INFLUENCE OF PLANT DENSITY AND FERTILIZER APPLICATION ON GROWTH, YIELD AND QUALITY OF SWEET PEPPER (*Capsicum annuum*) IN UASIN GISHU COUNTY.

BY

MILLICENT AKINYI BUNDE

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DECLARATION

DECLARATION BY THE CANDIDATE

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MILLICENT AKINYI BUNDE

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Sign………………………………. Date ………………………...

DECLARATION BY SUPERVISORS

This thesis has been submitted for examination by our permission as the University supervisors.

DR. ELIZABETH N. OMAMI

Sign ……………………………………. Date ……………………………

Department of Seed, Crop and Horticultural Sciences

University of Eldoret.

DR. THEOPHILUS M. MUTUI

Sign ……………………………………. Date ……………………………

Department of Seed, Crop and Horticultural Sciences

University of Eldoret

DEDICATION

I dedicate this thesis to my late father J. B. Bunde whose special interest in my education was the inspiration for this work.

ABSTRACT

Sweet pepper well known for its nutritional and medicinal values is also emerging as an important cash crop in the local and international markets. The quality of sweet pepper produced in Uasin Gishu is low thus failing to meet the standard specifications. This has led to rejection in the export market causing heavy losses to the farmers. Plant density and nitrogen are among the many factors which can influence growth, yield and quality of sweet pepper. The objective of the study was to determine the influence of plant density and different nitrogen levels on growth, yield and quality of sweet pepper. The field experiment was conducted from July 2009 to January 2010 in Turbo and Kapseret whereby, three plant densities 70 × 60cm (23,809 plants/ha, low), 70 × 45cm (31.746 plants/ha, intermediate), 70 × 30cm (47,619 plants/ha, high) and five nitrogen levels 0, 40.5, 81 , 121.5 (from CAN)) and 80KgN/ha (from farmyard manure) were combined in a factorial arrangement laid out in a randomized complete block design with three replications. The data was subjected to ANOVA using Genstat statistical package and means separated by Tukey's Studentized Range (HSD) at $P \leq 0.05$. The low and intermediate plant densities significantly hastened the onset of 50% flowering. Low plant density had a significant increase on fruit size as evidenced by increased fruit diameter. Applying 81 kgN/ha significantly hastened the onset of 50% flowering and recorded the lowest pest incidence. The interaction effects of plant density and nitrogen were significant whereby, a treatment combination of 70 × 45cm and 81kgN/ha recorded low pests and disease incidence while producing fruits of the specified diameter size. Turbo site produced vigorously growing sweet pepper plants which were tall, had the highest number of branches, took the shortest time to attain 50% flowering and produced the highest fruit yield. The intermediate plant density (70 × 45cm) and 81 kgN/ha produced high quality fruits and should be adopted by the growers to meet the export market standard. Sweet pepper should be grown in low altitude areas like Turbo for enhanced plant growth and high yield in Uasin Gishu County

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

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CHAPTER ONE

INTRODUCTION

1.1 Background information.

Sweet pepper (*Capsicum annuum*) is a warm season vegetable which originated from Tropical South America and Brazil prior to the 15th century (Khan *et al*., 2010). From America it spread to Tropical Asia (India, Malaysia, and Thailand) and Tropical Africa (Senegal, Nigeria, Sierra Leone, Ghana, Sudan and Kenya). It is the most popular and widely used condiment all over the world (Anon, 2010b). Production of sweet pepper is widespread in Kenya and mainly used as a food colouring and flavouring agent. Sweet pepper is consumed both as fresh and dehydrated spices (Bosland and vostava, 2000). The leaves are consumed as salads, soups or eaten with rice. Important nutrients and minerals are contained in the fruits in different proportions depending on the stage of ripening (Anon, 2008a). Sweet green pepper when raw contains approximately 6.7g carbohydrates, 0.2g fats and 0.9g proteins per 100gm (Anon, 2010c). Medical cases such as asthma, fevers, varicose veins and digestive problems can be treated using sweet pepper. External application of sweet pepper relieves pain due to neuralgia and can be used to prevent sea sickness (Anon, 2008b). Colour and flavour extracts are used in the food and feed industries in the making of sauce and poultry feeds respectively. Sweet pepper extracts have shown positive response against pests (Gachimu and Ndong' a, 2005).

The nutritional and medicinal aspects of sweet pepper have led to an increase in demand and is currently being promoted by many exporting companies in Uasin Gishu County. Food and Agriculture Organization (FAO) statistics estimate world production of capsicum peppers at 21.3 million tons from an area of 1.6 million ha (average yield – 13.4 tons/ha) (Anon, 2007). China is the largest producer with 10 million tons followed by Mexico (1.9 million tons), Turkey (1.5 million tons), Nigeria (715,000 tons from 90,000 ha) and Ghana (270,000 tons from 75,000 ha) (Anon, 2007). The FAO statistics are incomplete or unreliable for African countries as production from intercropping and home gardens is often not included. Data presented comes from only 13 out of the 47 countries of Tropical Africa. In 2007, the total acreage in the country under sweet pepper was 990 ha. Total production was 9300 tons valued at Kshs. 297,000M (HCDA, 2008). In the same year, Uasin Gishu County produced 40 tons valued at Kshs.1.2M. The targeted acreage in Uasin Gishu for the crop in that year was approximately 10 ha, although the achievement was 4 ha (MOA, 2007). This gave an average yield of approximately 10 tons/ha, although with good management yield of up to 15 tons/ ha can be achieved (Onchieku, 1998).

Some of the factors which affect growth, yield and quality of sweet pepper are production systems (controlled environment or open field), climatic conditions. Plant nutrition, planting densities. varieties, post-harvest handling and biotic factors such as pests and diseases (Neginahal *et a*l., 2009). In greenhouse production system, fruit yield and quality can be improved as the adverse environmental conditions are controlled (Jovicich *et al*,.1998). Being a warm season vegetable, sweet pepper performs better in low altitude areas in the tropics and in summer and autumn in the temperate regions (USAID, 2006). Plant density is a major factor which determines the degree of competition for resources between plants. Yield per plant decreases as the plant density increases due to competition for the available resources such as water, nutrients and light. Nasto *et al.*, (2009) reported that increasing plant density resulted in greater yield (kg/ha) of bell pepper. Wider spacing led to an increase in fruit yield per plant with bigger and more cracked fruits in tomatoes as compared to closer spacing (Law-Ogbomo and Egharevba, 2009). The spacing aspect should be considered in sweet pepper production and export as the requirement specifies the fruit diameter size as 40mm - 45mm. In addition the fruits should be free from blemishes and pest attacks (HCDA, 2007a). Plant density affects growth characteristics such as height and branching which ultimately determines the size and quality of the fruit. Yield per unit area tends to increase as plant density increases up to a point and then declines (Akintoye *et al*, 2009).

Plant nutrition is important in crop husbandry as it involves the supply of various plant nutrients in their available forms, in required amounts for plant growth and in proper balance with other nutrients. Nutrients play different roles in plants. Nitrogen is important for vegetative growth and a major constituent of chlorophyll; phosphorus is important for root development, flowering and fruit development while potassium controls the opening and closing of the stomata hence maintaining the fluid balance in the plant cells. Fertilizer application affects crop production and nitrogen is important for good plant establishment and expected growth (Uddin and Khalequzzaman, 2003).

The role played by nitrogen in sweet pepper production is very important. Being responsible for vegetative growth, the size and quality of the fruit will depend on the amount of nitrogen applied. Qawasmi *et al*., (1999) reported that increasing the rates of nitrogen applied in sweet pepper plants increases the uptake of nitrogen by plants and at the same time stimulates the uptake of potassium and phosphorus through the synergistic effect of nitrogen on them. Nitrogen is the main constituent of amino acids in proteins and lipids thus acting as structural compounds in chloroplasts (Basela and

Mahadeen, 2008). The correct nitrogen level will help in regulating the standard of sweet pepper as other nutrients will play their roles effectively. On quality, it is clearly indicated that the fruits should be free from mechanical damage, pest attacks and conform to the specified size. Reiley and Shry (2004) and Kirimi *et al*., (2011) reported that high nitrogen rates reduce fruit firmness in tomatoes causing deterioration. Such fruits are easily damaged during post-harvest handling and the damaged spots are entry points for pathogens.

1.2 Problem Statement

The quality of the sweet pepper fruits produced in Uasin Gishu County is low and this has led to rejection in the export market. According to Canken International which is an exporting company, only 30% of sweet pepper fruits delivered by farmers at the cold storage facilities in Eldoret Airport is accepted. The rest is rejected due to failure to meet the required standard specifications with regards to conformity to uniformity, size, shape; Maximum Residue Levels (MRLS) and the presence of quarantine pests. In 2007 Uasin Gishu County achieved 10tons/ha although the potential is 15tons/ha. The area under cultivation and production of sweet pepper in the country decreased by 2.9% and 8.2% respectively in 2011 as a result of pests and diseases mainly white flies and bacterial wilt (HCDA, 2011). Global Good Agricultural practices (GAP) which was implemented in 2005, puts a lot of emphasis on quality of the produce. Since then more stringent measures on quality have been taken. This has barred small holder participation. Thus the continued growth of Kenya's horticultural export and the ability of small holder farmers to participate in any growth cannot be taken for granted (HCDA, 2007b).

After rejection, the produce ends up in the local market at a throw away price because sweet pepper deteriorates rapidly. The price of sweet pepper fruits in the local market ranges from 30 to 50 shillings per kilogram. In Germany which is the main importer of sweet pepper minimum and maximum prices range from €3.91/kg to €16.17/kg (USAID 2006). Post harvest losses have been estimated to be 26-35 % for locally marketed fruits and as high as 50 % for exported fruits (HCDA, 2003). A number of poor handling practices often result in substantial post harvest losses. Such practices include inappropriate harvesting indices, poor harvesting techniques, poor packaging materials and poor transportation. Sweet pepper should be harvested at the cooler times of the day (early in the mornings or late in the evenings) when they are turgid. Turgid fruits snap easier and maintain their quality much better than fruits harvested during the hotter times of the day. Depending on the market requirements fruits may be harvested at mature green, just turning, fruits with more green than colour , more colour than green or full colour. When the fruits are harvested at immature stage their shelf life and marketability reduce. Such fruits shrivel due to moisture loss and decay easily. Bacterial rots are the major post harvest diseases which lower the quality of sweet pepper Bruising, damaged stems and damaged pericarps during handling expose the fruits to bacterial organisms which cause rotting.

1.3 Objectives

Overall Objective

The overall objective was to improve the marketable yield and quality of sweet pepper in Uasin Gishu County.

Specific Objectives

The specific objectives were:-

1. To determine the influence of plant density on growth, yield and quality of sweet pepper grown in Uasin Gishu County.
2. To evaluate the effect of nitrogen on growth, yield and quality of sweet pepper grown in Uasin Gishu County.

1.4 Justification

The ultimate quality of the export produce depends on the management of the entire supply chain (Korstern *et al*., 2008). Hence the need to investigate the sweet pepper supplies chain from the initial point of production to the final point of export. Until recently sweet pepper production in Uasin Gishu had been restricted to local consumption. However with the recent promotion by the exporters many farmers have gone into commercial production mainly as an export crop. There are challenges specific to sweet pepper which need to be addressed before the economic benefits are realized. In Tropical Africa, vegetable crops are grown at wide and random spacing due to intercropping and relay cropping systems which produce big but cracked fruits (Law-ogbomo and Egharevbe, 2009). In a competitive market, total yield may be less important than yield of high quality product (Kahn and Leskovar, 2006). Researchers in the world have devoted most of their attention to plant nutrition since nutrient supply is considered to be the most limiting factor in growth and productivity of sweet pepper (Neginahal *et al*., 2009). Hence farmers need to know the specific plant densities and the nitrogen rates which produce marketable sweet pepper fruits. The aim of the field experiment was to determine the plant density and nitrogen levels that would produce sweet pepper fruits of the desired export qualities with economic yield.

1.5 Hypotheses

1**: Alternative Hypothesis**

Plant density has a significant effect on growth, yield and quality of sweet pepper grown in Uasin Gishu County.

2**: Alternative Hypothesis**

Nitrogen has a significant effect on growth, yield and quality of sweet pepper grown in Uasin Gishu County.

CHAPTER TWO

LITERATURE REVIEW

2.1 Botanical characteristics of sweet pepper

Sweet pepper (*Capsicum annuum*) also known as red pepper, bell pepper and cherry pepper belongs to the solanaceae family (Rice and Rice, 2003). The annual or short lived perennial grows to a height of 1.5m. It has well developed tap roots with many lateral roots. Stems are branched, erect or semi-prostate fleshy and often round or slightly angular at the base (Tindall, 1993). The leaves are alternate, simple, ovate to lanceolate with entire margins, variable in size up-to 12cm long and 7.5cm wide. The flowers are single with petals colours ranging from white to green. The fruit is a many seeded berry and generally bell-shaped with thick flesh, variable in size and colour (green, yellow, orange, red) depending on the stage of maturity (Anon, 2007).

2.1. 2 Varieties of sweet pepper

Varieties of sweet pepper are categorized based on maturity (early, mid-season or late), fruit types (cherry, bell, wax, pimento, paprika, cayenne, jalapeno) and pungency (non-pungent, mildly moderately or highly pungent) (Anon, 2007). Some of the sweet pepper varieties are California Wonder, Yolo Wonder, Emerald Giant, Chinese Giant, Florida Giant and Ruby Giant. The most commonly grown varieties in Uasin Gishu County are California Wonder and Yolo Wonder. Yolo Wonder matures in about 74 days and is resistant to tobacco mosaic virus. The fruits are about 10cm long, 8.9cm in diameter, block shaped and smooth. California Wonder matures in about 75 days; fruits are about 11.4cm long, 9.5cm in diameter, mostly 4-lobed, very smooth and attractive. Slightly smaller and earlier (65 to 70 days) strains of this type are also available under the name of early California Wonder (Anon, 2010d).

2.1. 3 Ecological requirements

Sweet pepper is commonly grown up to 2000m above sea level in the tropics depending on minimum temperature and frost conditions. The crops can be grown in a wide range of well drained soils, preferably fertile loam soils with high organic matter with optimum pH 5.6 – 6.5. An annual rainfall of 600m – 1200mm is sufficient for sweet pepper growth and development (Onchienku, 1998). Excessive rainfall causes fruit decay, while water deficiency results in bud and flower abscission. Despite the need for warm weather conditions, extreme heat reduces fruit setting in many varieties. When temperatures are above 32.2^0C, excessive flower dropping occurs due to infertile pollen production which ultimately reduces fruit set. Many fruits produced at mean temperatures above 26.7^0C are likely to be small or poorly shaped because of injury to the flowers. In general maximum growth occurs in the temperature range 21^0C - 25^0C. Early flowering and maturing of fruits are favored by high temperatures which also tend to reduce the setting of fruit. Temperature reduction through shading was found to reduce sun-scald damage of the fruits from 36% in full sunlight to 3-4% under 26% and 47% shading (Rylski and Spigelman, 2003).

2.1.4 Emerging challenges in horticultural production and export

Rules in the export market have changed and the minimum requirement for a product to be considered must comply with the regulations. Despite the tight conditions, Kenya can produce high quality produce due to the favorable climatic conditions. Sweet pepper fruits from Malawi, Zambia and West Indies are of high quality thus giving Kenya a tough competition in the international market (Muthoka and Mulinge, 2005). In order to benefit from the business, sweet pepper farmers need to improve their production skills. Kenya Good Agricultural Practices (KENYAGAP) was developed in June 2006 with the aim of advising Kenyan farmers and exporters on GAP requirements (HCDA, 2007a). Fresh Produce Exporters Association of Kenya (FPEAK) and Kenya Flower Council (KFC) are recognized internationally and they play important roles of advising producers on quality aspects, advertising Kenya produce abroad and providing market labels for the produce. The carbon dioxide food miles debate which had threatened the horticultural industry in Kenya finally ended after studies indicated that Kenyan produce caused less pollution. In Cranfied University, it was found that air freight green beans from Kenya account for the emission of less carbon dioxide than British beans (Anon, 2008c). A more recent study in Cranfied University showed that a rose in Kenya produces 5-8 times less carbon dioxide than a rose grown in Netherlands (Walwright, 2007). In Tanzania, Horticulture Development Council of Tanzania (HODECT) was formed with an objective of ensuring maximum realization of economic benefits to the country and its people through promotion of production, processing and export of horticultural crops in local and export market (Hucha, 2008).

2.2 Propagation and field establishment

In sweet pepper production, all the pre and post harvest practices must be performed as recommended in order to achieve high yield and good quality fruits. The crop is mostly started in the nursery although direct field establishment can be done. In order to enhance germination the seeds are soaked in water overnight or pre-germinated in growth chambers. The crop is managed in the nursery for about 4 weeks before transplanting in the main field.

2.2.1 Pests and diseases of sweet pepper

Pests and diseases lower the quality of sweet pepper fruits leading to rejection in the export market hence the need to carry out the recommended preventive and control measures. Some of the pests are green peach aphids, red spider mites and American bollworms. Green peach aphids are vectors of viral diseases like cucumber mosaic virus and potato virus X and Y which cause spotting on fruits (Onchieku, 1998). A major pest which leads to rejection of horticultural produce from Kenya in the European Union is American bollworm. (Anon, 2008d). Fungal diseases including blight, leaf spot and fusarium wilt are prevalent in Uasin Gishu and controlled culturally by practicing crop rotation and applying fungicides.

Blossom end rot is a physiological disorder caused by several factors including inadequate amount of calcium in the fruit due either to low levels of available calcium or inadequate levels of moisture (Anon, 2010a). The problem usually appears as a soggy sunken area on the blossom end of the fruit. With time the area darkens and becomes more concave. This can be controlled by planting resistant varieties, regular watering, avoiding over fertilization with nitrogen and supplying calcium as a top dress in calcium deficient soils. Fruit cracking is common on red fruits and is caused by differences in day and night temperatures. Care should be taken to ensure that the fruits are not wet during the night and early morning. Mature fruits are less flexible and hence more prone to cracking. Excessive radiation during the dry season causes sunscald. Prevention can be done by correct pruning methods and by the use of shade cloths.

2.2.2 Harvesting and handling activities

Harvesting starts 2-3 months after planting and continues for another 2-3 months. It is important to harvest at the right stage using the proper harvesting tools to avoid damaging the fruits. In developing countries where the bulk of the vegetables are produced by small scale farmers the fruits are harvested manually and so losses due to improper harvesting techniques are high (Anon, 2009). Generally the produce is handled in batches and subjected to a wide range of environmental conditions (Nyanjage *et al*., 2005). After harvesting, the fruits should be selected under a shade whereby damaged and diseased fruits should be removed. If this is not done, good fruits are mixed with diseased and damaged fruits and this leads to rapid deterioration. Finally the produce is transported in open vehicles where the temperatures are extremely high and so on reaching the market the quality and yield are drastically reduced.

2.3 Growth, yield and quality of vegetables as affected by plant density

2.3.1 Other vegetables

In tomatoes, increased plant density reduced the fruit yield per individual plant although the yield per hectare was increased (Agele *et al*., 2000). Effects of row arrangements and plant density on yield and quality of tomatoes indicated that increasing the plant density by reducing the plant spacing within the row increased yield by 3-5 tons/ha. Row arrangement and plant density did not affect fruit size or soluble solids (Warner *et al*, 2002).

According to Law-Ogbomo and Egharevbe (2009), a combination of plant density and NPK fertilizer application increased the productivity of tomatoes as they positively influenced the plant height at maturity, days to 50% flowering and fruit yield. Njoku and Muoneke (2008) reported that the leaf area index of cowpeas was highest with the highest planting density.

A study on the effects of nitrogen and spacing on greenhouse tomatoes indicated that an application of 80kgN/ha and spacing of 50 × 30cm produced the highest fruit yield (Kirimi *et al.,* 2011). Paranjpe *et al.*, (2003) reported that malformation of fruits was not significantly increased by increased plant densities. Closer spacing resulted in high yield and less cracked tomato fruits per plant as compared to wider spacing (Andani *et al.*, 1998).

2.3.2 Capsicum species

In a study on dynamics of growth and yield components responses of bell pepper to row cover and population density, fruit yield increased with increasing plant densities. Functional covers increased absolute growth rate but decreased unit leaf rates. High population densities decreased absolute growth but both treatments promoted shoot biomass accumulation per unit area (Jollife and Gaye, 2000). The results from a study on the effects of different plant densities on growth and yield characteristics of sweet pepper in Asia (Iran) indicated that the highest lateral stem numbers and leaf numbers were obtained by plant spacing of 30 by 100cm while yield per plant decreased with increasing plant densities (Aminifard *et al.,* 2010a). In greenhouse production, marketable yield (number and weight per m^2) increased linearly with plant density (Jovicich *et al.,* 1998). Field trials carried out in The Sudan in Gezira to determine the optimum spacing and nitrogen application using California Wonder cultivar indicated that closely spaced plants and nitrogen application increased marketable yield and the number of fruits per hectare. However it dropped with more nitrogen application. Plant height, number of branches per plant and number of leaves were not significantly affected by either closer spacing or nitrogen application (Ahmed, 2001).

Cebula (1995) reported that sweet pepper plants grown at 8 plants per m^2 and pruned to 1 shoot obtained higher yield than those grown at 2 plants per m^2 and pruned to 4 shoots in greenhouse production. Maya *et al., (*1997) recorded higher fruit weight in the closer spacing of 60 x 30cm and higher levels of nitrogen and potassium although quality parameters like ascorbic acid and Total Soluble Solids (TSS) were not significantly influenced by the treatments. Choudhary and Singh (2006) reported that maximum fruit yield per hectare was recorded at 60 x 50cm spacing which was significantly higher over 75 x 50cm spacing but at par with 45 x 50cm. Similar results were reported by Patel *et al.,* (2002). Capsicum planted at a spacing of 45 × 45cm yielded the highest number of fruits per plant with high mean fruit weight during summer in Asia (Mantur *et al.,* 2007).

A study conducted in Nigeria to determine the effects of plant density and nitrogen fertilizer on the growth and yield of sweet pepper, indicated that high nitrogen levels produced the tallest plant with the highest number of branches and the largest fruits. There was an increase in plant height and number of branches as the spacing increased from 30 x 60cm to 60 x 75cm (Ekwu and Okporie, 2006). Aminifard *et al.,* (2012) reported that vegetative characters (plant height, lateral stem numbers, leaf size) decreased with increasing plant densities while nitrogen significantly increased plant height at vegetative and reproductive stages.

Dasgan and Abak (2003) reported that a spacing of 80 × 30cm with three shoots per plant was more economical for sweet pepper cultivation as quality characteristics such as fruit weight, fruit length, fruit diameter, fruit volume and total soluble solids were not significantly reduced by plant density and the number of fruits per plant. The highest marketable sweet pepper fruits with the largest proportion of large sized fruits was achieved with a plant density of 6 plants/m^2 in greenhouse production (Lee and Liao, 2006).

2.3.3 Sweet pepper spacing

Plant spatial arrangement is a crop management practice that has been used to increase yield per unit area. When the intra row spacing is wide, fruit yield per plant increases but production per unit area is reduced (Jovicich *et al.*, 1998. Higher plant densities in sweet pepper results in more but small sized fruits as compared to low plant densities, The recommended sweet pepper spacing is given as a range of 60 - 80cm by 35 - 45cm. So farmers use different spacings depending on cultivars, soil conditions and environment factors (Tindall, 1993). Ridge width for growing sweet pepper may be 75 - 90cm with inter plant spacing of 45 - 60cm and for transplanting in flat plots, a spacing of 60 by 45cm is recommended in Nigeria (Anon, 2010d). In Uasin Gishu, a close spacing of 45 × 45cm is used in greenhouse production while in open field production some of the spacings used are 60 × 60cm; 60 × 40cm and 50 × 50cm. In rely and intercropping systems, plants are randomly spaced depending on the available space (MOA, 2007).

2.4 Growth, yield and quality of vegetables as affected by nitrogen

2.4. 1 Other Vegetables

An Application of 104kgN/ha gave the highest leaf yield in black nightshade (15tons/ha), but was not significantly different from 52kgN/ha (14.8tons.ha) and 78kgN/ha (14.8tons/ha) (Opiyo, 2005). Aminifard *et al*. (2010b) observed that increasing nitrogen rates significantly increased plant vegetative growth (plant height, lateral stem number and leaf chlorophyll content) in egg plants growth under field conditions. Investigations on the effects of different levels of nitrogen fertilizer on grown and yield of romaine lettuce (*Lactuca sativa* L.) indicated that nitrogen had a significant effect on growth characteristics, accelerating head formation and delaying the bolting date (Boroujerdnia and Ansari, 2007). Ezzart *et al.,* (2011) reported that application of nitrogen fertilizer in the form of compost at a rate of 9 tons/ha and Ammonium sulphate at a rate of 90 kgN/ha with GTU (nitrification inhibitor) in potato (*Solanum tuberosum* L.) fields were the most effective treatments for improving nitrogen utilization efficiency. A study on the effective utilization of organic and inorganic nitrogen sources on potatoes indicated that shoots dry matter, leaf area index and plant height increased significantly with increasing nitrogen rates (Najm *et al.,* 2010). Kirimi *et al.*, (2011) and Samaila *et al*., (2011) observed that nitrogen rates between 45 kgNha and 90 kgN/ha produced more marketable tomato fruits as compared to nitrogen rates above 100kgN/ha.

2.4.2 Capsicum species

Khan *et al*. (2010) reported that plant height and the number of branches increased significantly with increasing nitrogen doses up to 100kgN/ha. Amor (2007) reported that plant fresh weight and total leaf weight progressively reduced in organic farming as compared to conventional and integrated farming in sweet pepper production. Osman and George (2007) reported that high nutrient levels of nitrogen., potassium and phosphorus resulted in the highest fruit yield in greenhouse sweet pepper production.

According to Hedge (1988) high nitrogen levels of 180 kg/ha gave the highest fruit yield of 18.0 tons/ha and the highest nutrient uptake in an experiment to determine fruit yield and nutrient uptake in sweet pepper as affected by soil moisture regime and nitrogen fertilization. A study on organic waste (sludge) revealed that application of sanitized sludge on sweet pepper improved yield without loss of food nutritional quality in terms of fruit size and vitamin C, glutathione and capsaicinoid contents (Anon, 2010e). Investigations on the effect of planting methods and nutrients levels on productivity and nutrient uptake of chili indicated that high nutrient levels significantly increased the uptake of nitrogen, potassium and phosphorus by chili (Neginahal *et al.*, 2009). Johnson and Decoteau (1996) reported that lower and higher nitrogen rates were undesirable for sweet pepper growth as marketable fruits decreased at low and high nitrogen rates.

2.4.3 Nutrient requirements of Sweet peppers

The solanaceous group of vegetables (tomatoes, egg plant and sweet pepper) generally take up large amounts of nutrients. The amount of nutrients they take up depends on the quality of fruit and dry matter they produce, which is influenced by genetic and environmental variables. In order to produce one ton of fresh fruits, sweet pepper needs to absorb 3-3.5 kgN, 0.7-1 kgP and 5-6 kgK (Hedge, 1988). General nutrients recommendations are 130 kgN /ha, 80 kgP/ha and 110 kgK/ha (Anon, 2010b). Local recommendations may vary depending on soil types and environmental conditions. Generally , a basic dressing of 250 kg/ha DAP is recommended followed with a top dressing of 100 kg/ha CAN when the plants are about 15cm high (2 weeks after transplanting) and 4 weeks later with 200 kg/ha CAN. The crop thrives best with an application of 10-20 tons of well rotted manure per hectare depending on soil conditions (Anon, 2007). Marti and Mills (1991) reported that sweet pepper prefers nitrogen in nitrate form as this increases nutrient uptake and fruit yield. Timely weed control is necessary to reduce nutrient competition. There are no specific fertilizer application rates for sweet pepper grown for export in Uasin Gishu County. After the fruits have been rejected, most farmers tend to adjust the rates either by increasing or by reducing and some end up not applying any fertilizer (MOA, 2007).

The results from the different studies carried out on sweet pepper clearly show that the influence of plant density and fertilizer application on sweet pepper vary depending on climatic conditions, production systems, varieties and cultural practices. Although sweet pepper is an important export crop in Uasin Gishu County, very little is known on the fertilizer (nitrogen) requirements and plant densities which can produce high quality fruits with the specified export qualities in open field production.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study sites

The field experiment was conducted in Turbo and Kapsaret divisions in Uasin Gshu County, Kenya between July 2009 and January 2010.

Turbo Division

It is located at (0^0, 31'N and 34^0, 75'E). Altitude ranges 1500 - 1900m above sea level. The soil type is mainly acrisols which are well drained, deep, and brown to dark sandy clay. The area lies in the UM_4 Agro-ecological zone where maize, wheat, livestock and horticultural crops are the major enterprises. The area experiences long rains from the end of March with a long cropping season. Short rains come in September. Average rainfall is 1300mm per annum and the average temperature is 23^0C - 25^0C, the minimum is 18^0C (MOA, 2007).

Kapseret Division

It is located at (0^0, 29'N and 30^0, 25'E). Altitude ranges 1600 - 2030m above sea level .Soil type is mainly ferralsols with variable fertility, mainly low. The area lies in the LH Agro-ecological zone, wheat, maize and barley zone. The long rains start at the end of March with a long cropping season. Short rains come in September. The average rainfall is 930mm. per.annum and the average temperature is 17^0C - 24^0C, while minimum is 9^0C (MOA 2007).

3.1.1 Soil and farmyard manure analysis

Soil samples (0 - 30cm depth) from the experimental sites and farmyard manure were analyzed to determine the pH, nitrogen, phosphorus and organic carbon levels in

Chepkoilel soil science laboratory. The analysis was done using Okalebo *et a*l., (2002) procedure. The farmyard manure was well decomposed having undergone the decomposing process for three months. The materials used in the preparation of the farmyard manure included crop residues and animal waste from cattle, poultry and goats. The farmyard manure had been kept under a temporary store well protected from adverse weather conditions such as rain and excess heat.

3.1.2 Preparation for planting, pricking out and transplanting

Sweet pepper seeds of California Wonder were pre-germinated on filter papers (whatman, 125mm) in the germination chambers at 30 - 35^0C and relative humidity 75% - 80% in Chepkoilel seed laboratory. This was done in the last week of July 2009. After the emergence of the first leaves (4 - 5 days), the seedlings were transferred to polythene sleeves of size 6 by 4cm in the glass house in Chepkoilel. The potting media used in the sleeves was prepared by mixing top soil, murram, sand and farmyard manure in the volume ratio 2:1:1:1 respectively. A contact pesticide, mocap 10 GR (a.i ethoprophos) at a rate of 50kg/ha was added during the infilling of the polythene sleeves to control soil borne pests especially nematodes. The seedlings were raised in the glass house for one month (August 2009) after which they were transplanted in the experimental sites in September 2009 after having attained a height of 8 - 10cm and having 4 true leaves. All the nursery management practices were performed as recommended.

3.1.3 The layout of the Experimental plot

The experimental plot measuring 20 × 13 ($260m^2$) was divided into three blocks each having 15 experimental units of 2 × 2 (4 m^2) with paths of 0.5 m separating them.

20M

BLOCK 1 BLOCK 2

BLOCK 3

13M

N3S3	FYSI	N2S1		N3S2	FYS1	N2S3		N3S2	NOS3	FYS1
NOS2	N3S1	N2S3		N0S2	N3S3	N0S1		N0SI	FYS3	N1S3
FYS2	N0S3	N3S2		N2S1	N0S3	N3S1		N2S2	N3S3	N2S3
FYS3	N0S1	NIS2		N1S1	FYS2	N1S3		N3S1	N2S1	FYS2
N1S1	N2S2	N1S3		N2S3	NIS2	FYS3		N0S2	N1S2	N1S1

Figure 3.1 the layout of the experimental plot.

Key
Plant density
S1 – 70 × 60 cm
S2 – 70 × 45 cm
S3 –70 ×30 cm

Nitrogen
N0 - 0 kgN/ha
NI - 40.5 kgN/ha
N2 - 81 kgN/ha
N3 - 121.5 kgN/ha
FY – 80kgN/ha (Farmyard manure).

3.1.4 Transplanting in the experimental sites

Initial ploughing was done, which was followed by harrowing. The crop was subjected to different plant density treatments during transplanting. Plant density was varied in the experimental units whereby three plant densities were adopted, 70 × 60cm (23, 809 plants per ha) low plant density, 70 × 45cm (31,746 plants per ha) intermediate plant density and 70 × 30cm (47, 619 plants per ha) high plant density (Ahmed, 2001). During transplanting, farmyard manure was only applied in the experimental units where it was the source of nitrogen at a rate of 25tons/ha giving 80KgN/ha

3.1.5 Top dressing

It was during top dressing that the different nitrogen levels using CAN (27:0:.0) were applied. The different levels were 0, 40.5, 81 and 121.5 kgN/ha. The first split application was done 2 weeks after transplanting whereby 13.5, 27 and 40.5 kgN/ha were applied. Top-dressing was not done in the experimental units where farmyard manure was the source of nitrogen. The second split application was done 4 weeks later with an application of 27, 54 and 81 KgN/ha.

3.1.6 Weeding

Timely and careful weeding was done to reduce competition for nutrients and prevent mechanical damage to the various plant parts. Mulching was done to suppress the weeds and also to prevent soil moisture loss.

3.1.7 Pests and disease control

Aphids and red spider mites were controlled with a spray of *Dictator Plus* 2.8.7 EC at a rate of 0.8litres/ha. The diseases observed were blight and leaf spot which were controlled with an application of Milraz WP 76 at a rate of 2kg/ha see (Appendix i Plate 1). Field sanitation was also practiced to minimize the use of pesticides.

3.1.8 Harvesting and handling

Generally harvesting started from the 10th week after transplanting and continued for 6 weeks. The fruits were harvested at mature green stage when they were firm. The stalk was carefully cut using a sharp knife ensuring a smooth cut. The harvested fruits were then taken to a shade where cleaning and sorting was done. Finally the produce was packed in crates and transported to the market.

3.2 Experimental Design

Randomized Complete Block Design (RCBD) was used and the treatments were combined in a factorial arrangement, whereby two factors were investigated i.e. plant density and nitrogen at three and five levels respectively. The treatments were replicated three times giving a total of 45 experimental units.

Treatment combinations:

Treatment 1 - 0KgN/ha +70 × 60cm.

Treatment 2 - 0KgN/ha + 70 × 45cm.

Treatment 3 - 0KgN/ha+70 × 30cm.

Treatment 4 - 40.5KgN/ha +70× 60cm.

Treatment 5 - 40.5KgN.ha+70× 45cm.

Treatment 6 - 40.5KgN.ha + 70 × 30cm.

Treatment 7 - 81KgN/ha + 70 × 60cm,

Treatment 8 - 81KgN/ha + 70 × 45cm.

Treatment 9 - 81KgN/ha + 70 × 30cm.

Treatment 10 - 121.5KgH/ha + 70 × 60cm.

Treatment 11 - 121.5KgNha + 70 × 45cm.

Treatment 12 - 121.5KgN/ha + 70 × 30cm

Treatment 13 - 80KgN/ha (farmyard manure) + 70 × 60cm.

Treatment 14 - 80KgN/ha (farmyard manure) + 70 × 45cm.

Treatment 15 – 80KgN/ha (farmyard manure) + 70 × 30cm.

3.3 Data Collection

3. 3.1 Vegetative parameters

Plant height and the number of branches per plant

During transplanting, three plants were tagged at random in each experimental unit and their initial heights were taken at this stage. These were the plants used in measuring plant height and counting the number of branches every fortnight. Plant height was measured using a meter rule from the ground level to the growing tip of the main stem and expressed in centimeters.

3.3.2 Days to attainment of 50% flowering

The number of days taken after transplanting for 50% of the plants in the experimental units to flower was recorded.

3.3.3 Fruit yield per experimental unit

Generally harvesting started 10 weeks after transplanting and continued for 6 weeks. Harvesting was done on weekly basis. The mature fruits harvested per experimental unit from each harvest were weighed in kilograms, summed up and expressed as yield per experimental unit.

3.3.4 Quality parameters

Fruit diameter

Three mature fruits were picked at random in each experimental unit and the diameter measured using a tape measure and recorded in millimeters. Scoring for different pests and diseases was done according to procedure laid by Sutherland *et al., (*1996) shown below. Three plants were picked at random in each experimental unit for scoring.

Pests

Aphids

Scale 0 - 3 where

0 = no aphids present

1 = less than 50 individuals per plant

2 = 50 - 100 individuals per plant

3 = greater than 100 individuals per plant

Diseases

General protocol for scoring severity of leaf disease e.g. powdery mildew

Scale 0 - 3 where

0 = no spots

1 = 1 - 10% (few spots) on < 50% of leaves

2= 1 - 10% spots on > 50% of leaves or 10 – 30% spots on < 50% of the leaves.

3 = > 30% spots on > 50% of leaves

Blight (*Phytophthora capsici*) disease severity model

Present + absence –

Bacterial wilt (*Pseudomonas solanacearu*m)

Presence + Absence –

Viral disease – presence + absence –

Bacterial spot (*Xanthomones campestris*) - portion of fruit affected.

Blossom end rot – portion of fruit affected.

Mechanical damage

Three mature fruits were picked at random in each experimental unit and observed for mechanical damage.

3.4 Statistical analysis

The experimental data was subjected to Analysis of variance (ANOVA) using GLM in Genstat (2005). The general linear model in the analysis was:-

$Уijk = \mu + Ti + Bij + Lij + I\ \varepsilon jk$

Where;	Уijk	= Plot observation
	μ	= Mean of plot observation
	Ti	= Treatment effect
	Bij	= Block effect
	Lij	= Interaction effect
	εijk	= Experimental error

Means were separated by Tukey’s Studentized Range (HSD) at $P \leq 0.05$.

CHAPTER FOUR

RESULTS

4.1 Soil and farmyard manure characteristics

The soils were strongly acidic according to classification by Kenya Agricultural Research Institute (KARI) (Kanyanjua *et al.*, 2002). The C: N was slightly lower than 10:1 which is normally found in cultivated land (Table 4.1). The soils were low in nitrogen (< 0.2%) and phosphorus (< 10mg/kg) all below the critical levels indicated in the brackets as described by Okalebo *et al* (2002).

Table 4.1 Soil and farmyard manure characteristics of the experimental sites

Parameter	**Turbo**	**Kapsaret**	**Farmyard manure**
N (%)	0.14	0.12	0.32
P %mg/kg	5.8	5.2	6.5
0. C (%)	2.9	2.8	3.3
P^H	4.9	4.5	6.7
C:N	9.06:1	9.33:1	10: 1

4.2 Effects of plant density and nitrogen on plant height (cm)

Plant Density had no significant effect on the height of sweet pepper throughout the experimental period (2 weeks.4 weeks, 6 weeks, 10 weeks, 14 weeks and 16 weeks) in Turbo. (Table 4.2). Data taken at 6 weeks indicated that an application of 121.5 kgN /ha resulted in significantly taller plants as compared to control (Table 4.2). However, this treatment was not significantly different from 80KgN/ha (farmyard manure) (Table 4.2). Nitrogen treatment had no effect on plant height in the rest of the experimental period compared to control (2 weeks, 4 weeks, 10 weeks, 14 weeks and 16 weeks) (Table 4.2). See appendix iii (1)

Table 4.2 Effects of plant density an nitrogen on plant height (cm) during the experimental period at Turbo

TREATMENTS							
Plant Density	Initial	2wks	4 wks	6 wks	10 wks	14 wks	16 wks
70 x 60cm	6.82a	12.51a	1922a	30.00a	48.44a	55.27a	60.60a
70 x 45cm	7.16a	11.98a	18.67a	32.07a	48.69a	55.80a	62.16a
70 x 30cm	7.78a	13.0a	19.49a	32.20a	47.33a	56. 20a	61.96a
$HSD_{0.05}$	0.99	1.40	2.11	3.42	4.24	4.09	4.56
Nitrogen							
0 kgN/ha	6.49a	11.22b	18.52 ab	29.11c	49.26a	54.25a	58.74a
40.5 kgN/ha	7.19a	13.30 ab	18.41 ab	30.07bc	46.52a	53.56a	59.56a
81 kgN/ha.	7.22a	12.41 ab	18.15b	28.89c	46.89a	56. 33a	63.48a
121.5 kgN/ha	7.81a	13.49 a	19.07a	35.56a	48.37a	55.56a	61.44a
80KgN/ha	7.63a	13.22ab	21.48a	34.82ab	49.44a	58.74a	64.63a
$HSD_{0.05}$	1.4 9	2.10	3.19	5.15	6.40	6.17	6.87
CV%	5.2	8,6	2.0	5.3	6.0	6.9	8.6

Means followed with the same letters are not significantly different at $P \leq 0.05$

In Kapseret, Planting sweet pepper at high plant density (70 × 30cm) resulted in significantly taller plants at 4 weeks as compared to low plant density (70× 60cm) (Table 4.3) while the intermediate plant density (70 × 45cm) resulted in plants of medium height (Table 4.3). Plant density had no significant effect on the height of sweet pepper plants in the rest of the experimental period (2 weeks, 6 weeks, 8 weeks. and 12 weeks) (Table 4.3). Applying different levels of nitrogen in the form of farmyard manure or CAN had no significant effect on the height of sweet pepper as compared to control throughout the experimental period (Table 4.3). See appendix iii (1)

Table 4.3 Effects of plant density and nitrogen on plant height (cm) during the experimental period in Kapseret

Treatments	**Initial**	**2weeks**	**4 weeks**	**6 weeks**	**8 weeks**	**12 weeks**
Plant Density						
70 x 60cm	9.84a	13.11a	15.60b	18.98a	21.60a	24.60a
70 x 45cm	10.20a	13.98a	16.84a	19.96a	22.71a	25.93a
70 x 30cm	11.00a	13.98a	17.82a	19.82a	22.56a	25.20a
$HSD_{0.05}$	2.06	2. 13	2.16	2.22	2.2 9	2.52
Nitrogen						
0 kgN/ha	11.70a	14.44a	17.70a	20.04 ab	22.52 ab	25.85 ab
40.5 kgN/ha	10.15a	12.70a	16.22a	18.26b	20.93b	22.67b
81 kgN/ha	10.00a	13.56a	15.52a	18.67 ab	21.44 ab	25.63 ab
121.5 kgN/ha	10.30a	13.30a	15.78a	19.33 ab	21.85 ab	25.30 ab
80KgN.ha	9.59a	14.44a	18.56a	21.63a	24.70a	26.78 a
$HSD_{0.05}$	3.11	3.21	3.25	3.35	3.46	3.80
C.V%	6.0	6.3	4.5	4.7	4.7	6.9

Means followed with the same letters are not significantly different at $P \leq 0.05$

4.3 Effects of plant density and nitrogen on the number of branches

Plant density had no significant difference on number of branches throughout the experimental period (2 weeks, 4 weeks, 6 weeks, 10 weeks and 14 weeks) in Turbo (Table 4.4). Data taken at 6 weeks indicated that nitrogen rate of 81kgN/ha resulted in sweet pepper plants with more branches as compared to control (Table 4.4). However, this treatment was not significantly different from 121.5 kgN/ha, 80KgN/ha (farmyard manure) and 40.5KgN/ha (Table 4.4). In the rest of the experimental period, nitrogen had no significant effect on the number of branches (2 weeks, 4 weeks, 10 weeks, and 14 weeks) (Table 4.4). See appendix iii (2)

Table 4.4 Effects of plant density and nitrogen on the number of branches during the experimental period in Turbo

	Number of branches				
Treatments	2weeks	4weeks	6weeks	10weeks	16 weeks
Plant Density					
70 x 60cm	4.00a	5.00a	7.00a	13.00a	32.00a
70 x 45cm	3.00a	5.00a	7.00a	13.00a	31.00a
70 x 30cm	3.00a	5.00a	8.00a	12.00a	29.00a
$HSD_{0.05}$	0.74	0.71	0.93	1.58	3.90
Nitrogen					
0 kgN/ha	3.00a	5.00a	7.00b	13.00a	29.00a
40.5 kgN /ha	3.00a	5.00a	7.00 ab	12.00a	30.00a
81 kgN/ha	4.00a	5.00a	8.00a	14.00a	33.00a
121.5 kgN/ha	4.00a	5.00a	8.00a	14.00a	33.00 a
80 KgN/ha/ha	3.00a	5.00a	7.00 ab	12.00a	30.00a
$HSD_{0.05}$	1.10	1.06	1.41	2.39	5.88
C.V%	8.8	4.4	2.3	3.4	8.0

Means followed with the same letters are not significantly different at $P \leq 0.05$.

In Kapseret, at 4 weeks low plant density (70 × 60cm) produced sweet Pepper plants with more branches as compared to high plant density (70 × 30cm) (Table 4.5). The intermediate plant density (70 × 45cm) resulted in moderately branched sweet pepper plants (Table.4.5). Plant density had no significant effect on the number of branches in the rest of the experimental period. (2 weeks, 6 weeks, 8 weeks and 12 weeks) (Tsable 4.5). Application of different levels of nitrogen in form of CAN or farmyard manure had no significant effect on the number of branches as compared to control throughout the (Table 4.5).See appendix iii (2)

Table 4.5 Effects of plant density and nitrogen on the number of branches during the experimental period in Kapseret

Number of branches					
Treatments	**2weeks**	**4 weeks**	**6 weeks**	**8 weeks**	**12 wks**
Plant Density					
70 x 60cm	2.00a	2.00a	4.00a	6.00a	13.00a
70 x 45cm	2.00a	2.00 ab	4.00a	6.00a	13.00a
70 x 30cm	2.00a	2.00b	4.00a	5.00a	12.00a
$HSD_{0.05}$	0.58	0.57	0.91	1.10	2.31
Nitrogen					
0 kgN/ha	2.00 ab	2.00a	4.00a	6.00a	13.00ab
40.5 kgN/ha	2.00b	2.00a	4.00a	6.00a	10.00b
81 kgN/ha	2.00a	2.00a	4.00a	5.00a	11.00 ab
121.5 kgN/ha	2.00 ab	2.00a	4.00a	6.00a	15.00a
80KgN/ha	2.00a	2.00a	5.00a	6.00a	13.00 ab
$HSD_{0.05}$	0.87	0.85	1.37	1.66	3.47
C.V%	37	18.1	9.1	9.7	6.8

Means followed with the same letters are not significantly different at $P \leq 0.05$.

4.4 Interaction effects of site, plant density and nitrogen on the height of sweet pepper

Sweet pepper plants grown in Turbo were taller than those grown in Kapseret (Table 4.6). A treatment combination of 121.5 KgN/ha and 70 × 60cm produced the tallest plants in Turbo while the shortest plants came from 40.5KgN/ha and 70 × 45cm in Kapseret (Table 4.6). See appendix iii (3).

Table 4.6 Interaction effects of site, plant density and nitrogen on plant height at harvesting stage (cm).

	Spacing (cm)	Nitrogen rates (KgN/ha).				
Site		0	40.5	81	121.5	80
Turbo	70 × 60	54.65	51.17	57.33	73.31	67.37
	70 × 45	55.24	63.61	54.75	65.18	62.02
	70 ×30	50.55	62.32	59.16	51.09	61.00
Kapsaret	70 × 60	27.03	27.02	26.01	26.38	22.02
	70 × 45	25.76	21.31	27.51	25.28	25.02
	70 × 30	27.23	27.05	26.23	22.57	22.02
HSD	Site × spacing × nitrogen			4.512		
CV%				2.30		

4.5 Interaction effects of site, plant density and nitrogen on the number of branches.

Plants grown in Turbo had more branches as compared to those grown in Kapseret (Table 4.7). A treatment combination of 121.5KgN/ha and 70 × 60cm produced sweet pepper plants with the highest number of branches while the least number of branches came from a combination of 0KgN/ha and 70× 30cm (Table 4.7). See appendix iii (4).

Table 4.7 Interaction effects of site, plant density and nitrogen on the number of branches

	Spacing(cm)		Nitrogen rates (Kg/ha)				
Site			0	40.5	81	121.5	80
Turbo	70×60		30.00	31.00	31.00	36.00	31.00
	70×45		30.00	35.00	32.00	30.00	30.00
	70×30		26.00	25.00	35.00	26.00	34.00
Kapsaret	70×60		17.00	12.00	15.00	14.00	11.00
	70×45		14.00	10.00	14.00	14.00	13.00
	70×30		9.00	10.00	14.00	13.00	10.00
HSD	Site× Spacing × nitrogen				3.143		
CV%					2.30		

4.6 Interaction affects of plant density and nitrogen the quality of sweet pepper in Turbo

An interaction of 81KgN/ha and 121.5KgN/ha with high (70 × 30cm) and intermediate (70 × 45cm) plant densities resulted in the lowest aphids and leaf spot incidence while 40.5KgN/ha and 70 × 60cm recorded the highest aphids and leaf spot attacks (Table 4.8). A combination of 121.5KgN/ha and 70 × 45cm produced the largest sweet pepper fruits (table 4.8). Mechanical damage and blossom end rot were not recorded.

Table 4.8 Interaction effects of plant density and nitrogen on the quality of sweet pepper in Turbo

Treatment	Aphids	Leaf spot	Fruit diameter (mm)	Mechanical damage	Blossom end rot
0KgN/ha+70×60cm	0.22	0.33	46.10	0	0
0KgN/ha+70×45cm	0.56	0.55	50.00	0	0
0KgN/ha+70×30cm	0.56	0.44	41.00	0	0
40.5KgN/ha+70×60cm	1.50	1.33	46.10	0	0
40.5KgN/ha+70×45cm	0.33	0.33	43.30	0	0
40.5KgN/ha+70×30cm	0.22	0.22	41.66	0	0
81KgN/ha+70×60cm	1.33	0.40	52.00	0	0
81Kg/ha+70×45cm	0.11	0.11	42.00	0	0
81KgN/ha+70×30cm	0.11	0.11	39.37	0	0
121.5KgN/ha+70×60cm	1.00	1.00	47.00	0	0
121.5KgN/ha+70×45cm	0.11	0.11	53.00	0	0
121.5KgN/ha+70×30cm	0.11	0.11	40.00	0	0
80KgN/ha+70×60cm	0.99	0.77	47.20	0	0
80KgN/ha+70×45cm	0.44	0.56	45.55	0	0
80KgN/ha+70×30cm	0.33	0.33	40.50	0	0
HSD	0.608	O.529	6.363	0.	0

4.7 Interaction effects of plant density and nitrogen on the quality of sweet pepper in Kapseret

Treatment Combinations of 40.5KgN/ha +70× 60cm; 81KgN/ha + 70 × 60cm and 80KgN/ha + 70 × 45cm resulted in the lowest aphids and leaf spot incidence (Table 4.9). The highest aphids and leaf spot incidence were recorded in a treatment combination of 40.5KgN/ha and 70 × 30cm (Table 4.9). An interaction of 0KgN/ha with 70 × 60cm produced the largest fruits which were highly damaged while 80KgN/ha and 70 × 30cm resulted in the smallest fruits (Table 4.9).

Table 4.9. Interaction effects of plant density and nitrogen on the quality of sweet pepper in Kapseret

Treatment	Aphids	Leaf spot	Fruit diameter (mm)	Mechanical damage	Blossom end rot
0KgN/ha+70×60cm	1.00	1.00	54.00	0.66	0
0KgN/ha+70×45cm	0.88	1.00	48.00	0.44	0
0KgN/ha+70×30cm	0.33	0.33	46.10	0	0
40.5KgN/ha+70×60cm	0.11	0.11	41.60	0	0
40.5KgN/ha+70×45cm	0.11	0.20	40.00	0	0
40.5KgN/ha+70×30cm	1.33	1.20	38.88	0.20	0
81KgN/ha+70×60cm	0.11	0.11	50.00	0	0
81Kg/ha+70×45cm	0.33	0.77	38.00	0	0
81KgN/ha+70×30cm	0.11	0.11	43.00	0	0
121.5KgN/ha+70×60cm	0.67	0.66	48.30	0	0
121.5KgN/ha+70×45cm	0.77	0.33	46.60	0	0
121.5KgN/ha+70×30cm	1.00	1.00	37.00	0	0
80KgN/ha+70×60cm	0.11	0.67	47.77	0.20	0
80KgN/ha+70×45cm	0.11	0.11	41.11	0.10	0
80KgN/ha+70×30cm	1.10	1.20	31.00	0	0
HSD	0.784	0.748	6..354	0.077	0

4.8 Effects of plan t density and nitrogen on the days to 50% flowering and fruits yield

In the combined data analysis, planting sweet pepper at the intermediate plant density (70 × 45cm) took fewer days to attain 50% flowering as compared to those planted at high plant density (70 × 30cm) (Table 4.10). However the intermediate plant density was not significantly different from low plant density (70 × 60cm) (Table 4.10). Applying 81 kgN/ha hastened the onset of flowering in sweet pepper as compared to control (Table 4.10). All the other nitrogen treatments had no significant effect on the number of days to 50% flowering as compared to control (Table 4.10).

Planting sweet pepper at the intermediate plant density (70 × 45cm) resulted in higher fruit yield as compared to low plant density (70 × 60cm) although all the three plant density treatments were not significantly different (Table 4.10). Application of nitrogen in the form of CAN or farmyard manure had no significant effect on the fruit yield as compared to control (Table 4.10). Sweet pepper grown in Turbo took a shorter time to attain 50% flowering and produced high fruit yield as compared to those grown in Kapseret (Table 4.10). See appendix iii (5).

Table 4.10 Effects of plant density and nitrogen on days to 50% flowering and fruits yield

Plant density	**Days to 50% flowering**	**Fruit weight (Kg/m^2)**
70× 60cm	44.20a	1.50a
70 × 45cm	42.30b	1.60a
70 × 30cm	45.30a	1.57a
HSD $_{0.05}$	2.25	0.33
CV (%)	0.2	3.4
Nitrogen		
0KgN/ha	46.61a	1.65a
40.5KgN/ha	44.44ab	1.22a
81KgN/ha	41.17b	1.50a
121.5KgN/ha	44.11ab	1.68a
80KgN/ha	43.33a	1.71a
HSD $_{0.05}$	3.39	0.49
CV (%)	0.5	3.4
Site		
Turbo	36.96b	1.93a
Kapsaret	50.91a	1.17b
HSD $_{0.05}$	1.53	0.22
CV(%)	8.28	34.16

Means followed with the same letters are not significantly different at P≤ 0.05

4.9 Interaction effects of site, plant density and nitrogen on the days to 50% flowering

An interaction of 81KgN/ha with all the three plant densities enhanced flowering in Turbo while treatment combinations of 81KgN/ha + 70 ×45cm; 0KgN/ha +70 ×30cm; 40.5KgN/ha + 70 × 30cm and 80KgN/ha + 70 × 60cm took the longest period to attain 50% flowering in Kapsaret. (Table 4.11). See appendix iii (5).

Table 4.11 Interaction effects of site, plant density and nitrogen on days to 50% flowering

	Spacing (cm)	Nitrogen (KgN/ha)				
Site		**0.KgN/ha**	**40.5Kg/ha**	**81KgN/ha**	**121.5KgN/ha**	**80KgN/ha**
Turbo	70 × 60	42.00	42.00	35.00	35.33	35.00
	70 × 45	41.67	35.33	35.00	35.33	35.33
	70 × 30	41.67	35.00	35.00	41.67	35.33
Kapseret	70 × 60	49.33	43.00	48.67	53.67	55.67
	70 × 45	49.33	43.00	55.67	49.33	43.00
	70 × 30	55.67	55.67	54.67	51.67	55.67
HSD	site× plant density × nitrogen			4.008		
CV%	Site × plant density × nitrogen			0.80		

4.10 Interaction effects of site, plant density and nitrogen on fruit yield Kg/4m^2.s

A Treatment combination of 80KgN/ha and 70 × 30cm gave the highest fruit yield in Turbo while the lowest fruit yield came from 80KgN/ha and 70 × 60cm in Kapseret (Table 4.9). See appendix iii (6).

Table 4.12 Interaction effects of site, plant density and nitrogen on fruit yield Kg/4m^2

	Spacing (cm)	Nitrogen (KgN/ha)				
Site		0	40.5	81	121.5	80
Turbo	70 × 60	1.45	2.16	1.27	2.04	1.68
	70 × 45	2.23	1.44	2.00	2.04	2.31
	70 × 30	1.82	2.04	1.42	2.43	2.64
Kapsaret	70× 60	2.53	1.86	0.73	1.09	0.36
	70 × 45	0.57	1.13	1.05	1.93	0.57
	70 × 30	0.56	1.29	1.72	1.06	0.77
HSD	Site× plant density × nitrogen.			0.371		
CV%				0.80		

CHAPTER FIVE

DISCUSSION

5.1 Effects of plant density and nitrogen on plant height

Investigation at different growth periods indicated that at 4 weeks in Kapseret high plant density (70 × 30cm) resulted in the tallest sweet pepper plants while the shortest plants came from low plant density (70 × 60cm). This difference in plant height at the vegetative phase can be attributed to competition for available space and light resulting in tall plants. Similar increase in plant height at high plant densities were reported by Pandey *et a*l., (1996), Umesh (2008) and Papadopoulous and Ormrod (1991). These findings were in conflict with observations of Elatir (2002), De-viloria *et al*., (2002) and Ara *et al.,* (2007) who reported the highest plant height at vegetative and flowering stages at decreased plant densities. They attributed this to the availability of resources for growth under low plant densities.

In Turbo, data taken at 6 weeks indicated that an application of 121.5kgN/ha resulted in the tallest plants while the shortest plants were recorded in control. This increase in height resulting from high nitrogen levels can be due to an increase in nitrogen uptake which enhances growth and development (Patil and Biradar, 2001). This was in agreement with Bar *et al.,* (2001), Khan *et al*., (2010) and Aminifard *et al*., (2012). At harvesting stage, an interaction of 121.5KgN/ha with 70 × 60cm produced the tallest plants. This can be attributed to availability of nitrogen and adequate resources for growth.

Sweet pepper plants grown in Turbo were taller than those grown in Kapsaret. This can be attributed to the difference in altitude in the two sites. Turbo is lower (1500m - 1900m above sea level) and warmer than Kapsaret which is at 1600m - 2030m above sea level. The conditions in Turbo enhanced plant growth as Soethe *et al*., (2008) reported that in the tropics, Above ground Net Primary Productivity (ANPP) usually decrease with increasing altitude mainly due to low photosynthesis and direct impact of low temperature on plant growth.

5.2 Effects of plant density and nitrogen on the number of branches

At 4 weeks in Kapseret, low plant density (70 × 60cm) had the highest number of branches while the lowest number of branches was observed in high plant density (70 ×30cm). The widely spaced plants were able to utilize the available space and resources which resulted in more branching. Law-Ogbomo and Egharevba (2009) reported that low plant density per unit area produces more vigorous crops than higher plant densities. Samin (2008) explained that as plant density increases competition for water, .nutrients and light increases and this restricts vegetative growth, these results were in agreement with those reported by Jovicich *et al*., (2003), Abubaker (2008) and Hossein *et al*., (2006).

Investigation on the number of branches as influenced by nitrogen indicated that at 6 weeks in Turbo, 81kgN/ha produced the highest number of branches while the least number of branches were recorded in control. Nitrogen is an essential nutrient as it a major component of amino acids and enzymes and so is very necessary during the vegetative stage (Basela and Mahadeen, 2008). The reduced branching at this particular stage could be attributed to the absence of nitrogen. At harvesting stage, an interaction of 121.5KgN//ha with 70 × 60cm produced plants with highest number of branches. This increase in the number of branches at high nitrogen levels can be attributed to increased nutrient uptake associated with increased nutrient levels. Neginahal *et al., (*2009) showed that nitrogen when applied at the highest level 150kgN/ha increased leaf area enhancing the process of photosynthesis which led to more vegetative growth. Similar results were reported by Ekwu and Okporie (2006) who had the highest number of branches with the highest nitrogen levels. The widely spaced plants were highly branched as they had enough nutrients and light for maximum vegetative growth. These results concurred with the findings of Umesh (2008).

Sweet pepper plants grown in Turbo had more branches as compared to those grown in Kapseret. This can be attributed to the soil characteristics in the two sites. Turbo soils are mainly acrisls, well drained, deep and thus able to provide the plants with the nutrients required for growth and development. On the contrary, Kapseret soils are mainly ferralsols with variable fertility mainly low so deficient in some nutrients. The mean temperature in Turbo favor sweet pepper growth while Kapseret records very low minimum temperature of 9^0C which is unfavorable for sweet pepper growth and development

5.3 Interaction effects of plant density and nitrogen on aphids and leaf spot incidence.

In Turbo, an interaction of 81KgN/ha and 121.5KgN/ha with high (70×30cm) and intermediate (70 × 45cm) plant densities recorded the lowest aphids and leaf spot incidence The highest pest and disease incidence was observed in a combination of 40.5KgN/ha and 70 × 60cm. Similar findings were reported by Yamamura (2002) who observed that increasing the number of collard plants per hectare reduced the number of pests per leaf surface thereby reducing the damage on the crop. Further observations were that the number of insect pests per plant decreased with increased plant density as a result of dilution of colonies among the plants. Accordingly incidences of insect borne viral diseases decrease with increasing plant densities. Application of 121.5 kgN/ha and 81KgN/ha led to low pest incidence probably due increased nitrogen uptake leading to the availability of other nutrients for growth and development. Patil and Biradar (2001) observed that increased nitrogen rates enhanced the uptake of potassium and phosphorus. Warner *et al*., (2004) stated that maximum marketable fruit yield was achieved with nitrogen rate of 150kg/ha, whereby marketable fruits were those with fruit size greater than 40mm, without cracks, blemishes, diseases and other physiological disorders.

In Kapseret, generally low plant densities resulted in low pest incidence while high plant densities recorded high incidence. Plant density influences the interaction among pests and diseases and most fungal diseases increase with increasing plant densities due to the mode of transmission (Yamamura, 2002) .The climatic conditions in this area could not produce vigorously growing plants as indicted by growth parameters. The closely spaced plants which experienced competition for available resources were weak and prone to pest and disease attack. Low and intermediate nitrogen levels led to reduced pest incidence It was also observed that high nitrogen levels led to increased pest and disease incidence. This was in agreement with Warner *et al*. (2004) who reported that nitrogen application above 100kgN/ha increased yield of green fruits but little yield of marketable fruits was observed with rates above 150kgN/ha. The difference in the climatic conditions in Turbo and Kapseret could have contributed to the contrasting results. In Kapseret the plants were stunted and those planted at low plant density and the intermediate plant densities were able to utilize the available space for growth and development and were able to resist pest and diseases.

5.4 Interaction effects of plant density and nitrogen on fruit diameter, mechanical damage and blossom end rot.

In Turbo an interaction of 121.5KgN/ha with 70 × 45cm produced the largest fruit while the smallest fruit came from 40.5KgN/ha and 70 × 30cm. The largest fruits in Kapseret came from a combination of 0KgN/ha and 70 × 60cm while a treatment combination of 80KgN/ha and 70 × 30cm produced the smallest fruits. The interactions indicate that the fruit size increased at low plant densities. This can be attributed to more vegetation leading to more dry matter accumulation, more leaf area and ample sunlight under low plant density (Umesh, 2008). This was in agreement with the findings of Nagendraprasad (2001) in bell pepper. The competition for resources experienced by closely spaced plants resulted in lower weight and fruit volume (Aminifard *et al.*, 2012). However, fruits from widely spaced plants were not firm a factor which leads to deterioration in many fruits. The reduced firmness was probably due to low accumulation of assimilates. This was in agreement with the findings of Kirimi *et al*., (2011) who explained that the reduced firmness resulted from low assimilates as most of the radiation was lost through the wide space instead of being used for assimilate formation.

In Turbo application of 121.5 kgN/ha recorded the highest fruit diameter while the smallest fruit diameter was recorded in 40.5 kgN/ha . Similar results were reported by (Bar *et al*., (2007), Devi *et al*., (2001) in egg plant production, Akambi *et al*., (2007) and Ajula *et al.*, (2007). This increase in fruit size with increased nitrogen rates can be attributed to its availability for biomass production which forms the basis for all production phases (Johnson and Decoteau, 1996). In Kapseret, the control treatment produced the largest fruits which might have resulted from exogenous factors not quantified in the experiment.

Mechanical damage was minimal as harvesting was carefully and technically done subjecting the fruits to very little or no physical damage (Anon, 2007) There was adequate moisture in the soil and root damage was minimal thus calcium uptake was not interfered with hence blossom end rot was controlled (Anon, 2010a).

5. 5 Effects of plant density and nitrogen on the number of days to attainment of 50% flowering.

The intermediate plant density (70 × 45cm) took the least number of days to attain 50% flowering (42.30days), while high plant density (70 × 30cm) took the longest period to attain 50% flowering (45.30days). These findings were in agreement with Foster *et al.* (1993) who reported that higher plant density restricts light penetration and dry matter accumulation thus reducing flower bud development. The widely spaced plants (70 × 60cm) utilized the available resources for more vegetative growth delaying the reproductive stage. Applying 81kgN/ha enhanced flowering (41.17 days) while control took the longest time to attain 50% flowering (46.61 days). This can be attributed to the fact that nitrogen encourage vegetative growth which enables the plant to enter the next stage i.e reproductive stage, thus in the absence of nitrogen this stage is delayed. However with increased nitrogen levels 121.5 kgN/ha, days to 50% flowering also increased (44.11 days). These results were in agreement with Aminifard *et al*., (2010b) in egg plant production. It means that nitrogen enhanced vegetative growth but retarded reproductive growth. Guohua *et al*., (2001) found that flowering was delayed with increase in nitrogen rates due to diversion of photosynthates for vegetative growth of plants. . Accordingly a treatment combination of 81KgN/ha and the three densities took the shortest period to attain 50% flowering. Sweet pepper plants grown in Turbo flowered earlier than those grown in Kapseret due to the favourable climatic conditions.

5.6 Effects of plant density and nitrogen on fruit yield (Kg/4m^2).

The intermediate plant density (70 × 45cm) recorded the highest fruit yield while low plant density recorded the lowest yield. This increase in yield with increased plant densities can be attributed to high plant population resulting in more fruit yield per unit area. Similar results were observed by Russo (2003), Nasto *et al.*, (2009) and Khasmakhi-Sabet *et al., (*2009) who reported that the greatest fruit yield of sweet pepper and other plants were obtained from plants grown at high densities The intermediate plant density (70 × 45cm) produced the highest fruit yield probably due to an early crop as it was able to balance vegetative and reproductive growth.

An application of 80KgN/ha (Farmyard manure) gave the highest fruit yield followed by 121.5 kgN/ha. The lowest fruit yield came from 40.5kgN/ha although the treatments were not statistically different from control. This can be attributed to the fact that nitrogen encouraged vegetative growth and branching which led to more reproductive structures and biomass production This was in agreement with the findings of Khan *et al.*, (2010) and Devi *et al*., (2002) who found better fruit girth, fruit weight and fruit yield level of egg plant with an application of 120kgN/ha. An interaction of 80KgN/ha (farmyard manure) with high (70 × 30cm) and low (70 × 60cm) produced the highest and the lowest fruit yield respectively. This increase in fruit yield at increased plant densities resulted from the number of fruit per unit area. Farmyard manure recorded the highest fruit yield probably due to the fact it reduces the acidity in the soil making it more favorable for sweet pepper growth and development.

6.1 Conclusions.

Based on the findings of the study, Plant density and nitrogen had an influence on growth, reproductive and quality parameters and can be used to improve the quality and marketable yield of sweet pepper grown in Uasin Gishu County. Plant height, the number of branches and fruit diameter increased at low plant density (70 × 60cm) while the intermediate plant density (70 × 45cm) took the shortest time to attain 50% flowering.

Plant height and the number of branches increased at high nitrogen levels (121.5KgN/ha). Applying nitrogen at 81 kgN/ha hastened the onset of 50% flowering while 80KgN/ha in form of farmyard manure produced the highest fruit yield which were of low quality.

The interaction effects were significant whereby 121.5KgN/ha and 70 × 60cm produced vigorous growing sweet pepper plants. The moderate nitrogen level (81KgN/ha) combined with the three plant densities and enhanced flowering and produced the highest quality fruits A treatment combination of 80KgN/ha (farmyard manure) and 70 × 30cm produced high fruit yield unfortunately high incidence of aphids and leaf spot were observed .

Turbo site produced vigorously growing sweet pepper plants which were tall, had the highest number of branches, took the shortest time to attain 50% flowering and produced the highest fruit yield.

6.2 Recommendations

Sweet pepper should be grown in low altitude areas like Turbo in Uasin Gishu County for enhanced plant growth and high yield. In addition the intermediate plant density (70 × 45 cm) and 81kgN/ha should be adopted by growers.

In this treatment combination the plants were able to utilize the available resources efficiently for the production of high quality sweet pepper fruits with the specified size in the export market (40- 45mm) thus recording high marketable fruit yield..

6.3 Suggestions for future research

The effects of pruning methods and plant density on growth, yield and quality of sweet pepper.

The yield of sweet pepper as influenced by cutting of the tips at different stages and harvesting duration.

The influence of the different types of manure on the growth, yield and quality of sweet pepper.

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APPENDICES

Appendix I : Management practices in the experimental sites

Plate 1: Management practices in the experimental sites

Turbo site : Source : Author, 2009

Kapseret site**:** Source : Author, 2009

Appendix II: Mature fruits

Plate 2. Mature fruits.

70 x 45cm + Nitrogen 81kgN/ha (Kapseret)

70x60cm + 81kgN/ha (Kapseret)

70 x 30cm + 81kgN/ha (Turbo)

70 x 60cm + 81kg N/ha (Turbo)

70 x 45cm + 81kgN/ha (Turbo)

Source : Author, 2009

Appendix III: Analysis of Experimental Results.

Genstat system.

Analysis of variance.

Variate: Initial height Turbo (1)

Source of variation	d.f	s.s	m.s	v.r	F.Pr.
Block. stratum	2	12.904	6.452	1.64	
Nitrogen	4	31.807	7.952	2.02	0 .096
Spacing	2	21.170	10.595	2.69	0. 072
Spacing . nitrogen	8	26.904	3.363	0.85	0. 557
Residual	118	464.852	3.938		
Total.	134	557.4			

Analysis variance
Variate:%-4weeks
Analysis of variance
Variate %6 weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	104.193	52.096	6.92	
BLOCK *units* stratum					
NITROGEN	4	85.437	21.359	2.84	0.027
SPACING	2	27.793	13.896	1.85	0.163
NITROGEN.SPACIN G	8	93.541	11.693	1.55	0.147
Residual	118	888.696	7.531		
Total	134	1199.659			

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	256.71	128.36	2.83	
BLOCK *units* stratum					
NITROGEN	2	1129.01	282.25	6.23	<.001
SPACING	4	53.73	26.87	0.59	0.554

NITROGEN.SPACING	8	548.19	68.52	1.51	0.160
Residual	118	5347.29	45.32		
Total	134	7334.93			

Analysis of variance
Variate:%10- weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	761.64			
BLOCK *units* stratum			380.82	5.81	
NITROGEN	2	170.84			
SPACING	4	46.98	23.42	0.65	0.627
NITROGEN.SPACING	8	1345.02	168.13	0.36	0.700
Residual	118	7733.24	65.54	2.57	0.013
Total	134	10057.73			

Analysis of variance
Variate: %14-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	1334.54	667.27	10./01	
BLOCK *units* stratum					
NITROGEN	2	441.23	110.31	1.66	0.165
SPACING	4	19.73	9.87	0.15	0.863
NITROGEN.SPACING	8	585.30	73.16	1.10	0.370
Residual	118	7862.13	66.63		
Total	134	10242.93			

Analysis of variance
Variate: % 16-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	2506.95	1253.47	14.94	
BLOCK *units* stratum					
NITROGEN	2		169.38	2.02	0.096
SPACING	4	677.53	32.23	0.38	0.682
NITROGEN.SPACING	8	64.46	74.39	0.89	0.530
Residual	118	595.10	83.89		
Total	134	9899.05			

Analysis of variance
Variate: initial-height - Kapseret

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	21.08	10.54	0.62	
BLOCK *units* stratum					
NITROGEN	2	69.45	17.36	1.02	400
SPACING	4	31.53	15.76	0.93	0.399
NITROGEN.SPACING	8	136.55	1707	1.00	0.438
Residual	118	2008.03	17.02		
Total	134	2266.03			

Analysis of variance
Variete:%2-Weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	59.24	29.62	1.69	
BLOCK *units* stratum					
NITROGEN	2	61.67	15.42	0.88	0.479
SPACING	4	22.53	11.27	0.64	0.528
NITROGEN.SPACING	8	212.50	26.56	1.51	0.160
Residual	118	2070.98	17.55		
TOTAL	134	557.437			

Analysis of variance
Variate: % 4-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	98.80	49.40	2.64	
BLOCK *units* stratum					
NITROGEN	2	186.56	46.64	2.50	0.046
SPACING	4	111.64	55.82	2.99	0.054
NITROGEN.SPACING	8	140.73	17.59	0.94	0.486
Residual	118	2205.20	18.69		
Total	134	2742.93			

Analysis of variance
Variate:% 6-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	71.39	35.70	1.85	
BLOCK *units* stratum					
NITROGEN	2	190.33	47.58	2.47	0.048
SPACING	4	25.30	12.48	0.66	0.521
NITROGEN.SPACING	8	219.81	27.48	1.43	0.193
Residual	118	2273.94	19.27		
Total	134	2780.77			

Analysis of variance
Variate:% 8-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	99.38	49.69	2.37	
BLOCK *units* stratum					
NITROGEN	2	233.44	58.36	2.79	0.030
SPACING	4	32.58	16.29	0.78	0.461
NITROGEN.SPACING	8	185.27	23.16	1.11	0.364
Residual	118	2469.70	20.92		
Total	134	3019.73			

Analysis variance
Variate:% 12-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	384.93	192.47	7.39	
BLOCK *units* stratum					
NITROGEN	2	256.93	64.23	2.46	0.049
SPACING	4	40.13	20.07	0.77	0.465
NITROGEN.SPACING	8	131.87	16.48	0.63	0.749
Residual	118	3075.07	26.06		
Total	134	3888.93			

Analysis of variance (2)
Variate:%2-weeks-Turbo branches

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	10.370	5.185	2.47	
BLOCK *units* stratum					
NITROGEN	2	7.156	1.789	0.85	0.496
SPACING	4	6.059	3.030	1.44	0.241
NITROGEN.SPACING	8	24.756	3.094	1.47	0.175
Residual	118	248.074	2.102		
Total	134	296.415			

Analysis of variance
Variate:% 4-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	5.615	2.807	1.53	
BLOCK *units* stratum					
NITROGEN	2	5.230s	1.307	0.71	0.586
SPACING	4	8.015	4.007	2.18	0.118
NITROGEN.SPACING	8	34.059	4.257	2.31	0.024
Residual	118	217.052	1.839		
Total	134	269.970			

Analysis of variance
Variate:% 6-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	+2.904	1.452	0.44	
BLOCK *units* stratum					
NITROGEN	2	44.859	11.215	3.37	0.012
SPACING	4	18.015	9.007	2.71	0.071
NITROGEN.SPACING	8	45.985	5.748	1.73	0.099
Residual	118	392.652	3.328		
Total	134	504.415			

Analysis of variance
Variate: % 10-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	18.86	9.43	0.92	
BLOCK *units* stratum					
NITROGEN	2	58.67	14.67	1.43	0.227
SPACING	4	41.79	20.90	2.04	0.134
NITROGEN.SPACING	8	56.36	7.04	0.69	0.701
Residual	118	1206.47	10.22		
Total	134	1382.15			

Analysis of variance
Variate: % 14-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	700.68	350.34	5.81	
BLOCK *units* stratum					
NITROGEN	2	307.26	76.81	1.27	0.284
SPACING	4	197.04	98.52	1.64	0.199
NITROGEN.SPACING	8	565.63	70.70	1.17	0.321
Residual	118	7109.99	60.25		
Total	134	8880.59			

Analysis of variance
Variate:% 2-weeks- Kapsaret branches

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	44.859	22.430	18.10	
BLOCK *units* stratum					
NITROGEN	2	12.267	3.067	2.47	0.048
SPACING	4	5.437	2.719	2.19	0.116
NITROGEN.SPACING	8	20.933	2.617	2.11	0.040
Residual	118	146.252	1.239		
Total	134	229.748			

Analysis of variance
Variate: % 4-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	13.378	6.689	5.63	
BLOCK *units* stratum				1.69	
NITROGEN	2	8.044	2.011	1.69	0.156
SPACING	4	11.200	5.600	4.71	0.011
NITROGEN.SPACING	8	20.800	2.600	2.19	0.033
Residual	118	140.178	1.188		
Total	134	193.600			

Analysis of variance
Variate:% 6-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	15.126	7.563	2.40	
BLOCK *units* stratum					
NITROGEN	2	20.370	5.093	1.62	0.174
SPACING	4	0.726	0.363	0.12	0.891
NITROGEN.SPACING	8	46.385	5.798	1.84	0..76
Residual	118	371.096	3.145		
Total	134	453.704			

Analysis of variance
Variate:% 8-weeks

BLOCK stratum	2	32.548	16.274	3.33	
BLOCK *units* stratum					
NITROGEN	2	13.585	3.396	0.69	0.597
SPACING	4	23.570	11.785	2.41	0.094
NITROGEN.SPACING	8	38.281	4.785	0.98	0.456
Residual	118	577.007	4.890		
Total	134	684.993			

Analysis of variance
Variate: %12-weeks

Source of variance	d.f	S.s	M.s	V.r	F pr.
BLOCK stratum	2	68.80	34.40	1.70	
BLOCK *units* stratum					
NITROGEN	2	358.41	89.60	4.42	0.002
SPACING	4	35.24	17.62	0.87	0.422
NITROGEN.SPACING	8	287.05	35.88	1.77	0.090
Residual	118	2392.09	20.27		
Total	134	3141.60			

Analysis of variance (3).

Variate: height.

Source of variation	d.f	s.s	m.s	v.r	F.Pr.
Block. stratum	2	59.52	29.76	1.95	
Site	1	26866.60	266866.60	1762.31	<. 001
Spacing	2	25.64	12. 82	0.84	0. 437
Nitrogen	4	79. 89	19. 97	1.31	0. 277
Site . Spacing	2	14. 96	7. 48	0.49	0. 615
Site. Nitrogen	4	384. 37	96.09	6. 30	<. 001
Spacing . nitrogen	8	651. 23	81.40	5. 34	<. 001

Site . spacing . nitrogen	8	600. 20	75. 02	4. 92	<. 001
Residual	58	884. 21	15. 25		
Total.	89	29566. 62			

Variate: Branches (4).

Source of variation	d.f	s.s	m.s	v.r	F.Pr.
Block. stratum	2	14. 867	7.433	2. 01	
Site	1	7398. 400	7398.400	2000.8 1	< .001
Spacing	2	104. 067	52. 033	14. 04	<. 001
Nitrogen	4	98. 044	24. 511	6. 63	<. 001
Site . spacing	2	1. 400	0. 700	0. 19	0. 828
Site . nitrogen	4	51. 822	12. 956	3. 50	0. 012
Spacing . nitrogen	8	158. 822	19.853	5.37	<. 001
Site . spacing . nitrogen	8	215. 711	26. 964	7. 29	<. 001
Residual	58	214. 467	3. 698		
Total.	89	8257. 600			

Variate: Flowering (5).

Source of variation	d.f	s.s	m.s	v.r	F.Pr.
Rep. stratum	2	7. 200	3. 600	0. 60	
Site	1	4120. 900	4120. 900	685. 24	<. 001
Spacing	2	229.400	114.700	19.07	<. 001
Nitrogen	4	182.778	45.694	7.60	<. 001
Site . spacing	2	131.400	65.700	10.92	< . 001
Site . nitrogen	4	250. 156	62.539	10.40.	<. 001
Spacing . nitrogen	8	174. 489	21.811	3.63	0. 002
Site . spacing . nitrogen	8	475.378	59.422	9.88	<. 001
Residual	58	348.800	6.014		
Total.	89	5920.500			

Variate: Weight.(6).

Source of variation	d.f	s.s	m.s	v.r	F.Pr.
Block. stratum	2	0. 00967	0. 00483	0. 09	
Site	1	13.413281	13.41381	259.44	<. 001
Spacing	2	0. 05027	0. 02513	0.49	0. 618.
Nitrogen	4	1. 90593	0. 47648	9. 20	<. 001
Site . spacing	2	1. 65926	0. 82963	16.02	<. 001
Site . nitrogen	4	4. 54122	1.13530	21. 93.	<. 001
Spacing . nitrogen	8	8. 06716	1. 00840	19.48	<. 001
Site . spacing . nitrogen	8	6. 82040	0. 85255	16.47	<. 001
Residual	58	3. 00306	0. 05178		
Total.	89	39.48978			