GROWTH, FRUIT YIELD AND QUALITY RESPONSES OF TWO VARIETIES OF TOMATO (*Lycopersicum esculentum* (L.) TO NITROGEN SOURCES AND ORGANIC MULCHES AT KADAWA, KANO STATE, NIGERIA

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ABSTRACT

Three field trials were conducted in the dry season of 2016, 2017 and 2018 at the Irrigation Research Farm of Institute for Agricultural Research, Kadawa (11^{0}39’ N 080’ 027’E, 500 m above sea level) located in the Sudan savanna ecological zone of Nigeria, to study the growth, fruit yield and quality responses of two irrigated varieties of tomato (*Lycopersicum esculentum* (L.) to nitrogen sources and organic mulches. Treatments consisted of two tomato varieties (UC82B and Rio Grande), two organic mulches (rice straw and sugar-cane peels) at recommended rates 5.5 t ha^{-1} and 11.0 t ha^{-1} (4 cm thick) respectively and a control (No mulch), and three nitrogen sources (mineral fertilizer, poultry droppings and mineral fertilizer + poultry droppings) at recommended rate of 90 kg N ha^{-1} with a control (No application). Varieties and nitrogen sources were assigned to the main plots while sugar-cane peels mulch was assigned to the sub plots and replicated three times. Results showed that Rio-Grande variety produced taller plants, wider canopy, high relative growth rate, net assimilation rate, low evapo-transpiration rate, longer days to 50% flowering and higher fruits yield of 57.89 % and marketable yield of 63.54 % over UC82B. Result from quality analysis has shown that the two varieties did not differ significantly ($P \leq 0.05$) from each other in all the quality traits evaluated. Tomato fruit qualities (appearance, decay, shelf life) as well as nutritional qualities were significantly enhanced by nitrogen sourced from organic sources than the unfertilised plots (control) while inorganic nitrogen sources contributed the least. Application of nitrogen sources showed that mineral fertilizer + poultry droppings showed superiority over poultry droppings and mineral fertilizer but did not differ significantly in their effect on growth and development. The growth and yield characters were significantly enhanced by organic mulching materials with rice straw and sugar cane peels showing a non significant difference compared to un-mulched plots. However, interaction of mineral fertilizer + poultry droppings in combination with any of the variety of tomato was significantly higher ($P \leq 0.05$) in enhancement of most of the growth and yield character but did not differ significantly with poultry droppings and mineral fertilizer in combination with any of the organic mulching materials with both varieties of tomato. Results from correlation and path analysis have shown that number of leaves gave the highest direct contributions in 2016 and 2017 while plant height gave the highest direct contribution in 2018. However, the highest individual percentage contribution was by plant height while the highest combined percentage contribution was by plant height via leaf area index. Cultural techniques capable of prompting the enhancement of characters such as number of leaves, canopy spread, plant dry weight and plant height should be considered with number of leaves playing the most important role and therefore should be given prominence. Cost and return analysis has indicated that poultry droppings (2.88 t ha^{-2}) using sugar-cane peels mulch (11.0 t $^{ha-1}$) with Rio-Grande gave the highest gross margin. Based on the results obtained from this study it can be concluded that Rio-Grande was superior to UC82B for higher fruit yield while for higher fruit quality any of the variety could be use. Poultry droppings at recommended rate (2.88 t ha^{-2}) should be applied for increased growth, fruit yield and quality of tomato on sustainable bases. Sugar-cane peels mulch (11.0 t ha^{-1}) is recommended as a suitable replacement to rice straw mulch.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

According to Food and Agricultural Organization (FAO, 2016), world production of tomato amounts to 177,042,359 tonnes with China as the largest producer with 56,423,811 tonnes followed by India with 18,399,000 tonnes and United States with 13,038,410 tonnes (FAO, 2016). In Africa, Egypt is the highest producer of tomato with 7,943,285 tonnes followed by Nigeria with 2,243,228 tonnes and occupying thirteenth position in the world (FAO, 2016). In general, average world yield of tomato as at 2015 was 33.99 t ha^{-1} with 4.8 million hectares of land dedicated to tomato production (FAO, 2015). The yield potential of tomato has been reported to range from 60 to 100 t ha^{-1} (Varela *et al.*, 2003; Bok *et al.*, 2006). However, the productivity of tomatoes in Nigeria is between 7 - 20 t ha^{-1} which is below the potential yield of the crop.

Nigeria ranks 13th on the global tomato production scale and accounts for 10.79 % of Africa's and 1.2 % of total world production of tomato. However, Kano State ranks top in the country with dry season cultivation of over 30,000 hectares of irrigated tomato in the Kano River Irrigation Project (KRIP) covering Kura, Bunkure, and Garun Malam Local Government Areas in the State (Anon, 2013). Savanna ecological zone is predominantly a tomato growing region in Nigeria. According to Ibrahim (1999), a relatively high yield of up to 30 t ha^{-1} is obtainable in the region (Sudan ecology) due to favourable weather conditions during the dry season when temperature is about 25 ^{o}C and humidity ranges from 50 to 70 %. Yield of tomato is generally low in Nigeria, with average yield of 20 t ha^{-1} in the northern part, while in the southern and eastern parts average yield is 10 t ha^{-1} and 5 t ha^{-1} respectively, (FAO, 2013).

1.2 Environmental Requirements

Tomato can be grown on a variety of soil types provided proper soil amendments and cultural practices suitable to the crop are undertaken (Naika *et al.*, 2005). On clay soil, the addition and incorporation of rice hull at the rate of 10 t ha^{-1} will improve aeration and tilth of the soil. The ideal soil pH range for tomato is from 5.4 to 6.8 (Dagoon, 2001). Tomato is classified as a fruit vegetable which is grown in the cool and warm regions of the world. There is however varieties developed for warm regions only just as there are those that are developed for wet season and those developed for dry season. The climate of Nigeria especially the savanna agro-ecology offers the most suitable condition for the performance of heat tolerant tomato varieties particularly during the dry season which has relatively low temperature, relative humidity and pest and disease infestation.

Tomato is known to be a warm season crop. It can survive certain level of cold units but are intolerant of very low temperatures. The crop requires very stable temperature ranges with minimums and maximums not being too wide apart. The minimum temperature is around 10°C while maximum is 34°C. Optimum temperature for tomato ranges from 21-24^{0}C. Temperature variation might result in reduced yields or poor fruit quality. At optimum temperatures, good quality seeds will take about seven days to emerge after germination. Temperature affects flowering and pollination, while hot and dry weather leads to drying of the flowers which stops pollination and reduce yield. If temperatures are below 15^{0}C or above 29^{0}C, pollen release is restricted, resulting in incomplete fertilization of ovules. This causes collapsed fruit walls and formation of deep indentation in the fruit, a phenomenon called catface (Peirce, 1987; Bok *et al*., 2006).

Relative humidity is a very important factor in terms of growth, incidence of disease and fruit quality in tomato production. Both high and low humidity have adverse effects on tomato production. However, the occurrence of long periods of high relative humidity is normally considered to be most serious. According to Walker and Duncan (1956), high relative humidity can favour overall plant growth due to a reduction in plant water stress. Low relative humidity on the other hand is associated with reduced growth and yield as well as other problems such as fruit maladies (radial cracking of tomatoes). Relative humidity of 70 % is optimal for pollination, fruit set and development. Very high humidity keeps the pollen too damp and sticky (pollen dumping). This phenomenon reduces the chance of sufficient pollen transfer from anthers to stigma (Mariam, 2017).

Tomato is the second most consumed vegetable in the world after potato (Grandillo *et al.*, 1999). Tomato is grown for home consumption in the backyard gardens of almost every homestead across sub-Saharan Africa. It is a cash crop for both small and medium-scale commercial farmers (Varela *et al.*, 2003). Tomato is consumed in diverse ways. The fruits are eaten raw, as ingredient in many dishes, sauce, salads and drinks. While it is botanically a fruit, it is considered as a culinary.

According to United States Department of Agriculture (USDA, 2012), many tomato products are good sources of potassium and vitamins A, C and E. Tomato products contain similar amounts of potassium and folate compared with other popular vegetables, but tomato products are superior sources of vitamin C. In comparison with the other regularly consumed vegetables, only carrots are better dietary source of vitamin A than tomato-based foods.

The fruit of tomato is rich in lycopene which may have beneficial health effect. According to Joseph and Yoav (2004), research has demonstrated that several health benefits are clearly associated with tomato products in the diet. The natural tomato oil increases the bio-availability of phytonutrients. For maximum benefit, dietary supplement customers who have opted for a nutritional approach should consider products containing a standardized tomato extract that supplies many of the active phytonutrients. The antioxidant effect of lycopene is potentially beneficial in disease prevention for both cardiovascular disease (CVD) and prostate cancer. Lycopene in tomato reduces the development of CVD by reducing inflammation, inhibiting cholesterol synthesis, and improving immune function (Petr and Erdman, 2005)

1.3 Statement of Research Problem

Commercial production of tomato relies mostly on exotic varieties and production is essentially restricted to the northern Guinea savanna and the Sudan savanna ecologies due to favourable climatic conditions, particularly high insulation and low relative humidity. However, because of its nutritive and commercial values, production of exotic tomato has also spread to the southern and derived Guinea savanna ecologies where hitherto, the traditional varieties are produced. Consequently, exotic tomato varieties have almost replaced the traditional varieties of southwest Nigeria. In the Sudan and northern Guinea savanna of Nigeria, observation has shown that farmers' choice of varieties for increased yield of tomato depends more on such characteristics as size and firmness of fruit rather than exploring other important characteristics such as adaptation of the varieties to environmental conditions.

Inorganic fertilizer application is the fastest way of meeting the nitrogen need of crop plants like tomato. However, inorganic fertilizers are out of reach of small and medium scale farmers due to increasing cost. The problems associated with the use of inorganic fertilizers are environmental pollution and ecological imbalances they cause. Nitrogen, being the most important primary nutrient needed for the satisfactory growth and development of tomato in the savanna, is in limited quantity in the soil. The beneficial effects of inorganic fertilizers have been deemed short of immeasurable significance of the organic sources of nutrients. The shortage, high cost and negative residual effects of synthetic fertilizer have limited their use for vegetable production amongst smallholder farmers in Nigeria. Continuous use of inorganic fertilizers increases the acidity of the soil. This in turn limits the activities of beneficial microorganisms and percentage assimilability of available nutrients in the soil. This could in turn result in imbalance of nutrient content in the soil.

Most organic manure recommendations for tomato that are based on rates do not take into consideration the type and nitrogen content of the manure before making recommendation to farmers and this has led to variations in organic manure recommendation even within the same ecological zone.

Tomato production during the dry season takes the largest percentage of the total production of tomato in Nigeria. Moisture conservation is an important agronomic practice for increased production of tomato. Inorganic mulching materials such as black polythene has been recommended as the most effective way of conserving soil moisture but has some detrimental effects on soil condition such as poor circulation of air and negative impact of chemical on soil condition. Organic mulching materials such as rice straw with little or no detrimental effect on soil condition have been recommended for farmers in the Sudan savanna ecology due to its availability but its use as livestock feed has made it scarce. The availability of sugarcane peels constitute an agricultural waste, but also to the climatic variables when burnt, thereby leading to climate change could be used alternatively as an option to conserve moisture for the plants and maintain a safe environment for agricultural sustainability.

1.4 Justification of the Study

Tomato production is left in the hand of small and medium scale farmers. Studies in Nigeria have shown that there is high demand for fresh tomato. Scarcity during the hot dry season (March-June) has been attributed to under production. Farmers use minimum of the improved techniques, thus any practice to be recommended to increase yield and improve quality must be simple, affordable and applicable to small scale production.

To meet the increasing demand for tomato in Nigeria due to population increase, tomato varieties that are most adapted to climatic or environmental conditions need to be developed for optimum production.

To address the problem of deteriorating condition of the environment especially soil quality, a natural and safe but profitable method of enriching the quality of the soil that is less expensive such as the use of suitable organic material need to be adopted. Organic fertilizers such as poultry droppings and organic mulches such as sugar-cane peels mulch can be employed as an effective source of nitrogen, for water conservation. To develop the commonly grown varieties in the savanna where production is concentrated, there is need to standardize production technology, especially under local climatic and edaphic conditions, so that farmers of the area can get maximum benefit from tomato production with limited irrigation resources as well as to increase production and also maintain a safe environment under dry season condition.

Alternative nutrient sources that are environmentally friendly for improved yield and quality such as the use of organic manure which is capable of changing the structure of the soil over time and improve the water conservation of the soil which will ultimately enhance productivity can also be developed. Sustainability in agro-ecosystems involves environmentally friendly techniques based on biological and non-chemical methods (Bonato and Ridray, 2007).

Application of organic fertilizers has been a traditional practice of maintaining soil fertility. Apart from the nutrients they supply, they can improve soil physical and chemical properties.

1.5 Aim and Objectives of the Study

This research was conducted to investigate the responses of two tomato varieties as influenced by organic mulches and nitrogen sources. The study was therefore designed to achieve the following objectives:

I. To assess the effects of nitrogen sources and organic mulches on the growth, yield and nutritive fruit qualities of two tomato varieties.

II. To determine if there is any significant interaction between varieties, nitrogen sources and organic mulching materials on the crop yield.

III. To study correlation and path-coefficient analysis of some important characters of tomato varieties.

IV. To determine the cost benefit return on investment in tomato production using the different factor treatments and their combination.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin

Tomato, (*Lycopersicum esculentum* (L.) H. Karst) belongs to the family *Solanaceae* and genus *Solanum.* Tomato is an edible, often red fruit berry of the nightshade *Solanum lycopersicum* commonly known as a tomato plant. Tomato originated from South American Andes, in what is now called Peru, Bolivia, Chile and Ecuador where they grew wild. Tomato was first cultivated by the Azecs Incas as early as 700 AD. It was first used as food in Mexico and spread through the world following the Spanish colonization of the Americas. However, the Spanish explorers introduced tomato into Spain and it was later taken to Morocco, Turkey and Italy. It was widely believed that tomato was poisonous and its use as food crop was only accepted in the 18th century. Tomato is now one of the most popular and widely grown vegetables around the world (Kimura *et al.*, 2008).

2.2 Taxonomy

In 1753, tomato was placed in the genus *Solanum* by Linnaeus as *Solanum lycopersicum* L. (derivation, 'lyco', wolf, plus 'persicum', peach, i.e., "wolf-peach"). However, in 1768, Philip Miller placed it in its own genus, and named it *Lycopersicon esculentum*. This name came into wide use but was in breach of the plant naming rules. Technically, the combination: *Lycopersicon lycopersicum* (L.) H. Karst would be correct, but this name (published in 1881) has hardly ever been used. Therefore, it was decided to conserve the well-known *Lycopersicon esculentum,* making this the correct name for the tomato when it is placed in the genus *Lycopersicon*. However, genetic evidence by Peralta and Spooner (2001) has now shown that Linnaeus was correct in the placement of the tomato in the genus *Solanum*, making the Linnaean name correct.

Tomato plants grow to heights of between 1 and 3 feet. Their stems are woody and weak and tend to vine over other types of plants. The leaves of tomato plant are between 4 and 10 inches in length. Tomato plants have pinnate leaves and each petiole has between five to nine leaflets. The plants produce flowers which are yellow in colour with five lobes (Isabel, 2015).

2.3 Response of Variety to Season

Genotype and environment interact to determine how a crop grows whereas, growth determines yield. The relationship between these factors includes farming operations such as cultural practices, irrigation and drainage. There exist a lot of variations in tomato varieties for different characters like plant height, maturity, fruit shape, weight, yield, colour and quality. A number of researchers have also investigated the usefulness of morphological and physiological parameters as indices of plant yield. Singh *et al.* (2002) observed high genetic variation in tomato for plant height, number of days to fruit set, number of fruit clusters per plant, number of fruits per plant, fruit weight per plant and fruit yield per plant. The high genetic variation observed for these traits offers an opportunity for indirect selection for yield in tomatoes. In many species of tomato, high temperatures inhibit reproductive organ and development (Sawicki *et al.,* 2015). Some cultivars such as Roma VF have a greater adaptation while others provide a valuable source of variability in breeding material. Ojo *et al.* (2013) reported that Roma savanna

VF has the potential for good performance in the southern Guinea savanna ecology of Nigeria. UC82B was reported to show superiority over Roma VF and other local varieties in terms of growth and yield attributes in the Guinea savanna (Olaniyi *et al.*, 2009; Isah *et al.,* 2014). However, Hussaini *et al.* (2013) reported that there are no significant differences in fresh fruit yield between UC82B and Petomech VF in the Sudan savanna. It was therefore considered appropriate to make a comparative study even among commonly grown exotic cultivars of tomato to screen for high yielding varieties suitable to agro-climatic conditions of the Sudan savanna. However, effort is on by breeders to develop heat and drought tolerant varieties. High temperature decreased the yield, number of fruit and fruit weight (Adams *et al*. 2001). The choice of tomato variety depends on a number of factors ranging from production potential, market demand, regional adaptability, disease resistance and the use of the product (Orzolek *et al.*, 2006). Presently, there are tomato cultivars and hybrids which can be cultivated in climate different from the site of origin and which could also serve as sources of genes for improvement of adapted varieties. However, commercial cultivation of tomatoes in Nigeria exhibits seasonality with much of the production concentrated in the relatively cool and dry period under irrigation or in the 'fadamas'. Environmental temperature extremes coinciding with critical stage of plant development often cause a major threat to crop productivity under field condition. It is fairly well known that temperature has a marked effect on fruit setting in tomato varieties. Fruit setting is usually poor when the temperature is either relatively low or relatively high. Although the use of improved varieties has increased tomato production in the tropics, the full potential of the crop has not been achieved when compared to the temperate countries where fruit yields are almost double that of the tropics. The low yield obtained in the tropics has been attributed to unsuitable cultural practices (Znidarcic *et al*., 2003).

Roma VF is known for its adaptability to both dry and wet season conditions and that gave it a wider popularity over other varieties of tomato. UC82B which was evaluated for its adaptability in the southern part of Nigeria gave a promising result by exhibiting a higher fruit yield than Ibadan and Ogbomosho local (Olaniyi *et al.*, 2009).

2.4 Effect of Nitrogen Sources on Growth and Yield of Tomato

Despite the economic importance and nutritional value attached to tomato, its optimum yield in the tropical countries especially the Sudan and Northern Guinea savanna where production is concentrated is yet to be attained due partly to declining nitrogen content of savanna soils. Because of the low nitrogen status of savanna soils, nitrogen is considered the most important single nutrient for the satisfactory growth and development of most vegetable crops like tomato. The use of nitrogen fertilizers in the production of vegetables has increased by 21% between 1997 and 2003 (Mubashir *et al*., 2010). Nutrients especially nitrogen is needed for optimum yield of cultivated crops (Adeputu, 1986). In a review of soil fertility trial in horticulture in Nigeria between 1975 and 2005, Ehigiator *et al.* (2005) made a nitrogen recommendation of 50-100 kg N ha^{-1} for vegetable crops such as tomato. Reasons of low yield of crops are imbalanced fertilizer use, improper nitrogen sources and high rate of leaching of nitrogen (Akhtar *et al*., 2010). Nitrogen plays an important role in plant parts such as chlorophyll, amino acid, proteins and pigments. It is most essential for vigorous growth branching/tillering, leaf development and enlargement, root expansion, high photosynthetic activity and formation of protoplasm (Khan *et al*., 2013). There are different types of nitrogen sources including urea, NPK, poultry droppings, cow dung, compost, green and farmyard manure and a number of others.

Application of inorganic fertilizer is the simplest way to meet the nitrogen need of most vegetable crops like tomato but is detrimental to the environment and its availability is out of reach of many small holder farmers due to high cost. Nutrient imbalance and soil physical degradation hinder sustainable use of inorganic fertilizers in the tropics (Ewulo *et al*., 2008). The shortage, high cost and negative residual effects of synthetic fertilizer have limited their use for vegetable production among peasant farmers in Nigeria. Continuous use of inorganic fertilizers increases the acidity of the soil, thus limiting the activities of beneficial microorganisms.

In order to sustain soil fertility over a long period of time, the use of organic manure is been advocated. This is because the nutrients contained in organic manures are released more slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma and Mittra, 1999). Abou *et al*. (2005) also reported that manures provide a source of all necessary macro and micro nutrients in available forms, thereby improving the physical and biological properties of the soil. The use of organic fertilizers can result to high growth, yield and quality of crops. They contain micro and macro nutrients essential for plant growth and growth promoting factors like Indoleacetic acid (IAA), Gibberellic acid (GA), as well as some beneficial microorganisms (Natarajan, 2007; Sreenivasa *et al.*, 2010). Organic manures can improve soil- plant-water relations by modifying bulk density, total porosity and consequently, increasing plant growth and water use efficiency (Obi and Ebo, 1995).

Akanin and Ojeniyi (2007) reported that application of poultry droppings (20 t ha^{-1}) gave the highest value of number and weight of fruit of tomato while bulk density and temperature of the soil were reduced with the levels of poultry droppings. Also, addition of poultry droppings was found to increase soil organic matter, moisture content, and leaf N, P, K, Ca and Mg concentration while soil bulk density was reduced.

Seasonal and environmental variations determine organic manure recommendation. In the savanna ecological zone of Nigeria, most especially the Sudan savanna where large quantity of tomato is produced due to favourable growing condition, research has shown variation in poultry droppings recommendation. Olaniye and Ajibola (2008) recommended poultry droppings as a suitable replacement for inorganic fertilizer in tomato production at the rate of 6 t ha^{-1} as this rate was observed to have significantly increased the yield and quality of the fruit. However, another work conducted by Eliakira and Peter (2014) recommended 8 t ha^{-1} as sufficient for tomato plants. Hussaini *et al.* (2013) reported that application of poultry droppings at the rate of 12 t ha^{-1} resulted in more number of fruits with large diameter and higher fresh yield of the two varieties of tomato evaluated (UC82B and Petomech VF) in the Sudan savanna agro ecological zone of Nigeria. In another work conducted in the Sudan savanna ecology, application of 4 t ha^{-1} cured (pre-treated) poultry droppings was recommended (Jibrin *et al.,* 2014). Adesina *et al*. (2014) in their study revealed that growth and yield of pepper fruit in the south western Nigeria could significantly ($P<0.05$) be improved by the application of PM at 3.0 tons/ ha^{-1}.

2.5 Effect of Organic Mulches on Growth and Yield of Tomato

Mulching is one of the simplest and beneficial practices for soil and water conservation. Mulching is simply a protective layer of material (sourced from grass, palm fronts, leaves, rice straw) that is spread on top of the soil to prevent it from blowing and being washed away. The mulching practice yields benefits ranging from the conservation of moisture in the soil thus saving the need for frequent irrigation, protection of soil from erosion, reduction of compaction of soil due to impact of heavy rainfall, maintenance of a more even soil temperature and prevention of weed growth to check loss of soil nutrients.

Mulching is commonly recommended for use to reduce water loss due to evapotranspiration (ET). The amount of mulch used in vegetable garden would also reduce water use by similar amount (John, 2006). Improving water efficiency is an ongoing goal in agricultural production especially in Nigeria where water resources are limited. One reason for the push to use less water in agriculture is because of increasing demand generated by the growing population. As a way of addressing the issue, farmers are yearning for new ways to reduce their water demand for irrigation. However, mulching is one cultural practice which can be used to address this problem.

Organic mulches sourced from agricultural waste can be used to significantly conserve soil moisture, provide more resources for crops and reduce the overall cost of production (Michael, 2013). Apart from the role played by mulching as simply a covering over the soil that regulates soil temperature, smother weeds, it also protects low growing crops from resting on the ground which prevent fruit rot and also keeps water from splashing on the soil to cause hard pans which blocks the pores. As organic mulch gradually decays, it increases organic matter content of the soil and eventually humus in the soil. This is responsible for increase nutrient and moisture retention. Organic mulching materials are readily available and affordable especially for the small holder tomato grower.

The use of mulches in vegetable production is undergoing a radical change away from high input, non-renewable resources, such as plastic, to the use of high-residue organic materials from cover crops. It has been reported that mulch also can increase the incidence of diseases such as fruit worm and sun scotch on fruits. According to Rwenzaula *et al.* (2005), rice straw was the best in enhancing crop performance followed by grass and finally saw-dust and all the organic mulch regimes used in their work excelled the control in reducing weed and blossom end rot in tomato. Bender *et al.* (2005) also reported that grass mulch caused significant negative effect on cracking of most of the varieties of tomato used. The use of organic mulching material is recommended as a more viable option for vegetable growers instead of inorganic mulch material in an attempt to reduce chemical inputs for weed control in tomato production (Elaine *et al.*, 2011). Plant-based mulch is reported to be more effective in reducing soil temperature and that these improvements of crops growing environment resulted in increased tomato growth and fruit yield (Awodoyin *et al.,* 2007). Bienuenida (2014) evaluated organic mulch source from dry papaya and dry banana leaves and recommended papaya mulch for enhancing the plant and final caudex. Moses and Tuarira (2014) evaluated two different organic mulching materials (trash grass mulch and sawdust mulch) on onion production and reported that trashed grass mulch played a significant role in terms of growth and yield. Mateen-ul-Hassan *et al.* (2005) in his work on effectiveness of organic and inorganic mulching reported that economic comparison indicated that 4 inch (10.2 cm) thick wheat and grass mulch was more efficient than expensive polythene mulch in tomato production in Pakistan.

The addition of mulch, at all mulch thicknesses, conserved soil water compared to when no mulch was used. The differences in soil water content likely influenced some of the plant growth factors measured. Wood chip mulch helped conserve soil water, which in turn had some effects on plant growth Van Donk *et al*. (2011). Goitom *et al.*, (2017) who evaluated different organic mulches (rice straw, sorghum straw, sesame straw, Sudan grass and a control) indicated that organic mulching had significant effect on soil moisture content when compared to the control. However, Sesame straw conserved highest soil moisture content as compared with respective mulch material. The highest yield (664 kg ha^{-1}) was recorded with Sudan grass while the lowest grain yield (190 kg ha^{-1}) was recorded with no mulch.

The choice of organic mulch will depend on what is available of organic mulching material which may includes rice straw, sugarcane trash, cut grass, leaves, seaweed hay etc. According to Owen (2013), the availability of sugarcane mulch and its non detrimental effect on soil condition make it a good choice for vegetable production and should be applied between 3-10 cm thick and that it allows easy penetration of water and contributes to the health of the soil. Observation has shown that in the Sudan and Northern Guinea savanna ecology of Nigeria, sugarcane peels from the consumption of raw sugarcane during the dry season has caused environmental threat which has contributing negative effect on climate change. Sugarcane trash and rice straw also showed an appreciable profit in tomato production compared to black polyethylene which proved the most economical mulch for tomato production (Rajbir, 2005).

2.6 Interaction Effects of Nitrogen Sources, Varieties and Organic Mulches on Growth and Yield of Tomato

Complementary use of nitrogen sources and organic mulches may be beneficial to achieving a sustainable crop production. Integrated soil fertility management practices' involving judicious combinations of nitrogen sources and organic mulches is recommended as a feasible and viable technology to sustain agriculture and ensuring higher crop yields with least deterioration of soil quality.

Adequate fertilizer application, influences tomato growth and fruit yield more than other cultural practices (Akanbi *et al.*, 2005). Unfortunately, nitrogen sources such as NPK fertilizers are mostly applied through synthetic sources, which are known for some notable defects, such as substantial leaching losses volatilization and harmful residual effects (Tejada *et al.*, 2005). To develop a reasonable environment friendly and sustainable technology, there is need to integrate organic and inorganic fertilizer materials, so as to successfully supplement the widely-used inorganic fertilizers (Babajide and Salami, 2012).

Moses and Tuarira (2014) observed a significant interaction between trashed grass mulch in combination with organic and inorganic fertilizer than sawdust in combination with organic and inorganic fertilizer. When two varieties of tomato (Cochoro and Miya) were evaluated with both inorganic mulch (black and white polythene mulch) and organic mulch (grass mulch) the higher marketable yield obtained from grass mulch on miya variety over the inorganic mulching materials in combination with the varieties was attributed to its favourable effect on soil temperature and soil moisture which subsequently created conducive condition for root growth and development (Habtamu *et al.,* 2016).

2.7 Correlation and Path Coefficient Analysis Between Growth, Yield Components and Fresh Fruit Yield

Crop productivity is influenced by the genetic characteristics of the cultivar, growing environment and management practices. Yield is a complex character and selection for yield and yield components deserves considerable attention. A crop breeding program, aimed at increasing the plant productivity requires consideration not only of yield but also of its components that have direct or indirect bearing on yield. Correlation and path coefficient analysis give an insight into the genetic variability present in populations. Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Path analysis splits the correlation coefficients into direct and indirect effects of a set of dependent variables on the independent variable thereby aids in selection of elite genotype. An improvement in yield and quality in self pollinated crop like tomato is normally achieved by selecting the genotypes with desirable character combinations existing in nature or by hybridization. Information on the nature and extent of variability present in genetic stocks, heritability, genetic advance and interrelationship among various characters is a prerequisite for framing any selection program. According to studies carried out by Shashikanth and Dhotre (2012) on correlation and path analysis using thirty tomato genotypes. Fruit yield had a positive and highly significant association with number of fruits per plant and number of branches per plant strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield and it is also suggested that hybridization of genotypes possessing combination of above characters is most useful for obtaining desirable high yielding segregation. Path coefficient analysis revealed that number of flowers per cluster and number of branches per plant had the highest positive direct effect on fruit yield both at genotypic and phenotypic levels and most the fruit related traits contributed of fruit yield mainly through number of branches. Hence, it would be essential to lay stress on these characters in selection program aiming at increasing the yield. Rajasekhar *et al.* (2013) reported that tomato traits such as plant height, number of fruits per plant, fruit length, fruit width and ascorbic acid had high positive direct effects on fruit yield per plant. Hence, direct selection for these traits is done for improving fruit yield per plant. High heritability coupled with high genetic advance as percent of mean indicates operation of additive gene action which was observed in characters plant height, root to shoot ratio, number of primary branches per plant, number of flowers per cluster, number of clusters per plant, fruit set (%), number of fruits per cluster, number of fruits per plant, fruit length, fruit width, average fruit weight, fruit yield per plant, number of locules per fruit, ascorbic acid, lycopene content, stomatal diffusive resistance, relative water content and chlorophyll content. Hence, directional selection for the above characters could be effective for desired genetic improvement (Sigh and Cheema, 2005). Haydar *et al.* (2007) reported that plant height at flowering, number of flowers in three clusters/plant, days to flowering and total number of fruits at harvesting period also contributed yield directly. The results indicate that for increasing yield, selection should be based on plants bearing more fruits of larger size and weight.

2.8 Effects of Nitrogenous Fertilization on Fruit Quality of Tomato

According to Ferreira *et al.* (2006), tomato yield was previously the main criterion used to evaluate the efficiency of various farming practices for crops such as tomato, while the quality of fruit was not an important criterion. However, due to the emphasis on the importance of healthier foods, attention has recently been focused on the agronomic practices implemented during the production of food in order to develop products with better nutritional qualities. Cultural practices such as nutrient application are presumed to be factors influencing quality of tomato before and after harvest (Watkins and Pritts, 2001).

Productivity has been traditionally the main criteria considered for evaluating the effects of cultivation techniques for tomato crop. However, factors related to fruit quality have been increasingly studied. For vegetable crops such as tomato, quality is controlled genetically as well as influenced by environmental conditions, such as mineral nutrition. Application of mineral nutrient sources can influence nutritional and structural complexes of plants as a consequence of effects on biochemical and physiological processes such as photosynthesis and translocation of photo assimilate.

The acceptance of crop produced can be influenced by the source of nutrients involved in its production. In the recent past, some studies have been conducted to elucidate the beneficial effects of adding crop residue compost into the soil. The practice improves soil physical, chemical and biological activities as well as improving crop yields and nutritional values (Akanbi and Togun, 2002; Adediran *et al*., 2003). Aurelice, *et al.* (2013) observed and suggested that tomato fruits from organic farming experienced stressing conditions that resulted in oxidative stress and the accumulation of higher concentrations of soluble solids as sugars and other compounds contributing to fruit nutritional quality such as vitamin C and phenolic compounds. Poiroux-Gonord *et al.* (2010) proposed a more in-depth study of the interactions existing between factors (light and temperature, for instance, genetic factors × environmental factors), between processes (primary metabolism and ontogeny, for example), and between organs (as there is some evidence that photooxidative stress in leaves affects antioxidant metabolism in fruits).

Tomato fruits are important sources of vitamins and minerals in the human diet and they are rich in antioxidants and bioactive compounds which are secondary metabolites produced by plants. Phenolic compounds, ascorbic acid, and lycopene, are examples of bioactive compounds found in tomato (Rocha and Silva, 2011). Effect of mineral fertilizers on the vitamin content of plants has received very little attention by scientists in recent years. A review of literature, however, has revealed nitrogen fertilizers, especially at high rates, seem to decrease the concentration of vitamin C in many different fruits and vegetables, among them potatoes, tomatoes and citrus fruits, the major sources of this vitamin in human nutrition in many societies. Nitrogen fertilizers are also shown to increase the concentrations of carotenes and vitamin B1 in plants. Since excess use of nitrogen fertilizers increases the concentration of NO_3 in plant foods and simultaneously decreases that of ascorbic acid, a known inhibitor for the formation of carcinogenic N-nitroso compounds from nitrite, it appears that the use of these fertilizers may have a double negative effect on the quality of food plants. Vitamin C and several carotenoids have antioxidant properties and reportedly reduce the risk of cardiovascular diseases and some forms of cancer (Anon, 2018).

Mineral nutrition controls the physiological processes of plants and can influence the amount of some organic and inorganic compounds in the plant (Hassan *et al,* 2012). In tomato fruits, some authors have observed the effects of nitrogen (N) fertilization on antioxidant activity, vitamin C content, as well as antioxidant compounds, and nitrate content (Kopsell, 2016: Kemal *et al*., 2007). More than 90% of the vitamin C in human diets is supplied by fruits and vegetables, of which tomato is the most important (Vallejo et al., 2002). Simonne *et al.* (2007) reported that increasing N rate resulted in a decrease in vitamin C content from 44 to 35 mg per 200 grams, and a reduction in titratable acidity from 0.47 to 0.38 percent citric acid. Lutein, beta carotene, and color were not affected by N rate. Soluble solids decreased with N rate for the first harvest but increased with N rate for second harvest. Although there were slight treatment effects, the authors concluded that overall N rate had little impact on selected quality parameters.

Tomato antioxidant components depend on the cultivar, growing conditions, growing season, maturation stages both in production and post-harvest and mineral nutrition (Ilahy *et al,* 2011; Borguini *et al.,* 2013). Lycopene is the most abundant antioxidant compound in tomatoes and it imparts the characteristic red color to the majority of existing tomato cultivars on the market. Lycopene and other bioactive compounds, are responsible for antioxidant activity of tomatoes, which prevents the oxidation of essential molecules caused by free radicals, and contribute significantly to the maintenance of human health, including the prevention of heart disease and prostate cancer.

Nitrogen fertilizers, especially at high rates, seem to decrease the concentration of vitamin C in many different fruits and vegetables, among them potato, tomato and citrus fruits, the major sources of this vitamin in human nutrition in many societies. Nitrogen fertilizers are also shown to increase the concentrations of carotenes and vitamin B_1 in plants. The crude protein, total phosphorus (P), potassium (K), and iron (Fe) content of fruits increased with increasing levels of N application and were highest with 300 kg. Highest iron content was recorded (0.10%) with higher doses of N. Higher levels of N nutrition reduced the ascorbic acid content in fruits. More frequent split application of nutrient N or greater proportion of organic source enhanced the shelf life of fruits (Rajiasree and Pillai, 2009). Since excess use of nitrogen fertilizers increases the concentration of NO_3 in plant foods and simultaneously decreases that of ascorbic acid, a known inhibitor for the formation of carcinogenic N-nitroso compounds from nitrite, it appears that the use of these fertilizers may have a double negative effect on the quality of food plants. Vitamin C and several carotenoids have antioxidant properties and reportedly reduce the risk of cardiovascular diseases and some forms of cancer. Whether long-term consumption of food plants grown with excess use of nitrogen fertilizers would have an overall positive or negative effect on the total intake of antioxidative vitamins by consumers warrants investigation (Mozafar, 2008). Reducing nitrogen fertilization limited environmental pollution, on the one hand, and may improve, on the other hand, both growers' profits, by limiting nitrogen inputs, and fruit quality for consumers, by increasing tomato sugars content. It was concluded that primary and secondary metabolites could be affected as a result of a specific response to low nitrogen, combined with a lower degree of vegetative development, increasing fruit irradiance, and therefore modifying fruit composition (Camille *et al.*, 2009).

Fertilizer is a major part of crop production expenses for tomato but it is critical for successful crop yields and high fruit quality. Recommended target nutrient rates are currently 300 Kg NPK (15:15:15) + 45 Kg N ha^{-1} urea (46%) with phosphorus (P) and potassium (K) rates adjusted downward or eliminated if soils can supply some or all of these nutrients as determined by soil testing (Mylavarapu 2009; Olson & Santos, 2010; Isah *et al*., 2014).

In relation to nitrogen (N) uptake in plants, it has been shown that plants can absorb both inorganic ammonium ions (NH_4) and nitrate ($NO_3^{-1)}$. Some studies have shown that the application of high levels of NH_4 and low levels of NO_3^{-1} improves fruit quality (Marino *et al.*, 2001; Flores *et al.*, 2003). Differences in the supply and availability of nutrients in various fertilizers can affect the production of secondary metabolites (Toor *et al.*, 2006).

Postharvest product quality develops during growing of the product and that could be maintained but not improved by postharvest technologies. This could be achieved through selection of genotypes with better keeping quality when harvested at optimum maturity Ramakrishnan *et al.*, 2010; Vijay *et al.*, 2010a). Moreover, Tan (2006) indicated that available genetic material allows discrimination of external and internal quality attributes that must satisfy consumer requirements and indulgences.

2.9 Effects of Variety on Some Fruit Qualities of Tomato

Postharvest losses in tomato can be either quantitative or qualitative. Even though emphasis in crop research nowadays is increasingly shifting from quantity to quality of produce, there is still little improvement in the quality of commercially produced tomato varieties, hence resulting in high quality losses. Postharvest quality status of tomato partly depended on some pre-harvest practices carried out during production. Some of these factors are fertilizer application, pruning, maturity stage, cultivar selection, and irrigation. The potential quality of fruit is dependent on the cultivar type. Different cultivars are characterized by different quality parameters, making some more desirable to the producers and consumers than others. The choice of a high-yielding tomato cultivar with desired fruit qualities and longer shelf life is therefore a vital decision a producer must take (Hanna, 2009). Failure to select an appropriate cultivar may lead to lower yield, low quality fruits, or less market acceptability. Fruits of different cultivars differ in size, colour, texture, and flavor as well as storage potential. Getinet *et al.* (2008) reported the influence of tomato cultivar on some postharvest qualities of tomatoes stored under different conditions. Getinet *et al.* (2011) established that tomato cultivar Roma VF had higher sugar content while maintaining lower weight loss as compared to cultivar Marglobe. Cultivar selection is therefore critical to the postharvest storage life and eating qualities of tomato.

CHAPTER THREE

3.0 MATERIALS AND METHODS

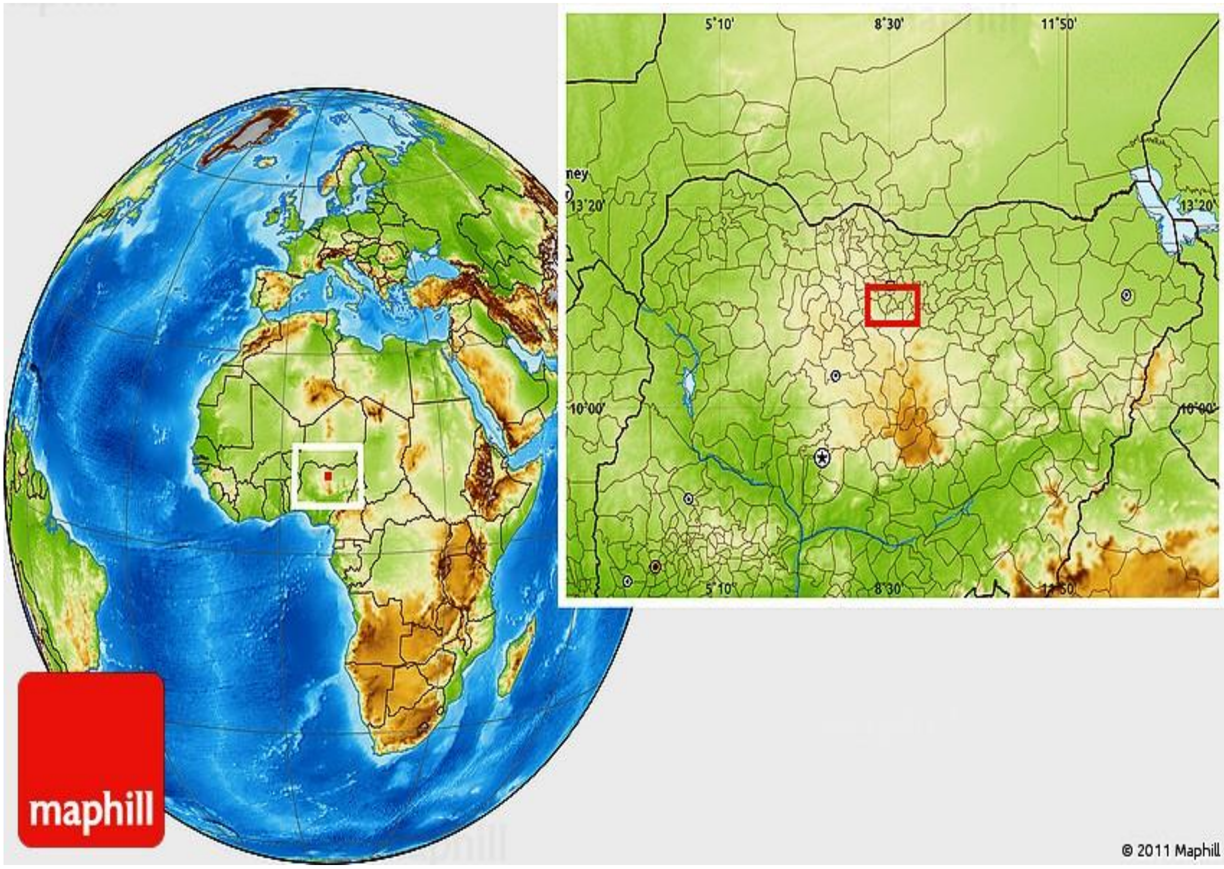
3.1 Experimental Site

Three field trials were conducted in the dry seasons of 2016, 2017 and 2018 dry seasons at the Irrigation Research Farm Institute for Agricultural Research, Kadawa (11^0 N 39',08^0 02" E 500m above sea level) located in the Sudan savanna ecological zone of Nigeria (plate I). Meteorological data including daily temperature and relative humidity during the period of the experiment were obtained from meteorological stations of the Institute for Agricultural Research, Kadawa and International Institute of Tropical Agriculture Kano branch in the two seasons and are presented in Table 4.1, 4.2 and 4.3. Soil samples from locations at a depth of 0-15 cm were randomly collected from the experimental sites using hand auger. The soil samples in each location were bulked, dried, ground, sieved and subjected to physical and chemical analyses and the poultry droppings was analyzed using the method described by Agbenin (1995).

3.2 Treatments and Experimental Design

Treatments consisted of factorial combination of two tomato varieties (UC82B and Rio Grande) and four nitrogen sources: control, mineral fertilizer (NPK at 300 kg ha^{-1}+Urea at 97.82 kg ha^{-1}), poultry droppings (2.88 t ha^{-2}) and mineral fertilizer + poultry droppings. Organic mulches: No mulch, rice straw (5.5 t ha^{-1}), and sugar-cane peels (11.0 t ha^{-1}). Variety and nitrogen source assign to the main plot and organic mulches assign to sub-plot and arranged in a split plot design with three replications. The mineral fertilizer was (N.P.K 15:15:15) at 300 kg ha^{-1} to supply 45 kg ha^{-1} of nitrogen, 45 kg ha^{-1}

of P_2O_5 and K_2O at two weeks after transplanting and Urea (46% N) at the rate of 97.82 kg ha^{-1} was used to supply 45 kg ha^{-1} of nitrogen as second dose to give a total of 90 kg N ha^{-1}. The nitrogen content of the poultry droppings (PD) used was determined in the laboratory and the value obtained was used to compute the quantity of poultry dropping needed to supply 90 kg ha^{-1}. A mixture of mineral fertilizer (N.P.K-15:15:15) and poultry dropping at 45 kg N ha^{-1} each was applied to supply a total of 90 N ha^{-1}.



Source*:* *www.maphill.com/nigeria/kano/bunkure/kadawa-maps/physical-map*

Plate I: World map showing physical location of Kadawa, Kano Nigeria

3.3 Description of Varieties

3.3.1 UC82B

This is a short variety (50-60 cm) with semi determinate growth habit and open pollinated with maturity period of 70-75 days after transplanting. It is heat sensitive and has high yield potential (30-35 t ha^{-1}). It is a processing type with a square shaped red fruit containing many seeds. The fruit is 95-100 g, firm and can store for about two weeks when harvested at green stage. It is resistant to *Verticillium dalhiae* and *Fusarium oxysporum* (Anon, 2016).

3.3.2 Rio Grande

Rio Grande tomato fruits can form clusters and does well in condition of weather extremes, both hot and cold and it is heat sensitive. Maturity period is 75-80 days from transplanting, with fast germination and vigorous plant growth. The fruit is large (8 cm) in diameter, pear-shaped tomato and deep red in colour. It is a cylindrical elongated fruit in shape with a very good shelf life and transportability and with yield potential of 30-40 t ha^{-1} (Anon, 2016). It has good disease resistance against Leaf Roll Virus. Rio Grande is a trailing tomato with a determinate growth habit. The fruit weight is 100-110 g with a cylindrical elongated and very firm flesh and good flavour (Anon, 2016).

3.4 Physical and chemical properties of the soil at experimental site

Six soil samples were taken randomly from the site each year at 0-15 cm depth. The samples were bulked to give one composite sample for physical analysis using standard procedures by Agbenin (1995).

3.5 Manure and Analysis

Poultry dropping (broiler) from deep litter system used was analyzed to determine the nutrient contents such as N, P and K as well as some exchangeable bases such as calcium, magnesium and sodium using standard procedures by Agbenin (1995).

3.6 Meteorological Data

Meteorological information such as temperature and relative humidity of the experimental site were collected from the Institute for Agricultural Research Weather Station Kadawa.

3.7 Cultural Practices

3.7.1 Nursery practice

The tomato varieties were sown separately on a well prepared nursery bed by drilling. The beds were mulched with dry grass after sowing and then irrigated with the use of a watering cane as found necessary. The mulch was removed immediately after seedling emergence (4 days) and rearranged between drill-rows of the emerged seedlings.

One week before translating (3 weeks old) to the open field, irrigation was suspended in order to expose the seedlings to open field condition for better seedling establishment. The seedlings were properly irrigated two days to transplanting to harden them up.

3.7.2 Land preparation

The experimental site was ploughed, harrowed and made into ridges 75 cm apart for easy marking out and later prepared manually into sunken beds (plots) of 3×3 m dimension preparatory to transplanting the crop seedlings. Cured poultry dropping was incorporated into the soil as par the treatments after bed preparation, two weeks prior to transplanting the tomato. The mulch (rice straw and sugarcane peels) was laid over the plots four weeks after transplanting according to the treatments.

3.7.3 Transplanting

Four-week old seedlings (4-5 leaf stage) were transplanted to the open field at a spacing of 50 cm × 60 cm. This was done in the evening when radiation was less to reduce transplanting shock. Transplanting was done on 7th January, 2016, 10th December, 2016 and 4th January, 2018 during 2016, 2017 and 2018 dry seasons respectively.

3.7.4 Irrigation

Irrigation was done through controlled flooding of plots. Seven days irrigation interval was used at early growth stage (1 to 4 weeks after transplanting) to ensure better establishment and later extended to 14 days interval.

3.7.5 Fertilizer application

Inorganic fertilizer (300 kg ha $^{-1}$ NPK 15:15:15) was applied at 2 WAT to supply the first dose of 45 kg ha^{-1} of N, P and K respectively while urea (46 %) was use to supply the other 45 kg ha^{-1} of N at 4 WAT.

3.7.6 Weeding

The entire field was weeded manually with the use of small hand hoe at 3 and 6 WAT.

3.7.7 Pest and disease control

CyperDiforce, (cypermethrin at 30 g/l + dimethoate at 250 g/l) was applied for pest control. Four sprayings using CP 15 sprayer were carried out at weekly interval and commenced at 6 WAT.

3.7.8 Harvesting

Harvesting was carried out at physiological maturity (when the fruit colour changed to yellowish-red), three times in 2016 and 2018 dry seasons and five times in 2017 dry season, depending on ripening.

3.8 Data Collection

Five plants were tagged in the net plots and use for the purpose of collecting morphological parameters at 5, 7 and 9 WAT. Destructive sampling was done by uprooting three plants outside the net plots for the purpose of collecting growth parameters such as leaf area, leaf area index, crop growth rate, relative growth rate and net assimilate rate at 3, 5, 7 and 9 WAT.

3.8.1 Plant height (cm)

This was measured with a meter rule from the base of the plant to the apex (terminal bud) of each of the five randomly tagged plants per plot at 5, 7 and 9 WAT and the mean value calculated.

3.8.2 Number of productive branches

The total number of productive branches from the five randomly tagged plants was counted at 5, 7 and 9 WAT.

3.8.3 Number of leaves

Number of functional leaves from each of the five randomly tagged plants was counted at 5, 7 and 9 WAT.

3.8.4 Plant canopy spread

The width of the randomly tagged plants per plot was measured using a meter rule to determine the extent of plant canopy spread and expressed in cm.

3.8.5 Plant dry weight

Three plants were uprooted at 5, 7 and 9 WAT from outside the net plot and then oven dried at 75 ^{0}C to a constant weight to obtain the dry weight in g.

3.8.6 Leaf area index

The Leaf Area Index (LAI) was taken directly by the use of Ceptometer (PAR/LAI) with model number LP-80 ACCUPAR.

3.8.7 Crop growth rate

This is the rate of dry matter production per unit of time as described by Radford (1967) as stated below.

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{GA}\, g/m^2/wk$$

where, W_1 and W_2 are dry weights of sampled plant in g plant $^{-1}$ at time point T_1 and T_2 in weeks and GA is the ground area.

3.8.8 Relative growth rate (RGR)

This is the cumulative dry matter increment per unit of time using the formula as described by Radford (1967).

$$RGR = \frac{logW_2 - logW_1}{T_2 - T_1}\; g/g/wk$$

where, W_1 and W_2 are dry weight of sampled plant in g plant $^{-1}$ at time point T_1 and T_2 in weeks

3.8.9 Net assimilation rate

This was computed with the following formula given by Radford (1967).

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{1}{LA}\; \text{g/cm2/wk}$$

where W_1 and W_2 are dry weight of sampled plant in g plant $^{-1}$ at time point T_1 and T_2 in weeks and LA = Leaf area.

3.8.10: Crop Evapotranspiration

The rate of evapotranspiration was determined using volumetric method at three different cycles by the use of soil moisture meter (VG-Meter-200). The first measurement was taken a day after the first irrigation event and next irrigation event (14 days). This was to allow moisture content of the soil to drop to field capacity and drainage to become negligible. This was to ascertain whether subsequent water loss could be attributed essentially to evapotranspiration. The second and third soil measurement was taken on the 28th and 42th day after the previous irrigation event, respectively. This was just prior to the next irrigation event, at 14-days interval. The measurements were repeated until the cropping period ended at 12 WAT with 42 day period. Evapotranspiration coefficient (Etc) was calculated from the change in soil moisture content in successive measurement from the following relationship derived as described by Michael (2006).

$$ET_C = \sum_{i=1}^{n} \frac{M_1 - M_2}{100} . Di$$

where, ETc = evapotranspiration from the root zone for 14-day measurement interval (mm); n = number of soil layers sampled in the root zone depth, D; M1i = gravimetric water content (%) at the time of the first measurement in the ith layer; M2i, volumetric water content (%) at the time of the second sampling in the ith layer; D = depth of the ith layer of the soil (mm).

3.8.11: Number of days to 50% flowering

Number of days from transplanting to the time that about half of the total plant population in each plot had flowered was counted and recorded.

3.8.12: Stem girth at first harvest (cm)

The stem girth was determined at first harvest. At 3 cm from the base of the plant, a Vernier caliper was used to measure the diameter of the stem and the value was multiplied by two to obtain stem girth.

3.8.13: Fruit diameter (cm)

Fruit diameter was determined by measuring the diameter of five randomly selected fruits from the net plot with a Vernier calliper.

3.8.14: Number of fruits

This was determined by counting the number of fruits from each of the five randomly sampled plants per plot.

3.9.15 Total fresh fruit yield

This was determined by weighing the total number of harvested fruits per net plot with the use of a top loader balance and then converted to tonnes per hectare.

3.8.16 Marketable fruit yield

This was determined by selecting only undamaged and disease free fruits per plot then weighed in kilogram and converted to tonnes per hectare.

3.8.17 Tomato fruit storage for quality studies

Tomato fruits free from diseases and injury were selected from harvested fruits and transferred to a well ventilated room in Kadawa irrigation research unit of IAR-ABU Zaria in Kano. The fruits were arranged on the floor under laid with cellophane sheet on treatment bases as illustrated in plate II. At daily interval, virtual assessment of the fruits was carried for 14 days. During each assessment, separation of rotten fruits was carried out leaving behind only healthy fruits. At 14 days after storage, the cumulative number of degenerated fruits in storage were determined and used in calculating the fruit spoilage in percentage.

3.8.18 Fruit general appearance

Fruit general appearance was scored by overall rating that included freshness (green calyx), decay, firmness, defects, colour on a scale of 1 to 5 with: 0 to 1= Poor, 2 to 3= Good and 4 to 5= Very good as described by (Mondal, 2000).

3.8.19 Fruit decay

Decay of fruit was recorded as soon as fungal mycelia (microbial infection) appeared on the calyx or peel of the fruit. Decay was expressed as a percentage of the total initial fruit number stored.

3.8.20 Fruit shelf life

The shelf life was observed from the start of harvesting and extended up to the time the fruit was rotten (Mondal, 2000).

3.8.21 Fruit N, P and K contents

Three randomly sampled fruits were sliced and sun dried for 48 hours to a constant weight and taken to the laboratory for fruit N, P and K analysis as described by AOAC (2002).

3.8.22 Fruit vitamin A, E and C contents

Five randomly sampled fruits were sliced and weighed before being sun dried for 48 hours to a constant weight. These were taken to the laboratory for fruit vitamin A, E and C analysis using liquid chromatography method (LC) as described by AOAC (2002; 2003).

3.9 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) as described by Steel and Torrie (1987). Treatment means were separated using Duncan Multiple Range Test as described by Duncan (1955). Simple correlation was also carried out to assess the magnitude and type of relationship between the morphological/growth and marketable fruit yield.

The direct and indirect effect of individual and combined (two factors) contributions of yield component to fruit yield was determined using path coefficient analysis.

3.10 Cost and Return Analysis

The fruit yield data was subjected to cost and return analysis. The returns and variable cost were computed to compare the profitability of the factors and the combination. The gross margin was calculated based on the prevailing market price in each year using the formula as described by Olukosi and Erhabor (1988).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Soil properties of the experimental site

Table 4.1 shows the physical and chemical properties of the soil at the experimental site before the commencement of the trial. The soil was of loam textural class with mild alkaline pH. Nitrogen content of the soil was low, while organic matter was very high. Potassium content was medium while phosphorus was high. Calcium and magnesium contents were very high. Electrical conductivity of the soil was low, indicating that the soil was non saline.

4.1.2 Poultry droppings

Table 4.2 shows the chemical properties of poultry droppings used in the three years. Nitrogen content of poultry droppings used was 2.57 % in 2016, 3.67 % in 2017 and 3.36 % in 2018. These were the values used to determine the quantity of poultry dropping to supply the plants with the recommended nitrogen dose.

4.1.3 Meteorological information of the experimental site

The weather data during the experimental period are shown in table 4.3. In 2016, maximum temperature ranged from 23.5 to 38.8^0 C and minimum temperature ranged from 11.1 to 24.8^0 C while maximum relative humidity (RH) ranged from 43.3 to 75.9 % and minimum RH ranged from7.9 to 22.7 %. In 2017, maximum temperature ranged from 22.8 to 41.7^0 C and minimum temperature ranged from12.9 to 26.7^0 C while minimum RH ranged from22.9 to 52.5 %. In 2018, maximum temperature ranged from 20.7 to 51.7^0 C and minimum temperature ranged from 8.8 to 23.6^0 C while maximum RH ranged from 36.8 to 70.8 % and minimum RH ranged from 10.6 to 24.8 %.

Table 4.1: Physical and chemical properties of the soil at experimental site (0-15 cm) during 2016, 2017 and 2018 dry seasons

	2016	2017	2018
Soil properties			
Sand (g kg^{-1})	420	390	430
Silt (g kg^{-1})	450	480	420
Clay (g kg^{-1})	130	130	132
Textural class	Loam	Loam	Loam
pH in H_2O 1:2.5	7.90	6.70	7.50
pH ($CaCl_2$)	6.80	5.80	6.55
Organic matter (g kg^{-1})	7.89	13.75	7.65
Available phosphorus (mg kg^{-1})	10.92	11.73	12.5
Total nitrogen (g kg^{-1})	0.63	0.99	0.55
Ca^{++} (cmol kg^{-1})	4.60	3.00	3.7
Mg^{++} (cmol kg^{-1})	1.58	0.83	2.13
K^{+} (cmol kg^{-1})	0.15	0.13	0.11
Na^{+} (cmol kg^{-1})	6.54	0.33	0.32
H^{+}+Al^{3+} (cmol kg^{-1})	0.05	0.04	0.04
ECEC (cmol kg^{-1})	6.59	4.89	5.6
EC (dS m^{-1})	0.013	0.015	0.015

Source: Soil science Department Faculty of Agriculture, Ahmadu Bello University Zaria.

Table 4.2: Nutrient levels of the poultry droppings used

Chemical properties	2016	2017	2018
N **(g kg^{-1})**	2.57	3.67	3.36
P **(mg kg^{-1})**	2.5	10	10
K **(mg kg^{-1})**	10	30	30
Ca **(mg kg^{-1})**	40	20	30
Mg **(mg kg^{-1})**	40	10	20
Na **(mg kg^{-1})**	50	30	60

Source: Soil science Department Faculty of Agriculture, Ahmadu Bello University Zaria.

Table 4.3: Meteorological data showing mean temperature and relative humidity at Kadawa during 2016 dry season

Months	Days	Temperature (^{0}C)		Relative humidity (%)	
		Minimum	Maximum	Minimum	Maximum
		2016			
January	0-10	11.07	23.48	10.13	43.30
	11-20	NA	NA	NA	NA
	21-31	NA	NA	NA	NA
February	0-10	13.15	27.63	10.03	46.33
	11-20	14.16	31.79	7.93	55.13
	21-31	16.6	33.07	9.89	51.39
March	0-10	20.59	36.77	11.86	61.38
	11-20	22.6	35.85	22.71	74.77
	21-31	22.55	36.85	13.58	62.98
April	0-10	23.1	37.84	19.16	64.17
	11-20	24.75	38.61	19.89	75.87
	21-31	22.37	38.8	12.92	63.94
		2017			
January	0-10	13.6	28	45.4	NA
	11-20	12.9	28.8	37.6	NA
	21-31	16.27	25.18	36	NA
February	0-10	17.4	23.5	38.8	NA
	11-20	19.9	22.8	33.8	NA
	21-31	20.56	27.33	22.33	NA
March	0-10	20.2	38.1	25.9	NA
	11-20	21.7	34.8	25.7	NA
	21-31	21.45	37.36	24.09	NA
April	0-10	26.5	41.7	51.2	NA
	11-20	26.7	40.7	52.5	NA
	21-31	25.3	41.5	43.6	NA
		2018			
November	0-10	17.0	32.3	11.8	48.2
	11-20	15.8	51.7	11.9	63.0
	21-30	23.6	36.1	14.6	70.8
December	0-10	18.5	32.9	15.3	45.6
	11-20	21.3	48.8	24.8	41.7
	21-31	19.2	22.9	19.7	29.8
January	0-10	13.5	30.1	11.1	41.2
	11-20	16.1	22.2	13.1	42.6
	21-31	14.5	20.7	18.9	36.8
February	0-10	8.8	21.7	10.55	39.2
	11-20	NA	NA	NA	NA
	21-31	NA	NA	NA	NA

Source: International Institute of Tropical Agriculture (IITA) weather unit in Kadawa, Kano.

4.1.4 Major pests and diseases

Common insect pests found were Canker worm and Horn worm which are caterpillars that affect the fruits and leaves respectively. A leaf miner moth (*Tuta absoluta)* commonly called tomato Ebola is another pest that was noticed during the experiment. The common diseases during the experiments include *Septoria leaf spot and early blight* causing small round spot with light centre on the leaves and yellowing of leaves, respectively. Some physiological disorder that causes leaf roll was also observed due to extreme weather conditions.

4.1.5 Plant height

Table 4.4 shows the response of plant height of irrigated tomato variety under varying nitrogen source and organic mulch in 2016, 2017 and 2018 dry seasons in Kadawa. In 2016 growing season, variety UC82B produced significantly taller (19.2 cm) plants than Rio-Grande (18.0 cm). The heights of the plants were significantly comparable (25.8 cm and 25.2 cm) at 7 weeks after transplanting (WAT). However, plants of Rio-Grande grew significantly taller (39.9 cm) than those of UC82B (35.1 cm) at 9 WAT. In 2017, plants of Rio-Grande grew significantly taller (28.4 cm) at 5 WAT than UC82B (25.2 cm). The superiority in plant height of Rio-Grande over UC82B was maintained at 7 WAT. The two varieties produced plants of comparable height at 9 WAT. In 2018 season, plants of Rio-Grande were significantly taller at 5 and 9 WAT than UC82B with 23.5 cm and 38.1 cm, respectively. There was significant difference between plant heights of the two varieties at 7WAT.

Nitrogen significantly enhanced plant height of tomato. For example, in 2016, poultry droppings and MF + PD significantly produced taller plants that were comparable at 5 and 9 WAT, while at 7 WAT, all the nitrogen sources significantly produced taller plants that were comparable than the unfertilized plots. In 2017, MF + PD resulted in the production of significantly taller plants compared with plants of other nitrogen treatments at 5 and 7 WAT, the plants were however similar in height at 9 WAT for PD and MF + PD treatments. At 5 WAT in 2018, MF + PD resulted in the production of significantly taller (28.2 cm) plants than plants of the remaining nitrogen treatments with height ranging between 22.1 and 25.2 cm. However, the nitrogen sources with exception of the control produced plants which did not significantly differ in their heights at 7 and 9 WAT.

Mulching also promoted height of plants in all growth stages and seasons. For instance in 2016, sugar cane peels mulch produced taller plants at all growth stages (5, 7 and 9 WAT) which were similar to those produced under rice straw mulch. Furthermore, plots which received sugar cane peels as mulch produced significantly taller plants than the un-mulched plots. In 2017, rice straw mulch resulted in the production of significantly taller plants (28.5 cm and 59.8 cm) than the un-mulched plots (25.6 and 55.2 cm) at 5 and 9 WAT. Similarly, in 2018, rice straw and sugar cane peels produced similar taller plants which were significantly different from those in the control plots at 5 and 7 WAT. The two mulches schedules (rice and sugar cane peels mulch) produced plants of comparable height at 9 WAT.

Table 4.5 shows the interaction between nitrogen source and organic mulch on plant height of tomato at 9 WAT in 2016and 7 WAT in 2017 dry seasons. At 9 WAT in 2016, when any of the nitrogen sources was applied, plant heights were similar and significantly taller than those which did not receive nitrogen in the un-mulched plots. The significantly taller plants (43.0 cm) were produced with PD application in plots mulched with rice straw. However, application of any of the nutrient schedules in plots that were mulched with sugar cane peels mulch resulted in production of plants with comparable height (ranging between 37.7 and 41.1 cm).

In 2017 at 7 WAT, all the nitrogen schedules produced significantly taller plants than the control in the un-mulched plots. The height of 41.6 and 46.7 cm produced with PD and MF + PD in plots of rice straw mulch were statistically comparable. MF + PD produced significantly taller plants than the control in plots of rice straw mulch. When plots were mulched with sugar cane peels, any of the nitrogen sources produced plants with comparable height.

Table 4.4: Main effects and interactions of variety, nitrogen source and organic mulch on plant height (cm) of irrigated tomato during 2016, 2017 and 2018 dry seasons

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	19.2a	25.8	35.1b	25.2b	38.3b	56.9	23.5b	37.1	38.1b
Rio-Grande	18.0b	25.2	39.7a	28.4a	42.5a	58.8	26.5a	38.5	41.9a
SE±	0.3	0.6	0.6	0.5	0.6	1.2	0.5	1.2	0.9
Nitrogen source (N)									
No application	17.8b	23.9b	34.4c	25.3b	35.8c	53.8b	22.1c	31.0b	34.9b
Mineral fertilizer (MF)	18.0b	24.8ab	36.7bc	25.4b	40.7b	57.8b	24.5b	38.5a	42.1a
Poultry droppings (PD)	20.1a	26.6ab	40.0a	26.2b	40.1b	59.4a	25.2b	38.9a	40.5a
MF.+ PD	18.6ab	26.7a	38.6ab	30.1a	44.9a	60.2a	28.2a	42.9a	42.5a
SE±	0.5	0.8	0.9	0.7	0.9	1.7	0.7	1.6	1.3
Organic mulch (M)									
No mulch	17.4b	23.9b	35.8b	25.6b	38.9	55.2b	22.0b	32.0b	37.5
Rice straw	18.6ab	25.4ab	37.6ab	28.5a	41.8	59.8a	27.6a	42.1a	41.8
Sugarcane peels	19.9a	27.2a	38.7a	26.1ab	40.3	58.5ab	25.5a	39.3a	40.7
SE±	0.71	0.82	0.96	0.92	1.20	1.46	0.99	1.60	1.91
Interactions									
N×V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	*	NS	*	NS	NS	NS	NS
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting.

Table 4.5: Interaction between nitrogen source and organic mulch on plant height (cm) of tomato at 9 WAT in 2016 and 7 WAT in 2017 dry seasons

	Organic mulch		
Nitrogen source	No mulch	Rice straw	Sugarcane peels
	9 WAT (2016)		
No nitrogen	27.4d	37.8b	38.0b
Mineral fertilizer (MF)	38-2b	32.7c	37.7b
Poultry droppings (PD)	38.7b	43.0a	39.7ab
MF.+ PD	37.5b	37.0b	41.1ab
SE±		1.9	
	7 WAT (2017)		
No nitrogen	29.3d	40.2bc	37.8c
Mineral fertilizer (MF)	37.9c	40.5bc	43.6ab
Poultry droppings(PD)	38.9bc	41.6a-c	41.4a-c
MF.+ PD	40.0bc	46.7a	46.5a
SE±		2.4	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

4.1.6 Number of branches

The response of tomato variety to nitrogen source and organic mulch on number of branch in 2016, 2017 and 2018 dry season is presented in Table 4.6. At 5 and 7 WAT, in 2016 produced significantly more (2.1 cm and 3.8 cm) branches than Rio-Grande (1.5 cm and 3.3 cm).

In 2016, the three nitrogen sources produced similar number of branches which was significantly different from the unfertilized plots at 5 and 9 WAT (Table 4.6). However, at 7 WAT, MF and MF + PD produced comparable number of branches that were higher than PD and the unfertilized plots. In 2017, MF + PD recorded significantly higher number of branches than the remaining nitrogen schedules at 5 WAT. At 5 WAT the same year, MF + PD produced plants with significantly higher number of branches than any of the nitrogen schedules whereas at 7 and 9 WAT, MF and MF + PD produced higher number of branches than PD and the unfertilized plot. Similar trend was observed at 7 WAT in 2018. Furthermore, at 5 and 9 WAT in 2018, any of the nitrogen sources increased branch production compared to unfertilized plots.

Throughout the three growing seasons, mulching did not significantly enhance branch production except at 9 WAT in 2016 and 2017 where un-mulched plots produced plants with significantly fewer branches than plants from mulched plots.

Table 4.7 shows interaction between nitrogen source and variety on number of branches of tomato at 7 WAT in 2016 dry season. Nitrogen sources did not affect branching in Rio-Grande but affected branching in UC82B. UC82B plots treated with nitrogen sources produced significantly more branches than the untreated control. The number of branches varied from 2.9 - 4.5.

Table 4.6: Main effects and interactions of variety, nitrogen source and organic mulch on number of branches of irrigated tomato during 2016, 2017, 2018 and the mean results

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	2.1a	3.8a	5.0	1.7	3.8	8.7	1.6	4.0	10.3
Rio-Grande	1.5b	3.3b	5.0	1.7	4.0	8.6	1.6	3.8	9.7
SE±	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.2	0.3
Nitrogen source (N)									
No application	1.5b	3.1c	4.5b	1.6b	3.4b	7.9b	1.3b	3.1c	8.5b
Mineral fertilizer (MF)	1.9a	3.7ab	5.0a	1.6b	4.0ab	9.5a	1.6ab	4.1ab	10.6a
Poultry droppings (PD)	1.7ab	3.6b	5.1a	1.3b	3.7b	8.2b	1.6ab	3.7bc	9.8a
MF.+ PD	1.8ab	3.9a	5.4a	2.2a	4.4a	9.0ab	1.8a	4.7a	11.0a
SE±	0.1	0.1	0.2	0.1	0.2	0.4	0.1	0.2	0.4
Organic mulch (M)									
No mulch	1.7	3.4	4.5b	1.6	3.7	6.9b	1.4	3.8	9.3
Rice straw	1.9	3.5	5.2a	1.8	4.1	9.2a	1.7	4.1	10.2
Sugarcane peels	1.8	3.7	5.2a	1.6	4.0	9.8a	1.6	3.8	10.5
SE±	0.10	0.16	0.21	0.20	0.28	0.20	0.15	0.25	0.42
Interaction									
N×V	NS	*	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting

Table 4.7: Interaction of nitrogen source and variety on number of branches of tomato at 7 WAT in 2016 dry seasons

	Variety	
Nitrogen source	UC82B	Rio-Grande
No application	2.9c	3.3bc
Mineral fertilizer(MF)	4.1ab	3.3bc
Poultry droppings(PD)	3.8ab	3.3bc
MF.+ PD	4.5a	3.3bc
SE±	0.3	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

4.1.7 Number of leaves

Table 4.8 shows the effect of nitrogen source and organic mulch on number of leaves of tomato variety in 2016, 2017 and 2018 dry seasons. Variety UC82B produced significantly more number of leaves (42 and 90) than Rio-Grande (30 and 69) at 5 and 7 WAT, respectively in 2016.

In 2016 MF resulted in the production of significantly higher number of leaves compared to other nitrogen treatments at 5 WAT. Similar trend was observed at 7 WAT with PD showing superiority over other nitrogen treatments. However, at 9 WAT PD and MF had significantly higher number of leaves (197 and 206) compared with the unfertilised plots but was statistically similar with MF application.

Throughout the growing stages in 2016, mulching significantly enhanced leaves of the plants where un-mulched plots produced plants with significantly fewer leaves than plants from any of the mulching schedules. Similar trend was observed at 5 WAT in 2018. In 2017, mulching did not affect number of leaves in all growth stages.

Table 4.8: Main effects and interactions of variety, nitrogen source and organic mulch on number of leaves of irrigated tomato during 2016, 2017 and 2018 dry seasons

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	42a	90a	191	43	152	304	43.6	140.7	315.8
Rio-Grande	30b	69b	184	49	165	331	47.2	153.0	290.4
SE±	1.4	3.0	7.2	2.2	5.2	10.5	2.2	6.5	10.4
Nitrogen source (N)									
No application	31b	71b	161b	43b	145b	290b	34.7b	115.0c	247.7c
Mineral fertilizer (MF)	39a	82ab	184ab	43b	153b	307b	43.3b	152.6b	333.5ab
Poultry droppings (PD)	37ab	85a	197a	41b	138b	275b	43.7b	139.1bc	291.7bc
MF.+ PD	37ab	80ab	206a	57a	198a	397a	59.8a	180.7a	339.4a
SE±	2.0	4.2	10.2	3.1	7.4	14.8	3.1	14.7	14.7
Organic mulch (M)									
No mulch	32b	70b	159b	44	163	326	38.8b	131.3	272.8
Rice straw	38a	82ab	193a	46	153	305	47.5a	148.9	315.1
Sugarcane peels	37a	86a	206a	47	161	321	49.8a	160.4	321.4
SE±	4.9	0.1	11.3	3.7	12.8	25.5	3.00	10.86	17.43
Interaction									
N×V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. WAT=Weeks after transplanting.

4.1.8 Plant canopy spread

Table 4.9 shows the effects of variety, nitrogen source and organic mulch on canopy spread of irrigated tomato during 2016, 2017 and 2018 dry season. During 2016 growing season variety UC82B produced significantly wider canopy (18.7 and 33.2 cm) at 5 and 7 WAT. However, in 2018, plants of Rio-Grande grew significantly wider (18.8 and 46.9 cm) at 5 and 9 WAT. Canopy spread of the plants was not affected by Variety in 2017.

Any of the nitrogen sources produced significantly wider canopy spread which was statistically similar compared with the unfertilized plots at 7 and 9 WAT in 2016. Similar trend was observed at 5 and 9 WAT in 2017. However, in 2018, any of the nitrogen sources resulted in the production of significantly wider canopy compared with plants of the unfertilized plots at 7 WAT whereas at 5 and 9 WAT, MF and MF + PD produced wider canopy that was comparable than PD and the unfertilized plots.

Mulching promoted canopy spread in all growth stages in 2016 and at 5 and 9 WAT in 2018. In 2016, sugar cane peels enhanced wider canopy at all sampling period (19.1, 34.6 and54.9 cm). These width values were however similar to (18.3, 30.9 and 53.3 cm) produced with rice straw mulch at the same period. Similar trend was observed at 5 and 9 WAT in 2018.

Interaction was significant between nitrogen sources and organic mulches at 9 WAT in 2016 and 2018 as well as between nitrogen source, variety and organic mulch at 7 WAT in 2018.

Table 4.10 shows effects of nitrogen source × organic mulch interactions on canopy spread of tomato at 9 WAT during 2016 and 2018 dry seasons. In 2016, when any of the nitrogen sources was applied, plant canopy spread were comparable and significantly produced wider canopy than those which did not receive nitrogen in the un-mulched plots. Significantly wider canopy (63.2 cm) was produced with PD in plots mulched with rice straw. However, MF + PD resulted to the production of plants with wider canopy (60.4 cm) in plots that were mulched with sugar cane peels.

At 9 WAT in 2018, any of the nitrogen sources produced significantly comparable canopy spread on the un-mulched plots. When the plots were mulched with rice straw, any of the nitrogen sources resulted to statistically comparable canopy spread on the other hand MF + PD produced significantly wider canopy spread than the other nitrogen schedules that were also at par. However, similar trend was observed with the un-mulched plots when the plots were mulched with sugar cane peels.

Effects of nitrogen source , organic mulch and variety interactions on canopy spread of tomato at 7 WAT during 2018 dry season results is shown in Table 4.11. The combination of PD, sugarcane peels and Rio-Grande gave the widest canopy spread compared to untreated control plots.

Table 4.9: Main effects and interactions of variety, nitrogen source and organic mulch on canopy spread (cm) of irrigated tomato during 2016, 2017 and 2018 dry seasons

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	18.7a	33.2a	51.2	18.1	25.7	40.7	17.0b	24.5	42.3b
Rio-Grande	16.6b	30.6b	53.4	18.5	26.0	44.1	18.8a	25.6	46.9a
SE±	0.5	0.8	1.3	0.3	0.9	1.9	0.5	1.1	1.0
Nitrogen source (N)									
No application	16.5	29.2b	48.8b	16.6b	22.9	36.2b	14.1c	20.1b	37.8c
Mineral fertilizer (MF)	18.0	31.5ab	50.8ab	18.4ab	26.5	45.7a	19.0ab	26.5a	47.9a
Poultry droppings (PD)	18.0	34.0a	55.1a	17.9ab	27.0	43.2ab	17.8b	26.1a	43.4b
MF.+ PD	18.0	32.9a	54.6ab	20.3a	26.9	44.4ab	20.8a	27.4a	49.1a
SE±	0.7	1.1	1.9	1.1	1.3	2.6	0.71	1.6	1.4
Organic mulch (M)									
No mulch	15.5b	30.2	48.8b	17.3b	26.0	40.9	15.8b	23.4	41.1b
Rice straw	18.3a	30.9	53.3ab	19.8a	26.1	45.1	19.4a	25.0	46.9a
Sugarcane peels	19.1a	34.6	54.95a	17.8ab	25.4	41.2	18.6a	26.7	45.7ab
SE±	0.8	1.5	1.8	0.8	1.4	1.7	0.9	1.2	1.9
Interaction									
N×V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	*	NS	NS	NS	NS	NS	*
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	*	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting.

Table 4.10: Interaction between nitrogen source and organic mulch on canopy spread (cm) of tomato at 9 WAT during 2016 and 2018 dry seasons

	Organic mulch		
Nitrogen source	No mulch	Rice straw	Sugarcane peels
	9WAT (2016)		
No nitrogen	40.7e	54.1bc	51.7cd
Mineral fertilizer (MF)	53.2bc	44.3de	52.7bc
Poultry droppings(PD)	49.5cd	63.2a	55.0
MF.+ PD	51.8cd	51.5cd	60.4ab
SE±		3.6	
	9 WAT (2018)		
No nitrogen	21.5d	44.2bc	43.9bc
Mineral fertilizer (MF)	41.1c	46.2a-c	46.8a-c
Poultry droppings (PD)	43.5bc	45.5a-c	53.4a
MF.+ PD	45.1a-c	51.1ab	52.3ab
SE±		3.8	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

Table 4.11: Interactions between nitrogen source and organic mulch on canopy spread (cm) of tomato varieties at 7 WAT during 2018 dry season

	Variety					
	UC82B			Rio-Grande		
	Organic mulch					
Nitrogen source	No mulch	Rice straw	Sugar-cane peels	No mulch	Rice straw	Sugar cane peels
No application	8.9i	26.9c-e	24.4e-g	12.2i	22.1gh	26.4c-f
Mineralfertilizer(MF)	24.9d-e	22.5f-h	29.6bc	30.9b	23.3e-h	22.5f-h
Poultry dropping(PD)	28.3b-d	24.6d-g	20.1h	23.2e-h	29.1bc	36.0a
MF.+ PD	29.4bc	24.3e-g	29.7bc	24.5d-g	27.1b-e	29.5bc
SE±			3.3			

All means followed by same letters within row and column are not different at 5% level of significance using Duncan Multiple Range test DMRT.

4.1.9 Plant dry weight

Table 4.12 shows the response of plant dry weight of irrigated tomato as influenced by variety, nitrogen source and organic mulch during 2016, 2017 and 2018 dry seasons. Variety UC82B at 5 and 7 WAT produced significantly heavier plant dry weight (2.0 g and 9.0 g) than Rio-Grande (1.0 g and 5.3) respectively in 2016. Similar trend was observed at 9 WAT in 2018 with UC82B showing superiority over Rio-Grande.

Nitrogen sources did not affect plant dry weight at 5 WAT in 2016. At 7 and 9 WAT the same year, any of the nitrogen sources produced plants with similar and significantly heavier plant dry weight compared with unfertilised plots. In 2017 at 5 and 9 WAT, similar trend was observed but at 7 WAT, MF + PD resulted to significantly heavier plants dry weight of 9.6 g compared to the other nitrogen schedules which were statistically at par. However, in 2018, MF + PD resulted to heavier (2.1 g) plant dry weight compared to the control but were statistically comparable to MF with 1.8 g at 5 WAT. At 7 WAT, the same year, MF + PD resulted to heavier plant dry weight then the other nitrogen schedules. However, at 9 WAT any of the nitrogen sources produced statistically similar plant dry weight ranging from 29.9-31.9 g compared with 2.7 g from unfertilized plots.

Mulching promoted canopy spread at 9 WAT in 2016 with sugar cane peels which produced wider canopy spread (18.9 g) than the un-mulched plot but was statistically comparable to rice straw mulch (18.4 g). Conversely, similar trend was observed at 5 and 9 WAT in 2017 and at 5 WAT in 2018 with rice straw mulch showing superiority over sugar cane peels mulch.

Interaction was significant between nitrogen sources and organic mulches at 7 WAT in 2017 and highly significant in the same period in 2018.

Effects of nitrogen source × organic mulch interactions on plant dry weight of tomato at 7 WAT during 2017 and 2018 dry seasons is shown in Table 4.13. At 7 WAT in 2017, any of the nitrogen sources produced significantly similar plant dry weight on the un-mulched plots although, MF + PD had heavier plant dry weight than the other nitrogen schedules. When the plots were mulched with any of the organic mulches, MF + PD resulted to heavier plant dry weight than the other nitrogen schedules.

In 2018 at 7 WAT, any of the nitrogen sources produced significantly similar plant dry weight on the un-mulched plots. When rice straw was applied, MF + PD produced heavier plant dry weight (20.3 g). However, when sugar cane peels was applied, PD and MF + PD produced heavier plant dry weight (19.6 g and 17.1 g) respectively than the unfertilised plots.

Table 4.12: Main effects and interactions of variety, nitrogen source and organic mulch on plant dry weight per plant (g) of irrigated tomato during 2016, 2017 and 2018 dry seasons

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	2.0a	9.0a	18.4	1.7	5.7	26.5	1.7	12.3	40.0a
Rio-Grande	1.0b	5.3b	17.7	1.9	7.1	30.3	1.9	12.7	27.7b
SE±	0.2	0.5	0.7	0.1	0.5	3.9	0.1	0.7	0.8
Nitrogen source (N)									
No application	1.3	5.9b	15.4b	1.6b	5.0b	17.4b	1.5b	11.5b	25.7b
Mineral fertilizer (MF)	2.2	8.3a	19.3a	1.9a	5.9b	30.4ab	1.8ab	11.6b	29.7a
Poultry droppings (PD)	1.3	7.6ab	18.2a	1.8ab	5.2b	24.7ab	1.7b	10.5b	32.0a
MF.+ PD	1.3	6.9ab	19.2a	1.9a	9.6a	41.3a	2.1a	16.4a	31.9a
SE±	0.3	0.7	0.9	0.1	0.7	8.5	0.1	1.0	1.1
Organic mulch (M)									
No mulch	1.8	7.3	16.9b	1.6b	6.6	19.8b	1.4b	11.4	26.8
Rice straw	1.3	6.7	18.4ab	2.0a	6.4	35.3a	2.1a	14.2	30.8
Sugarcane peels	1.5	7.5	18.9a	1.9a	6.3	30.2ab	1.8a	12.0	31.8
SE±	0.2	0.8	0.6	0.1	0.5	3.9	0.1	1.0	2.0
Interaction									
N×V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	NS	NS	*	NS	NS	**	NS
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means within a column/factors followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting.

Table 4.13: Interaction between nitrogen source and organic mulch on plant dry weight (g) of tomato at 7 WAT during 2017 and 2018 dry seasons

	Organic mulch		
Nitrogen sources	No mulch	Rice straw	Sugarcane peels
	7WAT (2017)		
Nitrogen source			
No nitrogen	3.1d	5.2b-d	5.0b-d
Mineral fertilizer (MF)	4.7cd	7.3b	5.8bc
Poultry droppings(PD)	4.7cd	6.8bc	5.4b-d
MF.+ PD	6.2bc	12.0a	10.7a
SE±		1.0	
	7 WAT (2018)		
No nitrogen	4.4e	10.6d	10.5d
Mineral fertilizer (MF)	10.5d	14.7bc	9.6d
Poultry droppings (PD)	10.2d	10.6d	19.6a
MF.+ PD	11.8cd	20.3a	17.1ab
SE±		1.9	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMR.

4.1.10 Leaf area index (LAI)

Table 4.14 shows the main effect and interaction between varieties, nitrogen sources and organic mulches on leaf area index (LAI) of irrigated tomato during 2016, 2017 and 2018 dry seasons. Variety did not affect LAI in all the growth periods and across the years.

Any of the nitrogen sources with the exception of the control produced plants which did not differ in LAI significantly at 5 WAT. At 7 WAT the same year, MF produced significantly higher LAI (1.58) compared with other nitrogen schedules which were statistically comparable. However, at 9 WAT, any of the nitrogen sources with exception of the control produced significantly higher LAI which did not differ from each other. Similar trend was observed in all growth stages in 2017 and at 5 and 7 WAT in 2018. Nitrogen sources did not affect LAI at 9 WAT in 2017/2019.

Mulching promoted LAI in all growth stages in 2016 and at 5 and 9 WAT in 2018. In 2016, un-mulched plots produced plants with significantly lower LAI than plants from any of the mulching schedules. Similar trend was however observed at 5 and 9 WAT in 2018.

Effects of nitrogen source × organic mulch interactions on LAI of tomato at 9 WAT during 2017 dry season is shown in Table 4.15. Any of the nitrogen sources produced significantly and comparable LAI than the unfertilized plants on the un-mulched plots. When rice straw was used, PD and MF + PD had higher LAI than the control, but were statistically similar with MF + PD. However, when sugar cane peels were applied any of the nitrogen sources produced significantly similar LAI than plant of the unfertilized plots.

Table 4.14: Main effects and interactions of variety, nitrogen source and organic mulch on leaf area index (LAI) of irrigated tomato during 2016, 2017 and 2018 dry seasons

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	1.19	1.43	2.99	0.21	1.27	2.27	0.14	3.79	2.99
Rio-Grande	1.21	1.51	3.10	0.21	1.27	2.27	0.13	3.93	3.01
SE±	0.02	0.03	0.09	0.01	0.01	0.01	0.01	0.09	0.14
Nitrogen source (N)									
No application	1.12b	1.44b	2.83b	0.12b	1.13b	2.13b	0.11c	3.07b	2.68
Mineral fertilizer (MF)	1.25a	1.58a	3.28a	0.24a	1.31a	2.30a	0.15a	4.02a	3.00
Poultry droppings (PD)	1.22a	11.42b	3.04ab	0.24a	1.32a	2.32a	0.14ab	4.13a	3.18
MF.+ PD	1.21a	1.45b	3.04ab	0.23a	1.32a	2.32a	0.13b	4.21a	3.14
SE±	0.03	0.04	0.13	0.01	0.01	0.01	0.01	0.13	0.20
Organic mulch (M)									
No mulch	1.15b	1.29b	2.74b	0.20	1.25	2.25	0.12b	3.63	2.74b
Rice straw	1.22a	1.57a	3.21a	0.22	1.28	2.28	0.14a	4.03	3.20a
Sugar-cane peel	1.23a	1.56a	3.19a	0.20	1.27	2.27	0.14a	3.92	3.07ab
SE±	0.02	0.05	0.14	0.01	0.01	0.01	0.01	0.20	0.15
Interaction									
N×V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	NS	NS	NS	*	NS	NS	NS
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting.

Table 4.15: Interaction between nitrogen source and organic mulch on LAI of tomato at 9 WAT during 2017 dry season

	Organic mulch		
Nitrogen source	No mulch	Rice straw	Sugarcane peels
No nitrogen	2.08e	2.18c	2.12d
Mineral fertilizer (MF)	2.31ab	2.29b	2.32ab
Poultry droppings(PD)	2.32ab	2.33a	2.32ab
MF.+ PD	2.31ab	2.31ab	2.33a
SE±		0.02	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT

4.1.11 Crop growth rate (CGR)

Table 4.16 shows the main effect and interaction between varieties, nitrogen sources and organic mulches on crop growth rate (CGR) of irrigated tomato during 2016, 2017 and 2018 dry seasons. In 2016, variety UC82B produced significantly greater CGR (1.34 and 8.80 g.g.wk) than CGR of 0.61 and 5.32 g wk^{-1} $plant^{-1}$ from Rio-Grande. Similar trend was observed at 5 WAT in 2017 and 2018. However, at 9 WAT in 2018, UC82B produced significantly greater CGR (24.5 g wk^{-1} $plant^{-1}$) than 18.76 g wk^{-1} $plant^{-1}$ from Rio-Grande.

In 2017, CGR was not affected by nitrogen sources in all growth stages. In 2017, any of the nitrogen sources produced plants with significantly greater CGR compared to the unfertilized plots at 5 and 9 WAT whereas at 7 WAT, MF + PD showed superiority in CGR over other nitrogen schedules. However, similar result was observed at 5 and 7 WAT in 2018 but at 9 WAT in 2018, PD resulted to significantly greater CGR compared to unfertilized plots but was statistically comparable to MF.

Mulching significantly enhanced the plant CGR at 9 WAT in 2016 where plants from the un-mulched plots produced significantly lower CGR than plants from any of the mulching schedules. Similar trend was observed at 5 and 9 WAT in 2017 as well as at 5 WAT in 2018.

Interaction between nitrogen sources and organic mulches was significant at 7 WAT in 2017.

Table 4.17 shows effects of nitrogen source × organic mulch interactions on crop growth rate at 7 WAT during 2017 dry season. When any of the nitrogen sources was applied, plants CGR were statistically similar and significantly greater than those which did not receive nitrogen on the un-mulched plots. When any of the organic mulch (rice straw and sugar cane peels) was applied MF + PD produced significantly greater CGR (12.80 and 10.60 g wk^{-1} $plant^{-1}$) respectively than the other nitrogen schedules.

Table 4.16: Main effects and interactions of variety, nitrogen source and organic mulch on crop growth rate (g wk^{-1} $plant^{-1}$) of irrigated tomato during 2016, 2017 and 2018 dry seasons

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	1.34a	8.80a	12.00b	1.28b	4.95	26.01	1.28b	13.27	24.58a
Rio-Grande	0.61b	5.32b	15.47a	1.90a	6.53	29.05	1.94a	13.52	18.76b
SE±	0.22	0.65	0.80	0.08	0.65	4.36	0.11	0.93	1.23
Nitrogen source (N)									
No application	0.70	5.74	11.92	1.43b	4.16b	15.49b	1.40b	12.51b	17.72b
Mineral fertilizer (MF)	1.64	7.73	13.74	1.56ab	5.02b	30.56ab	1.51b	12.21b	22.65ab
Poultry droppings (PD)	0.76	7.79	13.95	1.56ab	4.15b	24.59ab	1.46b	10.99b	26.93a
MF.+ PD	0.81	6.98	15.34	1.83a	9.63a	39.58a	2.08a	17.83a	19.38b
SE±	0.32	0.92	1.13	0.11	0.91	6.17	0.16	1.31	1.74
Organic mulch (M)									
No mulch	1.30	6.93	11.92b	1.34b	6.26	16.47b	1.25b	12.39	19.35
Rice straw	0.73	6.79	14.51ab	1.80a	5.52	36.13a	1.96a	15.13	20.81
Sugarcane peels	0.89	7.46	14.78a	1.64ab	5.46	29.98a	1.62ab	12.64	24.85
SE±	0.311	1.00	0.93	0.12	0.62	4.54	0.17	1.15	2.63
Interaction									
N×V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	NS	NS	*	NS	NS	NS	NS
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting

Table 4.17: Interaction between nitrogen source and organic mulch on crop growth rate (g wk^{-1} $plant^{-1}$) of tomato at 7 WAT during 2017 dry season

		Organic mulch	
Nitrogen source	No mulch	Rice straw	Sugarcane peels
No nitrogen	2.55d	5.95bc	3.99b-d
Mineral fertilizer (MF)	5.08b-d	6.64b	3.34cd
Poultry droppings (PD)	3.99b-d	4.58b-d	3.89b-d
MF.+ PD	5.49bc	12.80a	10.60a
SE±		1.25	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

4.1.12 Relative growth rate (RGR)

Table 4.18 shows the main effect and interaction between varieties, nitrogen sources and organic mulches on relative growth rate (RGR) of irrigated tomato during 2016, 2017 and 2018 dry seasons. In 2016 growing season, variety UC82B produced significantly greater RGR than plants from Rio-Grande at 5 and 7 WAT. Conversely, Rio-Grande produced significantly greater RGR than plants from UC82B at 9 WAT in the same year. Similar trend was observed at 5 WAT in 2017 and 2018. In 2018, UC82B produced significantly greater RGR than Rio-Grande.

In 2016, though, MF produced plants with greater RGR (0.28 $g.g.wk^{-1}$) at 5 WAT compared with the unfertilized plots (0.16 $g.g.wk^{-1}$) however, these value was statistically comparable with PD with RGR values of 0.18 $g.g.wk^{-1}$. Nitrogen sources did not differ significantly in RGR at 7 and 9 WAT in 2016. In 2017, MF + PD resulted to significantly greater RGR compared to plant from unfertilized plots but were statistically comparable to PD at 5 WAT. At 7 WAT, MF + PD produced greater RGR than other nitrogen schedules while at 9 WAT any of the nitrogen schedules resulted in the production of plants with significantly greater and comparable RGR than the unfertilized plots. Similar response was observed at 5 WAT in 2018 with trend in 2017 at 7 WAT. However, at 9 WAT in 2018, PD produced plants with greater RGR compared with the unfertilized plot though; this value (1.00 $g.g.wk^{-1}$) was statistically comparable with MF with RGR value of 0.95 $g.g.wk^{-1}$.

Throughout the growing seasons, mulching did not enhanced RGR in plants except at 9 WAT in 2017 where un-mulched plots produced plants with significantly lower RGR than plants from any of the mulching schedules.

Interaction between nitrogen sources and organic mulches was significant at 7 WAT in 2017.

Table 4.19 shows effects of nitrogen source × organic mulch interactions on relative growth rate (g.g.wk^{-1}) of tomato at 7 WAT during 2017 dry season. MF + PD produced plants with the lowest RGR compared with any of the nitrogen schedules which were statistically comparable on the un-mulched plots. When rice straw was applied, MF gave the highest RGR of 0.65 g.g.wk^{-1} that was statistically similar to plants of the unfertilized plots (0.63 g.g.wk^{-1}). However, when sugar cane peels was applied, PD and MF + PD resulted to significantly greater RGR than the unfertilized plots and MF g.g.wk^{-1}).

Table 4.18: Main effects and interactions between variety, nitrogen source and organic mulch on relative growth rate (g.g.wk^{-1}) of irrigated tomato during 2016, 2017 and 2018 dry seasons

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	0.27a	0.79a	0.79b	0.31b	0.57	0.93	0.31b	0.92	0.97a
Rio-Grande	0.12b	0.65b	0.92a	0.50a	0.63	0.96	0.52a	0,91	0.90b
SE±	0.023	0.023	0.020	0.022	0.037	0.033	0.020	0.026	0.013
Nitrogen source (N)									
No application	0.16b	0.67	0.80	0.35bc	0.53b	0.78b	0.39b	0..90	0.88c
Mineral fertilizer (MF)	0.28a	0.74	0.86	0.33c	0.59b	1.00a	0.35b	0.90	0.95ab
Poultry droppings (PD)	0.18ab	0.74	0.86	0.44ab	0.51b	0.95a	0.40b	0.87	1.00a
MF.+ PD	0.17b	0.73	0.89	0.50a	0.78a	1.07a	0.53a	0.98	0.92bc
SE±	0.03	0.03	0.02	0.08	0.05	0.05	0.03	0.04	0.02
Organic mulch (M)									
No mulch	0.23	0.70	0.82	0.35	0.63	0.85b	0.39	0.89	0.91
Rice straw	0.16	0.75	0.86	0.43	0.58	1.03a	0.46	0.93	0.92
Sugarcane peels	0.19	0.71	0.89	0.43	0.59	0.97ab	0.40	0.91	0.98
SE±	0.04	0.05	0.03	0.04	0.04	0.05	0.04	0.03	0.03
Interaction									
N×V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	NS	NS	*	NS	NS	NS	NS
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting.

Table 4.19: Interaction between nitrogen source and organic mulch on relative growth rate (g.g.wk^{-1}) of tomato varieties at 7 WAT during 2017 dry season

	Organic mulch		
Nitrogen source	No mulch	Rice straw	Sugarcane peels
No nitrogen	0.45d	0.63bc	0.51b-d
Mineral fertilizer (MF)	0.62b-d	0.65b	0.50b-d
Poultry droppings (PD)	0.53b-d	0.47cd	0.93a
MF.+ PD	0.53e	0.58b-d	0.83a
SE±		0.08	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

4.1.13 Net assimilate rate (NAR)

Table 4.20 shows the main effect and interaction between varieties, nitrogen sources and organic mulches on net assimilate rate (NAR) of irrigated tomato during 2016, 2017 and 2018 dry seasons. In 2016 variety UC82B produced significantly greater NAR than plants from Rio-Grande at 7 WAT. Conversely, Rio-Grande produced significantly greater NAR than plants from UC82B at 9 WAT in the same year. Similar trend was observed at 5 WAT in 2017 and 2018. In 2018, UC82B produced significantly greater NAR than Rio-Grande at 9 WAT.

Nitrogen sources did not affect RGR at all growth stages in 2016. In 2017, in all growth stages, any of the nitrogen sources significantly produces plants that are statistically comparable with respect to NAR whereas in 2018 at 5 and 7 WAT, PD and MF + PD significantly produced plants that are statistically comparable with greater NAR than MF and unfertilized plots. However, at 9 WAT the same year, any of the nitrogen sources significantly produces plants that are statistically comparable with respect to NAR

Throughout the growing seasons, mulching did not affect RGR in plants except at 5 WAT in 2017 where un-mulched plots produced plants with significantly lower NAR than plants from any of the mulching schedules.

Table 4.20: Main effects and interactions of variety, nitrogen source and organic mulch on net assimilate rate ($g\ cm^{-2}\ wk^{-1}$) of irrigated tomato as during 2016, 2017 and 2018 dry seasons

	2016			2017			2018		
Factor levels/interactions	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)									
UC82B	0.09	0.13a	0.09b	0.27b	4.59	5.15a	1.60b	0.59	1.36a
Rio-Grande	0.04	0.09b	0.13a	0.40a	5.09	4.12b	2.42a	0.57	1.05b
SE±	0.02	0.01	0.01	0.02	0.53	0.31	0.12	0.03	0.08
Nitrogen source (N)									
No application	0.05	0.82	0.10	0.18b	3.30b	3.62b	1.72b	0.46c	0.99b
Mineral fertilizer (MF)	0.10	0.12	0.10	0.37a	5.45ab	5.26a	1.67b	0.52bc	1.14ab
Poultry droppings (PD)	0.05	0.13	0.12	0.37a	4.76ab	4.19ab	2.16ab	0.62ab	1.27ab
MF.+ PD	0.06	0.10	0.13	0.43a	5.85a	5.46a	2.48a	0.71a	1.41a
SE±	0.02	0.02	0.02	0.03	0.75	0.44	0.17	0.05	0.11
Organic mulch (M)									
No mulch	0.09	0.11	0.10	0.28b	4.16	4.57	1.88	0.55	1.15
Rice straw	0.05	0.11	0.11	0.39a	5.14	4.53	2.25	0.66	1.07
Sugarcane peels	0.60	0.11	0.11	0.33ab	5.22	4.79	1.90	0.53	1.39
SE±	0.02	0.02	0.01	0.03	0.48	0.43	0.19	0.05	0.15
Interaction									
N×V	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS	NS	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT) NS=Not significant. WAT=Weeks after transplanting.

4.1.14 Evapotranspiration rate

Table 4.21 shows the main effect and interactions of varieties, nitrogen sources and organic mulches on evapotranspiration rate (ET) of irrigated tomato during 2016 and 2017 dry seasons. Variety did not affect ET rate in both years of experimentation.

In 2016 nitrogen sources did not affect ET rate. In 2017, nitrogen sources significantly affects ET rate with plots fertilized with PD producing lowest amount of ET rate than plants from the unfertilized plots and MF + PD which are statistically similar. However in the same year, PD and MF did not differ significantly.

Organic mulch significantly influenced ET rate in both year where un-mulched plots resulted to higher ET rate compared to the two other mulching schedules which were statistically comparable.

Interaction between nitrogen sources and organic was significant in 2016.

Table 4.22 shows effects of nitrogen source × organic mulch interactions on ET rate of tomato during 2016 dry season. Any of the nitrogen sources resulted to significantly lower ET rate compared to the unfertilized plots when mulch was not applied. However when organic mulches were applied all the nitrogen schedules did not differ significantly from each other with regard to ET rate.

Table 4.21: Main effects and interactions of varieties, nitrogen sources and organic mulches on ET_c (mm) over 42 days period of irrigated tomato during 2016 and 2017 dry seasons

Factor levels/interactions	2016	2017
Variety (V)		
UC82B	293.46	406.70
Rio-Grande	235.07	362.38
SE±	29.46	18.98
Nitrogen source (N)		
No application	273.27	423.98a
Mineral fertilizer (MF)	249.43	381.11ab
Poultry droppings (PD)	230.69	307.14b
MF.+ PD	303.66	425.94a
SE±	41.66	26.85
Organic mulch (M)		
No mulch	429.07a	527.43a
Rice straw	198.95b	339.53b
Sugarcane peels	164.78b	286.67b
SE±	39.88	37.57
Interaction		
N×V	NS	NS
N×M	*	NS
V×M	NS	NS
N×V×M	NS	NS

All means within a column/factor followed by same letters are not different significant at 5% level of significance using Duncan Multiple Range Test DMRT. NS=Not significant. *=

Table 4.22: Interaction between nitrogen source and organic mulch on ET_C (mm) of tomato in 2016 dry season

		Organic mulch	
Nitrogen source	No mulch	Rice straw	Sugarcane peels
No nitrogen	677.4a	78.8d	63.7d
Mineral fertilizer (MF)	340.6bc	182.8cd	224.9bd
Poultry droppings(PD)	304.4bc	199.9cd	189.8cd
MF.+ PD	396.0b	334.4bc	180.7cd
SE±		79.8	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

4.1.15 Number of days to 50% flowering

Table 4.23 shows the main effect and interactions of number of days to 50% flowering of irrigated tomato as affected by varieties, nitrogen sources and organic mulches in 2016, 2017, 2018 and across the three seasons. In 2016, 2017 and across the three years (Mean), variety Rio-Grande produced significantly delayed number of days to 50% flowering (64, 55 and 48) than UC82B (51, 52 and 43) respectively.

Throughout the period of experimentation including the mean results, any of the nitrogen sources significantly delayed days to 50% flowering than plants from the unfertilized plots.

In 2016 and 2017, plants from the un-mulched plots delayed flowering than plants from any of the mulching schedules which were earlier and statistically similar. Similar trend was observed in 2018, but with plants mulched with sugar cane peels and those of un-mulched plots showing some statistical similarity.

Highly significant interaction was observed between nitrogen source and organic mulch as well as between nitrogen source, organic mulch and variety across the three years (Table 4.24).

When mulch was not applied, MF and PD delayed 50 % flowering than unfertilized plots and MF and PD. However, when rice straw was applied, any of the nitrogen sources resulted in the production of plants with significantly higher number of days to 50% flowering compared with plants from the unfertilized plots. Furthermore; when sugar cane peels were applied, all the nitrogen schedules did not differ statistically but MF and PD had higher number of days to 50 % flowering than MF + PD and unfertilized plots.

Table 4.23: Main effects and interactions of variety, nitrogen source and organic mulch on number of days to 50 % flowering of irrigated tomato during 2016, 2017, 2018 and across the three seasons

Factor levels/ interactions	2016	2017	2018	Mean
Variety (V)				
UC82B	51b	52b	25	43b
Rio-Grande	64a	55a	26	48a
SE±	0.8	0.6	0.9	0.4
Nitrogen source (N)				
No application	55b	50b	23b	43b
Mineral fertilizer (MF)	58a	55a	29a	47a
Poultry droppings (PD)	59a	55a	26ab	46a
MF.+ PD	58a	54a	25ab	46a
SE±	1.1	0.8	1.3	0.6
Organic mulch (M)				
No mulch	56b	52b	24b	44c
Rice straw	60a	54a	28a	47a
Sugarcane peels	58a	54a	25ab	46b
SE±	0.7	0.5	1.3	0.5
Interaction				
N×V	NS	NS	NS	NS
N×M	NS	NS	NS	**
V×M	NS	NS	NS	NS
N×V×M	NS	NS	NS	*

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT). NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting

Table 4.24: Interaction between nitrogen source and organic mulch on number of days to 50% flowering of tomato in the mean results

	Organic mulch		
Nitrogen source	No mulch	Rice straw	Sugarcane peels
No nitrogen	37c	45b	54b
Mineral fertilizer (MF)	46ab	50a	46ab
Poultry droppings (PD)	47ab	46ab	47ab
MF.+ PD	45b	48ab	45b
SE±		1.0	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

Table 4.25 significant interactions was observed between varieties, nitrogen sources and organic mulches on number of days to 50% flowering of tomato across the three years with the combination between MF , rice straw mulch and Rio-Grande variety delaying flowering compared to the untreated control which hasten flowering.

Table 4.25: Interactions between nitrogen source, organic mulch and variety on number of days to 50% flowering of tomato in the mean dry seasons

	Variety					
	UC82B			Rio-Grande		
	Organic mulch					
Nitrogen source	No mulch	Rice straw	Sugarcane peels	No mulch	Rice straw	Sugarcane peels
No application	32h	44fg	43g	43g	47c-e	47c-e
Mineralfertilizer(MF)	44fg	45e-g	43g	48cd	55a	49c
Poultry dropping(PD)	44fg	44fg	44fg	49cd	48cd	49c
MF.+ PD	43g	44fg	42g	46d-f	52b	47c-e
SE±			1.5			

All means followed by same letter within row and column are not different at 5% level of significance using Duncan Multiple Range test DMRT.

4.1.16 Stem girth at first harvest

Table 4.26 shows the main effect and interaction of varieties, nitrogen sources and organic mulches on stem girth at first harvest of irrigated tomato during 2016, 2017, and 2018 and across the three seasons. In 2016 variety Rio-Grande produced plants with significantly wider (1.00 cm) stem girth than plants with 0.92 cm stem girth from Rio-Grande.

Nitrogen sources significantly enhanced stem girth in 2016 and 2017 where any of the nitrogen sources resulted in the production of plants with significantly wider stem girth than plants from the unfertilized pots.

In 2016 and 2017, the two organic mulching schedules significantly produced plants with statistically similar stem girth that was better than plants on the un-mulched plots.

Table 4.26: Main effects and interactions of variety, nitrogen source and organic mulch on stem girth at first harvest (cm) of irrigated tomato during 2016, 2017, 2018 and across the three seasons

Factor levels/ interactions	2016	2017	2018	Mean
Variety (V)				
UC82B	0.92b	0.73	0.88	0.84
Rio-Grande	1.00a	0.74	2.01	1.25
SE±	0.03	0.01	0.83	0.27
Nitrogen source (N)				
No application	0.85b	0.58b	3.01	1.48
Mineral fertilizer (MF)	0.98a	0.82a	0.95	0.92
Poultry droppings (PD)	0.99a	0.76ab	0.90	0.88
MF.+ PD	1.02a	0.78a	0.93	0.91
SE±	0.04	0.06	1.17	0.39
Organic mulch (M)				
No mulch	0.88b	0.56b	2.55	1.33
Rice straw	1.01a	0.84a	0.91	0.92
Sugarcane peels	0.99a	0.81a	0.88	0.82
SE±	0.03	0.03	1.01	0.89
Interaction				
N×V	NS	NS	NS	NS
N×M	NS	NS	NS	NS
V×M	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT). NS=Not significant. WAT=Weeks After Transplanting.

4.1.17 Fruit diameter

Table 4.27 shows the main effect and interactions of varieties, nitrogen sources and organic mulches on fruit diameter of irrigated tomato during 2016, 2017, and 2018 and across the three seasons. Variety did not differ significantly on fruit diameter in the three years and across the years.

Nitrogen sources significantly enhanced stem girth in 2016, 2018 and across the years where any of the nitrogen sources resulted in the production of plants with significantly higher fruit diameter than plants from the unfertilized pots.

In 2016 and 2018, the two organic mulching schedules significantly produced plants with statistically similar fruit diameter that was better than plants from the un-mulched plots. However, in the mean results, plots mulched with rice straw produced plants with significantly higher fruit diameter than plants mulched with other mulching schedules.

Table 4.27: Main effects and interactions of varieties, nitrogen sources and organic mulches on fruit diameter (cm) of irrigated tomato during 2016, 2017, 2018 and across the three years

Factor levels/ interactions	2016	2017	2018	Mean
Variety (V)				
UC82B	7.04	4.97	5.32	5.78
Rio-Grande	6.75	5.32	5.47	5.85
SE±	0.15	0.06	0.09	0.12
Nitrogen source (N)				
No application	6.55b	4.40	4.53b	5.16b
Mineral fertilizer (MF)	7.26a	5.34	5.64a	6.08a
Poultry droppings (PD)	6.75ab	5.34	5.67a	5.92a
MF.+ PD	7.03ab	5.51	5.72a	6.09a
SE±	0.21	0.35	0.13	0.17
Organic mulch (M)				
No mulch	6.20bb	4.78	4.83b	5.27c
Rice straw	7.43a	5.64	5.74a	6.27a
Sugarcane peels	7.05a	5.64	5.61a	5.89b
SE±	0.226	0.316	0.116	0.135
Interaction				
N×V	NS	NS	NS	NS
N×M	NS	NS	NS	NS
V×M	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT). NS=Not significant. WAT=Weeks after transplanting.

4.1.18 Number of fruits

Table 4.28 shows the main effect and interactions of varieties, nitrogen sources and organic mulches on number of fruits of irrigated tomato during 2016, 2017 and 2018 as well as across the three seasons. In 2016 growing season, variety Rio-Grande produced plants with significantly higher (31) number of fruits than plants from Rio-Grande (25).

Nitrogen sources significantly enhanced number of fruits in 2016 and 2017 where any of the nitrogen sources resulted in the production of plants with significantly higher number of fruits than plants from the unfertilized pots. However, in the mean results, MF + PD resulted in the production of plant with significantly higher number of fruits but were statistically comparable to PD when compared to plants from the unfertilized plots.

In 2016 and the mean results, the two organic mulching schedules significantly produced plants with statistically and comparable number of fruits that was better than plants from the un-mulched plots.

Interaction was significant between nitrogen source and organic mulch as well as between nitrogen source, organic mulch and variety in the mean results.

Table 4.28: Main effects and interactions of variety, nitrogen source and organic mulch on number of fruits per plant of irrigated tomato during 2016, 2017, and 2018 and across the three seasons

Factor levels/ interactions	2016	2017	2018	Mean
Variety (V)				
UC82B	25b	46	25	34
Rio-Grande	31a	50	25	33
SE±	1.0	3.5	2.1	1.7
Nitrogen source (N)				
No application	24b	40b	21	28b
Mineral fertilizer (MF)	28ab	45ab	23	32b
Poultry droppings (PD)	28ab	48ab	25	34ab
MF.+ PD	29a	60a	30	40a
SE±	1.4	5.0	2.9	2.3
Organic mulch (M)				
No mulch	24b	43	23	30b
Rice straw	27ab	50	26	35ab
Sugarcane peels	32a	51	26	36a
SE±	1.9	3.7	2.3	1.6
Interaction				
N×V	NS	NS	NS	NS
N×M	NS	NS	NS	*
V×M	NS	NS	NS	NS
N×V×M	NS	NS	NS	*

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple range test (DMRT). NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting.

Table 4.29 shows effects of nitrogen source × organic mulch interactions on number of fruit of tomato across the three seasons. Any of the nitrogen sources showed a comparable and more number of fruits than the untreated control in the absence of organic mulches. When rice straw was applied, all the nitrogen schedules also did not differ statistically. However when sugar cane peels were applied, PD and MF + PD resulted in the production of tomato plants with significantly greater number of fruits compared with plants supplied with MF and plants from the unfertilized plots.

Table 4.30 shows the interaction of nitrogen source × organic mulch × variety on number of fruit of tomato across the three seasons with MF + PD in combination with sugarcane peels mulch on UC82B producing the highest number of fruit when compared to untreated control as well as other possible combinations.

Table 4.29: Interaction between nitrogen source and organic mulch on number of fruit of tomato across the three seasons (mean).

		Organic mulch	
Nitrogen source	No mulch	Rice straw	Sugarcane peels
No nitrogen	19c	32b	34b
Mineral fertilizer (MF)	32b	33b	31b
Poultry droppings(PD)	33b	38ab	38ab
MF.+ PD	31b	35b	47a
SE±		3.2	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

Table 4.30: Interaction between nitrogen source, organic mulch and variety on number of fruit of tomato across the three seasons

	Variety					
	UC82B			Rio-Grande		
	Organic mulch					
Nitrogen source	No mulch	Rice straw	Sugarcane peels	No mulch	Rice straw	Sugarcane peels
No application	19g	38b-d	29d-f	19g	26fg	40bc
Mineralfertilizer(MF)	28ef	35b-f	30d-f	36b-e	31c-f	32b-f
Poultry dropping(PD)	29d-f	36b-e	34b-f	36b-e	40bc	29d-f
MF.+ PD	41b	32b-f	56a	34b-f	37b-e	38b-d
SE±			4.5			

All means followed by same letters within row and column are not different at 5% level of significance using Duncan Multiple Range test DMRT.

4.1.19 Total fruit yield

Table 4.31 shows the main effect and interactions of varieties, nitrogen sources and organic mulches on total fruit yield of irrigated tomato during 2016, 2017, and 2018 and across the three seasons. In 2016 growing season, variety Rio-Grande produced plants with significantly higher (16.03 t ha^{-1}) fruit yield than plants with 6.75 t ha^{-1} fruits yield from UC82B. Conversely, in 2017, UC82B produced plants with significantly higher (22.99 t ha^{-1}) fruit yield than plants with 18.80 t ha^{-1} fruits yield from Rio-Grande.

Nitrogen sources significantly enhanced fruit yield in all the years including the mean results where MF, PD and MF + PD with comparable yields performed better than the untreated control.

With the exception of 2016 in which organic mulching did not differ significantly on fruit yield, the two organic mulching schedules significantly produced plants with statistically comparable and higher fruit yield than plants from the un-mulched plots.

Interaction was significant between nitrogen source and organic mulch as well as between nitrogen source, organic mulch and variety in the mean results.

Table 4.32 shows effects of nitrogen source × organic mulch interactions on fruit yield of tomato across the three seasons with highly significant interaction between nitrogen sources and organic mulches on fruit yield of irrigated tomato in 2018. Any of the nitrogen sources resulted in the production of plants with significantly higher fruits yield compared with plants from the unfertilized plots in all the mulching schedules.

Table 4.31: Main effects and interactions of variety, nitrogen source and organic mulch on fruit yield (t ha^{-1}) of irrigated tomato during 2016, 2017, and 2018 and across the three seasons

Factor levels/ interactions	2016	2017	2018	Mean
Variety (V)				
UC82B	6.75b	22.99a	15.80	16.88
Rio-Grande	16.03a	18.80b	16.93	15.56
SE±	0.66	1.00	0.63	0.48
Nitrogen source (N)				
No application	9.60b	16.43b	14.07b	13.36b
Mineral fertilizer (MF)	10.67ab	21.41a	17.64a	16.57a
Poultry droppings (PD)	12.30ab	21.34a	16.32ab	16.65a
MF.+ PD	13.00a	24.40a	17.44a	18.28a
SE±	0.93	1.41	0.89	0.70
Organic mulch (M)				
No mulch	10.46	18.27b	14.50b	14.41b
Rice straw	10.49	24.13a	17.69a	17.43a
Sugarcane peels	13.22	20.28ab	16.90a	16.80a
SE±	1.19	1.36	0.68	0.64
Interaction				
N×V	NS	NS	NS	NS
N×M	NS	NS	NS	**
V×M	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS

All means within a column/factor followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT). NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting.

Table 4.32: Interaction between nitrogen source and organic mulch on fruit yield (t ha^{-1}) of tomato across the three seasons

	Organic mulch		
	No mulch	Rice straw	Sugarcane peels
Nitrogen source			
No nitrogen	9.35d	14.46bc	13.09cd
Mineral fertilizer (MF)	14.39bc	17.82a-c	17.52a-c
Poultry droppings(PD)	16.17bc	18.39ab	17.66a-c
MF.+ PD	14.31bc	19.32ab	22.13a
SE±		1.66	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

4.1.20 Marketable fruit yield

Table 4.33 shows the effect of nitrogen sources and organic mulches on marketable fruit yield of irrigated tomato variety in 2016, 2017, and 2018 and mean. In 2016 growing season, variety Rio-Grande produced plants with significantly higher (11.85 t ha^{-1}) marketable fruit yield than UC82B with 4.32 t ha^{-1} fruits. Conversely, in 2017, UC82B produced significantly higher (20.01 t ha^{-1}) fruit yield than Rio-Grande with 16.37 t ha^{-1}.

Nitrogen sources significantly enhanced production of higher marketable fruit yield than plants from the unfertilized plots in all the years except in the mean results where plots with MF and MF + PD resulted in the production of comparable higher marketable fruit yield than the unfertilized plots.

With the exception of 2016, mulching with rice straw and sugar cane peels did not differ significantly on marketable fruit yield. These organic mulching schedules produced comparable marketable fruits yield than the un-mulched plots.

Interaction was highly significant between nitrogen source and organic mulch on fruit yield in the three years of the study.

Table 4.34 shows highly significant interaction between nitrogen sources and organic mulches on marketable fruit yield of irrigated tomato in the mean results. The use of MF, PD and MF+PD each with no mulch, and all the nitrogen schedules with rice straw mulch there was no significant difference. However when all the nitrogen schedules were used in the presence of sugar cane peels mulch, MF+ PD resulted in significantly higher marketable fruit yield of tomatoes.

Table 4.33: Main effects and interactions of variety, nitrogen source and organic mulch on marketable fruit yield (t ha^{-1}) of irrigated tomato during 2016, 2017, 2018 and across the three seasons

Factor levels/ interactions	2016	2017	2018	Mean
Variety (V)				
UC82B	4.32b	20.01a	13.83	14.02
Rio-Grande	11.85a	16.37b	15.14	13.16
SE±	0.55	0.83	0.57	0.46
Nitrogen source (N)				
No application	7.07b	14.48b	12.42b	11.33c
Mineral fertilizer (MF)	7.42ab	18.94a	15.31a	13.89ab
Poultry droppings (PD)	8.10ab	17.94ab	14.46ab	13.50b
MF.+ PD	9.76a	21.40a	15.75a	15.64a
SE±	0.78	1.37	0.81	0.65
Organic mulch (M)				
No mulch	7.70	15.89b	12.54b	12.05b
Rice straw	7.58	20.84a	15.92a	14.78a
Sugarcane peels	8.98	17.83ab	15.00a	13.93a
SE±	0.92	1.21	0.71	0.56
Interaction				
N×V	NS	NS	NS	NS
N×M	NS	NS	NS	**
V×M	NS	NS	NS	NS
N×V×M	NS	NS	NS	NS

All means within a column/factors followed by same letters are not different at 5% level of significance using Duncan Multiple Range Test (DMRT). NS=Not significant. *= significant at 5%. WAT=Weeks after transplanting.

Table 4.34: Interaction between nitrogen source and organic mulch on marketable fruit yield (t ha^{-1}) of tomato across the three seasons

	Organic mulch		
Nitrogen source	No mulch	Rice straw	Sugarcane peels
No nitrogen	8.15d	15.01bc	10.82cd
Mineral fertilizer (MF)	14.81bc	12.37b-d	14.48bc
Poultry droppings(PD)	13.41bc	15.93ab	11.16cd
MF.+ PD	11.82b-d	15.82ab	19.27a
SE±		1.12	

Means followed by the same letter within row and column are not significantly different at 5% level of probability using DMRT.

4.1.21 Fruit appearance

Figure 1 shows the main effect and interactions of variety, nitrogen sources and organic mulches on fruit appearance of irrigated tomato during 2017 and 2018. Tomato fruit appearance was not affected by variety in both years.

Nitrogen sources enhanced fruit appearance only in 2017 where PD and MF + PD resulted in the production of plant with significantly and comparable very good (4.39 and 4.22) fruit appearance respectively compared to plants from the unfertilized plots.

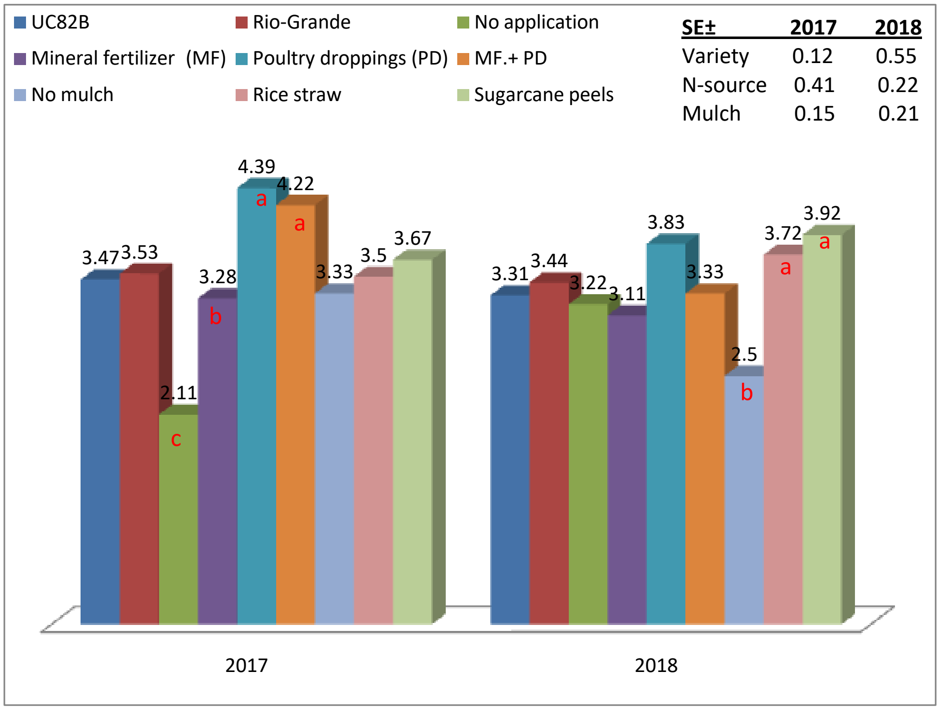
Mulching only enhanced fruit appearance in 2018 where the two organic mulching schedules significantly leads to production of fruits with statistically comparable good appearance than the un-mulched plots.

4.1.22 Fruit decay

The main effect and interactions of variety, nitrogen sources and organic mulches on fruit decay of irrigated tomato during 2017 and 2018 is shown in figure 2. Fruit decay was not affected by variety in both years.

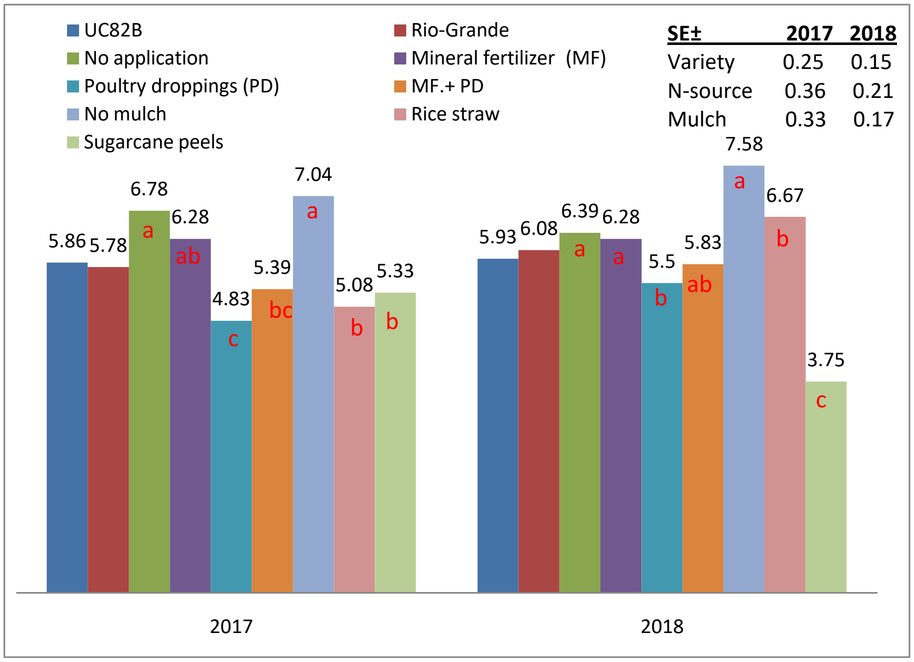
In both years, nitrogen sources enhanced fruit decay where PD resulted in the production of plants with lower cases of fruit decay although; it was statistically comparable with MF + PD when compared with fruits from unfertilized plots which produced plants with higher cases of fruit decay.

Mulching enhanced fruit decay in both years where the two organic mulching schedules significantly produced fruits with the lowest cases of fruit decay than fruits from plant of the un-mulched plots which had the highest cases of fruit decay.



All means within a treatment/factor followed by same letters are not different at 5% level of significance using Duncan Multiple range test (DMRT).

Figure 1: Main effect of varieties, Nitrogen source and organic mulch on fruit appearance of tomato



All means within a treatment/factor followed by same letters are not different at 5% level of significance using Duncan Multiple range test (DMRT).

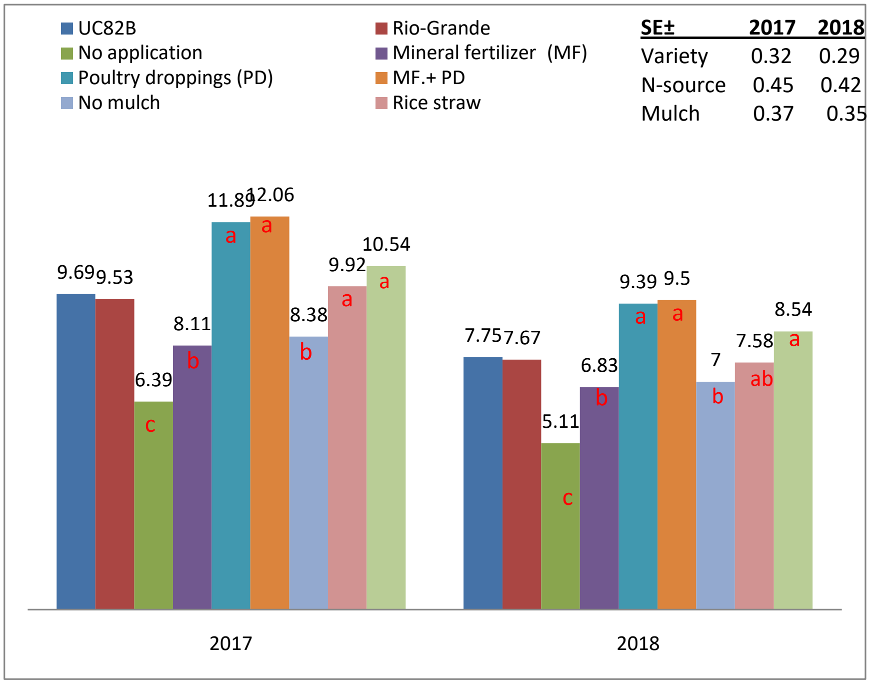
Figure 2: Main effect of varieties, nitrogen source and organic mulch on fruit decay of tomato

4.1.23 Fruit shelf life

Figure 3 shows the main effect and interactions of variety, nitrogen sources and organic mulches on shelf life of irrigated tomato during 2017 and 2018 seasons. Variety did not affect shelf life of tomato in both years.

In both years, nitrogen sources enhanced fruit shelf life where PD and MF + PD resulted in the production of fruits with significantly longer and comparable shelf life than fruits from unfertilized plots.

Mulching enhanced fruit shelf life in both years where the two organic mulching schedules significantly leads to production of plants that produced fruits with longer shelf life than fruits from plant of the un-mulched plots which had the shortest shelf life.



All means within a treatment/factor followed by same letters are not different at 5% level of significance using Duncan Multiple range test (DMRT).

Figure 3: Main effect of varieties, nitrogen source and organic mulch on fruit shelf life of tomato.

4.1.24 Fruit N, P and K concentration

The main effect and interactions of variety, nitrogen sources and organic mulches on fruit N, P and K content of irrigated tomato during 2017 is shown in figure 4. Variety did not affect fruit N, P and K content of tomato. In 2017, Rio-Grande produced fruits with significantly higher phosphorus content than fruits from UC82B. However, nitrogen and potassium contents of fruits were not affected by variety.

Nitrogen sources enhanced nitrogen, phosphorus and potassium contents of tomato fruits. For example, nitrogen and phosphorus contents were significantly increased with MF + PD than the other nitrogen schedules. However, PD and MF + PD significantly produce fruit with statistically higher and comparable potassium content than MF and unfertilized fruits.

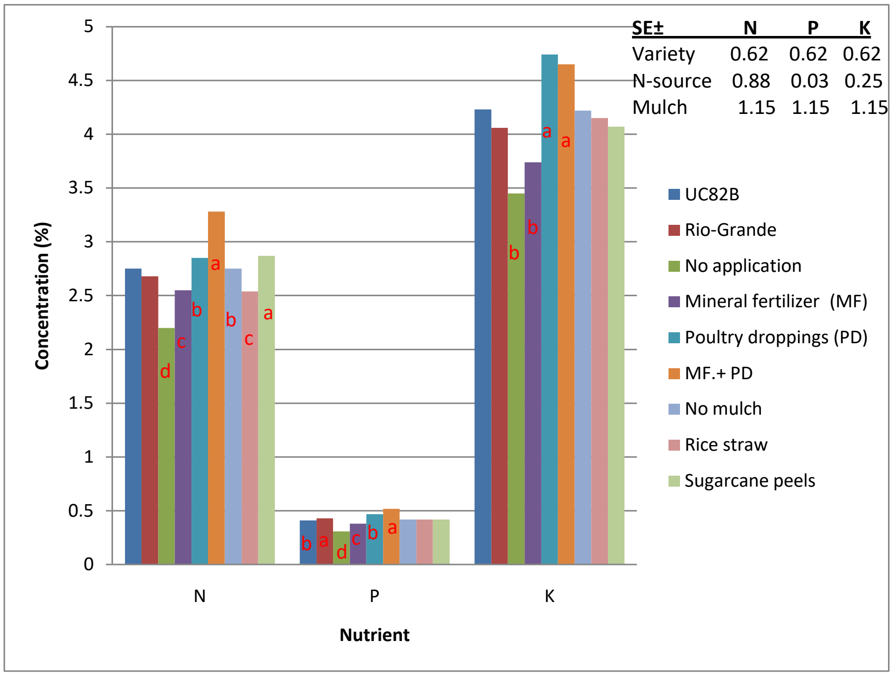
With exception nitrogen content that was significantly enhanced with sugar cane peels mulch when compared with rice straw mulch, fruit phosphorus and potassium contents were not affected by nitrogen sources.

4.1.25 Vitamin A, E and C concentration fruit

The main effect and interactions of variety, nitrogen sources and organic mulches on fruit N, P and K content in 2017 is shown in figure 5. Variety did not affect fruit vitamin A, E and C content of tomato.

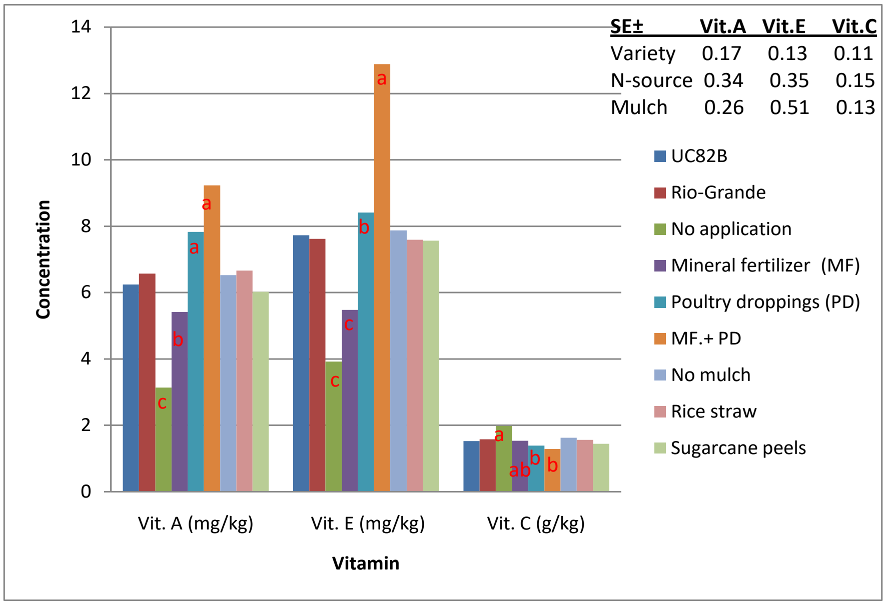
Nitrogen sources enhanced vitamins A, E and C. PD and MF + PD significantly produced fruit with statistically higher and comparable vitamin A content than fruits from MF and unfertilized plots. Vitamin E content of fruit was significantly increased with MF + PD than the other nitrogen schedules. However, any of the nitrogen sources significantly produced fruits with statistically comparable and lower vitamin C content than fruits from the unfertilized plots.

Organic mulching materials did not differ significantly on vitamin content of tomato fruit.



All means within a treatment/factor followed by same letters are not different at 5% level of significance using Duncan Multiple range test (DMRT).

Figure 4: Main effect of varieties, Nitrogen source and organic mulch on fruit N, P and K concentration of tomato in 2017



All means within a treatment/factor followed by same letters are not different at 5% level of significance using Duncan Multiple range test (DMRT).

Figure 5: Main effect of varieties, Nitrogen source and organic mulch on fruit vitamin A, E and K of tomato in 2017

4.1.26 Correlation

Table 4.35 shows matrix of correlation between yield, growth and yield components in 2016. Tomato characters such as number of branches, number of leaves, canopy spread, plant dry weight and fruit diameter expressed a positive and significant correlation with fruit yield, while that between number of fruits and final fruit yield was positively and highly correlated. Plant height, leaf area index and stem girth at first harvest exhibited a positive and non significant correlation with fruit yield whereas, crop growth rate, relative growth rate and net assimilation rate showed a significant but negative correlation with fruit yield. Number of days to 50% flowering showed a highly significant but negative correlation with fruit yield of tomato.

Table 4.36 shows matrix of correlation between yield, growth and yield components in 2017. Tomato characters such as number of branches, plant dry weight, leaf area index, crop growth rate, relative growth rate, number of days to 50% flowering and stem girth at first harvest exhibited a positive and significant correlation with tomato fruit yield while characters such as plant height, number of leaves, canopy spread, fruit diameter and number of fruit also showed a positive but highly significant correlation with fruit yield. However, net assimilation rate showed a significant but negative correlation with fruit yield.

Table 4.37 shows matrix of correlation between yield, growth and yield components in 2018. Characters such as plant height, number of branches, number of leaves, canopy spread, fruit diameter and number of fruits exhibited a positive and highly significant correlation with fruit yield while only plant dry weight and leaf area index showed a positive and significant correlation with fruit yield. However, Crop growth rate, relative growth rate, net assimilation rate, number of days to 50 % flowering and stem girth at first harvest showed a negative and non significant correlation with fruit yield.

Table 4.38 shows matrix of correlation between yield, growth and yield components in the combined results. Plant height, number of branches, number of leaves, leaf area index, fruit diameter and number of fruits exhibited a positive and highly significant correlation with fruit yield while canopy spread, crop growth rate and relative growth rate showed a positive and significant correlation with fruit yield. However, number of days to 50 % flowering showed a negative and non significant correlation with fruit yield while stem girth at first harvest showed a negative and significant correlation with fruit yield. Only leaf area index and net assimilation rate showed positive and non significant correlation with fruit yield.

Table 4.35: Matrix of correlation between yield, growth and yield components in 2016 dry seasons in Kadawa, Kano Nigeria

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00000													
2	0.52077**	1.00000												
3	0.61831**	0.60202 **	1.00000											
4	0.80786**	0.66976**	0.84572*	1.00000										
5	0.46246**	0.38487*	0.31622 *	0.39230*	1.00000									
6	0.38180*	0.32419*	0.27308NS	0.26566*	0.39258*	1.00000								
7	0.18496	-0.05168	-0.05489	0.01299	0.50498**	0.11050	1.00000							
8	0.18157	-0.04126	-0.11500	-0.02969	0.41874*	0.12628	0.93752**	1.00000						
9	0.10774	-0.06194	-0.11239	-0.01736	0.28852*	-0.37014*	0.76718**	0.78685**	1.00000					
10	0.39776*	0.12779	-0.01815	0.15180	0.25486*	0.32978*	0.45069**	0.51294**	0.31667*	1.00000				
11	0.53633**	0.43204*	0.44169*	0.50622**	0.32330*	0.33274*	0.05584	0.12216	-0.02372	0.38404*	1.00000			
12	0.55001**	0.49396**	0.50022**	0.57276**	0.36597*	0.39751*	-0.01046	-0.07760	-0.10485	0.07492	0.44452**	1.00000		
13	0.21408*	0.26605*	0.40262*	0.34668*	0.31051*	0.09502	-0.00469	-0.09691	-0.15543	-0.18892	0.19175	0.27746*	1.00000	
14	**0.19474**	**0.28789***	**0.43620***	**0.38256***	**0.30280***	**0.10929**	**-0.25319***	**-0.31732***	**-0.28081***	**-0.51243****	**0.17287**	**0.32924***	**0.50466****	**1.00000**

Df = n-2 =70 ** significant at 1% level of probability * significant at 5% level of probability

1. Plant height
2. Number of branches
3. Number of leaves
4. Canopy spread
5. Dry weight
6. Leaf area index
7. Crop growth rate
8. Relative growth rate
9. Net assimilate rate
10. Days to 50% flowering
11. Stem girth at harvest
12. Fruit diameter
13. Number of fruit
14. Fruit yield

Table 4.36: Matrix of correlation between yield, growth and yield components in 2017 dry seasons in Kadawa, Kano Nigeria

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.00000													
2	0.27732*	1.00000												
3	0.47899**	0.41474*	1.00000											
4	0.72536**	0.27902*	0.52350**	1.00000										
5	0.29177*	0.24191*	0.35279*	0.16177	1.00000									
6	0.31584*	0.22566*	0.01800	0.32642*	0.17055	1.00000								
7	0.26865	0.23283*	0.29434*	0.14360NS	0.99125**	0.16888	1.00000							
8	0.33535*	0.33188*	0.27705*	0.24514*	0.86786**	0.31676*	0.87757**	1.00000						
9	0.02435	-0.02773	0.15321	0.00977	-0.08447	-0.11196	-0.09348	-0.04124	1.00000					
10	0.39776*	0.12779	-0.01815	0.15180	0.25486*	0.32978*	0.45069**	0.51294**	0.31667*	1.00000				
11	0.53633**	0.43204*	0.44169**	0.50622**	0.32330*	0.33274*	0.05584	0.12216	-0.02372	0.38404*	1.00000			
12	0.55001**	0.49396 **	0.50022**	0.57276**	0.36597*	0.39751*	-0.01046	-0.07760	-0.10485	0.07492	0.44452**	1.00000		
13	0.21408NS	0.26605*	0.40262*	0.346688*	0.31051*	0.09502	-0.00469	-0.09691	-0.15543	-0.18892	0.19175	0.27746	1.00000	
14	**0.58337****	**0.38817***	**0.44980****	**0.55957****	**0.37762***	**0.31899***	**0.35556***	**0.40700***	**-0.28649***	**0.29921***	**0.35120***	**0.65429****	**0.54982****	**1.00000**

Df = n-2 =70 ** significant at 1% level of probability * significant at 5% level of probability

1. Plant height
2. Number of branches
3. Number of leaves
4. Canopy spread
5. Dry weight
6. Leaf area index
7. Crop growth rate
8. Relative growth rate
9. Net assimilate rate
10. Days to 50% flowering
11. Stem girth at harvest
12. Fruit diameter
13. Number of fruit
14. Fruit yield

Table 4.37: Matrix of correlation between yield, growth and yield components during 2018 dry season in Kadawa, Kano Nigeria

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	1.00000													
2.	0.43904*	1.00000												
3.	0.43732*	0.36460*	1.00000											
4.	0.81039**	0.63410**	0.58631**	1.00000										
5.	0.16885	0.23219*	0.44611**	0.31473*	1.00000									
6.	0.11339	0.38586*	0.26065*	0.28158*	0.43425*	1.00000								
7.	-0.02451	-0.10899	0.14488	-0.03851	0.75575**	0.15215	1.00000							
8.	-0.04296	-0.13563	0.12678	-0.08350	0.71598**	0.16755	0.96767**	1.00000						
9.	-0.05959	-0.23520*	0.06294	-0.12302	0.57581**	-0.22925	0.90257**	0.87852**	1.00000					
10.	-0.03434	0.05217	0.00438	-0.09522	0.07712	0.14471	0.12502	0.15315	0.04594	1.00000				
11.	-0.04865	-0.26159*	-0.18379	-0.22026	-0.20736	-0.21650	-0.10292	-0.07833	-0.00957	-0.13263	1.00000			
12.	0.52604**	0.54334**	0.49345**	0.64634**	0.44691**	0.42920*	0.21068	0.23141	0.06650	0.21530	-0.29301*	1.00000		
13.	0.49925**	0.42598*	0.39915*	0.63384**	0.31884*	0.30845*	-0.05568	-0.09049	-0.16397	-0.02796	-0.16232	0.39740*	1.00000	
14.	0.58101**	0.61132**	0.53136**	0.76752**	0.26192*	0.24766*	-0.05033	-0.09471	-0.11567	-0.02207	-0.28807*	0.63525**	0.52682**	1.00000

Df = n-2 =70 ** significant at 1% level of probability * significant at 5% level of probability.

1. Plant height
2. Number of branches
3. Number of leaves
4. Canopy spread
5. Dry matter
6. Leaf area index
7. Crop growth rate
8. Relative growth rate
9. Net assimilate rate
10. Days to 50% flowering
11. Stem girth at harvest
12. Fruit diameter
13. Number of fruit
14. Fruit yield

Table 4.38: Matrix of correlation between yield, growth and yield components in the mean results in Kadawa, Kano Nigeria

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	1.00000													
2.	0.37442**	1.00000												
3.	0.51876**	0.56728**	1.00000											
4.	0.37263**	0.14136*	0.33096**	1.00000										
5.	0.26812**	0.37348**	0.44551**	0.07534	1.00000									
6.	-0.22499*	0.07138	-0.01427	0.30970**	0.07665	1.00000								
7.	0.27809**	0.22885*	0.32607**	-0.03691	0.92889**	-0.06169	1.00000							
8.	0.21445*	0.21666*	0.25118*	0.00459	0.77234**	0.03452	0.86603**	1.00000						
9.	0.56673**	0.24094*	0.35787**	-0.23478*	0.16535*	-0.44198**	0.26638**	0.20174*	1.00000					
10.	0.21795*	-0.45982**	-0.23636*	0.13647*	-0.18461*	-0.06930	-0.02318	0.00551	0.12049	1.00000				
11.	-0.06100	-0.07657	-0.07694	-0.12237	-0.04919	-0.09913	-0.03534	-0.01770	-0.05422	-0.13263	1.00000			
12.	0.06447	-0.05201	0.10582	0.58427**	0.02819	0.37612**	-0.02387	0.03422	-0.27914**	0.21530	-0.29301*	1.00000		
13.	0.10620	0.43895**	0.38171**	0.38546**	0.30204**	0.30371**	0.09234	0.08389	-0.20058*	-0.02796	-0.16232	0.39740*	1.00000	
14.	0.28543**	0.69457**	0.54780**	0.24851*	0.39301**	0.11047	0.20812*	0.16544*	0.06465	-0.02207	-0.28807*	0.63525**	0.52682**	1.00000

Df = n-2 =70 ** significant at 1% level of probability * significant at 5% level of probability.

1. Plant height
2. Number of branches
3. Number of leaves
4. Canopy spread
5. Dry matter
6. Leaf area index
7. Crop growth rate
8. Relative growth rate
9. Net assimilate rate
10. Days to 50% flowering
11. Stem girth at harvest
12. Fruit diameter
13. Number of fruit
14. Fruit yield

4.1.27 Path analysis

Table 4.39 shows the direct and indirect contribution of growth and yield component of tomato to fruit yield in 2016, 2017 and mean data at Kadawa. In 2016 dry season, number of leaves of tomato gave the highest direct contribution to total fruit yield while the number of branches gave the lowest direct contribution to total fruit yield. On the other hand number of leaves via number of branches gave the highest indirect contribution to total fruit yield and also number of leaves via number of branches gave the lowest indirect contribution to total fruit yield in 2016.

Number of leaves of tomato gave the highest direct contribution to total fruit yield while in 2017 while plant height gave the lowest direct contribution to fruit yield. The highest indirect contribution in 2017 was by number of leave via leaf area index while the lowest indirect contribution was by number of branches via plant height.

In the combined results, plant height had the highest direct contribution to fruit yield whereas plant dry weight of tomato had the lowest direct contribution. Number of branches via plant height had the highest indirect contribution to fruit yield while plant dry weight via plant height had the lowest indirect contributions to total fruit yield.

Table 4.40 shows the percentage contribution of different growth and yield attributes of tomato to total fruit yield in 2016, 2017 and mean data. In both years, number of leaves of tomato gave the highest individual percentage contribution to fruit yield while plant height gave the lowest percentage contribution. In the combined result, plant height gave the highest individual percentage contribution to total fruit yield whereas canopy spread gave the lowest percentage contribution.

Number of leaves via canopy spread had the highest combined percentage contribution while plant height via plant dry weight gave the least combined percentage contribution in 2016. In 2017, numbers of leaves via leaf area index gave the highest combined percentage contribution to total fruit yield while plant height via number of leaves gave the lowest combined percentage contribution. In the combined results, plant height via leaf area index gave the highest combined percentage contribution to fruit yield while number of leaves via plant dry weight gave the lowest combined percentage contribution.

The residual effects in both years and the combined result were 28.38%, 43.44% and 36.98% respectively.

Table 4.39: The direct and indirect contribution of growth and yield component of tomato to fruit yield in 2016, 2017 and mean data at Kadawa Kano Nigeria

Yield Attributes	Plant height	Number of branches	Number of leaves	Canopy spread	Dry weight	Leaf area index	Total correlated
				2016			
Plant height	**-0.0930**	-0.1091	0.65193	0.0588	0.0511	-0.0390	0.5208
Number of branches	-0.0560	**-0.1813**	<u>0.8232</u>	0.0483	0.0431	-0.0590	0.6183
Number of leaves	-0.0623	-0.1533	**<u>0.9734</u>**	0.0599	0.0419	-0.0518	0.8079
Canopy spread	-0.0358	-0.0573	0.3819	**0.1528**	0.0619	-0.0410	0.4625
Dry matter	-0.0302	-0.0495	0.2586	0.0600	**0.1577**	-0.0148	0.3818
Leaf area	-0.0268	-0.0791	0.3724	0.0463	0.0172	**-0.1353**	0.1947
				2017			
Plant height	**-0.0207**	0.0332	0.1519	0.0233	0.0142	0.0754	0.2773
Number of branches	-0.0086	**0.0801**	0.2850	0.0340	0.0011	0.0874	0.4790
Number of leaves	-0.0058	0.0419	**<u>0.5443</u>**	0.0156	0.0206	0.1087	0.7254
Canopy spread	-0.0050	0.0283	0.0881	**0.0963**	0.0107	0.0734	0.2918
Dry matter	-0.0047	0.0014	0.1777	0.0164	**0.0630**	0.0620	0.3158
Leaf area	-0.0081	0.0360	<u>0.3046</u>	0.0364	0.0201	**0.1943**	0.5834
				2018			
Plant height	**<u>0.3062</u>**	0.1651	-0.0007	0.0193	0.0529	0.1263	0.6690
Number of branches	<u>0.1922</u>	**0.2630**	0.0213	0.0227	0.0417	0.1304	0.6714
Number of leaves	-0.0026	0.0657	**0.0851**	0.0016	-0.0655	0.0424	0.1267
Canopy spread	0.1110	0.1121	0.0026	**0.0533**	0.0188	0.0915	0.3893
Dry matter	-0.0966	-0.0655	0.0333	-0.0060	**-0.1675**	-0.0547	-0.3570
Leaf area	0.169892	0.15073	0.0158	0.0214	0.0402	**0.2276**	0.6257

- Underlined values = direct and indirect contribution
- Bold values = direct contribution
- Un-bold values = indirect contribution

Table 4.40: Percentage contribution of different growth and yield attributes of tomato tofruit yield in 2016, 2017 and mean data in Kadawa, Kano Nigeria

Variable	Percent Contributions (%)		
Individual contribution	2016	2017	Mean
Plant height	0.87	0.04	**9.38**
Number of branches	3.29	0.64	6.92
Number leaves	**94.75**	**29.63**	0.72
Canopy spread	2.33	0.93	0.28
Dry weight	2.49	0.40	2.81
Leaf area index	1.83	3.78	5.18
Combined Contribution			
Plant height via Number of branches	2.03	-0.14	**10.11**
Plant height via Number leaves	-12.13	-0.63	-0.04
Plant height via Canopy spread	-1.09	-0.10	1.18
Plant height via Dry weight	-0.95	-0.06	3.24
Plant height via Leaf area index	0.72	-0.31	7.73
Number of branches via Number leaves	-29.84	4.56	1.12
Number of branches via Canopy spread	-1.75	0.54	1.20
Number of branches via Dry weight	-1.56	0.02	2.19
Number of branches via Leaf area index	2.14	1.40	6.86
Number leaves via Canopy spread	**11.67**	1.70	0.03
Number leaves via Dry weight	8.15	2.24	-1.11
Number leaves via Leaf area index	-11.49	**9.52**	2.22
Canopy spread via Dry weight	1.89	0.21	0.20
Canopy spread via Leaf area index	-1.25	1.41	0.98
Dry weight via Leaf area index	-0.47	0.78	1.83
Residual	28.4	43.4	36.9
T0TAL	100	100	100

Plate II: Post harvest storage of tomato fruits

4.1.28 Cost and return analysis

The result of gross margin analysis (Table 4.41) indicate that the highest gross return of ₦302686.4 and a profit of ₦2.52 per naira invested was achieved by growing Rio Grande tomato variety with combination of PD and sugar cane peels mulch in 2016. Similarly, it was followed by producing UC82B with application of PD using sugar cane peels as mulch resulted to ₦265688.3 gross margin and a profit of ₦2.21k per naira invested. The least return of ₦-122335k loss was observed from growing Rio Grande with application of MF + PD using rice straw as mulch in which -0.72k was lost per naira invested.

Table 4.42 shows the Cost benefit and return analysis on investment of growing tomato varieties using different nitrogen sources and different organic mulching materials at Kadawa in 2017. The production of Rio Grande tomato using PD and sugar cane peels mulch application was the most profitable with ₦453,753.00 and a profit of ₦4.94k per every naira invested. This was closely followed by UC82B combined with application of PD and sugar cane peels mulch which gave a gross margin of ₦433,530.08k and a profit of ₦4.72k per naira invested. However in this research the production of UC82B tomato variety using application of MF and rice straw mulch brought a loss of ₦187,009.4k where 1.29k is lost per naira invested.

Table 4.41: Cost benefit and return analysis on investment of growing tomato varieties using nitrogen sources and organic mulches at Kadawa Kano Nigeria in 2016

Nitrogen source (V)	Variety (V)	Mulch (M)	Total yield t ha^{-1}	Average Price/basket	Total Revenue (TR)	Total Variable cost (TVC)	Gross Margin (GM)	GM/Each Naira invested
0	1	1	4.85	1000	80837.04	51648.15	29188.89	0.57
MF	1	2	10.60	1000	176714.8	173435	3279.784	0.02
PD	1	3	23.16	1000	386009.3	120321	265688.3	2.21
MF +PD	1	2	12.30	1000	205035.2	170026.2	35009.03	0.21
0	2	1	3.99	1000	66653.7	51648.15	15005.56	0.29
MF	2	2	3.40	1000	56748.15	173435	-116687	-0.67
PD	2	3	25.38	1000	423007.4	120321	302686.4	2.52
MF +PD	2	2	2.86	1000	47690.74	170026.2	-122335	-0.72
0	1	2	16.36	1000	272692.6	161216	111476.5	0.69
MF	1	3	20.32	1000	338668.5	127138.7	211529.8	1.66
PD	1	1	6.79	1000	113151.9	57049.38	56102.47	0.98
MF +PD	1	1	7.32	1000	122044.4	60458.26	61586.19	1.02
0	2	2	8.79	1000	146500	161216	-14716	-0.09
MF	2	3	7.99	1000	133279.6	127138.7	6140.895	0.05
PD	2	1	6.84	1000	114000	57049.38	56950.62	0.99
MF +PD	2	1	6.16	1000	102707.4	60458.26	42249.15	0.69
0	1	3	12.70	1000	211707.4	114919.8	96787.65	0.84
MF	1	1	7.07	1000	117820.4	63867.13	53953.24	0.84
PD	1	2	27.93	1000	465477.8	209617.3	255860.5	1.22
MF +PD	1	3	19.00	1000	316677.8	123729.9	192947.9	1.56
0	2	3	5.87	1000	97764.81	114919.8	-17154.9	-0.15
MF	2	1	4.64	1000	77320.37	63867.13	13453.24	0.21
PD	2	2	21.69	1000	361577.8	166617.3	194960.5	1.17
MF +PD	2	3	11.31	1000	188446.3	123729.9	64716.44	0.52

Calculation of total revenue is based on ₦1000 per basket (60 kg) of tomato the prevailing farm gate price at Kadawa and environ.

V1 = UC82B, V2 = Rio-Grande, M1 = No mulch, M2 = Rice straw, M3 = Sugar cane peel.

Table 4.42: Cost benefit and return analysis on investment of growing tomato varieties using nitrogen sources and organic mulches at Kadawa Kano Nigeria in 2017

Nitrogen source (V)	Variety (V)	Mulch (M)	Total yield t ha^{-1}	Average Price/basket	Total Revenue (TR)	Total Variable cost (TVC)	Gross Margin (GM)	GM/Each Naira invested
0	1	1	5.34	1400	124703.7	53648.15	71055.58	3.06
MF	1	2	15.53	1400	362444.5	175435	187009.4	1.29
PD	1	3	23.82	1400	555851.8	122321	433530.8	4.72
MF +PD	1	2	21.02	1400	490518.5	172026.2	318492.3	2.25
0	2	1	4.96	1400	115629.6	53648.15	61981.46	2.68
MF	2	2	19.09	1400	445407.4	175435	269972.4	1.86
PD	2	3	24.69	1400	576074.1	122321	453753.1	4.94
MF +PD	2	2	29.18	1400	680814.8	269026.2	411788.6	1.73
0	1	2	20.27	1400	472888.9	163216	309672.8	2.33
MF	1	3	18.93	1400	441777.8	129138.7	312639.1	3.17
PD	1	1	7.06	1400	164629.6	59049.38	105580.2	3.70
MF +PD	1	1	7.89	1400	184074.1	62458.26	121615.8	3.81
0	2	2	17.32	1400	404185.2	163216	240969.1	1.82
MF	2	3	16.80	1400	392000	129138.7	262861.2	2.66
PD	2	1	6.73	1400	157111.1	59049.38	98061.73	3.43
MF +PD	2	1	5.91	1400	137925.9	62458.26	75467.64	2.36
0	1	3	10.93	1400	255111.1	116919.8	138191.3	1.60
MF	1	1	8.77	1400	204555.6	65867.13	138688.5	3.92
PD	1	2	26.26	1400	612629.6	188617.3	424012.3	2.68
MF +PD	1	3	19.89	1400	464074	125729.9	338344.2	3.55
0	2	3	16.08	1400	375148.1	116919.8	258228.4	2.99
MF	2	1	7.82	1400	182518.5	65867.13	13453.24	3.30
PD	2	2	24.06	1400	561296.3	168617.3	194960.5	2.84
MF +PD	2	3	24.50	1400	571666.6	150729.9	64716.44	3.50

Calculation of total revenue is based on ₦1400 per basket (60 kg) of tomato the prevailing farm gate price at Kadawa and environ.
V1 = UC82B, V2 = Rio-Grande, M1 = No mulch, M2 = Rice straw, M3 = Sugar cane peel .

4.2 Discussion

4.2.1 Effects of season on growth and yield of tomato

Crop yield was higher in the dry season of 2017 (24.40 t ha^{-1}) than in 2016 (10.67 t ha^{-1}) and 2018 (17.67 t ha^{-1}). The performance of tomato depends largely on environmental factors which influence the growth and modify genetic potential of the plant. The performance of tomato in 2017 was satisfactory unlike in 2016 and 2018 that resulted in low yield. The performance of the crops in 2017 as exemplified by most of the growth characters may be due to favourable climatic condition (Table 4.3) which enhanced greater photosynthetic activities and hence increased assimilate production that was translocated to the fruit. The crop was transplanted in late November and therefore was able to exhibit its full genetic potentials unlike in 2016 and 2018 that low yield was observed. The observed low yields in 2016 and 2018 dry seasons may be attributed to delayed establishment of the trial which was done in January 2016 and 2018. This might have led to the crop inability to express its full potential. The high temperature and relative humidity recorded during the critical growth stages (Table 4.3) might have had unfavourable effect on vegetative mass. Hence, less assimilates partitioning to reproductive tissue due to poor resource utilization. The optimum growing temperature for satisfactory growth and development of tomato are 21 ^{0}C to 24 ^{0}C. If temperatures are below 15 ^{0}C or above 29 ^{0}C, pollen release is restricted resulting in incomplete fertilization of ovules. The hot and dry weather leads to drying of the flowers and stops pollination. This causes collapsed fruit walls and formation of deep indentation in the fruit, a phenomenon called catface (Peirce, 1987; Bok *et al.*, 2006). This results therefore agrees with the report of Ibrahim (1999) who stated that savanna ecological zone is predominantly a tomato growing region in Nigeria and relatively high yield of up to 30 t ha^{-1} is obtainable in the region due to favourable weather condition during the dry season when temperature is about 25 ^{0}C and relative humidity is between 50 % -70 %. Yield of tomato was lowest (16.03 t ha^{-1}) in 2016 and this may not be unconnected with severe outbreak of *Tuta absoluta* popularly known as tomato Ebola which occurred during the fruiting and harvesting stage in this study. This incidence led to the reduction in number of harvest frequency of three compared to five in 2017. However, the observed variation in yield across the three years with the best yield in 2017 dry season may be attributed to the residual effect of applied soil nitrogen over the three years of experimentation. However, the gradual drop in plant height and number of fruit in 2018 might be due to low residual nitrogen and organic matter (Table 4.1). In addition, the positive residual effect of organic mulching materials might have improved the aeration, water holding capacity, soil organic matter, microbial activities and increased micro nutrient content.

4.2.2 Response of variety on growth and yield of tomato

The varieties tested behaved differently in terms of growth characters. Rio-Grande performed significantly better than UC82B with respect to plant height, canopy spread and days to 50% flowering. On the other hand, UC82B performed significantly better than Rio-Grande in growth characters such as plant dry weight, CGR, RGR, NAR and ET rate. However, all the yield characters including the final fruit yield did not vary between the varieties in the mean results. It was only in 2016 and 2017 that variety was affected with Rio Grande exhibiting 63.54 % marketable yield increase over UC82B in 2016 whereas UC82B with 18.19 % marketable yield increase over Rio Grande in 2017. However, similar trend was observed with fresh fruit yield. The increased growth characters exhibited by Rio-Grande may be attributed to its genetic makeup. Yield increases through enhanced canopy of tomato plant under favourable weather condition could be attributed to greater sunlight interception on vegetative part which was expected to have increased fruit yield through increased assimilate production and transport to the sink organ. The days to 50 % flowering was prolonged in Rio-Grande variety. This trait suggests that Rio-Grande is a late maturing variety (Anon, 2016). Furthermore, the observed trend in this work is in agreement with the work of Singh *et al.* (2002) who observed high genetic variation in tomato for plant height, number of days to fruit set, number of fruit clusters per plant, number of fruit per plant, fruit weight per plant and fruit yield per plant. The non significant response observed from both varieties on all the yield characters especially fresh fruit yield could be due to the fact that reduced flowering and fruit setting due to temperature stress might have been responsible. Sato *et al.* (2011) suggested that cultivar differences in pollen release and germination under heat stress are the most important factors determining their ability of successful fruit setting.

4.2.3 Effect of Nitrogen sources on growth and yield of tomato

Characters measured including final fruit yield and marketable fruit yield were significantly influenced by application of nitrogen sources. Evapotranspiration was at its lowest rate with the application of poultry droppings compared to other nitrogen sources which resulted in higher ET rate especially the unfertilized plots which gave the highest ET rate. The fruit yield increase observed in this study may be due to increase in most of the vegetative plant part for better light interception for increase photosynthetic activities. However, the result obtained from this work is not unexpected because all the nitrogen sources evaluated in this work have been reported over time by different researchers to have positively influenced the growth and development of tomato varieties. The nitrogen contained in all the N-sources were probably used for synthesis of essential amino acid, enzymes and plant chlorophyll, energy formation and transfer, phosphorylation and hence increase in photosynthesis. The product of photosynthesis (assimilate) were then translocated to the fruit. Mineral fertilizer + poultry droppings enhanced the growth and development of tomato than all the other applied nitrogen sources. The favourable competition of nitrogen from poultry dropping in soil enhancement with inorganic sources may be due to physical and chemical advantages (improved aeration, water holding capacity, soil organic matter, microbial activities and increased micronutrient content) of added poultry droppings. Nutrients contained in organic manures are released slowly and are stored for a longer time in the soil, thereby ensuring a long residual effect (Sharma and Mittra, 1999). Low rate of Evapotranspiration observed in poultry dropping application may be due to their ability to bind the soil together thereby improving its moisture holding capacity which turn increased activities of beneficial soil micro organisms for better water use efficiency (WUE).

The work of Olaniye and Ajibola (2008) also show that poultry droppings recommendation is a suitable replacement for inorganic fertilizer in tomato production at the rate of 6 t ha^{-1}, as it was observed to have significantly increased the yield and quality of the fruit. However, another work conducted by Eliakira and Peter (2014) recommended 8 t ha^{-1} as sufficient for optimum yield and quality of tomato plants.

4.2.4 Effects of organic mulches on growth and yield of tomato

Results of this study shows that the generally performance of the crop was enhanced by organic mulching materials. The response of organic mulches to most growth and yield might be attributed to the ability of the mulch to conserve soil moisture and suppress weed which might have created favourable condition for plants to utilise growth resources which further led to delay flowering for better vegetative growth for enhanced photosynthetic activities and thus greater dry matter accumulation for increased fruit yield. This is in line with the report of Goitom *et al.,* (2017), that organic mulching had significant effect on soil moisture content when compared to the un-mulched plots. Conserved moisture is essential for nutrient transporting, translocation of assimilate, cell division, and cell differentiation.

Tomato plants in the un-mulched plots flowered earlier than those from mulched plots. This might be attributed to the fact that plants growing on bare field are often induced to false aging and therefore flower early. However, when fields are mulched, the growing plant absorbs sufficient moisture which it uses in efficient vegetative growth (luxuriant growth). This process delays the reproductive phase (flowering). Similar findings were observed by Van Donk *et al*. (2013) who reported delayed flowering with application of different level of mulch, compared to un-mulched plot. Komla (2013) reported that application of rice husk mulch was the most effective treatment in increasing the weight of fruits per plant, total fruit yield and mean fruit weight per plant. Similar reports were made by Ajibola *et al*., (2014) and Adesina *et al*., (2014) who both confirm the earlier workers.

Evapotranspiration rate was lower with any of the organic mulches compared to the un-mulched plots and this could be due to the physical and chemical advantages of organic mulch addition in soil moisture conservation thereby ensuring better water use efficiency (WUE).

4.2.5 Effect of interaction

Fresh fruit and marketable yield were higher with combined application of mineral fertilizer and sugar cane peels mulch which gave a yield of 22.1 and 19.3 t ha^{-1} respectively. The growth components were significantly enhanced by the combinations of poultry droppings and the combination of poultry droppings with any of the two applied organic mulches. Increased canopy spread, plant dry weight, number of days to 50 % flowering, number of fruit, total fruit yield, marketable fruit yield lower ET rate observed from such interactions could be due to the physical and biological advantage of organic matter in the soil in addition to nitrogen supply. This observed response may be due to the role played by organic mulch in conserving moisture, regulating soil temperature and conditioning the soil for better activity of the nitrogen supplied especially from the mineral fertilizers sources. In a previous study, Moses and Tuarira (2014) observed a significant interaction between trashed grass mulch with organic and inorganic fertilizer than sawdust in combination with organic and inorganic fertilizer for enhanced growth of tomato. When two varieties of tomato (Cochoro and Miya) were evaluated with both inorganic (black and white polythene mulch) and organic (grass mulch) the higher marketable yield obtained from grass mulch on Miya variety over the inorganic mulching materials in combination with the varieties was attributed to its favorable effect on soil temperature and soil moisture which subsequently created favorable condition for root growth and development (Habtamu *et al.*, 2016).

4.2.6 Correlation and Path coefficient analysis

The positive and significant correlation between all the growth and yield characters with the final fruit yield was observed with exception of characters such as LAI, CGR, RGR, number of days to 50% flowering and stem girth at first harvest which showed either a negative or non significant correlation with fruit yield as the case may be. Therefore, the result of this work has indicated the role played by most of these characters of tomato plant as a yield determining factor to the growth and fruit yield of tomato varieties. This response is not unexpected because the more the growth performance the more assimilates produced and subsequently the more the fruit yield. This result was similar to that of Singh *et al*. (2002), Singh and Cheema (2005), and Haydar *et al.* (2007) who reported and found that yield was correlated with the selection of growth parameters of tomato.

Path analysis has shown that number of leaves and plant height gave the highest individual percentage contribution to fruit yield. This suggests that canopy spread via number of leaves, LAI via number of leaves, LAI via plant height in this study gave the highest combined percentage contributions to fruit yield. The consistent role played by plant height and number of leaves in the direct and indirect contributions makes them important yield contributing factor for increase fruit yield. This finding corroborate with the work of Shashikanth and Dhotre (2012) who observed similar traits in direct cultivar selection for improved fruit yield of tomato. Consequently, the low residual values obtained from this study suggest that several characters considered in path analysis in this study enhanced the growth and development of tomato varieties.

4.2.7 Effect of treatments on some post harvest qualities of tomato fruit

Result from this study has shown that tomato fruit qualities did not vary among the varieties tested. However, fruit appearance, fruit decay, shelf life, nutrient (N, P and K) and vitamin (A, E and C) concentrations were significantly enhanced by nitrogen sources. This might be attributed to the source of the nitrogen source which is of organic origin. Against the backdrop of the fact that the performance trends of the organic nitrogen fertilizer source which showed superiority with regard to fruit quality traits over MF source might be due to the fact that organic N source have the ability to enhanced soil physical properties (water holding capacity, aeration etc) and greater and gradual release of nutrient. Similar findings by Rajiasree and Pillai (2009) reported that more frequent split application of nutrient N or greater proportion of organic source enhanced the shelf life of fruits. The significant higher interaction between PD and the two organic mulching materials that showed comparison effect is an indication of the superiority displayed by organic N-source over inorganic sources.

The superiority in N and P concentration recorded under MF + PD treatment could be attributed to the relative high N and P status of the applied MF + PD in comparison with MF alone and PD alone. The actively growing tomato fruit might have needed N for cell formation, protoplasm build-up and synthesis of metabolites including protein, while P is needed as phosphate for synthesis of Adenosine Triphosphate and numerous phosphoryllated compounds. It is evident that the applied MF + PD were able to meet the crop demand for these elements beyond the crop minimum requirement. The significant low N in tomato fruit under MF and PD treatments, might conversely, be due to its low N-status as revealed by analytical results (Table 4.23). There was observed significant difference ($P \leq 0.05$) with regard to K concentration in tomato fruit between the varying nitrogen sources with PD and MF + PD producing significantly ($P \leq 0.05$) higher fruit K concentration than MF and unfertilized plots (control). This is due to the fact that the two sources are from organic origin and were able to supply the nutrients in quantities beyond the crop minimal metabolic requirement than from only MF which is from inorganic source of K.

Significant difference ($P \leq 0.05$) was observed in mean A, E and C concentration, between the varying sources of nitrogen with PD and MF + PD which are statistically comparable being significantly higher than MF and the unfertilized plots which had the lowest vitamin A concentration (Table 4.24) while MF + PD had significantly higher vitamin E concentration than other nitrogen schedules. The superiority in A and E concentration recorded under PD and MF + PD treatment which are both of organic origin could be attributed to oxidative stress which most have exerted some pressure on the crops, thereby enhancing nutritional quality such as vitamin A and E concentration. This result corroborate with Aurelice, *et al.* (2013) who suggested that tomato fruits from organic farming experienced stressing conditions that resulted in oxidative stress and the accumulation of higher concentrations of soluble solids as sugars and other compounds contributing to fruit nutritional quality such as vitamins and phenolic compounds. Also, Poiroux-Gonord *et al.* (2010) reported that environmental stress (biotic or abiotic) is a major factor that can increase the concentrations in photochemical in fruit and vegetables.

However, organic N-sources (PD and MF + PD) were found to have reduced vitamin C concentration (Table 4.24). Similar findings were reported by Anon (2018) that nitrogen fertilizers, especially at high rates, seem to decrease the concentration of vitamin C in many different fruits and vegetables.

Significantly ($P \leq 0.05$) difference was observed between the varying organic mulching treatments with the two organic mulching materials showing a significantly higher and comparable fruit qualities such as good fruit appearance, less fruit decay, longer shelf life and higher fruit N concentration. Sugar cane peels mulch which was observed to be significantly similar but higher than rice straw mulch offered better protection for tomato fruit against direct contact with the soil which subsequently might have prevented infestation from soil born deceases and hence good fruit qualities thus further prolonged storage life of tomato fruit.

4.2.8 Cost and return analysis

In this study, tomato production using poultry droppings (PD) and sugar cane peels mulch with variety Rio-Grande gave highest gross margin and profit per naira (₦) invested. The lowest gross margin came from either mineral fertilizer (MF) or mineral fertilizer + poultry droppings and rice straw mulch on any of the tomato variety. This might be an indication of fertilizers sourced from inorganic sources could be responsible to favoured vegetative growth that may significantly affect the reproductive growth and development. Therefore the fruits produced from inorganic sources might not be bountiful enough to upset the cost of production.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the result of this study, it is concluded that Rio-Grande tomato is better than UC82B with fresh fruit yield and marketable yield increase of 57.89 % and 63.54 % respectively. Application of poultry droppings (2.88 t ha^{-1}) better enhanced plant growth, fruit yield and quality of tomato varieties compared to other nitrogen sources. Evapotranspiration (ET) rate was lowest and the farmer's gross return per each naira invested on production was highest when this source of nitrogen was applied. Sugar cane peels and rice straw used as mulch in this study enhanced the plant growth, yield and fruit qualities of tomato varieties. However, sugar cane peels mulch could be considered a good replacement for rice straw mulch in the Sudan ecology of Nigeria due to high cost of rice straw mulch that is increasingly used as livestock feed.

Application of mineral fertilizer + poultry droppings in combination with sugar cane peels mulch gave higher fresh fruit and marketable fruit yield of 22.1 t ha^{-1} and 19.3 t ha^{-1} respectively.

Results from correlation and path analysis have shown that number of leaves gave the highest direct contributions in 2016 and 2017 while plant height gave the highest direct contribution in 2018. However, the highest individual percentage contribution was by plant height while the highest combined percentage contribution was by plant height via leaf area index.

Cost and return analysis has indicated that poultry droppings (2.88 t ha^{-2}) using sugar-cane peels mulch (11.0 t ha^{-1}) with Rio-Grande gave the highest gross margin.

5.2 Contribution to Knowledge

The contributions of this study to knowledge are indicated by the following findings.

- Application of poultry droppings at recommended rate of 2.88 t ha^{-1} for enhanced growth, fruit yield and quality of any of the tomato varieties on sustainable basis.
- Sugar-cane peels mulch at 4 cm thickness (11.0 t ha^{-1}) is a suitable replacement to rice straw mulch in soil water conservation for sustainability in tomato production.
- For higher fruit yield of tomato, Rio-Grande is the best variety due to its superior genetic trait over UC82B in the Sudan ecological zone of Nigeria.

5.3 Recommendations

- A poultry dropping (2.88 t ha^{-1}) is recommended for enhanced growth, fruit yield and quality of tomato on sustainable basis.
- Sugar-cane peels mulch is recommended as a suitable replacement to rice straw mulch.
- Rio-Grande is recommended as the best variety for increased yield of tomato while for higher fruit quality any of the variety could be use.

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APPENDICES

Appendix I Constraint and Limitations of the Research Work

- This study focused mainly on organic fertilization approach to fruit yield enhancement of the tomato crop and attempted to draw a comparison with inorganic fertilizers. Only one source of organic manure and one source of inorganic fertilizer were explored out of the several options available within the Sudan savanna zone.
- Out of the several high yielding dry season varieties of tomato available to growers only two were featured in this work.
- Also only two organic mulching materials featured out of the several organic mulches available to growers. The streamlining was dedicated by the available resources.
- The trial was conducted in the same location in three years (Sudan savanna ecology) as opposed to evenly spread locations (Northern guinea and Southern guinea savanna). This was dictated by constraints of fund, materials and logistics.
- The fruit quality study of tomato was limited to selected qualities such as fruit appearance, decay and fruit shelf life as well as macro nutrients and vitamin contents while excluding micro nutrients and proximate analysis which tomato fruits are documented to be very rich in. this was due to scarcity of appropriate equipment.

Appendix II Suggestions for Future Research

- Multi location trial to cover the entire savanna ecological zone should be conducted and a re-evaluation of recommended nitrogen sources and organic mulches for yield and storage qualities of tomato varieties.
- Comparable determination of micro nutrients and proximate concentrations in tomato fruits produced by organic and in organic nitrogen sources should be conducted.
- Assessment of fungi load on tomato fruits at post harvest storage as affected by nitrogen sources and organic mulching materials of tomato varieties.
- Evaluation of rates, chemical and biological advantage of sugar cane peels mulch addition to the soil in vegetable production.

Appendix III: Field experiment layout in Kadawa (Split plot design)

N1V1	N2V1	N3V1	N4V1	N1V2	N2V2	N3V2	N4V2
M1	M2	M3	M2	M1	M2	M3	M2
M2	M3	M1	M1	M2	M3	M1	M1
M3	M1	M2	M3	M3	M1	M2	M3

RI

N4V1	N4V2	N2V1	N2V2	N1V1	N1V2	N3V1	N3V2
M1	M1	M1	M2	M3	M2	M1	M3
M3	M3	M3	M3	M2	M1	M3	M1
M2	M2	M2	M1	M1	M3	M2	M2

RII

N4V2	N1V1	N3V2	N2V1	N2V2	N3V1	N1V2	N4V1
M2	M1	M1	M2	M1	M3	M3	M1
M1	M3	M3	M1	M3	M2	M1	M2
M3	M2	M2	M3	M2	M1	M2	M3

RIII

KEY

V =VARIETIES

N =NITROEN SOURCES

M =ORGANIC MULCHES

Appendix IV: Poultry droppings calculations

2016 dry season

Nitrogen content of poultry droppings (PM) = 2.57 % = 2.57/100 = 0.0257 grams

Since 1 grams of PM = 0.0257 grams

1 Kg of PM = 0.0257×1000 =25.7 Kg

Recommended N-rate for tomato = 90 Kg N ha^{-1}

Therefore to supply 90 Kg N : 25.7 Kg × 90 Kg of N = 2313 Kg PM

Since I Kg = 1000 ton

Recommended PM N-rate = 2313 Kg /1000 = 2.313 t ha^{-1}

To apply 2.3 t ha^{-1} of PM to 9 m^{-2} kg/plot. = $\frac{\text{Rate to apply} \times \text{plot size}}{10,000}$ X 1000 in

Thus: - to apply 2.313 t ha^{-1} = $\frac{2.313 \times 9}{10,000}$ X 1000

= 20.8 / 10,000 = 0.00208 x1000 = **2.08 kg $plot^{-1}$**

2017 dry season

Nitrogen content of poultry droppings (PM) = 3.67 % = 3.67/100 = 0.0367 grams

Since 1 grams of PM = 0.0367 grams

1 Kg of PM = 0.0367×1000 =36.7 Kg

Recommended N-rate for tomato = 90 Kg N ha^{-1}

Therefore to supply 90 Kg N : 36.7 Kg × 90 Kg of N = 3303 Kg PM

Since I Kg = 1000 ton

Recommended PM N-rate = 3303 Kg /1000 = $\underline{3.303\ t\ ha^{-1}}$

To apply 3.303 t ha^{-1} of PM to 9 m^{-2} = $\frac{\text{Rate to apply x plot size}}{10,000}$ X 1000 in kg/plot.

Thus: - to apply 3.303 t ha^{-1} = $\frac{3.303 \times 9}{10,000}$ X 1000

= 29.72 / 10,000 = 0.00297 x1000 = **2.97 kg plot^{-1}**

2018 dry season

Nitrogen content of poultry droppings (PM) = 3.36 % = 3.36/100 = 0.0336 grams

Since 1 grams of PM = 0.0336 grams

1 Kg of PM = 0.0336×1000 =33.6 Kg

Recommended N-rate for tomato = 90 Kg N ha^{-1}

Therefore to supply 90 Kg N : 33.6 Kg × 90 Kg of N = 3024 Kg PM

Since I Kg = 1000 ton

Recommended PM N-rate = 3024 Kg /1000 = 3.024 t ha^{-1}

To apply 3.024 t ha^{-1} of PM to 9 m^{-2} = $\frac{\text{Rate to apply x plot size}}{10,000}$ X 1000 in kg/plot.

Thus: - to apply 3.024 t ha^{-1} = $\frac{3.024 \times 9}{10,000}$ X 1000

= 27.22 / 10,000 = 0.00272 x1000 = **2.72 kg plot^{-1}**

Appendix V: Analysis of Variance (Anova) Procedure

Source	df	SS	MS	F
Rep	(3-1)	2		
Main plot (NV-1)	(8-1)	7		
Error (a)	(3-1) (8-1)	14		
Sub (M-1)	(3-1)	2		
Int Main×Sub	(8-1) (3-1)	14		
Error (B) M(S-1) (r-1)	8(3-1) (3-1)	32		
Total R.N.V.M-1		71		

Appendix VI: Journal publications/Conference

- Ainika, J.N., Yusuf S.T., Odofin A.J, & Ibrahim H. (2018). Growth performance and Yield of irrigated tomato (*lycopersicum esculeatum (I) H. Karst*) as affected by nitrogen sources and organic mulches in Kadawa-Kano, Nigeria. *Nigerian Journal of Seed Science* (SJSS). Vol. (2) 2018

- J.N. Ainika, S.T. Yusuf, A.J. Odofin and H. Ibrahim. (2018). Correlation and path-coefficient analysis of some growth characters of two irrigated varieties of tomato (*lycopersicum esculeatum (I) H. Karst)* in Kadawa Kano state, Nigeria. *Journal of agriculture and environment.* Vol. (14) 1. ISSN 1595-465X

- Ainika, J.N., Yusuf S.T., Odofin A.J, Arunah L.A. & Ibrahim H. (2018). Fruit quality and Marketable fruit yield of dry season tomato varieties as influenced by nitrogen sources and organic mulches at Kadawa, Kano State Nigeria. *Proceedings 14th Annual Conference of Organic Agriculture in Tertiary Institutions in Nigeria. 25th-28th November, 2018.*