level on plant height (Table 2). The highest plant height (75.3 cm) was recorded when a spacing of 60 cm×25 cm supplied with 400 kgha^{-1}of NPK(17:17:17) fertilizer while the shortest plant height of 23.4 cm was recorded in plots with a plant spacing of 60 cm ×60 cm with no application of fertilizer (Table 2). In this study plant spacing and fertilizer level applied influenced the plant height of tomatoes. Plant height increased with increase in fertilizer level combined with reduced plant spacing..

Table (2) .The effect of spacing and fertilizer application on plant height of tomato

	Plant height (cm)				
	NPK 17:17:17 Fertilizer level (Kg ha^{-1})				Mean
Spacing	0	200	300	400	
60×25	56.4i	67.8j	71.7k	75.3l	**67.8**
60×45	38.8d	48.9f	53.8g	55.8h	**49.3**
60×60	23.4a	31.2b	36.2c	41.9e	**33.2**
Mean	**39.6**	**49.3**	**53.9**	**57.7**	**50.1**

CV (%) = **36.5**
LSD **0.75 (Spacing × Fertilizer level)**

LSD=least Significant Differences.CV= Coefficient of variation. Means in column followed by the same letter are not significantly different (P≤0.05).

The optimum plant spacing for optimal plant competition, optimum use of light, water and nutrients, will produce more yields (Tahmorespour *et al*., 2013). Moreover, plant spacing affects most of growth parameters of crops even under optimal growth conditions and therefore it is considered a major factor in determining the degree of competition between plants (Sangakkara *et al*., 2004). It is possible that increase in plant height following the decrease of plant spacing was brought about by the increase in the inter plant competition over light and the disruption of balance of growth regulators. It has been shown that the decrease in light penetration into middle and lower layer decrease auxin decomposition and thus plant height increases (Seyedi *et al*., 2013). Similar findings have been reported by Berglond and Helms, (2003) working with soya bean. Gasim (2001) reported that increase in plant height as result of increase in compound fertilizer is due to the fact that nitrogen promotes plant growth, increases number of internodes and length of internodes which result in progressive increase in plant height. However, plants that were grown in a wider spacing and reduced or no fertilizer applied resulted in shorter plants. This could be attributed to insufficient amounts of nutrients required to facilitate increase in plant height or might be due to minimal or no competition of light which is very important for photosynthesis; this is because when plant are crowded they tend to strive to access available light. Similar findings have been reported by (Adekiya and Agbede, 2009) who observed that NPK fertilizer significantly increased plant height in tomato compared to the control. In tomato seeds production, optimal spacing is very key, this is because substandard plant spacing results in high weed infestation, poor radiation use efficiency and low yields while dense plant spacing on the other hand causes lodging, poor light penetration in the canopy, reduce photosynthesis production due to shading of lower leaves and drastically reduce the yield (Lamerle *et al*., 2006)

4.2 NUMBERS OF LEAVES PER PLANT

The results indicated that there was a significant ($P \leq 0.05$) interaction between spacing and fertilizer level for number of leaves per plant (Table 3). The highest number of leaves (55 leaves per plant) was observed when a plant spacing of 60 cm × 60 cm was supplied with 400 $kgha^{-1}$ of NPK (17:17:17) fertilizer while the least number of leaves (6 leaves per plant) were produced in plots that had a combination of plant spacing of 60 cm ×25 cm and 0 $kgha^{-1}$ level of NPK (17:17:17). Number of leaves increased with increase in fertilizer level combined with increased in plant spacing.

Table (3) .The effect of spacing and fertilizer application on number of leaves of tomato

	Number of leaves				
	NPK 17:17:17 Fertilizer level ($Kgha^{-1}$)				Mean
Spacing	0	200	300	400	
60×25	6a	10b	13c	18d	**11.71**
60×45	13c	20e	28f	34g	**23.79**
60×60	27f	33g	44h	55i	**39.67**
Mean	**15.1**	**20.92**	**28.39**	**35.61**	**25.06**
CV (%) =**5.0**					
LSD **1.54**	**(Spacing × Fertilizer Level)**				

LSD=least Significant Differences. CV= Coefficient of variation. Means in column followed by the same letter are not significantly different (P≤0.05).

Number of leaves increased with increase in fertilizer level combined with increased plant spacing. This can be attributed to the increased supply of nitrogen and phosphorous through increased NPK fertilizer which led to increase production of leaves due to cell division and enlargement. The findings support the result of Adekiya and Agbede (2009) who found that NPK fertilizer significantly increased the number of leaves of tomato compared to control treatment. In addition, it is possible that with an increase in plant spacing and supply of more nutrients led to more space and more light. This means that the competitions of basic growth factors are reduced between plants and hence more leaves. Similar results were reported by Singh and Singh (2012) who reported that combinations of NPK 15:15:15 fertilizer and spacing had a positive influence in number of leaves of okra. Also similar findings were reported also by (Ghoneim, 2000) who found that combination of compound fertilizer with wider spacing on okra had more leaves than combination of narrow spacing with 0 $kgha^{-1}$ level (control) of compound fertilizer. The improvement of vegetative characteristic (numbers of leaves) with increase in fertilizer especially N in (NPK 17:17:17)) could also be attributed to increase uptake of nitrogen and it is associated role in chlorophyll synthesis and hence the process of photosynthesis and carbon dioxide assimilation leading to enhance growth. According to (Jasso-Charena *et al*., 2005) nitrogen stimulates vegetative growth resulting in increase in number of leaves. This is also in line with Jovicich *et al*., 2003 and Harverson and Bortolo, (2010) who reported higher increase in number of leaves of pepper as result of compound fertilizer increase combined with wider spacing compared with narrow spacing with no fertilizer. Widely spaced plants are more desirable in tomato seed production because they allow air circulation hence slow the spread of foliar diseases

4.3 NUMBER OF BRANCHES

The results indicated that there was a significant ($P \leq 0.05$) interaction between spacing and fertilizer level for numbers of branches (Table 4). The highest number of branches (13 branches per plant) was recorded when a plant spacing of 60 cm×60 cm supplied with 400 $kgha^{-1}$ of NPK (17:17:17) fertilizer while the least number of branches (2 branches per plant) was recorded in plots with a plant spacing of 60 cm ×25 cm with no application of fertilizer. Number of branches increased with increase in fertilizer level combined with increased plant spacing.

Table (4) .The effect of spacing and fertilizer application on number of branches on plant of tomato.

	Number of Branches				
	NPK 17:17:17 Fertilizer level (Kgha^{-1})				Mean
Spacing	0	200	300	400	
60×25	2a	3a	4a	5a	**3.625**
60×45	5a	6a	8a	10b	**7.333**
60×60	7a	10b	11b	13c	**10.125**
Mean	**4.639**	**6.361**	**7.750**	**9.361**	**7.028**

CV (%) = 6.9

LSD=0.39 (Spacing × Fertilizer Level)

LSD=least Significant Differences. CV= Coefficient of variation. Means in column followed by the same letter are not significantly different (P≤0.05).

Number of branches increased with increase in fertilizer level combined with increased plant spacing. This might be attributed to possible supplies of plant nutrients to the plant from NPK fertilizer which might promote lateral shoot growing. This could also be due to better nutrient supplied and wider spaced exposed to by the crop which gave more opportunity of space to crop. Similar result were reported by Singh and Singh (2012) who reported that combination of NPK 15:1515 fertilizer and spacing had a positive influence on number of branches in okra production. As indicated earlier wider spacing mean less competition among plants for growth resources as water, nutrient and solar radiation. This will mean more assimilates would be available for growth and hence greater allocation for more branches. This observation is in agreement with the report of Caliskan *et al.*, 2007 who reported that plants in wider spacing are capable of partitioning more resource to increase branch number. In addition (Smith, 2000) found that the phytochrome system of plant undergoes changes from red to far- red ration caused by shade and plants proximity to its neighbor, to which plants respond with increased height growth and decreased branching. Similar findings have also been reported by Ogundare *et al.*, (2015) who found that wider spacing combined with higher dosage of compound fertilizer gave significant higher number of branches than narrow spacing in tomato production. Tomato plant with many branches is more desirable to farmers because, better and earlier canopy formation will check the growth of weed hence reduce the cost of weeding and also reduce competition for light, water, nutrients and space from weed. More branches will accommodate more clusters which means more fruits and larger fruit size which can be attributed to higher number of fruit buds which ultimately raises seed output (jovicich *et al.*, 2003).

4.4 NUMBERS OF FRUITS PER CLUSTER

The results indicated that there was a significant (P≤ 0.05) interaction between spacing and fertilizer level on numbers of fruit per cluster (Table 5). The highest number of fruits per cluster (22) was recorded when a spacing of 60 cm×25 cm supplied with 400 $kgha^{-1}$ of NPK (17:17:17) fertilizer while the least number of fruit per cluster (1) was recorded in plots with a plant spacing of 60 cm × 60 cm with no application of fertilizer. Number of fruit per cluster increased with increase in fertilizer level combined with reduced plant spacing.

Table (5).The effect of spacing and fertilizer application on number of Fruit per cluster on plant of tomato.

	Number of fruits per cluster				
	NPK 17:17:17	Fertilizer level ($Kgha^{-1}$)			Mean
Spacing	0	200	300	400	
60×25	3a	9b	15d	22f	**12.125**
60×45	2a	5a	12c	17e	**9.250**
60×60	1a	4a	9b	12c	**6.333**
Mean	**2.111**	**5.722**	**12.056**	**17.056**	**9.236**

CV (%)= 8.9
LSD 1.33 (Spacing × Fertilizer Level)

LSD=least Significant Differences. CV= Coefficient of variation. Means in column followed by the same letter are not significantly different (P≤0.05).

In this study plant spacing and fertilizer level applied influenced the number of fruit per cluster of tomatoes. Number of fruits per cluster increased with increase in fertilizer level combined with reduced plant spacing. This might be due to the fact that less space available with more competition for soil nutrient, moisture and less light, might result to low photosynthetic activity and reduced growth and development. This resulted to smaller fruit as compared to wider spacing which has more nutrients and solar radiation which accelerate anabolic processes and ultimately the fruit size will be increased. The application of NPK (17:17:17) fertilizer at 400kgha^{-1} seems to have resulted to synthesis of more carbohydrate by virtue of having more source foliage which accelerates the fruit formation as compared to lower dosage of fertilizer. Similar finding were reported by Ogundare *et al., (*2015) who reported that there was significant higher marketable fruit yield of tomato in wider spacing than in narrow spacing. This study is also in agreement with Ahamd and Singh (2005) who reported that wider spacing minimizes competition for nutrient, water and light in okra production which resulted to bigger fruit. Moreover, at very narrow spacing (high plant population) with adequate nutrient would induce excessive foliage production. Excessive foliage production causes shading of some leaves. Consequently, leaves shading result in low fruit yield due to insufficient light interception. This study is also in line with Paththinige *et al*., 2008 who reported that, in most vegetables crop, appropriate plant spacing and fertilizer level lead to optimized plant growth and fruit yield whereas too high or low fertilizer and plant spacing could result in relatively lower yield and poor fruit quality.

4.5 SEED YIELD PER FRUIT

The results indicated that there was a significant ($P \leq 0.05$) interaction between spacing and fertilizer level on seed yield per fruit (Table 6). The highest seed yield per fruit (9.3g) was observed when a spacing of 60 cm×60 cm was supplied with 400 kgha^{-1} of NPK (17:17:17) fertilizer while the lowest seed yield per fruit (1.9 g) was recorded in plots with a plant spacing of 60 cm ×25 cm with no application of fertilizer. Seed yield per fruit increased with increase in fertilizer level combined with increased plant spacing.

Table (6) .The effect of spacing and fertilizer application on seed yield per fruit on plant of tomato.

	Seed yield per fruit				
	NPK 17:17:17 Fertilizer level ($Kgha^{-1}$)				Mean
Spacing	0	200	300	400	
60×25	1.9a	3.3b	5c	7e	**4.342**
60×45	2.9a	3.9b	6.9e	8.7g	**5.583**
60×60	2.7b	6.1d	7.7f	9.3h	**6.429**
Mean	**2.467**	**4.411**	**6.544**	**8.383**	**5.451**

CV (%)= **14.2**

LSD = **0.64 Spacing× Fertilizer Level)**

LSD=least Significant Differences. CV= Coefficient of variation. Means in column followed by the same letter are not significantly different (P≤0.05).

In this study plant spacing and fertilizer level applied influenced the seed yield per fruit of tomatoes. Seed yield per fruit increased with increase in fertilizer level combined with increased plant spacing. The possible reason for higher number of seed per fruit in wider spacing with higher level of fertilizer could be due to increase number of leaves and branches which increase chlorophyll content in plant, which is responsible for high rate of photosynthesis this means more assimilates will be translocated from source to the sink. Also the increase in fertilizer levels increased the seed yield per fruit by better uptake of all nutrient and increase translocation of photosynthetic material from source to sink. Similar findings has been reported by Saleem *et al*.,2003 who reported increase in seed maize production in wider spacing combined with higher fertilizer dosage compared to narrow spacing combined with lower fertilizer dosage. This could also be due to synthesis of protein, phospholipids, nucleotide, nucleic acids and certain enzyme which play important role in plant metabolism.NPK (17:17:17) fertilizer has 17 % Nitrogen and 17 % phosphorous which are important molecules of phospholipids, nucleotides and certain coenzyme which play important role in plant metabolism and shortage of either nitrogen and phosphorous result in the reduction of seed formation (Hillman and Gaiston, 1961). Similar results were obtain by Alexalbert (2007) who reported that in many crops wider spacing and higher fertilizer level is recommended for seed production. He further reported the benefit of high fertilizer level and wider spacing in sweet sorghum for development of bolder seeds that would improve the processed seed yield of the crop.

4.6 WEIGHT OF 1000 SEED

The results indicated that there was a significant ($P \leq 0.05$) interaction between spacing and fertilizer level on weight of 1000seed (Table 7). The highest weight of 1000 seeds(4 g) cm was recorded when a spacing of 60 cm ×25 cm supplied with 400 $kgha^{-1}$ of NPK (17:17:17) fertilizer was used while the least weight of 1000 seeds (2.8 g) was recorded in plots with a plant spacing of 60 cm ×60 cm spacing with no application of fertilizer. Weight of 1000 seeds increased with increase in fertilizer level combined with reduced plant spacing.

Table (7). The effect of spacing and fertilizer application on weight of 1000 seeds of tomato.

Weight of 1000 seeds					
	NPK 17:17:17 Fertilizer level (Kgha^{-1})				Mean
Spacing	0	200	300	400	
60×25	3.1a	3.5b	3.1a	4b	**3.27**
60×45	3.2a	3.5b	3a	3.2a	**3.22**
60×60	2.8a	3.1a	3.1a	2.9a	**2.97**
Mean	**3.03**	**3.37**	**3.06**	**3.15**	**3.15**

CV (%)= 8.7

LSD **0.52 (Spacing × Fertilizer Level)**

LSD=least Significant Differences. CV= Coefficient of variation. Means in column followed by the same letter are not significantly different (P≤0.05).

In this study plant spacing and fertilizer level applied influenced the weight of 1000 seed of tomatoes. Weight of 1000 seeds increased with increase in fertilizer level combined with reduced plant spacing. It is possible that with a decrease in plant spacing and supply of more nutrients led to competition of light between plants which is necessary for photosynthesis, Since there is reduced number of leaves and number of branches in narrow spacing, the assimilates are directed to the seeds formation, whereas in wider spacing with increased level of fertilizer some assimilates are directed to formation of branches and leaves hence enhancing vegetative growth at the expense of seed development. This might also be attributed to the fact that wider spacing with high level of fertilizer will favour increase growth of number of leaves and branches, hence increasing the surface area for transpiration. Excessive loss of water will result to decrease in weight of the seeds. Similar result were observed by (Yilmaz, 1999) who reported that 100 seed of soya beans was heavier in narrow spacing than in wider spacing. However results of the other researcher were not similar to the finding of this study. Taylor *et al*., 2005 reported that wider spacing combined with high fertilizer level will give heavier 100 seed of soya beans than narrow spaced with high fertilizer level.

4.7 SEED YIELD PER HECTARE

The results indicated that there was a significant (P≤0.05) interaction between spacing and fertilizer level on seed yield per hectare (Table 8). The highest seed yield per hectare (51.8 g) cm was recorded when a spacing of 60 cm × 60 cm was supplied with 400 $kgha^{-1}$ of NPK (17:17:17) fertilizer while the least seed yield per hectare (7.4 g) was recorded in plots with a plant spacing of 60 cm × 25 cm spacing with no application of fertilizer. Seed yield per hectare increased with increase in fertilizer level combined with increased plant spacing

Table (8) .The effect of spacing and fertilizer application on seed yield per hectare of tomato.

	Seed yield per hectare				
	NPK 17:17:17 Fertilizer level ($Kgha^{-1}$)				Mean
Spacing	0	200	300	400	
60×25	7.4a	20.5d	28.1e	39.2g	**23.804**
60×45	10.6b	34.5f	40.1g	49.6h	**33.687**
60×60	16.8c	42.6g	44.3g	51.81	**38.880**
Mean	**11.617**	**32.540**	**37.491**	**46.846**	**32.123**

CV (%) = 1.3

LSD **= 2.1 (Spacing × Fertilizer Level)**

LSD=least Significant Differences. CV= Coefficient of variation. Means in column followed by the same letter are not significantly different (P≤0.05).

In this study plant spacing and fertilizer level applied influenced the seed yield per hectare of tomatoes. Seed yield per hectare increased with increase in fertilizer level combined with increased plant spacing. The yield per hectare increased with lowest planting population and highest fertilizer application rate. This was probably due to decrease in competition of nutrient, space, water (moisture) among other requirements that are necessary to plant growth. This is made possible due to higher interception accrued to low planting population than at high planting population. Similar findings were obtained in sweet sorghum by (Alexalbert, 2007) who reported the benefit of wider spacing and increased fertilizer level for the development of bolder seeds that would improve the processed seed yield of the crop. The increase in seed yield from fertilizer application was due to better and early canopy formation which checked the growth and reduced competition for nutrients, light moisture and space from weed. While the increase in number of fruit and large fruit was attributed to higher number of fruiting bud which ultimately raised seed output (Jovicich *et al*., 2003). Similar findings were reported by (Medina-Lara *et al*., 2008) who noted that N:P:K 15:15:15 fertilizer combined with wider spacing increased seed yield in habenero pepper.

5.0 CONCLUSION

From the a fore mention discussion, it could be concluded that use of NPK 17:17:17 fertilizer application at rate of 400kgha^{-1} with a row spacing of 60cm×60cm led to an increase in number of branches, number of leaves and number of fruit per plant and hence high seed yield. Use of closer spacing of 60cm×25cm at all fertilizer level led to taller plant with fewer leaves and branches, low number of fruits per plant resulting in low seeds yield.

6.0 RECOMMENDATIONS

-In order to realize high seed yield in tomato, farmers should adopt fertilizer rate at 400kgha^{-1} and plant the crop at spacing of 60cm×60 cm.

-Studies on Nutritional need and Plant population of indeterminate varieties of tomato in seed production should be done.

-Study on cost benefit analysis of using organic fertilizer should be done to compare it with using inorganic fertilizer in tomato seed production.

-Further study on the use of wider spacing and higher level of organic fertilizer, 60 cm × 60 cm and 400 kgha^{-1} respectively, in tomato seed production should be done.

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APPENDICES

Analysis of variance

Variate: PLANT_HEIGHT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	3.8	1.9	1.94	
REP.SPACING stratum					
SPACING	2	28781.5	14390.8	14696.96	<.001
Residual	4	3.9	1.0	1.38	
REP.SPACING.FERTILIZER_LEVEL stratum					
FERTILIZER_LEVEL	3	6603.4	2201.1	3097.34	<.001
SPACING.FERTILIZER_LEVEL					
	6	85.8	14.3	20.12	<.001
Residual	18	12.8	0.7	0.00	
REP.SPACING.FERTILIZER_LEVEL.*Units* stratum					
	108	36026.2	333.6		
Total	143	71517.4			

Message: the following units have large residuals.

REP 1 SPACING 60×60 FERTILIZER_LEVEL 30	-0.7	s.e.	0.3
REP 2 SPACING 60×60 FERTILIZER_LEVEL 30	0.6	s.e.	0.3
REP 3 SPACING 60×25 FERTILIZER_LEVEL 0	0.7	s.e.	0.3

Tables of means

Variate: PLANT_HEIGHT

Grand mean 50.1

SPACING	60×25	60×45	60×60
	67.8	49.3	33.2

FERTILIZER_LEVEL	0	10	20	30
	39.6	49.3	53.9	57.7

SPACING	FERTILIZER_LEVEL 0	10	20	30
60×25	56.4	67.7	71.7	75.3
60×45	38.8	48.9	53.8	55.8
60×60	23.4	31.3	36.2	41.9

Standard errors of means

Table	SPACINGFERTILIZER_LEVEL		
			SPACING
			FERTILIZER_LEVEL
rep.	48	36	12
e.s.e.	0.14	0.14	0.25
d.f.	4	18	19.66
Except when comparing means with the same level(s) of			
SPACING			0.24
d.f.			18

Standard errors of differences of means

Table	SPACINGFERTILIZER_LEVEL		
			SPACING
			FERTILIZER_LEVEL
rep.	48	36	12
s.e.d.	0.20	0.20	0.36
d.f.	4	18	19.66
Except when comparing means with the same level(s) of			
SPACING			0.34
d.f.			18

Least significant differences of means (5% level)

Table	SPACING	FERTILIZER_LEVEL	SPACING FERTILIZER_LEVEL
rep.	48	36	12
l.s.d.	0.56	0.42	0.75
d.f.	4	18	19.66
Except when comparing means with the same level(s) of			
SPACING			0.72
d.f.			18

Stratum standard errors and coefficients of variation

Variate: PLANT_HEIGHT

Stratum	d.f.	s.e.	cv%
REP	2	0.20	0.4
REP.SPACING	4	0.25	0.5
REP.SPACING.FERTILIZER_LEVEL	18	0.42	0.8
REP.SPACING.FERTILIZER_LEVEL.*Units*	108	18.26	36.5

Analysis of variance

Variate: NO_LEAVES

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	13.764	6.882	1.60	
REP.SPACING stratum					
SPACING	2	18875.056	9437.528	2190.18	<.001
Residual	4	17.236	4.309	1.49	
REP.SPACING.FERTILIZER_LEVEL stratum					
FERTILIZER_LEVEL	3	8450.056	2816.685	971.89	<.001
SPACING.FERTILIZER_LEVEL					
	6	913.278	152.213	52.52	<.001
Residual	18	52.167	2.898	1.83	
REP.SPACING.FERTILIZER_LEVEL.*Units* stratum					
WEEK	3	10510.278	3503.426	2209.46	<.001
SPACING.WEEK	6	2886.389	481.065	303.39	<.001
FERTILIZER_LEVEL.WEEK	9	12.778	1.420	0.90	0.534
SPACING.FERTILIZER_LEVEL.WEEK					
	18	18.389	1.022	0.64	0.852
Residual	72	114.167	1.586		
Total	143	41863.556			

Tables of means

Variate: NO_LEAVES

Grand mean 25.06

SPACING	60×25	60×45	60×60
	11.71	23.79	39.67

FERTILIZER_LEVEL	0	10	20	30
	15.31	20.92	28.39	35.61

WEEK	1	2	3	4
	11.94	23.58	29.94	34.75

SPACING	FERTILIZER_LEVEL	0	10	20	30
60×25		5.58	9.75	13.33	18.17
60×45		13.33	20.00	28.00	33.83
60×60		27.00	33.00	43.83	54.83

SPACING	WEEK	1	2	3	4
60×25		6.17	11.17	14.00	15.50
60×45		12.17	22.25	28.00	32.75
60×60		17.50	37.33	47.83	56.00

FERTILIZER_LEVEL	WEEK	1	2	3	4

0	2.67	13.78	19.78	25.00
10	7.78	19.44	25.89	30.56
20	15.33	27.11	33.56	37.56
30	22.00	34.00	40.56	45.89

SPACING	FERTILIZER_LEVEL	WEEK	1	2	3	4
60×25	0		1.00	4.33	7.33	9.67
	10		3.67	9.00	12.33	14.00
	20		8.00	14.00	15.33	16.00
	30		12.00	17.33	21.00	22.33
60×45	0		2.00	12.00	17.00	22.33
	10		8.67	18.33	24.33	28.67
	20		16.00	26.33	33.00	36.67
	30		22.00	32.33	37.67	43.33
60×60	0		5.00	25.00	35.00	43.00
	10		11.00	31.00	41.00	49.00
	20		22.00	41.00	52.33	60.00
	30		32.00	52.33	63.00	72.00

Standard errors of means

Table	SPACING	FERTILIZER_LEVEL	WEEK	SPACING FERTILIZER_LEVEL
rep.	48	36	36	12
e.s.e.	0.300	0.284	0.210	0.520
d.f.	4	18	72	19.12

Except when comparing means with the same level(s) of			
SPACING			0.491
d.f.			18

Table	SPACINGFERTILIZER_LEVEL		
			SPACING
	WEEK	WEEKFERTILIZER_LEVEL	
			WEEK
rep.	12	9	3
e.s.e.	0.435	0.461	0.817
d.f.	16.58	75.04	73.97
Except when comparing means with the same level(s) of			
SPACING	0.364		0.799
d.f.	72		75.04
FERTILIZER_LEVEL			
		0.420	
d.f.		72	
SPACING.FERTILIZER_LEVEL			
			0.727
d.f.			72
SPACING.WEEK			0.799
d.f.			75.04

Standard errors of differences of means

Table	SPACINGFERTILIZER_LEVEL			
			WEEK	SPACING
				FERTILIZER_LEVEL
rep.	48	36	36	12
s.e.d.	0.424	0.401	0.297	0.736
d.f.	4	18	72	19.12
Except when comparing means with the same level(s) of				
SPACING				0.695
d.f.				18

Table	SPACINGFERTILIZER_LEVEL		
			SPACING
	WEEK	WEEKFERTILIZER_LEVEL	
			WEEK
rep.	12	9	3
s.e.d.	0.615	0.652	1.155
d.f.	16.58	75.04	73.97
Except when comparing means with the same level(s) of			
SPACING	0.514		1.130
d.f.	72		75.04
FERTILIZER_LEVEL			
		0.594	
d.f.		72	
SPACING.FERTILIZER_LEVEL			
			1.028
d.f.			72
SPACING.WEEK			1.130
d.f.			75.04

Least significant differences of means (5% level)

Table	SPACINGFERTILIZER_LEVEL		WEEK	SPACING FERTILIZER_LEVEL
rep.	48	36	36	12
l.s.d.	1.176	0.843	0.592	1.540
d.f.	4	18	72	19.12
Except when comparing means with the same level(s) of				
SPACING				1.460
d.f.				18

Table	SPACINGFERTILIZER_LEVEL		SPACING
	WEEK	WEEKFERTILIZER_LEVEL	
			WEEK
rep.	12	9	3
l.s.d.	1.299	1.299	2.302
d.f.	16.58	75.04	73.97
Except when comparing means with the same level(s) of			
SPACING	1.025		2.250
d.f.	72		75.04
FERTILIZER_LEVEL			
		1.183	
d.f.		72	

SPACING.FERTILIZER_LEVEL	
	2.050
d.f.	72
SPACING.WEEK	2.250
d.f.	75.04

Stratum standard errors and coefficients of variation

Variate: NO_LEAVES

Stratum	d.f.	s.e.	cv%
REP	2	0.379	1.5
REP.SPACING	4	0.519	2.1
REP.SPACING.FERTILIZER_LEVEL			
	18	0.851	3.4
REP.SPACING.FERTILIZER_LEVEL.*Units*			
	72	1.259	5.0

Analysis of variance

Variate: NO_BRANCHES

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.6806	0.3403	3.77	
REP.SPACING stratum					
SPACING	2	1020.7222	510.3611	5653.23	<.001
Residual	4	0.3611	0.0903	0.35	
REP.SPACING.FERTILIZER_LEVEL stratum					
FERTILIZER_LEVEL	3	436.2222	145.4074	565.91	<.001
SPACING.FERTILIZER_LEVEL	6	40.7778	6.7963	26.45	<.001
Residual	18	4.6250	0.2569	1.09	
REP.SPACING.FERTILIZER_LEVEL.*Units* stratum					
WEEK	3	530.0556	176.6852	748.31	<.001
SPACING.WEEK	6	88.6111	14.7685	62.55	<.001
FERTILIZER_LEVEL.WEEK	9	3.1667	0.3519	1.49	0.168
SPACING.FERTILIZER_LEVEL.WEEK	18	3.6667	0.2037	0.86	0.623
Residual	72	17.0000	0.2361		
Total	143	2145.8889			

Message: the following units have large residuals.

REP 1 SPACING 60×60 FERTILIZER_LEVEL 10	0.417	s.e.	0.179
REP 2 SPACING 60×25 FERTILIZER_LEVEL 20	0.375	s.e.	0.179
REP 2 SPACING 60×25 FERTILIZER_LEVEL 30	-0.375	s.e.	0.179

Tables of means

Variate: NO_BRANCHES

Grand mean 7.028

SPACING	60×25	60×45	60×60
	3.625	7.333	10.125

FERTILIZER_LEVEL	0	10	20	30
	4.639	6.361	7.750	9.361

WEEK	1	2	3	4
	3.972	7.444	7.417	9.278

SPACING	FERTILIZER_LEVEL	0	10	20	30
60×25		1.917	3.333	4.250	5.000
60×45		5.083	5.917	8.167	10.167
60×60		6.917	9.833	10.833	12.917

SPACING	WEEK	1	2	3	4
60×25		1.917	3.833	3.917	4.833
60×45		4.583	7.750	7.583	9.417
60×60		5.417	10.750	10.750	13.583

FERTILIZER_LEVEL	WEEK	1	2	3	4
0		1.667	5.000	5.000	6.889
10		3.222	6.667	6.556	9.000
20		4.667	8.222	8.222	9.889
30		6.333	9.889	9.889	11.333

SPACING	FERTILIZER_LEVEL	WEEK	1	2	3	4
60×25	0		0.333	2.333	2.000	3.000
	10		1.667	3.333	3.333	5.000
	20		2.333	4.333	5.000	5.333
	30		3.333	5.333	5.333	6.000
60×45	0		2.333	5.333	5.333	7.333
	10		3.000	6.333	6.000	8.333
	20		5.333	9.000	8.333	10.000
	30		7.667	10.333	10.667	12.000
60×60	0		2.333	7.333	7.667	10.333
	10		5.000	10.333	10.333	13.667
	20		6.333	11.333	11.333	14.333
	30		8.000	14.000	13.667	16.000

Standard errors of means

Table	SPACINGFERTILIZER_LEVEL			
			WEEK	SPACING
				FERTILIZER_LEVEL
rep.	48	36	36	12
e.s.e.	0.0434	0.0845	0.0810	0.1339
d.f.	4	18	72	21.16
Except when comparing means with the same level(s) of				
SPACING				0.1463
d.f.				18

Table	SPACINGFERTILIZER_LEVEL		
			SPACING
	WEEK	WEEKFERTILIZER_LEVEL	
			WEEK
rep.	12	9	3
e.s.e.	0.1290	0.1637	0.2774
d.f.	70.82	87.60	93.14
Except when comparing means with the same level(s) of			
SPACING	0.1403		0.2836
d.f.	72		87.60
FERTILIZER_LEVEL			
		0.1620	
d.f.		72	
SPACING.FERTILIZER_LEVEL			
			0.2805
d.f.			72
SPACING.WEEK			0.2836

d.f.			87.60	

Standard errors of differences of means

Table	SPACING	FERTILIZER_LEVEL	WEEK	SPACING FERTILIZER_LEVEL
rep.	48	36	36	12
s.e.d.	0.0613	0.1195	0.1145	0.1894
d.f.	4	18	72	21.16
Except when comparing means with the same level(s) of				
SPACING				0.2069
d.f.				18

Table	SPACING WEEK	FERTILIZER_LEVEL WEEK	SPACING FERTILIZER_LEVEL WEEK
rep.	12	9	3
s.e.d.	0.1824	0.2316	0.3923
d.f.	70.82	87.60	93.14
Except when comparing means with the same level(s) of			
SPACING	0.1984		0.4011
d.f.	72		87.60
FERTILIZER_LEVEL		0.2291	

d.f.		72		
SPACING.FERTILIZER_LEVEL				
			0.3967	
d.f.			72	
SPACING.WEEK			0.4011	
d.f.			87.60	

Least significant differences of means (5% level)

Table	SPACING	FERTILIZER_LEVEL	WEEK	SPACING FERTILIZER_LEVEL
rep.	48	36	36	12
l.s.d.	0.1703	0.2510	0.2283	0.3937
d.f.	4	18	72	21.16
Except when comparing means with the same level(s) of				
SPACING				0.4348
d.f.				18

Table	SPACING WEEK	FERTILIZER_LEVEL WEEK	SPACING FERTILIZER_LEVEL WEEK
rep.	12	9	3
l.s.d.	0.3637	0.4602	0.7791
d.f.	70.82	87.60	93.14

Except when comparing means with the same level(s) of

SPACING	0.3954		0.7971
d.f.	72		87.60
FERTILIZER_LEVEL			
		0.4566	
d.f.		72	
SPACING.FERTILIZER_LEVEL			
			0.7909
d.f.			72
SPACING.WEEK			0.7971
d.f.			87.60

Stratum standard errors and coefficients of variation

Variate: NO_BRANCHES

Stratum	d.f.	s.e.	cv%
REP	2	0.0842	1.2
REP.SPACING	4	0.0751	1.1
REP.SPACING.FERTILIZER_LEVEL			
	18	0.2534	3.6
REP.SPACING.FERTILIZER_LEVEL.*Units*			
	72	0.4859	6.9

Yield Parameters

Analysis of variance

Variate: Number_of_fruit_per_cluster

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	18.8611	9.4306	5.61	
REP.SPACING stratum					
SPACING	2	402.5278	201.2639	119.76	<.001
Residual	4	6.7222	1.6806	1.59	
REP.SPACING.Fertilizer_level stratum					
Fertilizer_level	3	2379.7083	793.2361	748.21	<.001
SPACING.Fertilizer_level					
	6	129.5833	21.5972	20.37	<.001
Residual	18	19.0833	1.0602	1.56	
REP.SPACING.Fertilizer_level.*Units* stratum					
	36	24.5000	0.6806		
Total	71	2980.9861			

Tables of means

Variate: Number_of_fruit_per_cluster

Grand mean 9.236

SPACING	60×25	60×45	60×60
	12.125	9.250	6.333

Fertilizer_level	0	10	20	30
	2.111	5.722	12.056	17.056

SPACING	Fertilizer_level	0	10	20	30
60×25		2.667	8.500	15.333	22.000
60×45		2.333	5.000	12.333	17.333
60×60		1.333	3.667	8.500	11.833

Standard errors of means

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
e.s.e.	0.2646	0.2427	0.4501
d.f.	4	18	18.64

Except when comparing means with the same level(s) of	
SPACING	0.4204
d.f.	18

Standard errors of differences of means

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
s.e.d.	0.3742	0.3432	0.6365
d.f.	4	18	18.64
Except when comparing means with the same level(s) of			
SPACING			0.5945
d.f.			18

Least significant differences of means (5% level)

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
l.s.d.	1.0390	0.7211	1.3339

d.f.	4	18	18.64

Except when comparing means with the same level(s) of

SPACING	1.2489
d.f.	18

Stratum standard errors and coefficients of variation

Variate: Number_of_fruit_per_cluster

Stratum	d.f.	s.e.	cv%
REP	2	0.6268	6.8
REP.SPACING	4	0.4583	5.0
REP.SPACING.Fertilizer_level	18	0.7281	7.9
REP.SPACING.Fertilizer_level.*Units*	36	0.8250	8.9

Analysis of variance

Variate: SEED_YIELD_PER_FRUIT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.3403	0.1701	0.33	
REP.SPACING stratum					
SPACING	2	52.9186	26.4593	51.63	0.001
Residual	4	2.0497	0.5124	2.72	
REP.SPACING.Fertilizer_level stratum					
Fertilizer_level	3	356.0726	118.6909	630.22	<.001
SPACING.Fertilizer_level					
	6	12.8436	2.1406	11.37	<.001
Residual	18	3.3900	0.1883	0.31	
REP.SPACING.Fertilizer_level.*Units* stratum					
	36	21.6850	0.6024		
Total	71	449.2999			

Message: the following units have large residuals.

REP 1 SPACING 60×60 Fertilizer_level 30 0.504 s.e. 0.217

Tables of means

Variate: SEED_YIELD_PER_FRUIT

Grand mean 5.451

SPACING	60×25	60×45	60×60
	4.342	5.583	6.429

Fertilizer_level	0	10	20	30
	2.467	4.411	6.544	8.383

SPACING	Fertilizer_level	0	10	20	30
60×25		1.867	3.333	5.017	7.150
60×45		2.850	3.850	6.933	8.700
60×60		2.683	6.050	7.683	9.300

Standard errors of means

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
e.s.e.	0.1461	0.1023	0.2119
d.f.	4	18	13.92
Except when comparing means with the same level(s) of			
SPACING			0.1772
d.f.			18

Standard errors of differences of means

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
s.e.d.	0.2066	0.1447	0.2996
d.f.	4	18	13.92
Except when comparing means with the same level(s) of			
SPACING			0.2506
d.f.			18

Least significant differences of means (5% level)

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
l.s.d.	0.5737	0.3039	0.6430
d.f.	4	18	13.92
Except when comparing means with the same level(s) of			
SPACING			0.5264
d.f.			18

Stratum standard errors and coefficients of variation

Variate: SEED_YIELD_PER_FRUIT

Stratum	d.f.	s.e.	cv%
REP	2	0.0842	1.5
REP.SPACING	4	0.2531	4.6
REP.SPACING.Fertilizer_level			
	18	0.3069	5.6
REP.SPACING.Fertilizer_level.*Units*			
	36	0.7761	14.2

Analysis of variance

Variate: %1000_seed_weight_g

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	0.30333	0.15167	0.53	
REP.SPACING stratum					
SPACING	2	1.24000	0.62000	2.16	0.231
Residual	4	1.14667	0.28667	1.89	
REP.SPACING.Fertilizer_level stratum					
Fertilizer_level	3	1.25111	0.41704	2.76	0.072
SPACING.Fertilizer_level					
	6	0.83556	0.13926	0.92	0.503
Residual	18	2.72333	0.15130		
REP.SPACING.Fertilizer_level.*Units* stratum					
	36	0.00000	0.00000		
Total	71	7.50000			

Tables of means

Variate: %1000_seed_weight_g

Grand mean 3.15

SPACING	60×25	60×45	60×60

3.27	3.22	2.97

Fertilizer_level	0	10	20	30
	3.03	3.37	3.06	3.14

SPACING	Fertilizer_level	0	10	20	30
60×25		3.07	3.53	3.10	3.37
60×45		3.20	3.50	2.97	3.20
60×60		2.83	3.07	3.10	2.87

Standard errors of means

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
e.s.e.	0.109	0.092	0.176
d.f.	4	18	17.14
Except when comparing means with the same level(s) of			
SPACING			0.159
d.f.			18

Standard errors of differences of means

Table	SPACING	Fertilizer_level	
			SPACING
			Fertilizer_level
rep.	24	18	6
s.e.d.	0.155	0.130	0.248
d.f.	4	18	17.14
Except when comparing means with the same level(s) of			
SPACING			0.225
d.f.			18

Least significant differences of means (5% level)

Table	SPACING	Fertilizer_level	
			SPACING
			Fertilizer_level
rep.	24	18	6
l.s.d.	0.429	0.272	0.524
d.f.	4	18	17.14
Except when comparing means with the same level(s) of			
SPACING			0.472
d.f.			18

Stratum standard errors and coefficients of variation

Variate: %1000_seed_weight_g

Stratum	d.f.	s.e.	cv%
REP	2	0.079	2.5
REP.SPACING	4	0.189	6.0
REP.SPACING.Fertilizer_level			
	18	0.275	8.7
REP.SPACING.Fertilizer_level.*Units*			
	36	0.000	0.0

Analysis of variance

Variate: Seed_yield_per_ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	2	3.1235	1.5617	0.35	
REP.SPACING stratum					

SPACING	2	2815.4679	1407.7339	314.35	<.001
Residual	4	17.9132	4.4783	1.90	
REP.SPACING.Fertilizer_level stratum					
Fertilizer_level	3	11992.8157	3997.6052	1692.43	<.001
SPACING.Fertilizer_level					
	6	352.9995	58.8333	24.91	<.001
Residual	18	42.5170	2.3621	14.47	
REP.SPACING.Fertilizer_level.*Units* stratum					
	36	5.8781	0.1633		
Total	71	15230.7149			

Tables of means

Variate: Seed_yield_per_ha

Grand mean 32.123

SPACING	60×25	60×45	60×60
	23.804	33.687	38.880

Fertilizer_level	0	10	20	30
	11.617	32.540	37.491	46.846

SPACING	Fertilizer_level	0	10	20	30
60×25		7.443	20.495	28.088	39.188
60×45		10.630	34.480	40.060	49.578
60×60		16.777	42.647	44.323	51.772

Standard errors of means

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
e.s.e.	0.4320	0.3623	0.6942
d.f.	4	18	17.14
Except when comparing means with the same level(s) of			
SPACING			0.6274
d.f.			18

Standard errors of differences of means

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
s.e.d.	0.6109	0.5123	0.9817

d.f.	4	18	17.14
Except when comparing means with the same level(s) of			
SPACING			0.8873
d.f.			18

Least significant differences of means (5% level)

Table	SPACING	Fertilizer_level	SPACING Fertilizer_level
rep.	24	18	6
l.s.d.	1.6961	1.0763	2.0699
d.f.	4	18	17.14
Except when comparing means with the same level(s) of			
SPACING			1.8642
d.f.			18

Stratum standard errors and coefficients of variation

Variate: Seed_yield_per_ha

Stratum	d.f.	s.e.	cv%
REP	2	0.2551	0.8
REP.SPACING	4	0.7482	2.3
REP.SPACING.Fertilizer_level	18	1.0868	3.4
REP.SPACING.Fertilizer_level.*Units*	36	0.4041	