PRODUCTIVITY OF TOMATO (*Lycopersicon lycopersicum*, Karst.) VARIETIES IN RESPONSE TO NPK FERTILIZER AND GREEN MANURE RATES.

BY

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A dissertation submitted to School of Postgraduate Studies, Ahmadu Bello University, Zaria in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agronomy.

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FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA.

JUNE, 2014

DECLARATION

I declared that this work in dissertation entitled: **PRODUCTIVITY OF TOMATO (*Lycopersicon lycopersicum*, Karst.) VARIETIES IN RESPONSE TO NPK FERTILIZER AND GREEN MANURE RATES** has been performed by me in the Department of Agronomy under the supervision of Professor E. B. Amans, Drs. E. C. Odion and A. A. Yusuf. Information in the text derived from literatures has been duly acknowledged and list of references provided. No part of this dissertation was previously presented for another degree or diploma at any university.

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The above declaration is confirmed

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Professor E. B. Amans Date

Chairman, Supervisory Committee

CERTIFICATION

This dissertation entitled: **"Productivity of tomato (*Lycopersicon lycopersicum*, Karst.) Varieties in response to NPK fertilizer and green manure rates"** by Abdulazeez Shero ISAH meets the regulations governing the award of the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate this piece of work to my parents Alhaji Isah Muhammad and Late Malama Salamatu Isah and the entire family for the support and affection given to me during the course of the study.

ACKNOWLEDGEMENTS

"Bisimillah- Rahman-Raheem". All praise belongs to Almighty ALLAH. I owe much all my sincere thanks to Professor E. B. Amans the Chairman, Supervisory Committee for the valuable, skillful, enthusiastic, encouraging and constant guidance for the conductance of this research work leading to useful and valuable conclusion. The same sincere appreciation to Drs E. C. Odion and A. A. Yusuf who co-supervised this piece of work for their keen interest, contributions and encouragements shown throughout the study. My warm appreciation goes to the Head of Agronomy Department, Dr. B. A. Babaji for his encouragement and advice during the course of the studies.

I wish to acknowledge the support of Horticultural Research Programme now Artemisia Research Programme of the Institute for Agricultural Research and MacArthur Foundation projects for their support. I am grateful to all the academic and non academic staff of the Department of Agronomy for their support and encouragements.

I am highly grateful to Professors V. B. Ogunlela, A. B Lawal, M. Mahmud, H. Mani, O. O. Olufajo, U. F. Chiezey, Drs A. I. Sharifai, U. L. Arunah, I. D. Adekpe, M. A. Mahadi, H. N. Kura, R. A. Yahaya and Dr. (Mrs) A. A. Mukthar for their encouragement and advice. My deep appreciation goes to my sisters Dr (Mrs) Suleiman Habiba, Hajia Woru Mariam and their families for always been there for me.

My sincere thanks to all my friends and classmates Jazuli Alhassan, Shehu Nai Dauda, Bello Yunusa, Daniya Emmanuel, Adamu Yakubu and Adamu Mohammed for their love, contributions and moral support. I extend my greatest thanks to all my family members for their prayers, love and sacrifice, which served as a source of inspiration to complete this work especially, my dear wife Mrs Hauwa Isah and my children for their patience.

Finally, I appreciate the prayers and encouragements of my colleagues and friends Dr. Umar Gunu , Dr (Mrs) K. O. Mohammed, Mrs A. K. Abdulkareem, (Unilorin) Mr. F.T. Olawepo, J. O. Aiyedun, O. O. Ogundele, Dr (Mrs) N. B. Ojibara, A. S Kazeem and staff of Agricultural science Education Department (Kwara State College of Education, Ilorin). May Allah bless you all abundantly, Amin. Al-hamd lillah.

ABSTRACT

Field experiments were conducted in 2010-2011 and 2011-2012 dry seasons at Research Farm of the Institute for Agricultural Research, Samaru and Kadawa to study the productivity of tomato in response to NPK fertilizer and green manure rates. The treatments consisted of two tomato varieties (Roma VF and UC82B), four NPK 15-15-15 fertilizer rates (0, 150, 300 and 450 kg ha^{-1}) and three green manure rates (0, 5 and 10 t ha^{-1}), laid out in a split-plot design with three replications. The combination of variety and NPK fertilizer was assigned to main plot and green manure rate to the subplot. The variety UC82B was superior to Roma VF to all the measured growth parameters such as crop dry matter, leaf area index, crop growth rate and yield attributes such as fruit number per plant, fruit weight per plant; however Roma VF had higher fruit dry matter and fruit acidity content. NPK fertilization at 300 kg ha^{-1} significantly increased leaf area index, crop growth rate, fruit number per plant, weight per fruit, fruit yield per plant, fruit dry matter and total fresh yield at both locations. However, increasing NPK fertilizer rate beyond 300 kg ha^{-1} did not increase yield significantly. Application of 150 kg ha^{-1} NPK increased soil pH, soil N and reduce soil C:N, soil organic carbon at both locations. Green manure application at 10 t ha^{-1} resulted to significant increase in growth parameters and yield attributes such as fruit weight per plant, fruit dry matter, fresh fruit yield and fruit acidity in both locations. Generally, green manure application increases soil N, soil P, soil K, soil organic matter and reduced pH, C: N in both locations. Agronomic efficiency (AE) for both varieties of tomato was generally highest at the application of 150 kg NPK and at 10 t ha^{-1} of green manure (GM) at both locations. Decomposition of applied green manure was fast (4.5%) day^{-1} and the number of days to 50% decomposition was lowest (11 days) at application of 450 kg ha^{-1}NPK fertilizer at both locations. Regression of total fruit yield to NPK fertilizer response was quadratic while green manure showed linear response at all the locations. The tomato varieties responded differently to NPK application in both locations; for Roma VF the optimum rate was 270 kg ha^{-1} at Samaru and 280 kg ha^{-1} at Kadawa and UC82B the optimum rate was 260 kg ha^{-1} at Samaru and 270.2 kg ha^{-1} at Kadawa respectively. The combination of 150 kg ha^{-1} of NPK fertilizer and 10 t ha-^{1} of green manure will save about 50% when compared with 300 kg ha^{-1} NPK fertilizer rate alone. The highest percent contribution to fruit yield was obtained from fruits weight per plant at Samaru (20.1, 31.9 and 26.0%) and at Kadawa (22.7, 20.5 and 21.6%) in 2010-11, 2011-12 and mean while the highest indirect contribution was obtained from number of fruits via fruits weight per plant in both years and location. Economic analysis of tomato production at both locations indicated that application of 150 kg ha^{-1} and 10 t ha^{-1} using UC82B gave the highest gross margin as well as gross margin per naira (₦) invested of ₦ 1.23k and ₦1.41k gain at Samaru and Kadawa respectively. Based on the result obtained from this study, it can be concluded that variety UC82B was superior Roma VF for its higher yield while Roma VF could be selected for its better processing quality suitable for canning because of its high acidic properties. Lablab green manure is critical to soil fertility and improved the physicochemical properties of soil.

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CHAPTER ONE

INTRODUCTION

1.1 Origin and Distribution of Tomato

Tomato (*Lycopersicon lycorpersicum* Karst) belongs to the family *Solanaceae* (also known as the night shade family). The family also include other important vegetable crops such as potato (*Solanum tuberosum* L.), pepper (*Capsicum spp.* L.), eggplant (*Solanum melongena* L.) and tobacco (*Nicotiana tabacum*). All related wild species of tomato are native of the Andean region that includes part of Chile, Colombia, Ecuador, Bolivia and Peru (Sims, 1980). Although the ancestral forms of tomato grew in the Peru-Ecuador area, the first extensive domestication seems to have occurred in Mexico (Sims, 1980; Harvey *et al.*, 2002).

The Spaniard introduced tomato into Europe in the early 16th Century (Harvey *et al.*, 2002) and subsequently to Africa through Gibraltar and Morocco. Tomatoes were initially grown only as ornamental plants; fruits were considered to be poisonous because of the closely related and deadly night shade (*Solanum dulcamara*). The cultivated tomato reached its present status after a long period of domestication and it is now grown throughout the temperate and tropical climates (Harvey *et al.*, 2002).

1.2 Economic Importance of Tomato

Tomatoes are one of the most widely eaten vegetables in the world. Their popularity stems from the fact that they can be eaten fresh or in multiple of processed forms. Three major processed product are (i) tomato preservers (peeled tomatoes, tomato juice, tomato paste) (ii) dried tomato (tomato powder, tomato flakes and dried tomato fruits) and (iii) tomato based foods (e.g. tomato soup, tomato sauces, chili sauces, ketchup). Tomato is rich source of vitamins A, B and C with acidic properties that bring out other flavour (Rakesh and Adarsh, 2010).

In the recent decades the consumption of tomatoes has been associated with prevention of several diseases (Wilcox *et al.*, 2003, Sharoni and Levi, 2006) mainly due to the content of antioxidants including carotenes, (Lycopene as well as β-carotene), ascorbic acid and phenolic compounds (Periago *et al*., 2009). Lycopene has been shown to have a strong antioxidant activity, it modulate hormones, immune systems and other metabolic pathway (Balasundram *et al*., 2006). Residue from processed tomato is the secondary raw material that is been considered a potential source of dietary fibre and bioactive compounds (Inmaculada *et al.*, 2011).

1.3 Environmental Requirements of Tomato

Tomato requires a relatively cool dry climate for high yield and premium quality. However, it is adapted to a wide range of climatic conditions from cool temperate to hot humid tropical. The optimum temperature for most varieties lies between 21^0C and 24^0C. The crop can survive a range of temperatures but the plant tissues are damage below 10^0C and above 38^0C (Tindall, 1983; Rice and Tindall, 1986). Tomato plant reacts to temperature variation during growth cycle in the tropical lowlands, the minimum temperature at night is very important and temperature below 21^0C can cause fruit abortion (Ploeg and Heuvelink, 2005; Islam *et al.*, 2011). Fruit setting is reduced by temperatures that are either low below (13^0C) or high (above 35^0C). Dry winds can also cause flower abortion. Mean temperatures below 13^0C and above 27^0C severely impair fruit set and destruction of pollen occurs when the maximum daytime temperature is 38^{0C} or more for 5–10 days. Fruit set is generally poor when night temperatures are above 20^0C for a few days both before and after anthesis. Both high and low temperature can adversely affect fruit quality particularly colour development (Islam *et al*., 2011). Light intensities below 11,000 lux retard plant growth and delay flowering. Tomato is not sensitive to day length and sets fruit in photoperiods ranging from 7–19 hours.

Large scale tomato production in Nigeria is mostly during the dry season in the northern part of the country because of favourable climatic conditions such as temperature, relative humidity and sun shine (Amans *et. al.,* 1986). Excessive rainfall or irrigation water supply causes adverse effects on the tomato crop if not staked or mulched due to the spread of fungal diseases (Quinn, 1980; Tindall, 1983). The plant however requires adequate water supply during its growth period, about 8-10 mm per day during the period of fruit development. Well fertile soil with good moisture retaining capacity and relatively high level of organic matter are best for tomato production (Tindall, 1983). Tomato can be grown in many soil types, from sandy loam to clay-loam soils that are rich in organic matter. It is sensitive to water logging and flooding and prefers well-drained soils. Many cultivars tolerate a wide range of soil conditions with pH levels of 5.0-6.5. The optimum soil pH range is 6.0-7.0, higher or lower pH can cause mineral deficiencies or toxicities. (Rice *et al*., 1990).

1.4 Production Trends and Constraints

The global production of tomatoes (fresh and processed) has increased by about 300% in the last four decades (Costa and Heuvelink, 2005). The world production of tomato figure in 2012 was 159.3 metric tonnes with China leading with 48.5 metric tonnes followed by USA recording 15.5 metric tonnes. Africa produced 10.8% of world production, Morocco is the leading producer in Africa with the production of 12.1 metric tonnes and Nigeria is the fourth in Africa and leads in West Africa sub region with an estimated output of 1.10 metric tonnes and average yield of 5-6 tonnes ha^{-1}. This is lower than average yield of 13.5 tonnes ha^{-1} in Africa and world average of 22.0 tones ha^{-1}(FAO, 2012)

Despite an increase in output of tomato production with corresponding land area, FAO (2012) stated that the yield level in Nigeria is low when compared to major producing countries like Ethiopia, Niger with average yield of 7.1 t ha^{-1}. Low soil fertility has been identified as one of the major problem facing small scale farmers in the tropics. The low fertility is caused by continuous cropping without additional soil fertility inputs (Mofuka *et al.*, 2007). In the savannah agro-ecology, decline in crop yields are associated with decline in soil organic matter content, even when large amount of external inputs such as fertilizers, organic manures and energy are applied to the system (Kayuki and Wortmann 2001; Khan *et.al*., 2007) and the inability of most farmers to acquire inputs for optimum production of the crop (Tarfa *et al*., 2001).

1.5 Justification and Objectives

Vegetable production systems in the tropics and elsewhere are very intensive and low yield of vegetable crops is a common occurrence in most production systems in the tropics (Schroth and Sinclair, 2003). Researchers have shown the potential yield of tomato in Nigeria savanna under dry season condition was reported to be 50 t ha^{-1} or more. Despite the high yield potential of tomato in savannah region, yield per hectare is still relatively low 7.1 t ha^{-1} (Erinle, 1989). The identified factors associated with this low yield include non-availability of improved and adaptable varieties, non availability or high cost of production inputs such as inorganic fertilizers and to a larger extent highly degraded soil with low inherent soil fertility that cannot support high and sustainable production system for long time (Ismaila *et al*., 2010).

Combined efforts directed towards ameliorating the fertility problems include use of bush fallowing, inclusion of legumes in crop rotation and as a component in cropping systems, use of inorganic fertilizers, farm yard manure and animal droppings. Some of the constraints that are associated with the above ameliorative efforts include shortening of the length of bush fallow below that which could have any meaningful impact on the natural recuperation of the soil nutrient because of population pressure (Chikoye *et al*., 2002, Ismaila *et al*., 2010, Styger and Fernandes, 2012). Companion leguminous crops do not usually have immediate benefit on availability of nutrient to other component crops, and on the long run, total contribution to soil nutrient is meager due to high carbon content of the residues.

Judicious application of inorganic fertilizers can undoubtedly improve crop yields, however, inorganic fertilizers are scarce and when available the price is often beyond the reach of resource poor farmer (Okpara *et al*., 2003; Okwu and Ukanwa, 2007). There has been increasing concern worldwide about increasing use of inorganic chemicals such as fertilizer in food production. Application of high rate of chemical fertilizers has been implicated in soil degradation process, nutrient imbalance, soil acidity and pollution risk (Henao and Baanante, 1999). Inadequate supply of essential nutrients during crop growth is known to have negative impact on the growth, reproductive capability and yield of the crop. Khan *et al.* (2007) reported that despite the use of forage legumes, soils suffered serious decline in their content of nitrogen and organic matter, except where regular manuring was involved. The benefits of organic manures in crop production are well known and the popular domestic sources are farm yard manure and animal droppings which are often not available in sufficient amount and their bulky nature makes their transportation difficult. Green manure has received renewed attention with emphasis on long term sustainability of agricultural system because it can be used as a source of soil nutrients and alternative to maintenance of soil fertility (Ali, 1999; Smil, 2000). Research have shown that the use of green manure crops for soil fertility restoration is among the most promising technologies to overturn the soil degradation problems for the rural poor (Tarawali, 1999). Herbaceous legumes (*Lablab purperues)* offer a low cost opportunity for maintaining soil fertility by contributing nutrients during decomposition as much as 200 kg N ha^{-1}, 30 kg P ha^{-1} and 60 kg K ha^{-1} (Baijukya, 2004; Ibewiro *et al*., 2005) which is an assured means of improving crop yields, quality and at same time improving soil fertility status in an economic and environmental friendly. Despite its significance in ameliorating soils, the use of green manure has not received the desired attention in vegetable production especially on tomato crop.

Tomato productivity at a given location depends on the potential of the genotype used and timely availability of resources. Crop variety is one of the vital factors that influenced yield. Tomato yield and quality have been reported to be under genetic control and hence do vary widely with cultivars (Oko-Ibom and Asiegbu, 2007). The use of appropriate variety may result in better growth and higher yield.

In view of the above, the present study was carried out with the following objectives:

i. to evaluate the growth and yield of two tomato varieties

ii. to evaluate the response of tomato varieties to green manure rates.

iii. to assess the response of tomato varieties to NPK fertilizer rates.

iv. to assess the economic return of tomato production using NPK fertilizer and green manure rates.

CHAPTER TWO

LITERATURE REVIEW

2.1 Growth, Yield and Quality of Tomato Variety

Watson (1952) postulated that the climate determines what crops can grow and weather determines the yield we got; indicating that environment plays a role in the production of crops. High yielding varieties and nutritional quality of crop is of great concern in crop production but environment does play its role in productivity of varieties (Derby *et al.*, 2004). The varietal differences in growth and yield might be attributed to the differences in ecological distribution of the tomato (Olaniyi, 2007).

In a study conducted in Nigerian Guinea savannah by Olaniyi *et al.* (2010) using seven varieties of tomatoes DT97-162, DT97-215A, Tropical, Roma VF, UC82B, Ibadan Local and Ogbomosho local revealed that despite environmental constraints encountered by these varieties during the growth period UC82B followed by Ibadan and Ogbomosho local still gave the highest growth, marketable and good quality fruit yield performance. This suggests that UC82B tomato variety has the ability to tolerate the environmental hazards and other yield constraints encountered during the growth periods than other varieties investigated.

Olaniyi and Fagbayide (1999) reported that variation in yield may also be due to genetic differences among the varieties since they were grown under the same environmental conditions. Lack of high yielding varieties combined with quality attributes is major constraints in tomato production in the tropics. Olaniyi *et al.* (2010) trial on tomato showed that Ibadan local had higher mean plant height while DT97-215A recorded lowest plant height. They further stressed that tomato plants growth pattern shows an initial slow growth in the nursery stage and the accelerated or exponential growth was observed in the field after the normal slow establishment of the plant after transplanting. In a study conducted in Tunisia, range of tomato cultivars were evaluated and concluded that tomatoes are adaptable to organic production (Riahi *et al.,* 2007). The nutrition quality of the tomato fruits depend on variety, state of maturity at harvest, amount of nutrient during growth, environmental stress and water management (Mikkelsen, 2005).

2.2 Effect of NPK fertilizer on Growth and Yield of Tomato Variety

In the past years, inorganic fertilizers were recommended for crop production to ameliorate low inherent fertility of soils in the tropics. Of the major nutrients, nitrogen (N) is often required in large quality by crops, primarily for vigour and yield. Crop N requirement is a physiological component which is directly related to generic potential of a crop and its growth condition (Zotarelli *et al.,* 2009). Nitrogen plays a key role in chlorophyll production and protein synthesis. When nitrogen is deficient in tomato, it develops yellow or pale leaves and growth is stunted (Moigradean *et al.,* 2007). Nitrogen is essential in carbon flow and protein synthesis of higher plant (Sugiharto *et al.,* 1996) and nitrogen being a constituent of proteins, co-enzymes and structural constituent of the cell, a deficiency interferes with protein synthesis and growth in general (Schrader, 1984; Haque *et al.,* 2001).

From studies conducted in conventional production systems, it is well known that addition of low levels of ammonium to a nitrate base system can have positive effect on growth Pilbean and Kirkby, 1992; Gill and Reisenaver, 1993) and on quality (Siddiqi *et al.,* 2002). On the other hand, nitrogen nutrition, especially at high levels, can result in plant growth disorder generally referred to as ammonium toxicity (Pilbean and Kirkby, 1992). Siddiqi *et al.* (2002) reported that N uptake in ammonium form can lead to calcium deficiency, which can result in blossom end rot damage of tomatoes. Nitrogen deficiency can result in stunted growth, yellowing of leaves, decrease in the number of fruits, smaller fruits size, poor colouration, sugars (sucrose), taste and storage quality of tomato. Higher doses of fertilizers can also reduce tomato yield by producing excess biomass at the expense of fruits and lodging of entire plant (Upendra *et al.,* 2003). Najafvand *et al.* (2008) reported that leaf area index (LAI) was greatest with higher N fertilizer with maximum values increasing from approximately 0.75-3 as N fertilizer increased from 0-300 kg N ha^{-1}. This was due to increased leaf number and leaf sizes when N rates were increased. Upendra *et al.* (2003) reported that because the nutritional qualities of tomatoes depend on the amount and type of nutrient taken from the growth medium, it is necessary therefore that adequate amount of nutrients should be available for the production and nutritional qualities of tomatoes. The nutrition quality of the tomato fruits depend on variety, state of maturity at harvest, amount of nutrient during growth, environmental stress and water management (Mikkelsen, 2005). Heeb *et al.* (2005a) reported that yield of red tomatoes increases with application of N fertilizer. Heeb *et al.* (2005b) reported N application could improve tastes and ascorbic acid content (quality attributes).

Tomatoes need moderate to high level of phosphorus and potassium, on deficient soils, there is need for supplementary P and K from external sources. Phosphorus is a vital component of adenosine triphosphate (ATP) which supplies the energy for many physiological processes in the plant. Phosphorus deficiency rarely produces spectacular growth deformity or stunting but is fundamental to the successful development of all crops and boost tomato nutritional qualities. Potassium is strongly recommended for the role it plays in the early stages of growth. Maximize concentration of K in leaf tissue prior to flowering enhance plant growth and increases flower production. Potassium is needed throughout the season and is a major component of the fruit at around 250 mg K per 100 g of tomato fruit (Diver, 2005). Use of high levels of potassium is particularly important under saline conditions to maintain plant growth. Excess sodium reduces the uptake and transfer of potassium through the plant and thus potassium levels need to be increased in order to maintain plant growth. The fruit also lacks firmness and has low brix levels when potassium is lacking (Diver, 2005).

The existing recommendation for field in the savanna area was 312 kg ha^{-1} of NPK fertilizer or 75 kg of NPK plus 300 kg ha^{-1} CAN as top dressing in split applied at 2 weeks after transplanting and 3 weeks after first fruit set (Anons, 2002). In southern eastern Nigeria, the application of 300 kg ha^{-1} compound fertilizer was recommend for optimum yield of tomato. Law-Ogbomo and Eghavevba (2008) recommended 400 kg ha^{-1} NPK fertilizer for the tomato varieties evaluated on growth indices and fruit yield.

2.3 Effect of Green Manure on Growth and Yield of Tomato Variety.

A green manure (GM) is a crop used primarily as a soil amendment and nutrient source for future crops. Legumes may add nitrogen (N) to the system through biological fixation in the presence of *Rhizobium* spp. and can correct phosphorus (P) imbalances typically associated with excess applications of animal manures. The slow release of N from decomposing GM residues may be synchronized for plant uptake (Wivstad, 1997; Bath, 2000). Unlike chemical fertilizers, legumes may fix and add large amounts of C to a cropping system and may drive long-term increases of soil organic matter and microbial biomass (Goyal *et al.*, 1992, 1999). Green manures may provide other benefits such as reduction of soil erosion, conservation of soil water, improved retention of other crop nutrients, and control of plant pests, pathogens and weeds with less reliance on off-farm chemical inputs (Bugg *et al.*, 1991, McSorley 1999; Ross *et al.*, 2001).

Benefits attributed to green manure include addition of nitrogen (when using legumes), addition of organic matter, increase in the conservation and availability of nutrient (Anon, 2011). Organic fertilizer such as green manure release nutrient not as fast as mineral fertilizer and therefore plant supplied with organic fertilizer often grow more slowly compared to plant fertilized with readily available mineral nutrients (Heeb *et al.*, 2005b). The potential nutrient contribution of green manure to a subsequent crop depends on both amount of nutrient accumulation and decomposition rate after incorporation in the soil system (Muhr *et al.*, 1999).

The integration of green manure legumes as cover crops into the smallholder farming systems has the potential to enhance yields of subsequent crops, an effect which can be largely attributed to increase in plant available N in the soil as a result of N release from the decomposition of the legume residues. In addition, with regard to soil amelioration, legumes are thought to be superior to non-legume green manure crops because they show an exceptional ability to utilize rather inaccessible soil phosphorus and potassium fractions (Yadvinder *et al*., 1992), hence improving availability of P and K to subsequent crops. However, understanding the nitrogen (N) mineralization patterns of green manure legume residues is crucial in the synchronization of N release from plant residue and uptake by subsequent crops. In coarse texture, high temperature and low rainfall, many soils contain little organic matter (less than 1-2%) and possess poor water and nutrient retention. This is especially true for agricultural soils that experience regular tillage and low carbon (C) input rates. Legumes utilized as green manures may be useful as a component of sustainability in such production environments.

Effective use of GMs is often hampered by lack of precise information about N availability for future crops. Nitrogen accumulation and subsequent release from decomposing GMs depends largely on residue composition and N concentration, temperature, water availability, and residue management (Andren *et al*., 1992; Schomberg *et al.,* 1994), which in turn depend on GM species, environment (climate, soil, microbial activities) and cropping system.

Soil-based residue decomposition and N-release generally occur faster for residues with lower C:N ratios and lignin and polyphenol contents, with optimum temperature and water availability (Andren *et al.,* 1992, Vigil and Kissel, 1995). Materials with low lignin:N, C:N ratios may control decomposition, while lignin:N ratio may become more important as it becomes higher. Decomposition of mixed materials over time may therefore involve control by C:N initially, then lignin:N as recalcitrant material makes up more of the remainder (Mueller *et al.,* 1998). Palm and Sanchez (1991) also found that polyphenol concentration may exert more control over breakdown rates than lignin and N concentrations for residues high in polyphenols. In a review Seneviratne (2000) found that residues with N concentration greater than 2%) does not affect N-release; C:N ratio was a good predictor of N release over a wide range of N content and polyphenol content better predicted N-mineralization than lignin:N in low N residues in tropical environments.

Leaf C:N ratio and lignin content is generally much lower than stems or roots of the same plant, and in most studies leaf decomposition and N release occurs significantly faster than for other tissues. Prolonged periods of N-immobilization (when decomposition results in a net accumulation of N) are often recorded for recalcitrant stems and roots (Collins *et al.*, 1990, Cobo *et al.,* 2002). On average, leaves decomposed five times faster than stems, decomposition was closely related to cell wall content and N release most dependent on lignin:N ratio. Cobo *et al.* (2002), found that decomposition and N-release was faster for stems mixed with leaves than for stems alone, and slower for leaves mixed with stems than leaves alone. Both the studies of Collins *et al.* (1990) and Cobo *et al.* (2002) showed the decomposition rate of different tissue types decomposing together was faster than predicted by summing individual decomposition rates. These studies suggest fungal decomposers may redistribute N from leaves to more recalcitrant tissues during decomposition.

Soil incorporation of plant residues may speed decomposition and N release by buffering temperature and water regimes relative to the surface. Thonissen *et al.* (2000) showed more rapid decomposition of soil incorporated residues than surface residues in no-till systems. Schomberg *et al.* (1994) also found greater N-immobilization potential for surface sorghum (*Sorghum bicolor*) and wheat (*Triticum aestivum*) residue, although initial N-immobilization was more rapid when the residues were buried. At peak immobilization (5 months to 1 year or more), highly recalcitrant (sorghum and wheat) residues tied up 150-170% of their initial N content. Nitrogen immobilization ended and release began only when 45-55% of the residue mass had decomposed. Bowen *et al.* (1993) found that 60-80% of N applied within 10 legume GMs was released as inorganic-N within 120-150 days after soil incorporation, while Thonnissen *et al.* (2000b) found similar levels of N-release to take place faster (within 2-6 weeks) for soybean (*Glycine max*) and vetch (*Vicia faba*). Mansoer *et al.* (1997) found less than 50% of N remaining in surface and soil-incorporated Sunn hemp (*Crotalaria juncea*), respectively, at 16 weeks after plant death. Most studies reviewed here found best correlation with two-pool exponential models for decomposition and N-release (Katterer *et al.,* 1998). More complex decomposition/N-release models exist that make use of residue quality, soil, and weather data to predict decomposition (Jones *et al.*, 2003).

2.4 Factors Affecting Decomposition of Green Manures

Decomposition of leaf litter is a key process of nutrient cycling in terrestrial ecosystem (Vitousek *et al.*, 1994; Aerts and de Caluwe, 1997). Litter decomposition is regulated by three interacting group of factors; 1) the physicochemical soil environment and the chemical properties of the organic matter acting through their regulation of the decomposer community species composition and activity (Beare *et al.*, 1992). 2) communication by which there is physical reduction in particle size and 3) leaching, which causes transport down the profile or removal from the system of liable resources in either changed or unchanged form (Heal *et al*., 1997). All the factors in turn also alter decay and nutrient turnover rates.

Green Manure decomposition and subsequent N release depend largely on residue quality and quantity, soil moisture and temperature and specific soil factors such as texture, mineralogy and acidity, biological activity and the presence of other nutrients (Myers *et al*., 1994). Studies on litter mineralization have linked rate of nutrient release to biochemical properties, especially lignin, polyphenols and N content (Palm and Sanchez, 1991; Palm *et al.*, 2001 and Nziguheba *et al.*, 2005).

Environmental conditions like soil moisture and temperatures affect decomposition and mineralization by influencing soil microbial activity (Agehara and Warneke, 2005). Jenkinson (1988) and Janssen (1999) reported that the rate of biological decomposition and consequent release of nutrient varies with ambient condition such as temperature, moisture, soil pH and other factors affecting microbial activity. Mineralization of N is positively correlated with C:N and polyphenol: N ratios (Lupwayi *et al.*, 2006). Decomposition and N release generally occur faster for organic materials with narrowed C:N and low lignin: N ratios a well as lower polyphenol (Lomander *et al.,* 1998).

Giller and Wilson (1991) reported that if a material contain small proportion of N relative to dry weight (i.e large C:N ratio), then the amount of N available for growth of the decomposition microorganisms will be limited and any mineralized N will tend to be depleted for the immediate used by microorganism ie immobilized for growth. They also reported that plant residue with high C:N ration greater than 30:1 are likely to decompose slowly with initial net immobilization of N, whereas plant residues with a small C:N ratio is likely to decomposed more rapidly with net mineralization of N occurring right from the beginning. The C:N ratio ranges from 10:1 to 30:1 in legumes and young green leaves, while cereal straw generally have ratio between 25 and 75 (Heal *et al.,* 1997). However legumes residues commonly have C:N ratios less them 30:1 and therefore tend to release N and decompose more rapidly them those residues with high C:N ratio (Giller and Wilson, 1991).

Decomposition and mineralization studies conducted by Nagarajah (1988) showed that N is released rapidly from green manure during the first 2-3 weeks after incorporation and then slows down. About 40 -50% of legumes residues can decompose in a month (Jenkinson and Ayanana 1997), while Taylor (1998), reported that it takes about three to six weeks for organic matter to adequately decompose in the tropics further more air-drying depresses rate of leaf decomposition. Immature plant material usually decomposes faster than mature material (Yadvinder *et al.*, 1992). Decomposition requires adequate moisture to proceed but excess water interferes with oxygen to decomposition facilitating microbes and causes major changes in the medium (soil), the nature and product of the process (Magid and

Kjaergaard, 2001). Moro and Domingo (2000) reported that decomposition is not fully complete and slower under anaerobic condition than under aerobic conditions. Blair *et al.* (1995) reported that it is likely that acidity slows down decomposition by restricting the activities of the soil microbial population to relatively small number of species. The amount of nutrient recycled in a soil system depend on the quality and quantity of the soil biomass but the rate of decomposition and nutrient release of the biomass is however, determined by its chemical composition and climatic conditions (Cadisch and Giller, 1997).

2.5 Effect of Green Manure on Soil Physical and Chemical Properties

Crop requirements and climate aside, soil fertility largely determines nutrient and water supplementation required in agricultural production – thereby having major economic and ecological implications. Texture, organic matter content, and chemical composition usually exert greatest influence on soil fertility (Brady and Weil, 1999; Tinker and Nye, 2000). Soil texture and chemical composition are interrelated and cannot be altered in any practical sense. In contrast, changes in soil organic matter (SOM) including content, spatial distribution, chemical properties (such as carbon-to-nitrogen ratio, C:N), and related soil biological properties (such as microbial biomass and activity) may be more readily driven by agricultural practices. Current management practices utilizing regular soil disturbance (tillage) and exclusively dependent on chemical fertilization may limit SOM equilibrium to the detriment of potential production and input use efficiency, especially in tropical, sandy areas. In such environments, leguminous green manure (GM) and reduced tillage approaches to soil fertility may provide significantly greater organic matter inputs and slow rates of organic matter decomposition compared to chemical fertilization, but without the often inhibitive costs and phosphorous imbalances associated with animal manure application.

Generally, organic matter associated with the finer (smaller) sized soil fractions – silt and clay – may experience more physical and chemical protection from decomposition than that associated with more coarse (larger) sized soil fractions. For example, even on a sandy loam soil with about 35% sand and 1.6% SOC, Kandeler *et al.* (1999) found most SOC associated with the clay-sized soil fraction (<2µm) and roughly 90-95% of total SOC accounted for within silt and clay-sized fractions together (<63 µm).

Early indicators of long-term changes in SOM are desirable given the time limitations of agricultural research. Pool size of coarse particles of SOM – known as the particulate organic matter (POM) often reflects the most recent additions of plant residues that have yet to undergo major decomposition. Magid and Kjaergaard (2001), show recent additions of plant residues primarily contributed to low soil bulk density ("light"; density < 1.4 g cm^{-3}) fractions of POM, with C-loss during the first 2-4 months occurring primarily from these light POM fractions. C:N ratios for all POM fractions in these studies also tend to decrease with decomposition over time. On sandy, loamy and clayey soils, Hassink (1995) studied decomposition rate constants of SOM, separating "macro organic" matter (>150 µm; heavy, intermediate and light densities) from "micro organic" matter (150-20 µm and < 20 µm), finding decomposition rate constants fastest for macro organic matter and for lighter fractions – independent of soil type. These results complement those of Kandeler *et al.* (1999), suggesting that larger-sized POM tend to be less physically protected within the soil matrix and that lighter POM facilitates enzymatic action. Wander and Bidart (2000), use an alternative POM separation into physically "loose" and "occluded" fraction. Consequently, changes in POM levels may provide early indication of ongoing changes of in SOM as well as potential soil nutrient release via decomposition.

Franzluebbers *et al.* (1995) found potential C and N mineralization and microbial carbon in the upper 30 cm of a silt, clay loam generally greater under zero tillage compared to conventional tillage. However, incorporation of crop residues in conventional tillage resulted in temporary increases in soil microbial carbon, potential carbon mineralization and immobilization of inorganic N, indicating immediate and rapid decomposition. Many other workers have shown slower decomposition and greater N-immobilization for surface applied residues compared to soil-incorporated residues

Incorporation of Lablab, crotalaria and garden pea, residues resulted in higher concentration of N and P in the soil than naturally fallow soil (Lelei *et al.,* 2009). Legumes are to be superior to non-legume green manure crops because they show an exceptional ability to utilize rather inaccessible soil phosphorus and potassium fractions (Yadvinder *et al.,* 1992) hence improving availability of P and K to subsequent crops. Similarly, Oguwole *et al.* (2010) reported that incorporation of residue of *Centrosema pascuorum* and *Parkia biglobosa* into soil increased total soil nitrogen which they attributed to the quality (ie nutrient composition of the incorporated residue. Rochester *et al.* (2001) reported that when leguminous crops are grown and used for green manures they provided up to 40% of nitrogen available in soils by the decomposition of nodules and biomass of the leguminous green manure crops organic amendment improve soil quality (Mandal *et al.,* 2003). The physical (structure and water retention capacity) chemical (nutrients and cation exchange capacity) and biological (micro flora and microfauna) properties can be improved by the addition of organic matter (Smith and Sharpley, 1990).

2.6 Interactive Effect of Green Manure and NPK Fertilizer on Growth, and Yield of Tomato

Intensive inorganic fertilizer usage in agriculture caused so many health problems and environmental pollution. To reduce and ameliorate the adverse effects of synthetic fertilizers and pesticides on human health and environment, new agricultural practices have been developed in organic agriculture, ecological agriculture or sustainable agriculture. (Aksoy, 2001; Chowdhury, 2004). The organic fertilizers take the place of inorganic fertilizers in sustainable agriculture and provide the nutritional requirements of plants while suppressing the plant pest populations.

Intensive cultivation and growing of exhaustive crops have made the soil deficient in macro and micro nutrients. The use of only chemical fertilizers creates nutrient imbalance in soils. Amongst the different organic manures, the green manure provides a good amount of nutrients to the soil (Tolanur, 2009). Integrated soil fertility management practices' involving judicious combinations of organic manures and chemical fertilizers is recommended as a feasible and viable technology to sustain agriculture ensuring higher crop yields with least deterioration of soil quality(Islam *et al.*, 2011). Early decomposition of green succulent legume such as sunnhemp and also farm yard manure (FYM) cause early release and availability of plant nutrients and these in turn might have favours the crop growth and yields than inorganic fertilizers (Tolanur, 2009).

Babajide and Salami (2012), reported that tomato responded best to integration of 30 kg N ha^{-1} of urea and 2.5 tons ha^{-1} of Tithonia-compost as reflected in best growth rate and fruit yield. The rate was found to be equally adequate for improved soil physical and chemical properties. Integration of organic and inorganic fertilizer is therefore essential for efficient soil management and crop production. Complementary use of organic and inorganic fertilizers may be beneficial to achieving a sustainable crop production, through improved and long-lasting soil moisture and nutrition (Togun *et al.,* 2004). Farmyard manures and compost are in limited supply and may have low and variable nutrient contents. The more readily available green manures constitute a valuable source of both N and organic matter (Kaushal *et al.,* 2010).

Leguminous and non-leguminous plants are used in the production of green manures. Leguminous plants can form symbiotic associations with *Rhizobium* bacteria in order to fix atmospheric N than non-leguminous plants. However, the influence of this organic matter on soil properties depends upon amount, type, size and dominant component of the added organic materials (Tejada *et al.,* 2005). The residues and ploughed-in green material of perennial grasses, as preceding crops, have a positive effect on the formation of productivity elements of cereal crops not only in the first year but also in the second year, which determines the productivity of the crop (Skuodiene and Nekrosiene, 2007).

Adequate fertilizer application, influences tomato growth and fruit yield more than other cultural practices (Akanbi *et al.,* 2005). Unfortunately, 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).

Most large scale farmers use synthetic fertilizers on their soils. In rural areas, chemical fertilizers are not readily available, yet without fertilizing the soil very low yields are obtained. As long as organic manures are available and comparable with synthetic fertilizers in yield improvement, their use as sources of plant nutrients for growing vegetable crops could assume an increasing importance (Ogunlela *et al.*, 2005). The ever increasing prices and scarcity of synthetic fertilizers coupled with concern of environmental pollution arising from their application have renewed interest in integrated plant nutrition, especially in the use of organic manures such as farm yard, kraal, compost and green manures to enhance plant growth and development.

The beneficial effects of combined organic and inorganic nutrients on soil fertility have been repeatedly shown, yet there are no guidelines for their management. The challenge is to combine organics of differing quality within organic fertilizers to optimize nutrient availability to plants. Numerous field trials indicate both added benefits and disadvantages of combining nutrient sources. Increased nutrient recovery and residual effects are associated with combined nutrient additions compared with inorganic fertilizers applied alone. Organic or green manure inputs should be considered as complete fertilizers (NPK), perhaps the best being those containing or releasing the nutrients in the ratios and rates required by crops.

2.7 Correlation and Path Analysis on Tomato Growth and Yield

Knowledge in respect of the nature and magnitude of associations of yield with various component characters is a pre-requisite to bring improvement in the desired direction. A crop breeding programme, aimed at increasing the plant productivity requires consideration not only of yield, but also of its components that have a direct or indirect bearing on yield. The coefficients of correlation describe the degree of association between independent and dependent variables. Path Coefficient analysis measures the direct influence of one variable upon another and permits the separation of correlation coefficient into components of direct and indirect effects (Jitendra and Devendra, 2011).

The phenotypic correlations were normally of genetic and environmental interaction which provided information about the association between the two characters. Genotypic correlation provides a measure of genetic association between the characters and normally used in selection, while environmental as well as genetic architecture of a genotype plays a great role in achieving higher yield combined with better quality. Path coefficient analysis is an important tool for partitioning the correlation coefficients into the direct and indirect effects of independent variables on a dependent variable. Hypothesized systems of causal relationships between yield components and yield can be tested using path analysis (Dewey and Lu, 1959; Duarte and Adams, 1972; Hancock *et al.*, 1984)

Bodunde (2002), reported that plant height, fruit diameter and fruit length were directly responsible for the determination of fruit yield in tomato. Fruit weight per plant exerted high positive and direct effect on fruit yield ha^{-1} were obtained by (Lakshmi and Mani, 2004; Singh and Cheema, 2005; Haydar *et al*., 2007). The path analysis confirmed that direct effect of fruit weight, number of fruits per plant and number of primary branches per plant whereas, indirect effect of plant height, fruit length, fruit width, number of calyx per fruit, and fruit yield per plant should be considered simultaneously for amenability in fruit yield of tomato (Prasad and Mathura, 1999).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Sites

The study was conducted at two locations in 2010-2011 and 2011-2012 dry seasons in the Institute for Agricultural Research, farm ($11^0$11'N, $07^0$38'E,686m above sea level) Samaru in the Northern Guinea Savanna and Kadawa ($11^0$39',$08^0$02'E 500m above sea level) in the Sudan savanna agro ecological zone of Nigeria.

Meteorological data including daily temperature, sunshine hours, and relative humidity during the period of the experiment were obtained from meteorological stations of the Institute for Agricultural Research Samaru and Kadawa in the two seasons and are presented in Appendices I and II.

Soil samples from locations at a depth of 0-30 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 physico-chemical analyses and green manure fodder also was analyzed using method described by A.O.A.C. (2002).

3.2 Treatments and Experimental Design

The treatments consisted of two tomato varieties (Roma VF and UC82B), four rates of NPK 15-15-15 fertilizer (0, 150, 300 and 450 kg ha^{-1}) and three rates of green manure (0, 5 and 10 t ha^{-1}). The treatments were arranged in a split-plot design with three replications. A factorial combination of NPK fertilizer and tomato varieties were assigned to the main plot treatment while green manure rates occupied the sub-plots.

3.3 Plot size

The plots were prepared as sunken seed beds with gross plot size 6.0 m x 3.0 m (18 m^2), while 5 m x 2 m (10 m^2) was net plot size. At Samaru, the land was previously cultivated with maize in 2010 and Sorghum in 2011 rainy season while at Kadawa the land was cropped with rice in rainy seasons in both years of the study and field layout is shown in appendix III.

3.4 Varietal Description

3.4.1 Roma VF

Roma VF is egg or pear shaped tomato that is available in red and yellow colour. It is an open pollinated variety with few seeds and is a good canning and sauce tomato. Its maturity period ranges between 65-75 days after transplanting. It has a medium growth height up to 121.9 cm with indeterminate growth habit. It is a high yielding variety and responds to full sunlight. It potential yield ranges from 25-35 t ha^{-1} with good storing character and the variety is resistant to fungal diseases such as Verticillium and Fusarium Wilt (Anon, 2011).

3.4.2 UC82B

UC82B is short or medium size, indeterminate variety with few branching; the fruits are medium to small red and round in shape containing many seeds. Its maturity period ranges between 60-70 days after transplanting. The fruits are firm with excellent holding ability that can last for about 2 weeks when harvested at green stage. It has a short determinate growth habit and spreading branches and potentially can produce up to 35-40 t ha^{-1} of fresh fruits on the average. It is a less heat tolerant variety, resistance to cracking and processing type (Ibrahim, 1999).

3.5 Cultural Practices

3.5.1 Land preparation

The fields were harrowed, ridged and marked into plots after which sunken seed beds were made manually.

3.5.2 Green manure production and incorporation

Lablab seeds were sown at spacing of 15 cm x 15 cm on each side of the ridge in Samaru on 25th October 2010 and 7th November 2011 and at Kadawa on 1st November 2010 and 16th November 2011 in plots where lablab fodder was incorporated. In all years, green manure was uprooted, weighed and incorporated 7 weeks after sowing (i.e. the onset of flowering) according to treatment and allowed to decompose for 2 weeks.

3.5.3 Nursery preparation

Seed beds of 1 m x 2 m were prepared on 29th November 2010 and 12th December 2011 at Samaru and 6th December 2010 and 14th December 2011 at Kadawa for establishment of tomato seedlings. NPK 15-15-15 at 25 g was applied per seed bed to the nursery. Seed of each variety was drilled 20 cm apart and lightly covered with soil. The nursery beds were mulched with straw grasses and irrigated with watering can. Immediately after seedling emergence the mulch was removed to facilitate seedlings establishment. The seedlings were regularly irrigated at regular intervals until they were four weeks old when they were transplanted.

3.5.4 Transplanting

Before removing the seedlings from the nursery, the main field beds were thoroughly irrigated and single super phosphate, 18% P_2O_5 thoroughly mixed with soil in ratio 1:3 and made into slurry. Roots of seedlings were dipped into the slurry and transplanted at spacing of 50 cm x 50 cm. This operation was done at Samaru on 27th December 2010 and 9th January 2012 and at Kadawa, on 3rd January 2011 and 9th January 2012, respectively and missing stands were replaced in each plot a week after transplanting (WAT)

3.5.5 Fertilizer application

Compound fertilizer (NPK 15-15-15) was applied at the rates of 0, 150, 300, 450 kg ha^{-1} according to treatments in two equal doses at 2 and 6 WAT through banding method of application.

3.5.6 Irrigation

Irrigation was done by controlled flooding to the plot at 5 days interval at the early growth stages and 7 days interval as the crop advanced in age.

3.5.7 Weed Control

Round up (Glyphosate) was applied at 1.0 kg a.i ha^{-1} two weeks before land preparation. Manual hoe weeding was also employed to control weeds at 4 and 8 WAT.

3.5.8 Pest and disease control

Sherpa plus EC (*Cypermethrin* + *Diamethoate*) at 1.15 kg a.i ha^{-1} was used to control insect pest and diseases biweekly commencing from 6 WAT.

3.5.9 Harvesting

Mature ripe fruits were manually harvested by hand picking as the colour changes from green to pink or reddish, spanning 5-6 pickings for both varieties.

3.6 Data Collection

Randomly selected five plants within the net plot were tagged for the purpose of recording growth data for periodic observation at 5, 7 and 9 weeks after transplanting (WAT).

3.6.1 Number of leaves $plant^{-1}$

Number of leaves from five (5) tagged plants was counted and the average number of leaves per plant later calculated and recorded as per treatment.

3.6.2 Plant height (cm)

Height was measured from the ground level to the growing tip of the crop. Measurements were taken from five (5) tagged plants and the average height calculated and expressed in centimeters.

3.6.3 Number of branches plant^{-1}

The number of branches of tagged plant was counted and average number of branches per plant was computed and recorded.

3.6.4 Crop dry matter (g)

Three plants from two outer rows at each sampling period were cut at ground level and oven dried to a constant weight, for 48 hrs weigh and expressed in grammes at different intervals (Hunt, 1982).

3.6.5 Leaf area index

The leaf area was determined by use of graph method (tracing) and leaf area index (LAI) was derived from the result of the leaf area and calculated as shown below

$$\text{LAI} = \frac{Leaf\ Area\ per\ Plant}{Land\ area}$$

3.6.6 Crop growth rate (g. wk^{-1})

Crop growth rate (CGR) is the rate of dry matter production per plant per unit time. It was calculated by using the following formulae and expressed as g. wk^{-1} plant^{-1} at 5-7 and 7- 9 WAT as described by Radford (1967).

$$\text{CGR} = \frac{W_{2-W_1}}{t_{2-t_1}} \ \text{g wk}^{-1}\ \text{plant}^{-1}$$

Where W_1 = dry weight of the plant at time t_1

W_2= dry weight of the plant at time t_2.

3.6.7 Relative growth rate (g g wk^{-1})

It is rate of increase in dry weight per unit dry already present and is expressed in g g^{-1} wk^{-1}. Relative growth rate (RGR) at various stages was calculated as suggested by Radford (1967) at 5-7 and 7- 9 WAT.

$$RGR = \frac{I_n W_{2-LnW\ 1}}{t_{2-\ t1}} \quad g\ g^{-1}\ wk^{-1}$$

Where ln = Natural log

W_1 = Dry weight of plant (g) at time t_1

W_2 = Dry weight of plant (g) at time t_2

3.6.8 Net assimilation rate (g cm^2 wk^{-1})

Net assimilation rate (NAR) is the rate of dry weight increased per unit leaf area per time. It was calculated by using the formula proposed by Watson (1952) at 5-7 and 7- 9 WAT.

$$NAR = \left(\frac{W_{2-\ W_1}}{t2-_{t_1}}\right)\ x\ \frac{LnLA\,2-LnLA\,1}{LA_{2-\ LA_1}} \quad g\ cm^2 wk^{-1}$$

Where ln = Natural log

LA_1 & W_1 = leaf Area (cm^2) and dry weight of plant (g) respectively at time t_1
LA_2 & W_2 = leaf Area (cm^2) and dry weight of plant (g) respectively at time t_2

3.6.9 Days to first flowering

Days to first flowering were recorded from the time of transplanting to first flower production in each plot was counted and recorded.

3.6.10 Fruit diameter (cm)

Five (5) fruits were picked at random from each plot and their diameter was measured using viernier caliper at the mid-section and divided by five to get the average fruit diameter and thereafter recorded for each plot.

3.6.11 Number of fruits plant^{-1}

Cumulative number of fruits from 5 tagged plants were counted within the net plots and divided by five to estimate the total number of fruits produced per plant.

$$Number\ of\ fruits\ per\ plant = \frac{Cumulative\ number\ of\ fruits\ harvested}{Number\ of plant\ in\ net\ plot}$$

3.6.12 Weight per fruit (g)

This was calculated as total weight of fruit per plant divide by number of fruit harvested per plant.

$$\text{Weight per fruit} = \frac{Total\ \ fruits\ \ weig\,ht\ /\ plant}{Total\ \ number\ \ \ fruits\ /pl\,ant} \quad \text{g. fruit}^{-1}$$

3.6.13 Fruit weight plant^{-1} (kg)

Weight of the fruits was calculated by adding the weight of harvested fruits from 5-6 pickings in the net plot and dividing by the number of plants in the net and expressed as fruit weight per plant in kilogram.

3.6.14 Total fruit yield (t ha^{-1})

The cumulative total fruit harvested from 5-6 pickings including the nonmarketable ones were weighed per plot and expressed in tonnes per ha^{-1}.

3.6.15 Marketable fruit yield (t ha^{-1})

From the total fruits harvested, all healthy fresh fruits free from cracks, insect damage and small sized fruits were separated to form the marketable yield and expressed in tonnes per ha $^{-1}$.

3.6.16 Nonmarketable fruit yield (t ha^{-1})

The rotten, insect damaged, small sized and cracked fruits that could not be sold were weighed and expressed in proportion to the total harvested fruits yield.

3.6.17 Agronomic efficiency (AE)

Is the economic product per unit of consumed nutrient which is an index that provides the accurate assessment of nutrient use efficiency with regard to soil nutrient content and differences between unfertilized and fertilized crops and was calculated from this equation below reported by Dobermann (2007).

Agronomic efficiency = $(Y-Y_0)/F$

Where Y – Crop yield with applied nutrients (kg ha^{-1})
Y_0 – Crop yield (kg ha^{-1}) in control treatment no fertilizer
F – amount of (fertilizer) nutrient applied (kg ha^{-1})

3.7. Fruit Proximate Analysis.

3.7.1 Total soluble solids (^{0}Brix)

Total soluble solids (TSS) are the amount of soluble constituent of the fruit juice and these are mainly sugars. A hand held refractometer was used to determine the sugar content of the fruit, which is an optical instrument that measured the amount of light refracted in the liquid. The refractometer was calibrated with distilled or deionized water by adding few drops to set the baseline readings to zero (0). This was done at harvest, 5 days and 10 days after harvest to monitor the sugar level of the fruits and the procedures of determining ^{0}Brix using hand held refractometer is itemized thus:

1. Five fruits were randomly sampled from each plot; each fruit was pierced and the juice was squeeze with dropper.

2. A few drops of the juice were placed onto the stage of the refractometer and viewed to take the ^{0}Brix reading and the readings were recorded.
3. Between samples the refractometer was cleaned with distilled water, dried and frequently observed that the baseline was set to zero (0).

3.7.2 Fruit dry matter (%)

Five randomly sampled fruits were made into slides and weighed before being oven dried for 48 hours to a constant weight. The moisture percentage was then determined by the difference in weights before and after oven drying. The percentage fruit dry matter was measured as the remaining weight of sample after oven drying and expressed as percentage dry matter. (A.O.A.C., 2002).

% fruit dry matter = $\frac{[(weight\ dry\ sample\ + contaner) - (weight\ empty\ container\ ]}{(weight\ wet\ sample\ + container\ ) - (weight\ empty\ container\ )} X\ 100$

3.7.3 Carbohydrate (%)

Carbohydrate as nitrogen free extract (NFE) was calculated as described by A.O.A.C. (2002):

%NFE = %Dry matter – (%Crude lipid + %Crude protein + %Ash + %Crude fibre)

3.7.4 Crude fibre (%)

Dried tomato fruits sample was diluted in 0.023M sulphoric acid and boiled under reflex for 30minutes. The solution was filtered and insoluble matter was discarded. The solution was then quantitatively transferred into 0.312M solution of sodium hydroxide (NaOH) and boiled again under reflex for 30minutes and filtered under suction. The insoluble part was washed with boiled water until the base was free. It was then dried at constant weight in the over set at 100^{0} C, cooled in a desiccators and weighted (C_2). The weighed residue was incinerated in a muffle furnace at 550^{0C} for two hours cooled in desiccators and re-weighed (C_3) (A.O.A.C., 2002) and calculated as:

$$\text{Crude fibre content (\%)} = \frac{C_{2-}C_3}{W} \times 100$$

Where C_2 = weight after base treatment

C_3 = weight after incinerated at 550^0C

W = original weight of sample

3.7.5 Fruit acidity (%)

Five fruits were used to determine the fruit acidity through titration method. The fruits were made into paste and 10 ml of the juice was extracted using the standard procedure.

1. 5ml of juice was dropped into the conical flask
2. 5 drops of phenolphthalein solution was added as indicator and burette filled with 50ml of 0.1% sodium hydroxide (NaOH) was titrated into the flask and swirl, until the colour became persistent pink for at least 30 seconds.
3. The amount of sodium hydroxide used in ml was recorded.

% acidity = 0.064 x ml of NaOH used

3.7.6 Crude protein (%)

The Kjeldahl method was used to determine total N in the fruit tissues. The sample was mixed with sulphoric acid to digest the organic matter in the presence of a catalyst. The solution was then distilled and the librated ammonic (NH_4) was titrated.

Crude protein = % N X 6.25 (A.O.A.C., 2002)

3.7.7 Ash (%)

Dry ashing was conducted by weighing the sample in crucibles in a muffle furnace at 105^0C temperatures for 4 to 8hrs. The residue and vessel is removed from the muffle furnace, and cooled in a desiccators and percent ash content was calculated from the formula;

$$\text{Ash content (\%)} = \frac{W_{3-}W_1}{W_{2-}W_1} \; x \; 100 \qquad \text{(A.O.A.C. (2002)}$$

Where W_1 = empty crucible
W_2 = weight of sample
W_3 = weight of residue

3.8 Decomposition Study of Fodder

Field decomposition of the fodder was conducted at each location in 2010-11 and 2011-12 to examine the rate of decomposition, days to 50% decomposition and the concomitant effect on soil fertility improvement.

Fresh leaves and stems of lablab were harvested at 7 weeks after sowing, chopped and weighed into 50 g per sample and put into litter bags. The bags were measured 20 cm x 20 cm in 2 mm nylon mesh bags and buried 10 cm depth into plots of inorganic fertilizer alone and control. Decomposition was monitored by harvesting the litter bags and analyzing the residues at stated intervals of 0, 3, 7, 14, 21, 28, 56 and 70 days from when green manure was introduced. At each sampling period, litter bags were removed weighted as initial weight and oven dried to constant weight for 24 hrs. The initial weight and over dried weight were used to calculate the following parameters.

a. **Mass loss percentage (%)** is the rate of litter loss to the soil and it was expressed in percentage using the formula described by Sewanee and Simmons (2003)

$$\text{Mass loss at } 105^0\text{C (\%)} = \frac{Initial\ \ Mass\ (g) - Final\ \ Mass\ (g)}{Initial\ \ mass\ (g)} \; x \; 100\%$$

Initial mass weight at sampling time and final weight after oven dry at sampling time.

b. **Average Mass Remaining (%)** = $\frac{Final\ \ weig\,ht(g)}{Initial\ \ weig\,ht(g)}\ x\ 100\%$

c. **Decomposition rate % per day** = $\frac{\%\ \boldsymbol{Mass\ loss}\ (\mathbf{105^{0\ C}})}{\boldsymbol{Length\ of\ Incubation}\ (\boldsymbol{day})}$

d. **Decay Constant (*k*)**

The decomposition of the plant material was monitored following the simple exponential decay model developed by Sewanee and Simmons (2003), based on field and laboratory evidence of decomposition rates:

Decay curve = $\ln\left(\frac{M_0}{mt}\right) = K.t$

Where M_0 = Mass weight of litter at Zero time (0)

M_t = Mass weight of litter at sampling time t, t = Time of incubation in days

k = Decomposition constant or exponential decay coefficient, ln = Natural logarithm

e. **The half-life** is a parameter used to facilitate the interpretation of plant residue decomposition data, which measures the period of time (t) required to decompose 50% of the material as shown below:

$T_{50} = \frac{0.693}{k}$

Where k = decomposition constant. 0.693 is correction factor for converting Ke to ½

3.9 Soil Analysis at Harvest

Soil samples were collected at harvest in 2010-2011 and 2011-2012 at Samaru and Kadawa at a depth of 0-30 cm in each plot according to treatments; these were analyzed to determine the following.

3.9.1 Soil pH

The soil pH analysis uses aqueous soil extract. The extract contains 20 g of soil sample from each plot and 20 ml of de-ionized (distilled) water was added. The content was stir for one minute, at 10 minute intervals for a period of 30 minutes. After 30 minutes the extract was ready for pH test. A calibrated pH meter using buffer 4 and 7 was used to measures the sample pH.

3.9.2 Soil total nitrogen (g kg^{-1})

The total nitrogen of the soil sample was determined by Micro Kjeldhal procedure. 1.0g of air-dried soil was weighed into 500 ml micro Kjeldhal flask and 20ml of concentrated sulphuric acid (H_2So_4) with 5 g of catalyst mixture (100:1:1000) 50 g of $CuS0_4$ + 0.5 g of selenium (TiO_2) 500 g of $NaSo_4$) was added. The Kjeldahl flask was placed on digestion rack and the tube into a part of digestion block. Heat to boiling point in Kjeldahl flask, the content was allowed to cool and 50 ml distilled water was added. Decant was transferred to 100 ml volumetric flask and brought up to 100 ml mark with distilled water 5 ml of 2% boric acid was placed into 100 ml conical flask and 4 or 5 drops of mixed indicator was added 10 ml of digest was pipette to a distillation flask (Reaction flask) and 10 ml of 40% NaOH was added. The receiving flask was allowed to collect 50ml of distillate which was titrated with 0.01m hydrochloric acid (HCl)

$$\% \text{ N} = \frac{0.014\ x\ normality\ \ of\ acid\ x\ vol.of\ digest}{weight\ of\ soil\ x\ aliquet\ \ taken}\ x\ 100$$

3.9.3 Soil available phosphorus (g kg^{-1})

Available phosphorus in soil was determined by dilute acid-fluoride extraction (Bray 1 Method). 5 g of air-dried and sieved 2 mm soil was weighed into 100 ml conical flask and 14ml of extracting solution (30ml of IM NH4F and 50ml of 0.5 HCl made up to one litre).

The content in flask was shaken for few minutes and filtered. 10ml of the filtrate was pipetted into 100 cm^3 beaker, 25 cm^3 of ammonium molybdate reagent and 5 cm^3 of stainow chloride dilute solution were mixed. After 10 to 15 minutes, the colour development at 890nm on a spectronic 20 was measured and absorption read off as described by Bray and Kurtz (1954) and modified by Murphy and Riley (1962).

$$\text{Available P (ppm)} = \frac{Absorbance\ \ x\ gradient\ \ x\ vol.of\ \ extract\ \ x\ dilution\ \ factor}{weig\,ht\ of\ \ sample\ \ x\ ali\,cquot\ \ taken}$$

3.9.4 Soil potassium (cmol kg^{-1})

Soil samples were determined using wet digestion method. Potassium standard stock solution, 100 ppm was prepared (0.1910 g of Kcl was weighted and dissolved in 1000 ml) capacity volumetric flask with distilled water to mark up. 5 g of air-dried soil was placed into digestion flask and 5ml of Nitric acid ($Hn0_3$) + perchloric acid ($HCLO_4$) mixture (2:1 by volume). The flask with content was placed on digestion hot plate in tune hood and heated until the fume from the flask turned while and digest became clear, it was removed and distilled water was added up to make up to 30ml content. The K was determined using a flame photometer.

$$\text{Soil K} = \frac{Titre\ \ x\ vol\ of\ \ extract\ \ x\ dilution\ \ factor}{weig\,ht\ of\ \ soil\ x\ aligent\ \ x\ 10} \qquad \text{cmol kg}^{-1}$$

3.9.5 Soil organic carbon and organic matter (g kg^{-1})

The organic carbon of the soil after experiment was determined by the wet oxidation method of Walkey-Balck as described by Nelson and Sommer (1996). Organic carbon was determined by weighing 1.0 gram of the soil into 250 ml conical flask and 10 ml of 0.16M potassium dichromate ($K_2CR_2O_7$) was added with 20 ml of concentrated sulphuric acid

(H_2SO_4) was added rapidly. The flask was swirled vigorously for a minute. Also 100 ml of distilled water was added to flask after standing for 30 minutes and 4-5 drops of ferroin indicator was added and was titrated with 0.5M Iron II Sulphate. The organic carbon was measured by wet oxidation with potassium dichromate ($K_2Cr_2O_7$).

Organic carbon % = $\frac{Black\ (B) - Titre\ (T) x\ NF\ x\ 0.003\ x\ correction\ \ factor\ (1.33) x\ 100}{weig\ ht\ of\ sample}$

Where NF = Normality of $FeSo_4$. $7H_2O$; which is obtained from the K_2CrO_4 thus:

Normality of $FeSO_4$ = $\frac{(Concenrtation\ \ x\ vol.)\ of\ K2cro4\ used}{Titre\ value\ of\ blank}$

The soil organic matter (SOM) was determined by calculation from the values of total organic carbon thus:

Organic matter % = Total organic carbon (%) x 1.72

where 1.72 is conversion factor

3.9.6 Soil C: N ratio

The carbon/nitrogen ratio measures the relative nitrogen content of organic materials. It was measured for soil carbon or for organic materials. The C: N ratio was obtained by dividing the nitrogen level by an average value for the concentration of carbon, as calculated

3.10 Partial Economic Analysis

The partial economic analysis was done using the partial budget procedure to determine the treatment combinations that would give acceptable return at low risk to farmer (CIMMYT, 1988). Economic analysis of the data was done based on the prevailing farm gate prices of input, operations and outputs. The following concepts used in the partial budget analysis are defined as follows: 1. Gross Revenue (GR) in ₦ per hectare is the product of average price of tomato and total yield for each treatment, 2. Total variable cost (TVC) in ₦ per hectare is the cost of labour and inputs which include seeds, fertilizer and chemicals. 3. Gross Margin (GM) in ₦ per hectare is the difference between gross revenue and total variable cost. 4 Gross Margin per ₦ invested is the gross margin divide by total variable cost (TVC).

3.11 Statistical Analysis of Data

All the data collected from the observations were subjected to analysis of variance (ANOVA) as described by Steel and Torrie (1987) and treatment means were compared using Duncan Multiple Range Test (DMRT) at a 5% probability level (Duncan, 1955). The magnitude and type of relationship between characters were assessed through simple correlation analysis (Little and Hill, 1978). The polynomial response of tomato yield to NPK fertilizer and green manure rate were determined by regression analysis (Barr and Goodnight, 1972). The direct and indirect contribution of fruit yield by selected characters of tomato were determined using path coefficient analysis as described by Dewey and Lu (1959).

CHAPTER FOUR

4.0 RESULT

4.1 Soil, Green Manure Analysis and Weather Data.

The analytical results of the soil before transplanting at the experimental sites are shown in Table 1. The soil at Samaru was loam and slightly acidic ranges from 5.60 to 6.20. The soil nutrient status was 0.72 g kg^{-1} organic carbon, 0.42 to 0.52 g kg^{-1} total nitrogen, 14.3 g kg^{-1} of available phosphorus and K was between 0.17 to 0.33Cmol kg^{-1}. Exchangeable bases were 1.80 cmol kg^{-1} Ca, 0.32 to 1.20 cmol kg^{-1} Mg, 0.25 to 0.19 cmol kg^{-1} Na, 0.19 to 0.22 cmol kg^{-1} H + Al as well as CEC of 7.11 to 8.65 cmol kg^{-1} of soil. At Kadawa, the soil was characterized as sandy loam and slightly acidic ranging from 6.0 to 6.4, organic carbon 0.73 to 2.03 g kg^{-1}, total nitrogen 0.30 to 0.53 g kg^{-1}, available phosphorus 12,3 to 25.3 g kg^{-1} , potassium ranges between 0.08 to 0.14 Cmol kg^{-1} while the exchangeable bases were 1.70 to 1.90 cmol kg^{-1} Ca, 1.25 to 1.30 cmol kg^{-1} Mg, 0.08 to 0.14 cmol kg^{-1} Na, 0.09 to 0.16 cmol kg^{-1} H + Al and CEC of 7.20 to 9.60 cmol kg^{-1} of soil.

The chemical composition of lablab fodder as green manure is presented in Table 2. The green manure nutrient composition showed high amount of total nitrogen ranges between 34.2 to 37.3 g kg^{-1} total phosphorus 5.5-6.1 g kg^{-1} potassium 10.8-12.1 g kg^{-1} while carbon was between 48.8-59.4% . However the fodder analysis showed a narrowed C:N ratios between 13-19 and the dry matter accumulation was between 424.0-460.5 g kg^{-1}.

Table 1: Physical and chemical properties of soils at experimental locations in Samaru and Kadawa during 2010-11 and 2011-12 dry seasons.

	Samaru		Kadawa	
	2010-11	2011-12	2010-11	2011-12
Physical properties (g kg^{-1})				
Sandy	420	440	500	520
Silt	300	310	220	300
Clay	280	250	280	180
Textural class	Loam	Loam	S/loam	S/loam
Chemical properties				
pH in water	5.60	6.20	6.4	6.00
pH ($CaCl_2$)	4.90	5.30	4.0	5.80
Organic carbon (g kg^{-1})	0.72	0.72	0.73	2.03
Available phosphorus (mg kg $^{-1}$)	14.3	14.3	25.3	12.3
Total nitrogen (g Kg^{-1})	0.42	0.52	0.30	0.53
Exchangeable bases (cmol kg $^{-1}$)				
Ca^{++}	1.80	1.80	1.70	1.90
Mg^{++}	0.32	1.20	1.30	1.25
K^{+}	0.17	0.33	0.08	0.14
Na^{++}	0.25	0.05	0.24	0.07
Exchangeable acidity	0.22	0.19	0.09	0.16
CEC	8.65	7.11	7.20	9.60

S/loam =Sandy loam

Table 2: Chemical composition of Lablab green manure used during the experimental periods at Samaru and Kadawa in 2010-11 and 2011-12

	Samaru		Kadawa	
Chemical composition	2010-11	2011-12	2010-11	2011-12
Total Nitrogen (g kg^{-1})	36.6	35.7	34.2	37.3
Total Phosphorus (g kg^{-1})	5.5	6.1	6.0	5.8
Potassium (g kg^{-1})	10.8	12.0	11.4	13.0
Calcium (g kg^{-1})	10.3	10.6	11.1	12.1
Carbon (%)	48.8	49.7	56.9	59.4
C:N ratio	13	14	17	19
Dry matter (g kg^{-1})	456.5	460.5	458.4	424.0

The weather data during the experimental period are shown in Appendices I and II. Maximum temperature in Samaru ranged from 28.1 to 34.7^{0}C in 2010-2011 and 29.8 to 33.7^{0}C in 2011-2012 while minimum temperature ranged from 14.8 to 20.3^{0}C in 2010-2011 and 13.2 to 20.9^{0}C in 2011-2012 with average relative humidity are 28.8 to 30.5% respectively. Daily sunshine hours ranged from 5.7 to 8.1 hrs day^{-1} in 2010-2011 and 4.8 to 8.7 hrs day^{-1} in 2011-2012. At Kadawa the average maximum temperature was 36.5^{0}C to minimum of 19.5^{0}C in 2010-2011 and 34.7^{0}C to 18.6^{0}C in 2011-2012. The average relative humidity in respective years was 32.3 and 33.2% while the mean sunshine hours are 9.3 and 8.6 hrs day^{-1} in 2010-2011 and 2011-2012.

4.2 Major weeds, pests and diseases

The common weeds found at both locations during the research were mostly annual broad leaf and grasses which include *Digitaria horizontalis, Ageratum conizoides,* various *Cyperus spp., Axonopus compressors* and *Portulaca oleracea* while common insect pests found were white flies (*Bamisia tabacci*), Spider mites (*Tetranychus urticae*), Tomato fruit worm (*Helicoverpa armegera*) and the common diseases during the experiments include bacteria wilt caused by *Ralstonia solanacearum* and Buckeyed rot of fruits.

4.3 Crop Parameters

4.3.1 Number of leaves plant^{-1}

The number of leaves per plant only differed significantly on varieties at 9 WAT in both seasons at both locations and also at 7 WAT at Kadawa in 2011-12 (Table 3). The number of leaves was more with UC82B than Roma VF.

Application of NPK fertilizer significantly increased number of leaves per plant at all the sampling stages at Samaru and only at 9 WAT at Kadawa 2010-11 (Table 3). In 2011-12, only number of leaves plant^{-1} was only significant at 9 WAT at Samaru and significant at 7 and 9 at Kadawa (Table 3). At Samaru in 2010-11, at 5 WAT the application of 150 kg ha^{-1} resulted in more number of leaves per plant which was similar to other rates but significantly higher than the control. At 7 and 9 WAT, the application of 450 kg of NPK fertilizer resulted in significant more number of leaves than the lower rates applied, while at Kadawa in 2010-11, increase in the rate of NPK applied resulted in significant increase in number of leaves at 9 WAT. Similarly at Samaru in 2011-12, the application of 450 kg NPK produced significantly more of leaves than the lower rates, however 150 and 300 kg were similar at 9 WAT. At Kadawa in 2011-12 at 7 and 9 WAT the application of 450 kg NPK had produced significantly more leaves than the control, but similar to other rates applied.

The application of green manure resulted in significant increase in the number of leaves per plant at 9 WAT in both seasons at Samaru while at Kadawa differences were significant at 9 WAT in 2010-11 and 5 WAT in 2011-12 (Table 3). At Samaru in 2010-11, the number of leaves were similar at all rates of green manure applied but significantly higher than the control treatment while at Kadawa in 2010-11, application of 10 t of green manure resulted in significantly more number of leaves than the lower rate and the control. In 2011-12 at Samaru at 9 WAT, number of leaves per plant significantly increased with increase rates of green manure while at Kadawa application of 5 t of green manure significantly produced more leaves which was similar to 10 t ha^{-1} of green manure.

Table 3: Number of leaves per plant of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	2010-11						2011-12					
	Samaru			**Kadawa**			**Samaru**			**Kadawa**		
Treatment	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)												
Roma VF	12.6	21.6	43.5b	24.3	49.4	55.8b	11.0	20.5	46.2b	19.7	40.6b	60.7b
UC82B	11.9	21.2	59.9a	27.4	52.2	75.4a	12.1	21.6	56.6a	24.6	52.1a	74.0a
SE±	0.39	0.53	0.65	1.66	3.55	1.50	0.56	0.89	1.03	1.67	3.46	3.86
NPK rate kg ha^{-1}(F)												
0	11.1b	16.5c	31.1d	24.6	46.2	49.8d	11.6	20.3	31.7c	20.0	36.9b	55.4b
150	12.8a	18.1c	43.2c	25.3	59.4	62.1c	11.0	20.5	39.8b	19.7	45.3ab	69.1ab
300	13.1a	23.4b	60.2b	27.1	51.1	69.9b	12.3	22.4	38.9b	23.0	48.1ab	69.7ab
450	12.2ab	27.6a	73.4a	27.1	51.9	80.6a	11.5	21.3	56.7a	26.0	55.0a	75.3a
SE±	0.48	0.74	0.92	2.34	5.03	2.12	0.80	1.27	1.45	2.36	4.90	5.46
Green manure rate t ha^{-1} (G)												
0	12.1	20.7	50.3b	24.0	49.3	61.0b	11.8	21.0	48.7c	18.8b	47.5	62.3
5	12.1	21.8	55.9a	26.5	52.2	65.2b	10.9	20.4	52.8b	22.6a	41.3	66.2
10	12.5	21.8	54.9a	27.1	55.0	70.7a	11.9	21.8	57.3a	25.1a	50.3	71.6
SE±	0.39	0.67	0.59	1.63	3.05	1.88	0.58	1.02	1.22	2.01	3.55	3.19
Interaction												
F x V	NS	NS	NS	NS	NS	**	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAT = Weeks after transplanting, **= significant at 1% level of probability. NS = Not significant.

Interaction of fertilizer rate by variety significantly affected the number of leaves per plant at 9 WAT at Kadawa in 2010-11 (Table 4). The number of leaves per plant increased with increase in rate of fertilizer up to 300 kg with both varieties. Considering the variety, UC82B had significantly produced more leaves per plant than Roma VF at all fertilizer rates except at 300 kg where they are similar. Combination of UC82B and 450 kg ha^{-1} NPK fertilizer gave more number of leaves while the least was obtained at the control treatment and variety Roma VF.

Table 4: Interaction between NPK fertilizer and variety on number of leaves per plant at 9 WAT at Kadawa in 2010-11.

	NPK fertilizer (kg ha^{-1})			
Treatment	0	150	300	450
Variety				
Roma VF	47.4f	61.7e	82.2b	72.1d
UC82B	72.3d	77.5c	82.5b	109.1a
SE±		3.00		

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

4.3.2. Plant height (cm)

There was significant difference on plant height between the varieties at 9 WAT at Samaru in both seasons while in Kadawa at 9 WAT in 2010-11 and 5 WAT in 2011-12 (Table 5). Roma VF was significantly taller at Samaru in 2010-11 while the reversed was observed in 2011-12 when UC82B produced taller plants than Roma VF and at Kadawa UC82B had taller plants at those sampling periods.

Table 5: Plant height per plant (cm) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11and 2011-12 dry seasons.

	2010-11						2011-12					
	Samaru			**Kadawa**			**Samaru**			**Kadawa**		
Treatment	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)												
Roma VF	18.9	32.3	68.7a	21.6	36.3	47.4b	24.4	39.2	50.2b	20.9b	33.5	49.5
UC82B	17.0	33.7	62.1b	24.0	39.5	52.2a	27.2	42.4	55.3a	23.9a	35.1	50.5
SE±	0.68	0.87	0.31	0.83	1.29	1.08	1.08	1.42	1.21	0.92	0.84	1.07
NPK rate kg ha^{-1}(F)												
0	13.3b	29.9c	41.6d	21.5	34.6b	45.8b	24.2	37.2b	48.4b	19.3b	30.2c	46.8b
150	19.8a	31.0bc	61.6c	22.5	35.8b	46.1b	26.7	38.8ab	48.0b	20.4b	31.4c	47.1b
300	19.1a	33.1ab	72.1b	23.2	39.0ab	53.1a	25.5	42.8ab	58.1a	22.6b	35.8b	51.0ab
450	19.6a	37.8a	80.2a	24.0	42.3a	54.4a	26.8	44.3a	55.4a	27.3a	39.8a	55.2a
SE±	0.96	1.24	0.43	1.18	1.82	1.53	1.54	2.01	1.71	1.30	1.20	1.52
Green manure rate t ha^{-1} (G)												
0	17.8	32.2b	66.0c	22.5	30.1b	41.9b	26.8	33.1b	44.4b	21.0	28.6c	44.1c
5	17.7	33.2b	68.2b	25.2	40.9a	52.9a	27.6	44.4a	56.5a	22.3	34.3b	49.4b
10	19.5	35.4a	69.5a	24.8	42.6a	54.6a	28.0	44.8a	57.3a	26.8	40.1a	56.4a
SE±	0.74	0.58	0.18	0.90	1.19	1.29	0.91	1.19	1.29	0.88	1.32	1.30
Interaction												
F x V	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x V	NS	NS	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAT = Weeks after transplanting, ** = significant at 1% level of probability. NS = Not significant.

Plant height increased with application of NPK fertilizer in both seasons and locations and the differences was significant at all the sampling periods at Samaru in 2010-11 and at 7 and 9 WAT in 2011-12. Also at Kadawa, significant differences were observed at 7 and 9 WAT in 2010-11 and all the sampling periods in 2011-12 (Table 5). At Samaru in 2010-11, application of 450 kg ha^{-1} produced significantly taller plants in all sampling period than other rate of fertilizer applied. However at 5 WAT, increasing fertilizer rate from 150 to 450 kg ha^{-1} did not differ significantly on plant height. At 7 WAT application of 450 kg ha^{-1} NPK fertilizer resulted in tallest plant but similar to when 300 kg ha^{-1} was applied, similarly NPK fertilization at 150 and 300 kg ha^{-1} did not differ significantly. At 9 WAT, there was corresponding increase in plant height with NPK fertilizer application from 150 to 450 kg ha^{-1} while at 7 and 9 WAT at Kadawa in 2010-11, applying fertilizer rate up to 300 kg ha^{-1} produced significantly taller plants than the lower rate and control treatment but further increase of fertilizer did not induce significant increase in plant height. At Samaru in 2011-12, at 7 WAT applied 450 kg ha^{-1} significantly increased plant height than the control but did not differ significantly from150 and 300 kg application rates. At 9 WAT, application of 300 kg fertilizer significantly produced taller plants which was similar to application of 450 kg NPK fertilizer while in Kadawa application of 450 kg significantly produce taller plant than the lower rates applied throughout the growth stages in 2011-12.

The incorporation of green manure rates significantly influenced plant height at 7 and 9 WAT at locations and seasons (Table 5). In the two sampling periods of 7 and 9 WAT, applied green manure of 10 t ha^{-1} significantly produced taller plants than the control treatment, although at Kadawa 2010-11 and Samaru 2011-12 applications of 5 and 10 t ha^{-1}

did not differ significantly. However in both seasons and locations the shortest plants were produced on untreated plots.

There was significant interaction between variety and NPK on plant height at 9 WAT in 2010-11 at Samaru (Table 6). The result showed that at a given NPK fertilizer rate there was significant difference between varieties where UC82B had taller plants from zero to 150 kg ha^{-1} but further increase to 300 kg ha^{-1} and above, Roma VF produced taller plants. At given variety, increasing NPK fertilizer rate from 0 to 300 kg ha^{-1} produced significant increase on plant height, but further increase caused reduction in plant height.

Interaction between green manure and NPK was significant on plant height at 9 WAT in 2010-11 (Table 7). The interaction of green manure and NPK rate on plant height at 9 WAT, showed that at a given rate of NPK, there was significant increase on plant height across all green manure rates. At a given green manure rate, application of 300 kg ha^{-1}NPK and 10 t $ha^{-1}$of green manure produced the tallest plant height at 9 WAT.

Green manure and variety interaction on plant height 9WAT was significant in 2010-11 at Samaru (Table 8). The result indicated that UC82B produced taller plants when compare to Roma VF in all the rate of green manure except at 10 t ha^{-1} where Roma VF produces taller plants than UC82B. At given variety, Roma VF significantly increased plant height with corresponding increased of green manure while UC82B did not responded significantly to green manure application from 0-5 t ha^{-1} but a further increase to 10 t ha^{-1}significant produced taller plant than the lower rate of application.

Table 6: Interaction between NPK fertilizer and variety on plant height at 9 WAT at Samaru in 2010-11

	NPK fertilizer (kg ha^{-1})			
Treatment	0	150	300	450
Variety				
Roma VF	43.5h	59.1f	96.7a	75.2c
UC82B	51.7g	64.0e	83.8b	68.9d
SE±		0.62		

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

Table 7: Interaction between NPK fertilizer and green manure rates on plant height at 9 WAT at Samaru in 2010-11

	NPK fertilizer(kg ha^{-1})			
Treatment	0	150	300	450
Green manure (t ha^{-1})				
0	43.9k	60.5h	87.9c	71.6e
5	48.9j	61.5g	89.8b	72.4e
10	50.1i	62.8f	92.8a	77.2d
SE±		0.36		

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

Table 8: Interaction between green manure and variety on plant height at 9 WAT at Samaru in 2010-11

	Green manure rate t ha^{-1}		
Treatment	0	5	10
Variety			
Roma VF	64.7d	69.1b	72.1a
UC82B	67.3c	67.1c	66.9c
SE±		0.26	

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

4.3.3. Number of branches plant^{-1}

The number of branches per plant between the varieties differed significantly at 9 WAT at Samaru in 2010-11 and 2011-12 (Table 9) where UC82B produced more branches than Roma VF.

The number of branches per plant significantly increased with increase in fertilizer application at Samaru at 5 and 9 WAT; and 7 and 9 WAT at Kadawa in 2010-11 and also at 7 and 9 WAT for both sites in 2011-12 (Table 9). At Samaru in 2010-11 at 5 WAT, applying 150 kg NPK fertilizer significantly increased number of branches but further increase did not significantly produce more branches. At 9 WAT, application of 300 kg NPK fertilizer resulted in more branches than the lower rates but similar to 450 kg NPK fertilizer. A similar trend was observed at Kadawa at 7 and 9 WAT in 2010-11. At both locations at 7 and 9 WAT application of 300 kg NPK fertilizer resulted in more number of branches per plant which was statistically similar to application of 450 kg ha^{-1}. Application of 300 kg ha^{-1} NPK fertilizer differed significantly from lower rate at all sampling period except at 9 WAT at Kadawa in 2011-12 application of 150 and 300 kg ha^{-1} NPK fertilizer were statistically similar.

Green manure application resulted in significant increase in number of branches per plant at 7 and 9 WAT in Samaru 2010-11 and all the sampling period at both locations and seasons (Table 9). In all the sampling periods at both seasons and locations, application of 10 t ha^{-1} green manure resulted in significant more branches per plant than the lower rate applied. At all the sampling period 5 t ha^{-1} green manure had significantly increased number of branches than the control except at 5 and 9 WAT in Kadawa in 2010-11 where similarity was observed in the control.

Table 9: Number of branches per plant of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	2010-11						2011-12					
	Samaru			**Kadawa**			**Samaru**			**Kadawa**		
Treatment	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)												
Roma VF	2.9	6.5	8.9b	3.5	7.2	8.4	3.8	7.3	7.9b	3.4	7.1	8.9
UC82B	3.1	6.5	10.1a	3.3	7.6	8.8	4.0	8.0	9.1a	3.5	8.0	9.4
SE±	0.17	0.24	0.25	0.15	0.23	0.42	0.20	0.28	0.25	0.21	0.18	0.30
NPK rate kg ha^{-1}(F)												
0	1.2b	6.0	7.7c	3.4	6.2b	7.2b	3.8	6.8b	7.2c	3.3	5.8c	7.9c
150	3.8a	6.9	8.8b	3.4	6.8b	7.8b	3.8	6.5b	7.9b	3.6	6.6b	8.9bc
300	3.6a	6.6	10.4a	3.4	8.0a	9.5a	3.9	8.3a	9.8a	3.6	8.4a	9.4ab
450	3.5a	6.5	11.1a	3.4	8.6a	9.8a	3.9	9.2a	10.0a	3.4	9.2a	10.4a
SE±	0.23	0.33	0.35	0.22	0.32	0.60	0.28	0.37	0.35	0.30	0.25	0.42
Green manure rate t ha^{-1} (G)												
0	2.8	5.5c	8.3c	3.2b	6.2c	7.8b	3.6b	6.6b	7.0c	2.4b	5.4c	7.4c
5	2.9	6.5b	9.7b	3.3b	7.6b	8.3b	3.6b	8.1a	8.7b	2.9b	8.1b	9.4b
10	3.3	7.7a	10.7a	3.7a	8.4a	9.8a	4.2a	8.4a	9.9a	3.8a	9.0a	19.8a
SE±	0.25	0.29	0.33	0.13	0.26	0.31	0.14	0.24	0.33	0.18	0.19	0.31
Interaction												
F x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
F x G	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
G x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAT = Weeks after transplanting, *= significant at 5% level of probability. NS = Not significant.

The variety and NPK fertilizer interaction was significant on number of branches per plant 7 WAT at Kadawa in 2011-12 (Table 10). Both varieties responded similarly to NPK fertilizer rate at 300 kg ha^{-1} but further increase of NPK had no significant effect on number of branches per plant.

Interaction between NPK fertilizer and green manure rates on number of branches per plant was significant at Kadawa at 7 WAT (Table 11). Considering green manure at control treatment number of branches per plant did not increase with NPK application from 0 to 300 kg ha^{-1} further increase of NPK fertilizer to 450 kg ha^{-1} significantly increased number of branches per plant which was similar to 150 kg NPK fertilizer. At 5 t ha^{-1} of green manure, number of branches increased significantly with increase in NPK fertilizer rate. At given NPK rates there was significant increase in number of branches per plant with increased amount of green manure whereas the combined application of 10 t ha^{-1} of green manure and 450 kg ha^{-1} NPK fertilizer resulted in more number of branches per plant than other combinations while the least number of branches was obtained from the control treatment.

4.3.4 Crop dry matter (g)

The varieties differed significantly in crop dry matter only at 7 and 9 WAT in 2010-11 at Kadawa, in 2011-12 at Samaru and all the sampling periods in Kadawa 2011-12 (Table 12). UC82B produced significantly higher crop dry matter per plant than Roma VF at these sampling periods at both locations.

The crop dry matter per plant increased with increase in the rate of NPK fertilizer applied and the differences were significant at 7 and 9 WAT at Samaru in 2010-11, at all the sampling periods at Kadawa in 2010-11 and at both locations in 2011-12 (Table 12).

Table 10: Interaction between variety and NPK fertilizer on number of branches per plant at 7 WAT at Kadawa in 2011-12.

	NPK fertilizer (kg ha^{-1})			
Treatment	0	150	300	450
Variety				
Roma VF	6.8d	7.3c	9.4a	9.7a
UC82B	7.1cd	8.8b	9.5a	9.7a
SE±		0.21		

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

Table 11: Interaction between NPK fertilizer and green manure rates on number of branches per plant at 7 WAT at Kadawa in 2011-12

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})				
0	4.8g	5.3fg	5.6fg	6.1def
5	7.0cd	5.5ef	9.5b	10.1b
10	7.8c	6.7de	10.3b	11.4a
SE±		0.38		

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

Table 12: Crop dry matter (g) per plant of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	2010-11						2011-12					
	Samaru			**Kadawa**			**Samaru**			**Kadawa**		
Treatment	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)												
Roma VF	7.2	11.5	25.5	11.1	17.6b	27.0b	10.1	19.7b	25.1b	8.5b	13.0b	28.8b
UC82B	7.4	11.7	26.9	13.1	21.7a	31.5a	12.2	23.7a	30.4a	11.1a	17.3a	34.5a
SE±	0.15	0.12	0.57	0.75	0.76	0.85	0.82	0.78	0.85	0.45	0.52	0.76
NPK rate kg ha^{-1}(F)												
0	7.5	10.4c	14.8d	10.7b	16.5b	24.2c	9.8ab	18.45b	23.9b	8.9c	12.8b	26.4b
150	7.8	11.4b	19.6c	10.1b	17.1b	27.9b	9.1b	18.9b	24.9b	8.1bc	13.2b	28.3b
300	7.5	11.6b	32.8b	12.8ab	21.6a	30.7ab	13.5a	25.5a	31.8a	10.6ab	16.6a	35.9a
450	7.8	12.9a	37.7a	14.6a	23.5a	34.2a	12.1ab	23.9a	30.1a	11.4a	18.0a	36.1a
SE±	0.22	0.18	0.81	1.06	1.08	1.21	1.17	1.10	1.21	0.64	0.74	1.08
Green manure rate t ha^{-1} (G)												
0	7.8	11.2b	22.7c	10.3b	17.1b	26.4b	9.1b	19.0b	24.9b	9.4	14.4	28.9b
5	7.2	11.4ab	25.8b	12.8b	20.5a	30.5a	11.6a	22.7a	28.9a	9.8	14.7	32.4a
10	7.8	12.0a	29.9a	13.3a	21.4a	34.7a	12.6a	23.3a	29.4a	10.1	16.3	32.8a
SE±	0.27	0.22	0.67	0.40	0.45	0.62	0.39	0.37	0.62	0.48	0.74	0.47
Interaction												
F x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAT = Weeks after transplanting, NS = Not significant.

At Samaru at 7 WAT in 2010-11, NPK fertilizer at 450 kg ha^{-1} significantly increased crop dry matter than the lower rate applied, although applied 150 and 300 kg ha^{-1} were at par but significantly higher than the control. At 9 WAT in Samaru 2010-11, there was significant increase in crop dry matter with increase in fertilizer rates. In 2010-11 at 5 and 7 WAT at Kadawa, application of 450 kg NPK fertilizer produced higher crop dry matter than the lower rates, though no differences was recorded between the application of 150 kg ha^{-1} NPK fertilizer and the control treatment. However, at Samaru in 2011-12, applied 300 kg ha^{-1} NPK fertilizer significantly increased crop dry matter beyond which there was no significant increase in all the sampling periods of study. Similar trends were observed at Kadawa in 2011-12, where application of 300 kg ha^{-1} NPK fertilizer resulted in significant increased in crop dry matter at all the sampling periods.

The application of green manure resulted in significant increases in the crop dry matter per plant in both seasons and locations (Table 12). At 7 WAT at Samaru in 2010-11, application of 10 t ha^{-1} of green manure resulted in significant higher crop dry matter than the lower rate, though 5 and 10 t ha^{-1} of green manure were at par. At 9 WAT there was corresponding increase in dry matter per plant with green manure rates. At Kadawa in 2010-11, at 5 WAT there no was increase in crop dry matter when 5 t ha^{-1} of green manure was applied but further increase to 10 t ha^{-1} resulted to significant crop dry matter accumulation. At 7 and 9 WAT in 2010-11, application of 5 t ha^{-1} green manure significantly increased crop dry matter which was similar to 10 t ha^{-1} green manure. In 2011-12 at Samaru in all the sampling periods, application of 5 t ha^{-1} of green manure increased crop dry matter than the control beyond which there was no increase significantly. Similar trend was observed at Kadawa at 9 WAT in 2011-12. There was no interaction between the factors throughout the sampling periods in both season and locations.

4.3.5. Leaf area index

The leaf area index per plant differed significantly with variety at all the growth stages at both locations and seasons except in Samaru at 9 WAT where the varieties did not differ significantly (Table 13). At both locations and years UC82B had higher leaf area index and significantly differed from Roma VF throughout its growth stages.

At both locations and years of study, NPK fertilization significantly increased LAI in all the growth stages sampled (Table 13). At Samaru 2010-11, applied NPK fertilizer rate at 450 kg ha^{-1} significantly increased LAI than the lower rates in all the sampling periods while at Kadawa in 2010-11, application of 450 kg ha^{-1} NPK fertilizer increased LAI but at 7 and 9 WAT 300 kg ha^{-1} NPK fertilizer had similar LAI value to 450 kg ha^{-1}. In 2011-12 at Samaru, application 300 kg ha^{-1} of NPK fertilizer resulted to increased LAI; further increase of NPK fertilizer to 450 kg ha^{-1} did not increase LAI at 5 WAT. At 7 and 9 WAT, application of 450 kg ha^{-1}NPK fertilizer resulted in larger LAI than the lower rates. While at Kadawa, at 5 WAT LAI was significantly higher at 450 kg ha^{-1} NPK fertilizer. At 7 and 9 WAT, application of 300 kg ha^{-1} NPK fertilizer significantly increased LAI beyond which there was no significant increase in LAI.

Incorporation of green manure significantly affected the leaf area index at both locations and years of study except at 7 and 9 WAT at Samaru and Kadawa in 2010-11 respectively, also at 7 and 9 WAT in Kadawa 2011-12 (Table 13). In all cases, application of 10 t ha^{-1} of green manure significantly resulted in higher leaf area index than lower rate and the control.

Table 13: Leaf area index per plant of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11and 2011-12 dry seasons.

	2010-11						2011-12					
	Samaru			**Kadawa**			**Samaru**			**Kadawa**		
Treatment	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT	5WAT	7WAT	9WAT
Variety (V)												
Roma VF	0.44b	1.06b	1.87	0.94b	1.09b	1.65b	0.89b	1.44b	1.75b	0.90b	1.41b	1.87b
UC82B	0.48a	1.26a	1.94	1.11a	1.52a	2.15a	1.05a	1.77a	2.11a	0.98a	1.56a	2.12a
SE±	0.010	0.039	0.034	0.020	0.044	0.165	0.020	0.038	0.042	0.008	0.031	0.043
NPK rate kg ha^{-1}(F)												
0	0.35b	0.68c	1.39d	0.84c	0.93b	1.42b	0.79b	1.21c	1.49c	0.83c	1.21b	1.59b
150	0.48a	1.18b	1.82c	0.89c	0.96b	1.50b	0.84b	1.23c	1.52c	0.84c	1.26b	1.69b
300	0.49a	1.42a	2.03b	1.14b	1.61a	2.23a	1.14a	1.88b	2.17b	1.01b	1.67a	2.17a
450	0.49a	1.32a	2.37a	1.23a	1.73a	2.40a	1.12a	2.11a	2.56a	1.11a	1.78a	2.31a
SE±	0.014	0.056	0.048	0.028	0.063	0.234	0.028	0.054	0.060	0.011	0.044	0.062
Green manure rate t ha^{-1} (G)												
0	0.44b	1.15	1.75b	0.99b	1.26b	1.94	0.92b	1.53c	1.82c	0.92b	1.47	1.97
5	0.45b	1.15	1.95b	1.04a	1.33ab	1.90	0.99a	1.61b	1.94b	0.92b	1.48	1.99
10	0.49a	1.21	2.01a	1.05a	1.35a	1.84	0.99a	1.68a	2.04a	0.96a	1.49	2.00
SE±	0.011	0.062	0.060	0.015	0.063	0.035	0.018	0.017	0.031	0.007	0.019	0.024
Interaction												
F x V	**	**	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G	NS	**	*	NS	NS	NS	NS	NS	NS	**	NS	NS
G x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAT = Weeks after transplanting,,* = significant at 5% , **= significant at 1% level of probability. NS = Not significant.

Interaction between NPK fertilizer and variety was significant at all the sampling periods in Samaru 2010-11(Table 14). In all cases variety UC82B combined with applied 450 kg ha^{-1} NPK fertilizer significantly resulted in higher LAI, though similar to combination of Roma VF and applied 300 kg ha^{-1} NPK fertilizer at 5 and 7 WAT in 2010-11, while least LAI was obtained in the combinations of Roma VF and control treatments at all the sampling periods.

Significant interaction between NPK fertilizer and green manure rates was observed on leaf area index at 7 and 9 WAT at Samaru in 2010-11 (Table 15). At 7 and 9 WAT, NPK fertilizer combination of 450 kg ha^{-1} and 10 t ha^{-1} of green manure produced higher LAI while the control levels produced the least. A similar result was obtained at 5 WAT in Kadawa 2010-11 (Table 16).

Table 14: Interaction between NPK fertilizer and variety on leaf area index at 5, 7 and 9 weeks after transplanting at Samaru in 2010-11

	NPK fertilizer (kg ha^{-1})			
Treatment	0	150	300	450
Variety		**5 WAT**		
Roma VF	0.24d	0.49b	0.50a	0.47b
UC82B	0.46c	0.49b	0.49b	0.51a
SE±		0.0065		
		7 WAT		
Roma VF	0.53f	1.30b	1.59a	1.13c
UC82B	0.83e	1.05d	1.26b	1.62a
SE±		0.0265		
		9 WAT		
Roma VF	1.19f	1.94c	2.15b	2.19b
UC82B	1.59c	1.91c	1.70d	2.55a
SE±		0.022		

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

Table 15: Interaction between NPK fertilizer and green manure rates on leaf area index at 7 and 9 weeks after transplanting at Samaru in 2010-11

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})		**7 WAT**		
0	0.25d	0.48ab	0.49ab	0.50a
5	0.35c	0.48ab	0.49ab	0.50a
10	0.45b	0.48ab	0.48ab	0.50a
SE±	0.009			
		9 WAT		
0	1.12h	1.50g	2.09c	2.25b
5	1.43g	1.92de	1.99cd	2.49a
10	1.62f	1.84de	2.05cd	2.54a
SE±	0.042			

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

Table 16: Interaction between NPK fertilizer and green manure rates on leaf area index at 5 weeks after transplanting at Kadawa in 2011-12

	NPK fertilizer rate kg ha^{-1}			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})				
0	0.82c	0.84c	1.00b	1.00b
5	0.82c	0.82c	1.02b	1.12a
10	0.83c	0.83c	1.01b	1.14a
SE±		0.014		

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

4.3.6 Crop growth rate (g wk^{-1})

There was significant difference in crop growth rate between the varieties at 5-7 WAT at Kadawa in 2010-11, also in 2011-12 at Samaru and Kadawa respectively (Table 17). At both locations UC82B significantly gave higher crop growth rate than Roma VF.

Crop growth rate per plant increased with application of fertilizer in both years and locations (Table 17). In 2010-11 at 5-7 WAT at Samaru, application of NPK up to 450 kg ha^{-1} produced significantly higher crop growth rate, however application of 150 and 300 kg ha^{-1} was not statistically different while the lowest CGR was obtained at the control which had similar CGR with 150 kg $ha^{-1}$of NPK fertilizer. At 7-9 WAT in 2010-11, increasing NPK fertilizer rate significantly increased CGR. Also at Kadawa, at 5-7 WAT in 2010-11 CGR, increased significantly up to 300 kg ha^{-1} of NPK fertilizer after which it was statistically at par with 450 kg ha^{-1}. In 2011-12 at Samaru and Kadawa a similar trends was found at 5-7 and 7-9 WAT respectively.

Green manure incorporation significantly affected the crop growth rate at 7-9 WAT at Samaru in 2010-11 and at 5-7 WAT at Kadawa 2010-11 and 2011-12 (Table 17). At Samaru, green manure application had significant effect on CGR, where applied 10 t ha^{-1} produced significantly higher CGR than the lower rate and control. Also at Kadawa, at 5-7 WAT in both years of study, incorporation of green manure at 10 t ha^{-1} resulted in in higher CGR per plant than the control. There were no factor interactions in all the sampling period throughout the years of study.

Interaction between variety and green manure was significant on CGR at 7-9 WAT at Samaru 2010-11 (Table 18. The combination of UC82B and applied 10 t ha^{-1} of green

Table 17: Crop growth rate (g wk^{-1}) per plant of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 dry seasons.

	2010-11				2011-12			
	Samaru		**Kadawa**		**Samaru**		**Kadawa**	
Treatment	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT
Variety (V)								
Roma VF	3.36	7.04	3.31b	4.68	4.80b	2.41	2.24b	7.94
UC82B	3.58	7.61	4.27a	4.92	5.81a	3.40	3.11a	8.62
SE±	0.110	0.280	0.185	0.353	0.191	0.251	0.160	0.458
NPK rate kg ha^{-1}(F)								
0	3.01c	2.19d	2.87b	3.84	4.31b	2.76	2.11b	6.64b
150	3.28bc	4.11c	3.50b	4.64	4.90b	3.03	2.23b	6.77b
300	3.56b	10.57b	4.29a	5.33	6.05a	3.10	3.03a	9.04a
450	4.05a	12.42a	4.49a	5.39	5.87a	3.20	3.30a	9.67a
SE±	0.150	0.401	0.261	0.499	0.270	0.360	0.227	0.647
Green manure rate t ha^{-1} (G)								
0	3.18	5.83c	3.42b	4.66	4.97	2.95	2.41b	7.83
5	3.65	7.15b	3.85ab	5.13	5.53	3.12	2.50b	8.20
10	2.60	8.99a	4.10a	4.62	5.35	3.01	3.11a	8.80
SE±	0.161	0.330	0.205	0.253	0.222	0.281	0.188	0.412
Interaction								
F x V	NS	NS	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS	NS	NS
G x V	NS	*	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAT = Weeks after transplanting, *= significant at 5% level of probability. NS = Not significant.

Table 18: Interaction between variety and green manure rate on crop growth rate ($g\ wk^{-1}$) between 7-9 weeks after transplanting at Samaru in 2010-11.

	Green manure rate ($t\ ha^{-1}$)		
Treatment	0	5	10
Variety			
Roma VF	6.21d	7.48b	7.42b
UC82B	5.44f	6.82c	10.55a
SE±		0.135	

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

manure produced the highest crop growth rate while the lowest was combination of control treatment with same variety. Holding the green manure rate constant and compare the varieties, UC82B differed significantly and produces higher CGR than Roma VF. However, on the variety, using Roma VF application of 5-10 t ha^{-1} green manure resulted in higher CGR than the control while CGR was increased with increase rate of green manure in variety UC82B.

4.3.7 Relative growth rate ($g\ g^{-1} wk^{-1}$)

Variety did not differ significantly in all the sampling periods at both locations and year of study (Table 19).

Application of NPK fertilizer resulted in significant increase in the relative growth rate at 7-9 WAT at Samaru (Table 19). At 7-9 WAT increasing rate of fertilizer from 0 to 300 kg ha^{-1} NPK fertilizer significantly increased the RGR, further increase to 450 kg ha^{-1} did not produced any significant increase on RGR.

Table 19: Relative growth rate per plant (g $g^{-1}wk^{-1}$) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry season.

	2010-11				2011-12			
	Samaru		**Kadawa**		**Samaru**		**Kadawa**	
Treatment	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT
Variety (V)								
Roma VF	0.45	0.81	0.24	0.45	0.35	0.47	0.21	0.58
UC82B	0.48	0.87	0.26	0.46	0.36	0.49	0.22	0.62
SE±	0.019	0.022	0.016	0.022	0.023	0.028	0.125	0.021
NPK rate kg ha^{-1}(F)								
0	0.43	0.61b	0.22	0.42	0.33	0.44	0.19	0.55
150	0.44	0.71b	0.27	0.52	0.33	0.46	0.22	0.63
300	0.48	1.00a	0.26	0.44	0.35	0.47	0.23	0.58
450	0.51	1.04a	0.24	0.43	0.38	0.57	0.23	0.63
SE±	0.027	0.031	0.022	0.031	0.032	0.039	0.017	0.030
Green manure rate t ha^{-1} (G)								
0	0.42	0.75b	0.24	0.42b	0.31b	0.53a	0.20b	0.59
5	0.52	0.87a	0.24	0.46ab	0.35ab	0.48ab	0.21ab	0.60
10	0.47	0.88a	0.24	0.49a	0.39a	0.43b	0.24a	0.61
SE±	0.026	0.025	0.015	0.015	0.017	0.020	0.010	0.025
Interaction								
F x V	NS	NS	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAT = Weeks after transplanting, NS = Not significant.

Application of green manure resulted in significant difference in RGR only at 7-9 WAT at Samaru and Kadawa in 2010-11, all the sampling periods at Samaru and at 5-7 WAT at Kadawa 2011-12 (Table 19). At 7-9 WAT 2010-11, relative growth rate were similar on the rates of green manure applied but significantly higher than control treatment in Samaru. At Kadawa in 2010-11, application of 10 t ha^{-1} of green manure significantly increased RGR at 7-9 WAT, which is also similar to 5 t ha^{-1} of green manure. Similarly the same trend was observed in all the sampling period in Samaru and 5-7 WAT at Kadawa in 2011-12. The interaction between the factors on RGR during the period of study was not significant.

4.3.8 Net assimilation rate (g. cm^{-2} wk^{-1})

There was significant difference between the varieties in both locations and years of study at 7-9 WAT at Samaru and Kadawa in 2010-11 and 5-7 WAT at Kadawa in 2011-12 (Table 20). At Samaru UC82B differed significantly on NAR from Roma VF and a similar difference was recorded at 5-7 WAT in Kadawa 2011-12. At 7-9 WAT in Kadawa, Roma VF had resulted to significant more NAR than variety UC82B.

Application of NPK fertilizer significantly influenced net assimilation rate at Samaru in all the sampling period in 2010-11, 5-7 WAT in 2011-12 and at Kadawa, 5-7 WAT in 2010-11 and all the sampling period in 2011-12 (Table 20). At Samaru in 2010-11, applied 450 kg fertilizer increased NAR than the lower rates in all the sampling period; however applied NPK fertilizer at 300 and 450 kg ha^{-1}, 150 kg ha^{-1} and control treatment were similar at 7-9 WAT. At 5-7 WAT at Kadawa in 2010-11, net assimilation rate increases with fertilization of NPK up to 300 kg ha^{-1} but further addition of fertilizer reduced net assimilation rate. At both locations in 2011-12, 450 kg ha^{-1} NPK fertilizer significantly increased NAR, though

Table 20: Net assimilation rate (g. cm^{-2} wk^{-1}) per plant of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	2010-11				2011-12			
	Samaru		**Kadawa**		**Samaru**		**Kadawa**	
Treatment	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT	5-7 WAT	7-9 WAT
Variety (V)								
Roma VF	2.1	1.7b	1.0	0.9a	1.7	0.8	0.7b	1.4
UC82B	2.1	2.1a	1.0	0.7b	1.6	0.7	0.9a	1.4
SE±	0.002	0.002	0.002	0.00	0.007	0.002	0.00	0.00
NPK rate kg ha^{-1}(F)								
0	1.6b	0.9b	0.9bc	0.8	1.5b	0.5	0.6c	1.1c
150	1.7b	1.1b	0.8c	0.7	1.6ab	0.6	0.7bc	1.3bc
300	1.9b	2.7a	1.4a	1.0	1.7ab	0.8	0.8b	1.5ab
450	2.8a	2.7a	1.1b	0.7	1.8a	0.9	1.1a	1.8a
SE±	0.004	0.004	0.00	0.032	0.031	0.004	0.00	0.00
Green manure rate t ha^{-1} (G)								
0	2.0	1.6b	0.9	0.8	1.6	0.7	0.7b	1.3
5	2.2	1.7b	1.0	0.9	1.7	0.7	0.7b	1.4
10	2.0	2.3a	1.1	0.8	1.7	0.8	1.0a	1.5
SE±	0.016	0.003	0.00	0.00	0.002	0.002	0.002	0.00
Interaction								
F x V	NS	NS	NS	NS	NS	NS	NS	NS
F x G	NS	**	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. WAT = Weeks after transplanting, **= significant at 1% level of probability. NS = Not significant.

there were some similarities in the treatments. At Samaru, applied 450 kg was significantly higher than the control and which was also similar to lower rate applied while at Kadawa at 5-7 and 7-9 WAT in 2011-12 application NPK fertilizer at 450 kg ha^{-1} significantly resulted to higher NAR per plant than 300 kg ha^{-1} and the control, however at 7-9 WAT 300 and 450 kg ha^{-1} NPK fertilizer application were at par.

Green manure application significantly increased NAR 7-9 WAT at Samaru 2010-11 and 5-7 WAT in Kadawa at 2011-12 (Table 20). At Samaru, Applied 10 t ha^{-1} significantly produced more NAR than the lower rate and the control while in Kadawa a similar trend was obtained at 5-7 in 2011-12.

Significant interaction between NPK fertilizer and green manure rates was observed on NAR at 7-9 WAT in 2010-11 at Samaru (Table 21). Holding the application of green manure rate constant, NAR significantly increased with increase in NPK fertilizer. However application of green manure at 10 t ha^{-1} and NPK at 450 kg ha^{-1} gave higher NAR while the least was recorded at control.

Table 21: Interaction between NPK fertilizer and green manure rates on net assimilation rate ($g.cm^2.wk^{-1}$) at 7-9 WAT at Samaru in 2010-11.

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})				
0	1.20h	0.80j	2.1f	2.30e
5	0.70k	0.90i	2.60d	2.80c
10	0.80j	1.60g	3.60b	3.80a
SE±	0.009			

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

4.3.9 Days to first flowering.

The response of varieties to days to first flowering was significant in 2010-11 and combined mean at Samaru and both years at Kadawa (Table 22). The result showed that Roma VF required significantly longer days to produce first flower than UC82B in both study period and the combined.

Application of NPK fertilizer had significantly affected days to flowering at Samaru 2010-11 and the mean while at Kadawa in all the period of study and the combined mean (Table 22). At Samaru in 2010-11, application of 450 kg NPK fertilizer significantly delayed flowering. At Kadawa in all the years and the combined, applied 450 kg ha^{-1} NPK fertilizer significantly delay flowering; however in 2010-11 applied 300 and 450 kg were statistically similar in numbers of days to first flower.

At both locations and years of study application of green manure significantly led to delay flowering compared to control plots in all the year of study and their combined means (Table 22). However application of green manure at 5 and 10 t ha^{-1} was statistically at par in both locations and years of study.

Interaction between NPK fertilizer and green manure rates was significant in 2010-11 and the combined means at Kadawa (Table 23). In 2010-11 and the combined application of 10 t ha^{-1} of green manure and 450 kg ha^{-1} NPK fertilizer significantly delayed flowering while the lowest days to flowering was obtained with control treatments. Similar result was obtained in the combined mean where the longer days to flowering was obtained at combined application of 450 kg ha^{-1} NPK fertilizer and green manure rates but the lowest was obtained no NPK fertilizer application and 5 t ha^{-1} green manure.

Table 22: Number of days to flowering of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Days to flowering					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	27.3a	26.7	26.6a	29.6a	26.0a	25.0a
UC82B	21.3b	25.0	23.7b	25.3b	22.3b	23.3b
SE±	0.87	0.89	0.61	0.63	0.63	0.71
NPK rate kg ha^{-1}(F)						
0	22.0c	23.0	21.6	21.5c	20.0c	21.3c
150	23.7bc	23.1	23.1	23.2b	20.2c	22.7b
300	25.5b	24.9	24.1	26.9a	23.7b	23.9b
450	31.2a	26.4	25.7	28.4a	29.9a	28.5a
SE±	1.23	1.24	1.27	0.75	0.75	0.74
Green manure rate t ha^{-1} (G)						
0	22.5b	21.9b	21.4b	20.5b	18.9b	19.9b
5	24.3a	23.3a	23.8a	27.3a	25.3a	26.3a
10	25.1a	24.0a	24.5a	26.3a	24.6a	25.0a
SE±	0.86	0.70	0.78	0.58	0.63	0.67
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	**	NS	**
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **= significant at 1% level of probability. NS = Not significant.

Table 23: Interaction between NPK fertilizer and green manure rates on days to first flower at Kadawa in 2010-11and mean.

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})				
		2010-11		
0	17.9f	18.4f	20.1de	21.1cde
5	18.9f	20.6e	22.2bcd	23.0b
10	21.7bcd	20.8de	22.4bc	27.2a
SE±		0.52		
		Mean		
0	20.4f	21.4ef	23.7cd	26.9b
5	20.3f	22.6de	23.8cd	25.1c
10	24.4	24.8c	25.1c	28.5a
SE±		0.56		

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

4.3.10 Fruit diameter (cm)

Response of variety, NPK fertilizer and green manure rates on fruit diameter at Samaru and Kadawa are presented in (Table 24). Tomato varieties did not differ significant on fruit diameter in all the year of study in Samaru while in Kadawa variety differed significantly, Roma VF produced significantly wider fruit diameter than UC82B in all the years and the combined data at Kadawa.

At both locations, years and their combined data, fruit diameter was significantly influenced by NPK fertilizer application (Table 24). In all cases, application of 300 kg ha^{-1} gave wider fruit diameter which was similar to application of 450 kg ha^{-1}.

Table 24: Fruit diameter (cm) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Fruit diameter (cm)					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	6.3	6.2	6.3	6.5a	6.0a	6.3a
UC82B	5.9	6.1	6.0	5.9b	5.7b	5.9b
SE±	0.19	0.15	0.12	0.22	0.10	0.08
NPK rate kg ha^{-1}(F)						
0	5.6b	5.4b	5.5b	5.5b	5.6b	5.6b
150	5.9b	5.8b	5.8b	5.9b	5.7b	5.8b
300	6.2ab	6.7a	6.5a	6.6a	6.0ab	6.3a
450	6.7a	6.6a	6.6a	6.7a	6.2a	6.5a
SE±	0.26	0.06	0.16	0.31	0.14	0.11
Green manure rate t ha^{-1} (G)						
0	5.8	5.7b	5.6b	5.4b	5.5b	5.5b
5	6.0	6.3a	6.1a	6.4a	5.9ab	6.2a
10	6.4	6.4a	6.4a	6.8a	6.4a	6.5a
SE±	0.26	0.18	0.16	0.23	0.21	0.15
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

Although, the control and 150 kg ha-^{1} NPK fertilizer did not differ significantly throughout and at both locations except at Samaru 2010-11 and Kadawa 2011-12 where applied 300 kg ha^{-1} was statistically similar to lowers rate and the control treatment.

Incorporation of green manure rate significantly increased fruit diameter at Samaru in 2011-12 and the combined, and all the years and mean at Kadawa (Table 24). At Samaru 2011-12 and the combined, fruit diameter did not differ significantly with application of 5 and 10 t ha^{-1} of green manure but produced wider fruits than the control. At Kadawa applied 5 t ha^{-1} gave significantly wider fruit diameter but a further addition of green manure rate had no significant effect on fruit diameter. The interaction between the factors on fruits diameter during the period of study was not significant in both locations.

4.3.11 Number of fruits plant^{-1}

Varieties differed significantly on number of fruits per plant at Samaru only in 2011-12 and Kadawa in 2011-12 and in the combined data (Table 25). At both locations, UC82B significantly produced higher number of fruits per plant than Roma VF.

The number of fruits per plant increased with increase in NPK fertilizer applied rate at both locations and years of study (Table 25). At Samaru in 2010-11 and the combined, applied 300 kg ha^{-1} NPK fertilizer significantly resulted to more number of fruits per plant than the lower rates but a further application beyond 300 kg ha^{-1} did not produce any significant increase in fruit number. However there was a decrease in number of fruits with addition of fertilizer rate beyond 300 kg in 2011-12. At Kadawa in 2010-11, application of 450 kg ha^{-1} NPK fertilizer significantly gave more number of fruits per plant than the lower rates applied. In 2011-12 and the combined, application of 150 kg ha^{-1} significantly increased

Table 25: Number of fruits per plant of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Number of fruits plant^{-1}					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	23.2	16.0b	19.6	15.2	41.2b	28.2b
UC82B	22.8	18.0a	20.4	15.2	48.7a	31.9a
SE±	0.62	0.23	0.26	0.19	1.61	0.82
NPK rate kg ha^{-1}(F)						
0	18.7c	15.5b	17.1c	14.3b	38.1b	26.2b
150	21.7b	16.5b	19.1b	14.3b	44.1ab	29.4ab
300	26.8a	19.6a	22.2a	15.0b	49.4a	32.2a
450	24.8a	16.4b	21.6a	16.4a	48.2a	32.2a
SE±	0.87	0.32	0.40	0.27	2.28	1.16
Green manure rate t ha^{-1} (G)						
0	16.5	14.5	15.5b	14.5	40.5b	27.8
5	16.7	15.2	15.9b	15.2	44.7ab	29.6
10	19.5	17.5	18.8a	15.5	49.7a	32.6
SE±	0.88	0.36	0.54	0.35	2.18	1.68
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	**	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **= significant at 1% level of probability. NS = Not significant.

number of fruit per plant but a further increase of NPK rate had no influence on number of fruits per plant.

Varying green manure rate significantly increased number of fruits per plant in the mean at Samaru and 2011-12 only at Kadawa (Table 25). At both locations, application of 10 t ha^{-1} of green manure resulted in significant more number of fruits per plant than the control, although at Kadawa application there was no significant difference between application rate of 5 and 10 t ha^{-1} of green manure.

Interaction between NPK fertilizer and green manure rates on number of fruits per plant in 2011-12 was significant at Kadawa (Table 26) indicated that keeping the green manure rate constant and varying the NPK rate from 0 to 300 kg ha^{-1} statistically produced more number of fruits plant. At 10 t ha^{-1} green manure, increased NPK at 450 kg reduced the number of fruits per plant significantly. Higher fruit number was produced at the combination of 150 kg ha^{-1} NPK fertilizer and 10 t of green manure but similar to 450 kg ha^{-1} NPK at the same rate of green manure.

Table 26: Interaction between NPK fertilizer and green manure rates on number of fruits per plant at Kadawa in 2011-12.

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure (t ha^{-1})				
0	24.0e	35.6cde	54.5ab	47.7bc
5	33.3de	31.4de	54.6ab	51.7ab
10	44.3bcd	54.2ab	62.3a	45.1bcd
SE±		4.36		

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

4.3.12 Weight per fruit (g)

UC82B had significantly produced heavier fruit weight than Roma VF at Samaru in 2011-12 (Table 27).

Application of NPK fertilizer was significant on fruit weight at Kadawa in 2010-11 and the combined analysis (Table 27). In 2010-11 and the combined data, application of NPK fertilizer at 150 kg ha^{-1} produced significantly heavier weight per fruit than the control but further increase of NPK fertilizer did not increased fruit weight. However there was no significant difference between application at 150 kg ha^{-1} NPK fertilizer and control in the mean data.

Green manure application significant influenced weight per fruit in 2010-11 and the combine mean at Kadawa (Table 27). In 2010-11 and combined application means, of green manure of 10 t ha^{-1} increased weight per fruit than the control, however 5 and 10 t ha^{-1} were statistically at par. None of the factors interaction was significant throughout the year and the combined data at both locations.

4.3.13 Fruit weight plant^{-1} (kg)

Table 28, showed the response of variety on fruit weight plant. Varietal response was significant only in 2011-12 in both locations where UC82B had significantly produced heavier fruit weight per plant than Roma VF which produced 20.3% and 31.5% higher in Samaru and Kadawa.

Table 27: Weight per fruit (g) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Weight per fruit (g)					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	38.7	36.1b	37.4	48.7	46.9	47.8
UC82B	36.8	38.5a	37.2	43.8	49.2	47.0
SE±	1.42	0.70	0.75	1.63	1.09	0.97
NPK rate kg ha^{-1}(F)						
0	35.5	37.5	36.5	47.5b	46.3	46.9b
150	37.6	37.8	37.7	48.5a	48.1	48.4ab
300	36.8	37.9	37.3	48.6a	49.5	49.5a
450	39.1	35.9	36.8	51.3a	48.4	50.1a
SE±	2.01	0.99	1.06	2.31	1.55	1.37
Green manure rate t ha^{-1} (G)						
0	36.9	36.6	37.2	44.5b	46.5	45.5b
5	37.5	37.2	37.3	46.2ab	48.2	47.2ab
10	36.6	38.1	37.3	49.5a	48.4	49.4a
SE±	1.13	0.99	0.94	1.26	1.21	1.24
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

Table 28: Fruit weight plant^{-1} (kg) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Fruit weight plant^{-1} (kg)					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	0.51	0.58b	0.54	0.30	0.29b	0.34
UC82B	0.45	0.69a	0.57	0.27	0.45a	0.36
SE±	1.080	0.470	0.607	0.363	0.262	0.221
NPK rate kg ha^{-1}(F)						
0	0.31c	0.58b	0.44c	0.20b	0.40	0.30b
150	0.46b	0.62b	0.54b	0.30a	0.42	0.36a
300	0.61a	0.71a	0.63a	0.30a	0.45	0.38a
450	0.55ab	0.64b	0.62ab	0.35a	0.43	0.39a
SE±	1.52	0.660	0.850	0.513	0.371	0.313
Green manure rate t ha^{-1} (G)						
0	0.43b	0.60b	0.52b	0.25b	0.40b	0.34b
5	0.44b	0.64ab	0.54b	0.28ab	0.42ab	0.34b
10	0.58a	0.67a	0.63a	0.32a	0.46a	0.39a
SE±	0.911	0.608	0.780	0.53	0.35	0.44
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

NPK fertilizer application significantly influenced fruit weight per plant in both years and the combined mean at Samaru and at Kadawa in 2010-11 and the combined mean (Table 28). At Samaru in 2010-11, application of NPK fertilizer of 300 kg ha^{-1} significantly increased fruits weight per plant but further addition of NPK decreased fruits weight per plant. In 2011-12 and combined a similar trend was observed in which 300 kg ha^{-1} resulted to heavier fruit weight per plant than the lower rate. At Kadawa 2010-11 and combined mean, application of 150 kg ha^{-1} resulted to significant increase in fruits weight per plant but a further addition of NPK fertilizer rate did not increase fruits weight per plant significantly.

At both locations and years of study, incorporating green manure significantly increased fruit weight per plant (Table 28). Application of green manure at 10 t ha^{-1} produced significantly heavier fruits weight per plant than the control treatment at both locations. None of the factors interaction was significant during the years and the combined at both locations.

4.3.14 Total fruit yield (t ha^{-1})

At both locations, the variety differs significantly on total fresh yield per ha^{-1} in 2011-12 and the combined mean (Table 29)**.** At Samaru, UC82B produced significantly higher total fruit yield ha^{-1} than Roma VF where it had 20.0% and 10.6% more fruits in 2011-12 and the combined. Similarly at Kadawa, total fruit yield ha^{-1} was higher in variety UC82B than Roma VF with 30.35 and 11.3% in 2011-12 and combined.

Applied NPK fertilizer significantly influenced total fruit yield ha^{-1} in all the years of study and the combined data at both locations (Table 29).

Table 29: Total fresh fruit yield (t ha^{-1}) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Total fresh fruit yield (t ha^{-1})					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	10.9	11.5b	11.2b	9.5	10.0b	9.8b
UC82B	10.9	13.8a	12.4a	8.9	12.5a	10.7a
SE±	0.40	0.29	0.25	0.28	0.27	0.19
NPK rate kg ha^{-1}(F)						
0	8.0c	11.5b	9.8c	7.1b	9.8b	8.5c
150	10.5b	12.4b	11.5b	7.4b	10.9a	9.2b
300	12.7a	14.2a	13.5a	10.5a	12.2a	11.4a
450	12.5a	12.5b	12.5ab	8.5a	11.9a	10.2ab
SE±	0.57	0.42	0.36	0.40	0.39	0.27
Green manure rate t ha^{-1} (G)						
0	10.3b	12.1b	11.2b	8.8b	10.3b	9.6b
5	10.3b	12.0b	11.4b	9.1ab	10.7b	9.9b
10	12.1a	13.3a	12.7a	10.1a	12.7a	11.4a
SE±	0.48	0.38	0.38	0.42	0.45	0.45
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	**	NS	*	**
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability, *= significant at 5% level of probability, **= significant at 1% level of probability. NS = Not significant.

At Samaru 2010-11, application of NPK fertilizer at 300 kg ha^{-1} produced significantly higher total fruit yield ha^{-1} than 150 kg ha^{-1} and the control but further addition of fertilizer did not significantly produce more fruit ha^{-1}. In 2011-12 and combined data, applied 300 kg ha^{-1} NPK fertilizer significantly increased total fruit yield ha^{-1}, however further NPK fertilizer application to 450 kg ha^{-1} significantly decreased total fruit yield ha^{-1}. At Kadawa in both years of study, application of 300 kg ha^{-1} produced significantly more total yield than the lower rate and control.

Green manure application significantly influenced total fruit yield ha^{-1} at both years of study and the combined analysis at both locations (Table 29). Application of 10 t ha^{-1} produced significantly higher total fruit yield ha^{-1} than 5 t ha^{-1} and the control in all the years of experimentation.

NPK fertilizer and green manure rates interaction was significant on total fresh fruit yield at Samaru in the combined mean is presented in Table 30. The result indicated that the combination of 150 kg ha^{-1} NPK fertilizer and 10 t ha^{-1} green manure produced the highest total fresh fruit yield which was similar to combined application of 300 kg NPK fertilizer and 10 t of green manure.

Interaction between NPK fertilizer and green manure rates was significant on total fresh fruit yield ha^{-1} at Kadawa in 2011-12 and in the combined means (Table 30). The interaction between NPK and green manure on total fresh fruit yield ha^{-1} showed that the combination of NPK fertilizer 300 kg ha^{-1} and l0 t ha^{-1}of green manure rate gave highest total fresh fruit yield ha^{-1} but similar to combination of 150 kg ha^{-1} NPK and 10 t ha^{-1} green manure and the control gave the lowest total fruit yield ha^{-1}.

Table 30: Interaction between NPK fertilizer and green manure rates on total fresh yield t ha^{-1} at Samaru (mean), Kadawa in 2011-12 and mean.

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})		**Samaru (Mean)**		
0	8.1e	9.7cd	10.5bc	9.9cd
5	9.3d	9.9cd	10.7bc	10.4bc
10	10.3bcd	12.5a	12.7a	10.9b
SE±		0.29		
		Kadawa 2011-12		
0	10.0f	10.6ef	11.3bcde	11.1def
5	10.3ef	10.8ef	11.5abcd	11.3bcde
10	11.3bcde	11.9abc	12.5a	12.3ab
SE±		0.35		
		Kadawa (Mean)		
0	9.0e	9.4de	10.5abc	9.9bcd
5	9.2de	9.6cde	10.7ab	10.2bcd
10	10.0bcd	10.8ab	11.4a	10.8ab
SE±		0.36		

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

4.3.15 Marketable yield (t ha^{-1})

The response of variety was significant on marketable yield in 2011-12 and combined data at both locations (Table 31). At both locations, UC82B produced significantly higher marketable yield ha^{-1} than Roma VF.

At Samaru, NPK fertilizer application at 300 kg ha^{-1} in 2010-11 significantly increased marketable yield over lower rate and control treatment but a further increase of NPK fertilizer to 450 kg ha^{-1} did not increase marketable yield and a similar trend was observed in the combined mean (Table 31). In 2011-12, application of 300 kg ha^{-1} NPK fertilizer significantly resulted to an increased marketable yield than the lower rate applied. Also at Kadawa, in all the years of study marketable yield increases with increased fertilizer rates of 300 kg ha^{-1} beyond which there was no significant increase on marketable yield.

At both locations, green manure rate significantly increased marketable yield ha^{-1} in all years of study and the combine mean (Table 31). In all cases, application of 10 t ha^{-1} green manure resulted to significant increase marketable yield than 5 t ha^{-1} green manure and control treatments. However in all cases, applied 5 t ha^{-1} of green manure and control treatment were similar except at Samaru in 2011-12 where application of 5 and 10 t ha^{-1} of green manure did not differ significantly.

NPK fertilizer and green manure rates interaction was significant on marketable yield at Samaru in combined mean is presented in Table 32. The result indicated that the combination of 300 kg ha^{-1} NPK fertilizer and 10 t ha^{-1}green manure produced the highest marketable fruit yield which was similar to combined application of 150 kg NPK fertilizer

Table 31: Marketable yield (t ha^{-1}) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Marketable yield (t ha^{-1})					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	10.0	10.7b	10.4b	8.8	9.9b	9.4b
UC82B	10.1	13.0a	11.6a	8.2	12.4a	10.3a
SE±	0.37	0.31	0.26	0.29	0.27	0.20
NPK rate kg ha^{-1}(F)						
0	6.9c	11.0b	9.0c	6.5b	9.8b	8.2b
150	9.6b	11.5b	10.6b	6.8b	10.2ab	8.5b
300	12.0a	13.3a	12.5a	9.9a	12.1a	11.0a
450	11.7a	11.5b	11.9a	8.7a	11.8a	9.3a
SE±	0.53	0.43	0.37	0.41	0.38	0.28
Green manure rate t ha^{-1} (G)						
0	9.5b	9.1b	9.3b	8.3b	10.2b	9.3b
5	9.4b	11.5a	10.5b	8.7b	10.7b	9.7b
10	11.2a	12.5a	11.9a	9.5a	12.6a	11.7a
SE±	0.25	0.36	0.31	0.28	0.20	0.24
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	**	NS	**	**
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **= significant at 1% level of probability. NS = Not significant.

Table 32: Interaction between NPK fertilizer and green manure rates on marketable yield (t ha^{-1}) at Samaru (mean), Kadawa in 2011-12 and mean.

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})		**Samaru (Mean)**		
0	6.9e	9.0cd	11.2ab	10.7bc
5	8.5de	10.0b	11.4ab	10.8bc
10	10.2bcd	12.9a	13.2a	11.0b
SE±		0.73		
		Kadawa 2011-12		
0	7.0e	9.0cde	13.2ab	10.2bc
5	8.3de	7.9de	13.1ab	12.8bcd
10	11.2bcd	13.4ab	15.1a	12.7bcd
SE±		0.89		
		Kadawa (Mean)		
0	7.3d	8.9c	9.7bc	9.0bc
5	8.5c	9.1bc	9.9bc	9.5bc
10	9.5bc	11.9a	12.0a	10.1b
SE±		0.36		

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

and 10 t ha^{-1} of green manure. However, the control treatments produced the lowest marketable yield.

Interaction between NPK fertilizer and green manure rates was significant on marketable fruit yield ha^{-1} at Kadawa in 2011-12 (Table 32). The interaction between NPK and green manure on marketable fruit yield ha^{-1} showed that the combination of NPK fertilizer 300 kg ha^{-1} and l0 t $ha^{-1}$of green manure rate gave highest marketable fruit yield ha^{-1} and combination in the control of both gave the lowest yield of 7.0 t ha^{-1} total fruit yield ha^{-1}.

The interaction between NPK fertilizer and green manure rates on marketable yield at Kadawa in the mean data is presented in Table 32. Using green manure at the control treatment while varying the NPK rate, marketable yield increased with applied NPK at 150 kg ha^{-1} further increase of fertilizer beyond 150 kg did not produced any significant increase on marketable yield. Application of 10 t ha^{-1} green manure combined with 150 kg NPK fertilizer produced the highest marketable yield which was similar to applied 300 kg NPK fertilizer. The lowest marketable yield was obtained on the control plots.

4.3.16 Nonmarketable yield (t ha^{-1})

Variety had no significant difference on nonmarketable yield in all the years and the combined data at both locations of Study (Table 33).

NPK fertilization influenced the nonmarketable yield in all the years at Samaru while at Kadawa in 2010-11 and combined analysis (Table 33). At Samaru, applied 450 kg ha^{-1} of NPK fertilizer produced significantly highest nonmarketable fruit yield than the control treatments in all the years and combined data while at Kadawa, a similar trend was

Table 33: Nonmarketable yield (t ha^{-1}) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Nonmarketable yield (t ha^{-1})					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	0.87	0.81	0.84	0.66	0.05	0.36
UC82B	0.83	0.84	0.83	0.67	0.06	0.36
SE±	0.054	0.057	0.040	0.060	0.004	0.030
NPK rate kg ha^{-1}(F)						
0	0.65c	0.58b	0.75b	0.53	0.05	0.27b
150	0.94ab	0.85a	0.82ab	0.64	0.07	0.35ab
300	0.75bc	0.85a	0.82ab	0.77	0.07	0.41a
450	1.06a	0.95a	0.95a	0.74	0.06	0.40ab
SE±	0.076	0.080	0.056	0.084	0.006	0.042
Green manure rate t ha^{-1} (G)						
0	0.81	0.89	0.85	0.67	0.06	0.35
5	0.84	0.87	0.83	0.68	0.06	0.37
10	0.89	0.76	0.82	0.64	0.07	0.36
SE±	0.068	0.091	0.068	0.067	0.007	0.036
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **= significant at 1% level of probability. NS = Not significant.

observed only in the mean data. However, applied 150 and 450 kg ha^{-1} NPK fertilizer rates were at par.

Table 33 present response of tomato to green manure rates on nonmarketable fruit yield. Green manure had no effect on nonmarketable fruit yield ha^{-1} in all the years of study and the combined mean at both locations. Also no significant interaction was noted on nonmarketable fruit yield ha^{-1} among the factors.

4.3.17 Agronomic efficiency (AE)

Agronomic efficiency which is kg of yield per kg consumed fertilizer at Samaru and Kadawa is presented in (Table 34). At Samaru in 2010-11, for NPK using 150 kg ha^{-1} fertilizer had highest agronomic efficiency value (20.2) in both varieties and using 450 kg ha^{-1} had the lowest (0.5). In 2011-12, using 150 or 300 kg ha^{-1} NPK fertilizer are similar which is higher than 450 kg ha^{-1}. In the combined, the result showed that among the three NPK fertilizers rate both varieties had better performance using 150 kg than higher rate meaning that further increase of fertilizer rate decreased agronomic efficiency. At Kadawa in all the years of study and combined, Roma VF had the best performance using 150 kg while UC82B was inconsistent between 150 and 300 kg ha^{-1}, though in combined data crop efficiency per consuming fertilizer is more than 150 kg ha^{-1}.

At both locations, years of study and the combined, green manure application on agronomic efficiency is presented in (Table 34). At both locations better agronomic efficiency was attained using 10 t ha^{-1} of green manure for both varieties studied.

Table 34: Agronomic efficiency of tomato varieties in response to NPK fertilizer and green manure rate at Samaru and Kadawa in 2010-11, 2011-12 dry seasons and mean.

		Agronomic efficiency (kg kg^{-1})					
		Samaru			**Kadawa**		
Variety	**NPK (kg ha^{-1})**	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Roma VF	0	-	-	-	-	-	-
	150	20.2	7.7	14.1	10.9	4.8	8.0
	300	8.9	7.7	8.3	2.1	8.1	5.1
	450	0.5	4.8	3.0	4.7	0.7	2.9
UC82B	0	-	-	-	-	-	-
	150	20.2	9.2	15.0	2.0	10.2	5.5
	300	8.9	9.2	9.2	10.2	6.0	8.7
	450	0.5	5.8	3.1	4.4	0.9	2.7
Variety	**GM (t ha^{-1})**						
Roma VF	0	-	-	-	-	-	-
	5	0.2	0.6	0.4	0.0	0.2	0.1
	10	0.2	0.8	0.5	0.2	2.7	1.5
UC82B	0	-	-	-	-	-	-
	5	0.2	2.6	1.2	3.2	1.4	2.3
	10	1.5	2.1	1.8	3.9	2.2	2.6

GM= Green manure

4.4 Fruit Proximate Analysis

4.4.1 Total soluble solid (^{0}Brix)

Neither Roma VF nor UC82B was significant on total soluble solids (TSS) of fruits in both locations and years except at harvest in Kadawa 2010-11 (Table 35). The result shows that Roma VF had significantly higher TSS than UC82B which was 13.5% higher at Kadawa.

Application of NPK fertilizer significantly influenced the total soluble solids at both locations (Table 35). At Samaru at harvest in 2010-11, applied NPK fertilizer at 450 kg ha^{-1} significantly increased total soluble solids of fruit but was statistically similar with 300 kg ha^{-1} of NPK fertilizer. However there was no significant difference between the control and 300 kg ha^{-1}. At 5 days after harvest (DAH) in 2010-11, the level of total soluble solid was not consistent; however application of 300 kg ha^{-1} of NPK fertilizer had significantly resulted in higher TSS than 150 kg ha^{-1} which had significantly lower. In 2011-12, there was no significant effect on total soluble solid after harvest except at harvest where application of 150 kg NPK fertilizer ha^{-1} had significantly lower in TSS. However at Kadawa in 2010-11, at harvest and 5 days after harvest increasing NPK from 0 to 150 kg ha^{-1} significantly increased TSS of tomato fruits but a further addition did not had significant increase of TSS. At 10 days after harvest, application of 150 kg ha^{-1} had significantly increased TSS than the control. Although application of 150 and 450 kg ha^{-1} NPK fertilizer was at par while application of 300 kg ha^{-1} and control were statistically similar. In 2011-12 similar result was obtained with NPK fertilization on TSS, in which application of 150 kg ha^{-1} increased TSS significantly but a further increase in NPK fertilizer at 150 kg ha^{-1} upwards had no significant effect on total soluble solids of the fruits.

Table 35: Total soluble solids (^{0}Brix) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11and 2011-12 dry seasons.

	2010-11						2011-12					
	Samaru			**Kadawa**			**Samaru**			**Kadawa**		
Treatment	At harvest	5DAH	10DAH	At harvest	5DAH	10DAH	At harvest	5DAH	10DAH	At harvest	5DAH	10DAH
Variety (V)												
Roma VF	4.9	5.8	5.1	4.2a	6.2	5.8	4.2	5.6	4.9	3.9	6.3	5.8
UC82B	4.6	6.1	4.8	3.7b	6.3	6.1	4.4	6.1	4.9	3.9	6.2	6.0
SE±	0.20	0.24	0.16	0.15	0.17	0.16	0.19	0.33	0.27	0.08	0.18	0.20
NPK rate kg ha^{-1}(F)												
0	4.2b	5.9ab	5.1	3.5b	5.2b	5.3c	3.8ab	6.2	4.7	3.2b	5.4b	5.5b
150	4.4ab	5.4b	5.2	4.3a	6.8a	6.5a	3.7c	5.9	5.1	4.4a	6.3a	5.6ab
300	5.2a	6.6a	4.8	3.8ab	6.7a	5.8bc	4.6ab	5.6	4.9	3.5b	6.5a	6.2ab
450	5.2a	6.0ab	4.7	4.2ab	6.2a	6.4ab	4.9a	5.6	4.9	4.6a	6.7a	6.5a
SE±	0.28	0.34	0.23	0.21	0.24	0.22	0.27	0.47	0.33	0.12	0.26	0.28
Green manure rate t ha^{-1} (G)												
0	3.8b	4.8b	4.5b	3.5b	5.7b	5.5	4.8ab	5.9ab	5.3	3.7b	5.9b	5.7
5	4.6b	5.7b	4.9ab	3.8b	6.1b	6.0	3.7b	4.9b	4.7	3.8b	6.2b	5.9
10	5.8a	6.5a	5.5a	4.5a	6.9a	6.4	4.8ab	6.8a	4.8	4.3a	6.7a	6.2
SE±	0.27	0.32	0.32	0.15	0.24	0.31	0.27	0.42	0.29	0.11	0.24	0.29
Interaction												
F x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. DAH = Days after harvest, NS = Not significant.

Incorporation of green manure significantly affected TSS in all the sampling period in 2010-11 and at harvest and 5 days after harvest in 2011-12 (Table 35). At all the sampling period application of green manure rate at 10 t ha^{-1} resulted to significantly higher TSS in 2010-11 and while control produced lowest TSS. Similarly at harvest and 5 days after harvest significant increase was noted on TSS with application of green manure at 10 t ha^{-1}. Interaction among the factors was not significant in all the sampling periods. At Kadawa application of green manure rate significantly affected TSS of fruits at harvest and 5 days after harvest in 2010-11 and 2011-12 (Table 35). The result showed that application of green manure rate at 10 t ha^{-1} produce higher TSS than 5 t ha^{-1} green manure and the control at both years

4.4.2 Fruit dry matter (%)

Variety differs significantly on fruit dry matter % throughout the study period and their means in both locations (Table 36) where Roma VF produced significantly more fruit dry matter than UC82B at both locations.

Application of NPK fertilizer significantly influenced fruit dry matter content throughout the years of study and their combined means at both locations (Table 36). Increased NPK fertilizer up to 300 kg ha^{-1} significantly increased fruit dry matter content beyond which there was no increment at both locations and years of study.

Green manure application significantly influenced fruit dry matter content throughout the period of study and their combined data (Table 36). At Samaru in 2011-12 and the mean fruit dry matter significantly increased with the corresponding increase of green manure rates while at Kadawa, application of 5 t ha^{-1} significantly produced higher fruit dry matter than the

Table 36: Fruit dry matter (%) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11, 2011-12 dry seasons

	Fruit dry matter (%)					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	6.8a	6.9a	6.9a	5.8a	5.3a	5.5a
UC82B	5.4b	5.4b	5.4b	4.7b	4.4b	4.6b
SE±	0.11	0.07	0.07	0.12	0.06	0.11
NPK rate kg ha^{-1}(F)						
0	5.8b	5.8b	5.8b	4.9b	5.0	4.9b
150	5.9b	6.4a	6.2ab	4.8b	4.9	4.9b
300	6.5a	6.2ab	6.3.a	6.7a	4.7	5.7a
450	6.3ab	6.1ab	6.2ab	4.6b	4.7	4.7b
SE±	0.15	0.10	0.09	0.33	0.09	0.15
Green manure rate t ha^{-1} (G)						
0	5.8	5.6c	5.7c	4.4b	4.6b	4.5b
5	6.0	6.1b	6.1b	5.5a	5.0a	5.2a
10	6.4	6.7a	6.6a	5.9a	5.0a	5.4a
SE±	0.14	0.09	0.09	0.20	0.08	0.15
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	*	*	**	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **= significant at 1% level of probability. *= significant at 5% level of probability. NS = Not significant.

Table 37: Interaction between NPK fertilizer and green manure rates on fruit dry matter (%) at Samaru in 2010-11, 2011-12 and mean.

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})		**2010-11**		
0	5.1e	6.1abcd	5.9bcd	6.8ab
5	6.5abc	6.1bcd	5.9bcd	5.6cde
10	6.7abc	6.5abc	7.0a	5.5cde
SE±	0.29			
		2011-12		
0	5.2e	5.4de	5.5de	6.2bc
5	6.1c	6.0cd	5.7cde	6.6ab
10	6.7a	6.9a	6.9a	6.2bc
SE±	0.39			
		Mean		
0	5.7d	5.8cd	5.2e	6.5ab
5	6.3ab	6.1bc	5.8cd	6.1bc
10	6.9a	6.7a	6.7a	5.8cd
SE±	0.15			

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

control beyond which there was no significant increase throughout the years and the combined mean.

Interaction between NPK and green manure was significant on fruit dry matter content in all the years at Kadawa and the combined mean (Table 37). In both years and the combined data, NPK fertilizer at 300 kg ha^{-1} and incorporation of green manure at 10 t ha^{-1} increased fruit dry matter significantly while the least was obtained in the control treatments.

4.4.3. Carbohydrate (%)

Variety did not differ significantly on percentage carbohydrate of the fruit through the years and the combined mean in both locations (Table 38).

Application of NPK fertilizer significantly affected fruit carbohydrate (%) in all the years of study and the combined mean at Samaru and Kadawa in 2010-11 (Table 38). In all the years and the combined at Samaru, application of NPK fertilizer from 0 to 300 kg ha^{-1} significantly decreased the percent carbohydrate content of tomato fruits but further addition of NPK did not significantly decreased the amount of carbohydrate in the fruit while at Kadawa, application of 150 kg ha^{-1} significant increased carbohydrate content but beyond this level there was significant decline on carbohydrate content of fruit. Although applied 450 kg ha^{-1} of NPK fertilizer was statically at par with application at 300 kg ha^{-1}.

Green manure significantly affected the amount of carbohydrate content in fruits in 2010-11 and the combined mean at Samaru (Table 38). In 2010-11, and combined analysis from 0 to 5 t ha^{-1} did not show significantly increased the percent carbohydrate but beyond 5 t ha^{-1} there was decrease in carbohydrate content which was similar with the control. At Kadawa, green

Table 38: Carbohydrate (%) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Carbohydrate (%)					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	55.1	55.6	55.4	55.3	57.3	56.4
UC82B	55.7	55.9	55.8	59.7	57.7	58.8
SE±	0.16	0.14	0.41	0.23	0.32	0.21
NPK rate kg ha^{-1}(F)						
0	56.2a	56.2a	56.4a	57.7ab	57.9	57.8
150	56.5a	56.4a	56.2a	58.0a	57.3	57.9
300	54.7b	54.9b	54.8b	56.7b	57.4	57.1
450	54.3b	55.4b	54.8b	57.5ab	56.9	57.2
SE±	0.21	0.20	0.58	0.32	0.46	0.30
Green manure rate t ha^{-1} (G)						
0	55.4ab	55.7	55.5ab	57.8	57.7	55.4
5	55.7a	55.9	55.8a	57.2	57.1	57.5
10	55.1b	55.7	55.4b	57.5	57.6	57.6
SE±	0.13	0.18	0.11	0.26	0.32	0.22
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	**	*	*	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **= significant at 1% level of probability. *= significant at 5% level of probability. NS = Not significant.

Table 39: Interaction between NPK fertilizer and green manure rates on fruit carbohydrate (%) at Samaru in 2010-11, 2011-12 and mean

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})				
		2010-11		
0	57.5a	55.2d	54.8e	54..5e
5	57.2a	56.5b	54.5e	54.5e
10	56.0c	55.7c	54.7e	53.9f
SE±	0.11			
		2011-12		
0	58.0a	55.0d	53.0f	53.0f
5	58.4a	56.0c	53.5e	53.4f
10	56.0c	56.7b	53.8e	51.5g
SE±		0.15		
		Mean		
0	57.3a	55.2e	54.8fg	54.9f
5	57.3a	56.6b	54.5h	54.9f
10	56.0c	55.7d	54.7gh	54.7gh
SE±	0.065			

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

manure rate did not influence the carbohydrate content of the fruit, throughout the years of study and the combined mean.

There was significant interaction between NPK fertilizer and Green manure rates on carbohydrate content of the fruits in the years and the combined at Samaru (Table 39). The interaction showed that the highest carbohydrate content of fruit was obtained at the control treatment in all years of study and the combine data while the lowest carbohydrate percent of fruit was obtained with the combination of NPK at 450 kg ha^{-1} and 10 t $ha^{-1}$of green manure.

4.4.4. Crude fibre (%)

Response of varieties was not significant on crude fibre in all the two years and their combine analysis at both locations (Table 40).

NPK fertilizer application at 150 kg ha^{-1}significnatly reduced the crude fibre content of tomato fruits in all the years and combined (Table 40). NPK fertilizer at150 kg ha^{-1} upwards resulted to further significant reduction in crude fibre at Samaru. At Kadawa, the application of NPK fertilizer was not significant on crude fibre in all the two years of study and their combined data.

At both locations, incorporation of green manure significantly influenced crude fibre contents in all the period of the study except in 2011-12 at Kadawa (Table 40). At Samaru in all years and in the combined mean, application of 5 t ha^{-1} of green manure reduced significantly crude fibre while a further addition to 10 t ha^{-1} had no significant increase on crude fibre. Similar trend was observed at Kadawa where the control treatment resulted in higher crude fibre.

Table 40: Crude fibre (%) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Crude fibre (%)					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	3.1	3.1	3.1	2.5	2.6	2.5
UC82B	3.1	3.1	3.1	2.6	2.5	2.5
SE±	0.05	0.05	0.05	0.10	0.11	0.09
NPK rate kg ha^{-1}(F)						
0	3.5a	3.5a	3.5a	2.7	2.8	2.7
150	3.1b	3.1b	3.1b	2.3	2.6	2.4
300	3.1b	3.1b	3.1b	2.8	2.5	2.7
450	2.9b	2.9b	3.1b	2.3	2.4	2.4
SE±	0.07	0.07	0.07	0.14	0.15	0.13
Green manure rate t ha^{-1} (G)						
0	3.3a	3.3a	3.3a	2.9a	2.8	2.9a
5	2.9b	2.9b	2.9b	2.6b	2.5	2.6b
10	3.0b	3.1b	3.0b	2.3b	2.5	2.4b
SE±	0.06	0.08	0.07	0.11	0.11	0.10
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	**	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter within the same column and treatment group are not significantly different at 5% level of probability. **= significant at 1% level of probability, NS = Not significant.

Interaction between NPK fertilizer and green manure rates on crude fibre was significant in the combined analysis at Samaru. (Table 41). The interaction between green manure and NPK fertilizer on crude fibre of tomato fruit showed that at given NPK rate, increasing green manure rate significantly reduced crude fibre. On the other hand, at any given green manure rate, increasing NPK fertilizer rate reduces crude fibre content. However, application at control levels of fertilization gave higher crude fibre of the fruits.

Table 41: Interaction between NPK fertilizer and green manure rates on crude fibre (%) at Samaru in mean.

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})				
0	3.75a	2.83e	3.16bc	3.33bc
5	3.25bc	3.16bc	2.42f	2.92de
10	3.41b	3.25bc	3.12cd	2.83e
SE±	0.086			

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

4.4.5. Fruit acidity (%)

The variety significantly differed on fruit acidity in all the years of study and the combine mean where UC82B had significantly lower fruit acidity than Roma VF at Kadawa (Table 42).

NPK fertilization significantly influenced fruit acidity at Samaru in 2010-11 and the combined mean in Kadawa (Table 42). At Samaru in 2010-11, application of 300 kg ha^{-1}

Table 42: Fruit acidity (%) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Fruit acidity (%)					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	0.44	0.44	0.44	0.42a	0.42a	0.42a
UC82B	0.45	0.45	0.45	0.39b	0.40b	0.40b
SE±	0.821	0.003	0.407	0.005	0.004	0.003
NPK rate kg ha^{-1}(F)						
0	0.44b	0.44	0.44	0.40b	0.41	0.40b
150	0.44b	0.44	0.44	0.43a	0.42	0.43a
300	0.46a	0.45	0.45	0.41b	0.40	0.40b
450	0.44b	0.44	0.44	0.41b	0.41	0.41b
SE±	1.154	1.160	0.576	0.007	0.005	0.005
Green manure rate t ha^{-1} (G)						
0	0.43	0.44	0.43	0.40b	0.41	0.40b
5	0.44	0.44	0.44	0.40b	0.41	0.40b
10	0.45	0.44	0.44	0.42a	0.42	0.42a
SE±	1.000	0.007	0.500	0.003	0.006	0.003
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

significantly increased fruit acidity but additional increase of NPK fertilizer to 450 kg ha^{-1} resulted to a decline in fruit acidity. At Kadawa in 2010-11 and combined data, applied NPK fertilizer to 150 kg ha^{-1} significantly resulted to higher fruit acidity but further increase of NPK fertilization significantly decreased the fruit acidity which was statistically similar with the control.

Green manure rate significantly influenced fruit acidity at Kadawa 2010-11 and the combined mean (Table 42). At Kadawa in 2010-11 and in the mean, increasing green manure rate produced significantly higher fruit acidity. No factor interactions were recorded at both locations and their mean.

4.4.6. Crude protein (%)

Response of varieties to crude protein was significant in all the two years and the combined mean at Samaru (Table 43). Crude protein of UC82B was significantly higher than Rama VF in both years at Samaru.

Application of NPK fertilizer significantly enhanced crude protein in all the years of study and their combined means at both locations (Table 43). At Samaru in 2010-11, application of 450 kg ha^{-1} NPK fertilizer significantly increased crude protein than the lower rates; applied NPK fertilizer at 150 and 300 kg ha^{-1} was statistically at par. In 2011-12 and combined mean increase NPK fertilizer from 0 to 150 kg ha^{-1} significantly increased crude protein but further addition of NPK fertilizer rate did not increase crude protein. The combined analysis showed that application of 150 and 300 kg ha^{-1} of NPK significantly increases crude protein than the control, although NPK fertilizer application at 300 and 450 kg ha^{-1} were statistically similar.

Table 43: Crude protein (%) of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Crude protein (%)					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	24.0b	23.7b	23.1b	27.2	26.9	27.1
UC82B	25.5a	24.7a	25.1a	27.1	27.3	27.2
SE±	0.29	0.24	0.25	0.22	0.32	0.22
NPK rate kg ha^{-1}(F)						
0	21.6c	21.7b	21.6c	26.3c	25.9b	26.2b
150	24.5b	24.6a	24.5b	26.4c	26.7b	26.5b
300	25.6b	25.4a	25.5ab	27.4b	27.8a	27.7a
450	27.3a	25.3a	26.3a	28.4a	28.0a	28.2a
SE±	0.42	0.35	0.36	0.31	0.45	0.31
Green manure rate t ha^{-1} (G)						
0	23.8b	23.7b	23.7b	26.9	26.8	27.1
5	24.3b	23.9b	24.1b	27.2	27.2	27.2
10	26.3a	25.0a	25.6a	27.3	27.4	27.1
SE±	0.33	0.30	0.21	0.24	0.38	0.25
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	**	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability.**= significant at 1% level of probability. NS = Not significant.

At Kadawa application of 450 kg ha^{-1} NPK fertilizer significantly increased crude protein in both years and combined mean, however in 2010-11 the application of 150 kg NPK fertilizer and control was similar while in 2011-12 and in combined mean, applied 300 and 450 kg NPK fertilizer was similar and significantly higher than lower rate and control.

Green manure application significantly influenced crude protein in all the years and the combine mean at Samaru (Table 43). In both years, and combined mean, incorporation of green manure at 10 t ha^{-1} produced significantly higher crude protein than the lower rate at Samaru

Interaction between NPK fertilizer and green manure rates was significant on crude protein at Samaru 2011-12 (Table 44). The highest crude protein was obtained in combined use of 300 kg ha^{-1} NPK fertilizer and 10 t ha^{-1} green manure. The lowest crude protein was obtained in the control treatments.

Table 44: Interaction between NPK fertilizer and green manure rates on crude protein (%) at Samaru in 2011-12

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})				
0	20.0e	23.7d	24.9bc	25.3abc
5	20.2e	24.6c	25.4ab	25.4ab
10	24.7c	25.3abc	25.8a	25.2abc
SE±	0.248			

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

4.4.7. Ash (%)

At both years and their combined analysis varieties did not differ significantly on ash percent of fruits at both locations (Table 45).

At both locations, percent ash of fruit was significantly influenced by application of NPK fertilizer in 2010-11 and combined mean at Samaru while in all years at Kadawa (Table 45). At Samaru 2010-11, application of NPK fertilizer at 450 kg ha^{-1} significantly increased percent ash of fruit. In the combined mean, application of 150 kg ha^{-1} did not differ in ash content of the fruit but a further addition of NPK fertilizer up to 300 kg ha^{-1} significantly produced higher ash content of fruit though it was statistically at par with applied 450 kg ha^{-1} while at Kadawa in all the years of study and the combined, increasing NPK fertilizer from up to 300 kg ha^{-1}, significantly produced higher ash content of fruit but a further increment did not significantly increase the ash content.

Green manure application had no significant influence on ash content of the fruits in the years of study and the combined data at both locations (Table 45). No interaction effect among the factors was observed on percent ash of the fruit.

Table 45: Ash **(%)** of tomatoes as affected by varieties, NPK fertilizer and green manure rates at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons.

	Ash (%)					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	9.8	9.7	9.7	7.9	7.8	7.9
UC82B	9.5	10.0	9.8	7.9	7.9	7.9
SE±	0.09	0.15	0.12	0.11	0.09	0.08
NPK rate kg ha^{-1}(F)						
0	9.5c	9.5	9.5b	7.2b	7.4c	7.3c
150	9.8bc	9.7	9.8b	7.5b	7.4c	7.4c
300	10.1b	9.7	10.0ab	8.6a	8.6a	8.6a
450	10.8a	10.1	10.5a	8.3a	8.2b	8.3b
SE±	0.13	0.22	0.17	0.149	0.132	0.107
Green manure rate t ha^{-1} (G)						
0	9.4	10.0	10.0	7.9	8.0	7.9
5	10.0	9.8	9.9	7.9	7.8	7.9
10	10.3	9.7	10.0	7.7	7.7	7.8
SE±	0.13	0.14	0.09	0.11	0.14	0.09
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

4.5 Field Decomposition Pattern

4.5.1 Mass loss (%)

Figures 1 and 2 present the percentage mass loss by decomposing green manure at Samaru and Kadawa. The weight loss of green manure was rapid from the litter bags during the first 14 days, with respect to NPK fertilizer application rate in order of 450, 300, 150 kg ha^{-1} and the control plot throughout the incubation period at both locations. The corresponding mass loss of green manure residue under NPK fertilizer after 10 days were 59.7, 45.9, 43.6, 31.3 and 56.2, 46.7, 36.5, 37.2% at Samaru and Kadawa respectively

4.5.2 Mass remaining (%)

The percent mass remaining of the green manure was more in the control plots than the plots treated with NPK fertilizer rates in a decreasing order as shown in Figures (3 and 4) at Samaru and Kadawa respectively. At the end of 70 days decomposition study, mass remain of fodder from 0, 150, 300 and 450 kg ha^{-1} NPK plots were 36.0, 22.6, 5.8, 3 and 38.1, 28.0, 10.0, 5.8% was yet to decomposed in the soil.

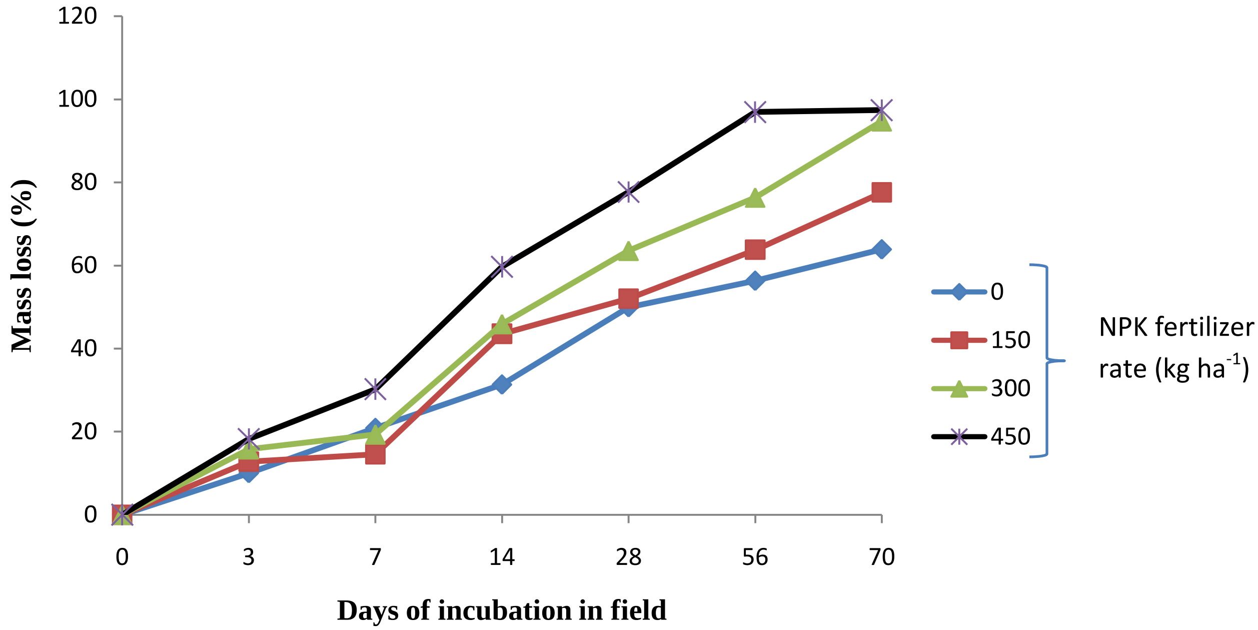

Figure 1: Percent mass loss of green manure as influenced by different NPK fertilizer rate at Samaru

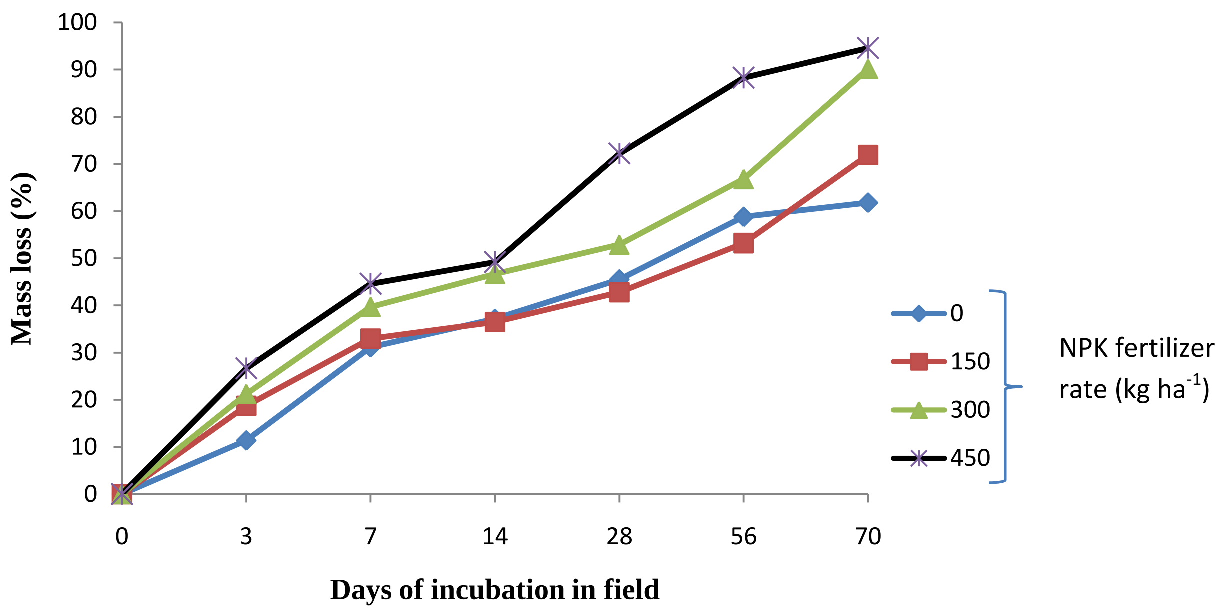

Figure 2: Percent mass loss of green manure as influenced by different NPK fertilizer rate at Kadawa

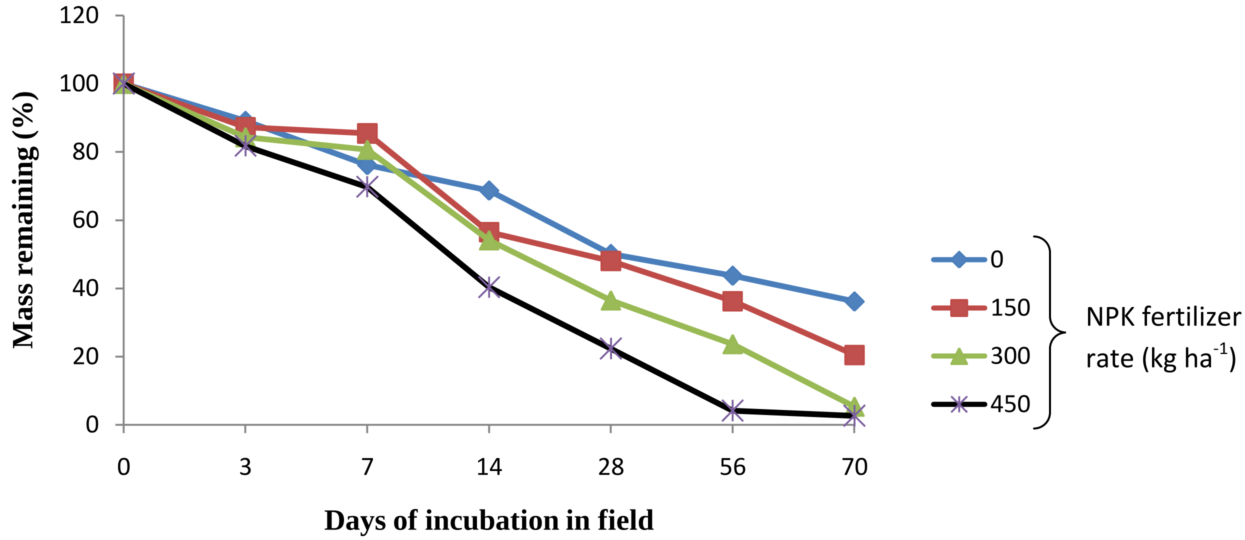

Figure 3: Percent mass remaining of green manure as influenced by different NPK fertilizer rate at Samaru

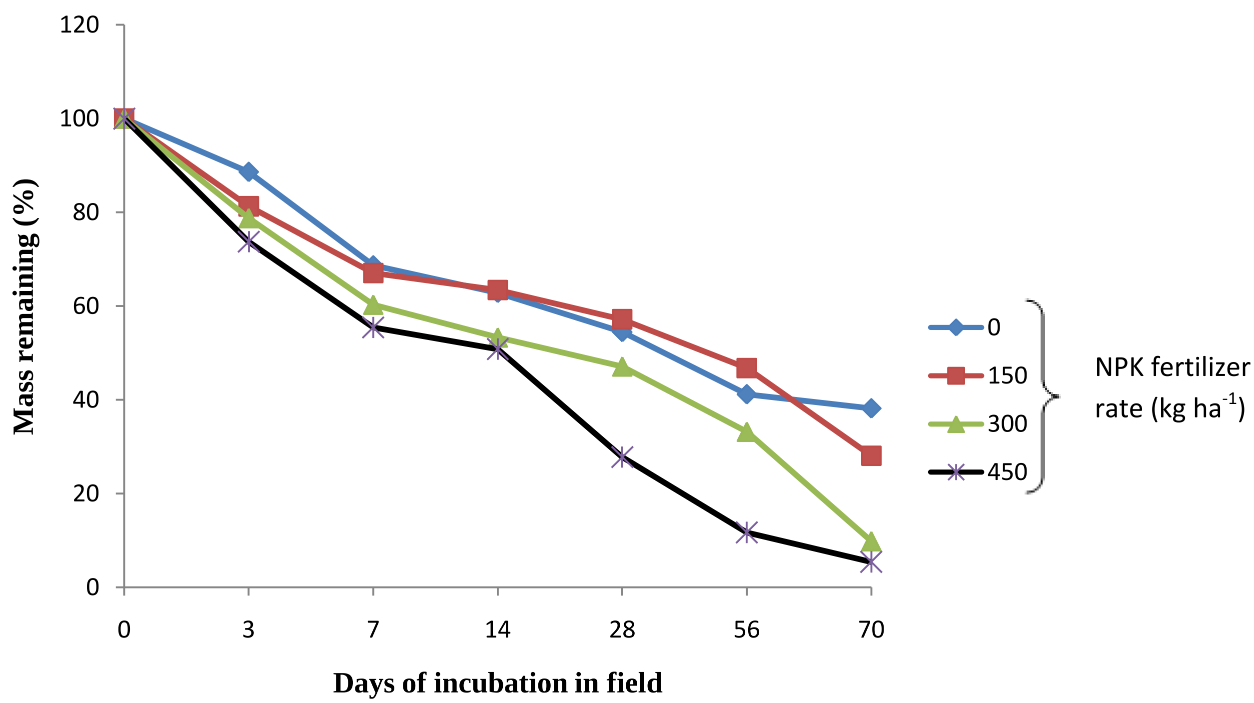

Figure 4: Percent mass remaining of green manure as influenced by different NPK fertilizer rate at Kadawa

4.5.3 Decomposition rate (day^{-1}) and days to 50% decomposition

The decomposition rate was higher at the highest fertilizer rate (450 kg ha^{-1}) and least at the control at both locations (Table 46). The decay constant was also highest at the highest fertilizer rate and least in the control; while the numbers of days to 50% decomposition was higher at the control and least at the highest fertilizer rate (11 days) at both locations.

Table 46: Effect of NPK fertilizer rate on decomposition rate per day, decay constant (k) and decomposition half life values of green manure buried at Samaru and Kadawa.

Treatment NPK rate (kg ha^{-1})	**Decomposition rate (% day^{-1})**	**Decay constant (k)**	**Days to 50% decomposition (t_{50})**
Samaru			
0	2.1	0.0304	22.8
150	2.4	0.0338	20.5
300	3.1	0.0424	16.3
450	4.8	0.0658	10.5
Kadawa			
0	2.6	0.0359	19.3
150	2.7	0.0381	18.2
300	3.5	0.0497	13.9
450	4.8	0.0658	10.5

4.6 Soil Chemical Properties after Harvest

4.6.1 Soil pH

Soil pH was not influenced significantly with cultivation of two tomato varieties at both locations during the experimental period (Table 47).

Application of NPK fertilizer significantly influenced soil pH at both locations, years of study and the combined analysis (Table 47). At Samaru, in all the years and combined mean increasing NPK fertilizer rate from 0 to 150 kg ha^{-1} produced no significant difference on soil pH but further addition of NPK significantly increased soil pH while at Kadawa a similar trend was observed that the soil pH increased with addition of NPK fertilizer.

At both locations incorporation of green manure significantly influenced soil pH in all the years and the combined mean at Samaru and in 2010-11 and combined at Kadawa (Table 47). Application of 10 ha^{-1}green manure resulted to significant improvement of soil pH at both locations; however applied 5 t ha^{-1} improved soil pH than control at Samaru while at Kadawa 5 and 10 t ha^{-1} was at par and significantly improved soil pH than the control treatment.

Interaction between variety and NPK fertilizer was significant on soil pH at Samaru in 2010-11 and combined mean (Table 48). In 2010-11, at given rate of NPK fertilizer there was no significant difference between the two varieties except at 300 kg ha^{-1} upwards where cultivation of Roma VF improved soil pH than UC82B; however at increase rate of NPK fertilizer to 450 kg ha^{-1} cultivation of UC82B had significantly improved soil pH. At given variety, control treatment of NPK fertilizer had significantly better soil pH value while higher rate of NPK fertilizer gave a significant lower soil pH value. In the combined mean; the combination of control treatment (no fertilizer) with any of the variety produce higher soil pH

Table 47: Influence of variety, NPK fertilizer and green manure rates on Soil pH (Water) after harvest at Samaru and Kadawa in 2010-11, 2011-12 and mean.

	Soil pH (Water)					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	5.2	5.3	5.2	5.7	6.1	5.9
UC82B	5.3	5.4	5.3	5.8	6.0	5.9
SE±	0.08	0.13	0.07	0.05	0.02	0.05
NPK rate kg ha^{-1}(F)						
0	6.0a	5.8a	5.9a	6.2a	6.0	6.0a
150	5.9a	5.8a	5.8a	6.0ab	5.9	5.9a
300	4.5b	5.4b	5.0b	5.9b	6.1	6.0a
450	3.8c	4.7c	4.3c	5.1c	6.2	5.6b
SE±	0.12	0.19	0.11	0.07	0.10	0.07
Green manure rate t ha^{-1} (G)						
0	4.3c	4.9c	4.6c	5.3b	6.1	5.7b
5	4.9b	5.3b	5.1b	5.5b	6.0	5.7b
10	6.0a	6.1a	6.1a	6.3a	6.1	6.2a
SE±	0.12	0.13	0.14	0.08	0.09	0.09
Interaction						
F x V	**	NS	**	NS	NS	NS
F x G	**	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. **= significant at 1% level of probability. NS = Not significant.

Table 48: Interaction between NPK fertilizer and variety on soil pH at Samaru in 2010-11 and mean.

	NPK fertilizer (kg ha^{-1})			
Treatment	0	150	300	450
Variety		**2010-11**		
Roma VF	6.7a	5.3b	5.2b	3.6d
UC82B	6.8a	5.1b	3.9d	4.1c
SE±		0.08		
		Mean		
Roma VF	6.3a	5.5b	5.1c	4.1e
UC82B	6.4a	5.4b	4.9c	4.5d
SE±		0.07		

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

Table 49: Interaction between NPK fertilizer and green manure rates on soil pH at Samaru in 2010-11.

	NPK fertilizer rate (kg ha^{-1})			
Treatment	0	150	300	450
Green manure rate (t ha^{-1})				
0	7.a	5.5c	5.6c	4.3de
5	6.3b	5.5c	4.1de	3.8ef
10	6.9a	4.4d	3.8ef	3.5f
SE±	0.17			

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT

value while significantly lower soil pH value obtained at higher NPK fertilizer rate. Regardless of the variety, increasing the NPK rate significant increases of soil pH was observed.

Significant interaction between NPK fertilizer and green manure rates was observed on soil pH at Samaru in 2010-11 (Table 49). The interaction between green manure and NPK fertilizer on soil pH in 2010-11 showed that higher soil pH value was obtained on the control treatments (ie. Neutral soil conditions) while the lower value of soil pH was obtained at 450 kg ha^{-1} NPK fertilizer and 10 t ha^{-1} green manure rates resulting too acidic conditions.

4.6.2 Soil total nitrogen (g kg^{-1})

Soil total N was not affected by cultivation of tomato varieties in all the years of study and at both locations (Table 50).

Application of NPK fertilizer significantly influenced soil total nitrogen in 2011-12 and combined mean at Samaru and Kadawa in 2010-11 (Table 50). At Samaru, 2011-12 and combined mean application of 150 kg ha^{-1} NPK fertilizer resulted to higher soil total nitrogen than 300 and 450 kg ha^{-1} which is significantly lower while at Kadawa in 2010-11 applied NPK fertilizer at 300 kg ha^{-1} significantly reduced soil total nitrogen but a further addition of NPK fertilizer rate increased soil total N which was similar to 150 kg ha^{-1} NPK fertilizer application.

Green manure incorporation significantly influenced soil total N at Kadawa in 2010-11 and the mean analysis (Table 50). In 2010-11 and combined mean, incorporation of green manure 10 t ha^{-1} produced significantly higher on soil total nitrogen than the control treatment but statistically at par with 5 t ha^{-1}. Interactions among factors were not significant.

Table 50: Influence of variety, NPK fertilizer and green manure rates on soil total N (g kg^{-1}) after harvest at Samaru and Kadawa in 2010-11, 2011-12 and mean.

	Soil N (g kg^{-1})					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	0.67	0.70	0.68	0.69	0.71	0.70
UC82B	0.66	0.73	0.70	0.70	0.68	0.69
SE±	0.025	0.014	0.014	0.009	0.013	0.009
NPK rate kg ha^{-1}(F)						
0	0.65	0.72b	0.68b	0.59c	0.71	0.71
150	0.67	0.79a	0.73a	0.71a	0.66	0.68
300	0.64	0.65c	0.64b	0.64b	0.71	0.67
450	0.69	0.71b	0.70ab	0.74a	0.69	0.71
SE±	0.035	0.019	0.020	0.013	0.018	0.013
Green manure rate t ha^{-1} (G)						
0	0.67	0.72	0.69	0.68b	0.71	0.67b
5	0.67	0.71	0.69	0.69ab	0.67	0.68b
10	0.65	0.72	0.68	0.72a	0.70	0.71a
SE±	0.019	0.013	0.014	0.015	0.011	0.010
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

4.6.3 Soil available phosphorus (g kg^{-1})

Soil available P did not differ significantly in both varieties plots at Samaru while at Kadawa in 2010-11 and combined where Roma VF plots had significantly more soil available P than UC82B plots (Table 51).

NPK fertilization significantly influenced soil available P in 2010-11 and combined data at Samaru and all the years at Kadawa (Table 51). At Samaru in 2010-11 and combined data, application of 150 kg ha^{-1} NPK fertilizer significantly increased soil available P but further addition of NPK fertilizer did not increased soil available P. At Kadawa in all the years and combined analysis, applied 450 kg ha^{-1} NPK fertilizer increased soil available P than the lower rate but similar to 300 kg ha^{-1} NPK fertilizer in 2010-11.

Green manure application significantly influenced soil available P in 2010-11 and 2011-12 at Kadawa (Table 51). In 2010-11, increasing green manure rate from 0 to 5 t $ha-^{1}$ significantly produced more soil available P but a further increased did not affect soil available P. In 2011-12 application of green manure rate up to 10 t ha^{-1} produced significantly more soil available P but statistically at par with the control treatment.

4.6.4 Soil exchangeable potassium (cmol kg^{-1})

Soil K significantly influenced tomato varieties at Samaru in 2011-12 and years of study and in the combined at Kadawa (Table 52). At Samaru, soil K significantly increased in Roma VF than UC82B plot while at Kadawa in the combined mean soil K was significantly higher in UC82B than Roma VF plots.

Table 51: Influence of variety, NPK fertilizer and green manure rates on Soil available P (mg kg^{-1}) at Samaru and Kadawa in 2010-11, 2011-12 dry seasons and mean.

	Soil available P (mg kg^{-1})					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	13.3	12.6	12.9	11.7a	11.5	11.6a
UC82B	12.3	11.5	12.6	9.8b	11.3	10.3b
SE±	0.71	0.34	0.36	0.35	0.68	0.29
NPK rate kg ha^{-1}(F)						
0	10.7b	11.8	11.2b	9.4b	11.3b	10.2bc
150	13.6a	11.8	12.8a	7.5b	11.3b	8.7c
300	13.0a	13.1	13.3a	12.3a	9.9b	11.3b
450	14.0a	13.7	13.6a	13.8a	13.4a	13.5a
SE±	1.01	0.49	0.51	0.50	0.97	0.41
Green manure rate t ha^{-1} (G)						
0	12.1	11.8	12.1	9.2b	11.2ab	10.5
5	13.5	12.7	13.2	11.6a	10.1b	11.0
10	12.8	13.3	12.9	11.4a	12.9a	11.3
SE±	0.53	0.47	0.41	0.51	0.45	0.41
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

Table 52: Influence of variety, NPK fertilizer and green manure rates on Soil K (cmol kg^{-1}) at Samaru and Kadawa in 2010-11, 2011-12 dry seasons and mean data.

	Soil K (cmol kg^{-1})					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	0.38	0.30a	0.34	0.12b	0.12b	0.12b
UC82B	0.39	0.28b	0.34	0.14a	0.62a	0.32a
SE±	0.015	0.007	0.007	0.027	0.094	0.049
NPK rate kg ha^{-1}(F)						
0	0.29d	0.25c	0.27c	0.11	0.12b	0.12b
150	0.37c	0.29b	0.35b	0.12	0.12b	0.12b
300	0.42b	0.32a	0.35b	0.12	0.12b	0.12b
450	0.47a	0.32a	0.39a	0.13	1.12a	0.52a
SE±	0.021	0.011	0.010	0.038	0.133	0.070
Green manure rate t ha^{-1} (G)						
0	0.37b	0.28	0.33	0.12	0.11b	0.12b
5	0.38b	0.29	0.34	0.11	0.31ab	0.11b
10	0.41a	0.29	0.34	0.13	0.66a	0.42a
SE±	0.016	0.010	0.013	0.016	0.141	0.099
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

At both locations, NPK fertilizer application significantly influenced soil exchangeable K in the years of study and the combined mean (Table 52). At Samaru in 2010-11, significant increase in soil K was observed with the corresponding increased in NPK fertilizer rates. In 2011-12 and combined, application of NPK fertilizer at 150 kg ha^{-1} resulted in significant increase in soil exchangeable K, however, no significant difference between application of NPK fertilizer at 300 and 450 kg ha^{-1} in 2011-12 while at Kadawa in 2011-12 and combined mean, 450 kg ha^{-1} NPK fertilizer significantly produced more soil exchangeable K than lower rates applied

Application of green manure rates significantly influenced soil exchangeable K at Samaru in 2011-12 and the combined at Kadawa (Table 52). Application of 10 t ha^{-1} of green manure increased soil exchangeable K than the control No factor interaction at both locations throughout the study period.

4.6.5 Soil C:N

Soil C:N significantly differ in tomato varieties plots at Samaru in 2010-11 and the combined mean at Kadawa (Table 53). At Samaru in 2010-11, Roma VF plots had higher soil C:N ratio than UC82B while at Kadawa UC82B plots had significantly higher soil C:N than Roma VF plots in 2010-11 and the combined mean.

At both locations, years of study and their combined mean, application of NPK fertilizer significantly influenced soil C:N (Table 53). Throughout the years at both locations, increasing rate of NPK fertilizer significantly reduced soil C:N ratio. However, the control plots produced higher ratios of soil C:N at both locations but similar to application of 150 kg ha^{-1} at Samaru in both years of study and the mean.

Table 53: Influence of variety, NPK fertilizer and green manure rates on Soil C: N at Samaru and Kadawa in 2010-11, 2011-12 dry seasons and mean data.

	Soil C: N					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	17.3a	11.0	12.0b	9.9b	13.1	11.5b
UC82B	13.0b	13.1	15.2a	13.7a	14.1	13.9a
SE±	0.52	0.75	0.57	0.37	0.69	0.46
NPK rate kg ha^{-1}(F)						
0	18.0a	13.5a	15.0a	14.7a	16.39a	15.6a
150	16.6a	14.5a	15.5a	13.1a	13.1b	13.1b
300	13.2b	10.1b	11.6b	10.7b	12.1b	11.4c
450	12.7b	10.7b	11.8b	8.8c	12.0b	10.4d
SE±	0.75	1.06	0.81	0.53	0.97	0.65
Green manure rate t ha^{-1} (G)						
0	16.6a	13.2a	14.8a	13.4a	15.2a	14.3a
5	14.7ab	12.7a	13.7a	12.5a	13.5b	13.0b
10	13.1b	10.2b	11.2b	9.6b	12.1c	10.8c
SE±	0.73	0.40	0.53	0.35	0.45	0.41
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

Green manure application significantly reduced soil C:N ratio at both locations with increased rates (Table 53). At Samaru through the period of study and at Kadawa in 2010-11, application of 5 t ha^{-1} did not differed significantly with control plots. However, C:N ratio was narrowed with increasing rates of green manure in 2011-12 and the combined mean. The factor interactions were not significant throughout the study period.

4.6.6. Soil Organic Carbon (g kg^{-1})

Soil organic carbon was not enhanced by the cultivation of either Roma VF or UC82B at both locations and the years of study (Table 54).

At both locations and years of study, NPK application significantly influenced soil organic carbon (Table 54). At Samaru, in all cases higher rate of 450 kg ha^{-1} NPK fertilizer resulted in reduction of soil organic carbon. At Kadawa in all years and the combine mean, application of 300 kg ha^{-1} NPK fertilizer produced significantly higher soil organic carbon than application of 150 and 450 kg ha^{-1} NPK fertilizer which was also similar to the control.

Soil organic carbon was significantly influenced by green manure application at Samaru in 2010-11 and at Kadawa in 2010-11 and the combined means (Table 54). At both locations, applied 10 t ha^{-1} of green manure significantly increased soil organic carbon over the control treatment. There was no significant interaction among the factors on soil organic carbon.

4.6.7. Soil Organic Matter (g kg^{-1})

Soil organic matter did not differ significantly by the cultivation of the two tomato varieties (Roma VF and UC82B) at both locations (Table 55).

Table 54: Influence of variety, NPK fertilizer and green manure rates on soil organic carbon ($g\ kg^{-1}$) at Samaru and Kadawa in 2010-11, 2011-12 dry seasons and mean.

	Soil organic carbon ($g\ kg^{-1}$)					
	Samaru			Kadawa		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	7.6	8.5	8.1	8.3	8.3	8.3
UC82B	7.4	7.6	7.6	8.2	8.1	8.2
SE±	0.10	0.33	0.17	0.37	0.39	0.37
NPK rate kg ha^{-1}(F)						
0	9.6a	7.0b	8.3a	8.2ab	8.2ab	8.2ab
150	8.1b	8.8a	8.4a	7.7b	7.7b	7.7b
300	6.7c	9.5a	8.1a	9.5a	9.5a	9.5a
450	5.5d	7.2b	6.3b	7.7b	7.5b	7.6b
SE±	0.14	0.46	0.25	0.52	0.55	0.53
Green manure rate t ha^{-1} (G)						
0	7.1c	7.9	7.5	7.8b	7.8	7.8b
5	7.4b	8.0	7.7	7.9b	8.1	8.0b
10	7.9a	8.5	8.2	9.2a	8.9	9.1a
SE±	0.11	0.43	0.28	0.41	0.42	0.23
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

Table 55: Influence of variety, NPK fertilizer and green manure rates on Soil organic matter ($g\ kg^{-1}$) at Samaru and Kadawa in 2010-11, 2011-12 and mean.

	Soil Organic Matter ($g\ kg^{-1}$)					
	Samaru			**Kadawa**		
Treatment	2010-11	2011-12	Mean	2010-11	2011-12	Mean
Variety (V)						
Roma VF	13.1	14.7	13.9	14.4	14.4	14.2
UC82B	12.8	13.3	13.1	14.3	14.0	14.4
SE±	0.206	0.53	0.28	0.63	0.54	0.55
NPK rate kg ha^{-1}(F)						
0	16.8a	12.1b	14.4a	14.2ab	13.9b	14.0b
150	14.0b	15.1a	14.5a	13.5b	13.1b	13.2b
300	11.5c	16.5a	14.0a	16.5a	16.8a	16.7a
450	9.5d	12.5b	11.0b	13.3b	13.0b	13.1b
SE±	0.29	0.75	0.40	0.89	0.77	0.78
Green manure rate t ha^{-1} (G)						
0	12.3c	13.7	13.0	13.5b	13.3b	13.4b
5	12.8b	13.8	13.3	13.7b	13.2b	13.5b
10	13.8a	14.6	14.1	15.8a	16.1a	15.9a
SE±	0.19	0.73	0.49	0.70	0.68	0.41
Interaction						
F x V	NS	NS	NS	NS	NS	NS
F x G	NS	NS	NS	NS	NS	NS
G x V	NS	NS	NS	NS	NS	NS
F x G X V	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) within the same column and treatment group are not significantly different at 5% level of probability. NS = Not significant.

Application of NPK fertilizer significantly influenced soil organic matter in all the years of study at Samaru and Kadawa (Table 55). At Samaru in all years and combined mean showed that increasing NPK fertilizer up to 450 kg ha^{-1} significantly reduced soil organic matter. At Kadawa, in all the years and the combined mean, application of 300 kg ha^{-1} NPK fertilizer produced more soil organic matter content than application of NPK fertilizer at 150 and 450 kg ha^{-1} which are similar with the control plots.

Green manure significantly influenced soil organic matter at Samaru in 2010-11 and all the years at Kadawa (Table 55) where 10 t ha^{-1} significantly improved soil organic matter. There were no factor interactions throughout the years of study and the combined mean in both locations.

4.7 Correlation Analysis

4.7.1. Correlation analysis at Samaru

The result of correlation analysis between fruit yield, growth and yield components of tomato in 2010-11, 2011-12 and combined data in Samaru are shown in Tables 56 – 58.

In 2010-11, fruit yield was found to be significantly and positively correlated with number of leaves per plant (0.469**), plant height (0.530**), leaf area(0.383*), crop dry matter (0.482*), crop growth rate (0.488**), relative growth rate (0.415*), number of branches at 9 WAT (0.363*), net assimilation rate (0.306*) number of fruits per plant (0.762**) and fruit weight per plant (0.776**) while the fruit yield did not significantly correlated with fruit diameter and weight per fruit.

Table 56 : Matrix of correlation coefficient between fruit yield, growth and yield components at Samaru in 2010-11 dry season.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.469**	1.000											
3	0.363*	0.626**	1.000										
4	0.530**	0.570**	0.473**	1.000									
5	0.383*	0.624**	0.487**	0.329*	1.000								
6	0.482**	0.852**	0.679**	0.708**	0.555**	1.000							
7	0.415*	0.754**	0.685**	0.669**	0.497**	0.884**	1.000						
8	0.488**	0.822**	0.657**	0.694**	0.512**	0.991**	0.881**	1.000					
9	0.306*	0.670**	0.581**	0.565**	0.252	0.860**	0.777**	0.891**	1.000				
10	0.088	-0.037	0.079	0.148	0.089	0.042	0.041	0.036	0.049	1.000			
11	0.762**	0.431*	0.483**	0.532**	0.345*	0.479**	0.411*	0.472**	0.319*	0.117	1.000		
12	0.254	-0.021	-0.215	0.103	0.086	-0.031	-0.059	-0.031	-0.096	0.026	-0.066	1.000	
13	0.776**	0.371*	0.345*	0.528**	0.324*	0.413*	0.340*	0.400*	0.248	0.132	0.884**	0.377	1.000

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

1. Total fruit yield
2. No. of leaves plant^{-1}
3. No. of branches plant^{-1}
4. Plant height
5. Leaf area
6. Crop dry matter plant^{-1}
7. Relative growth rate
8. Crop growth rate
9. Net assimilation rate
10. Fruit diameter
11. No. of fruits plant^{-1}
12. Weight per fruit
13. Fruits weight plant^{-1}

Table 57: Matrix of correlation coefficient between fruit yield, growth and yield components at Samaru in 2011-12 dry season.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.485**	1.000											
3	0.385*	0.555**	1.000										
4	0.162	0309*	0.612**	1.000									
5	0.235	0.618**	0.591**	0.479**	1.000								
6	0.177	0.394**	0.527**	0.549**	0.630**	1.000							
7	-0.013	-0.004	-0.145	-0.180	-0.038	-0.097	1.000						
8	-0.015	0.088	0.073	0.191	0.159	0.553**	0.419**	1.000					
9	-0.119	-0.260	-0.267	-0.188	-0.436**	0.081	0.367*	0.716**	1.000				
10	0.103	0.224	0.253	0.239	-0.031	0.036	-0.204	-0.221	-0.204	1.000			
11	0.695**	0.588**	0.497**	0.236	0.354*	0.245	-0.119	-0.049	-0.201	0.144	1.000		
12	0.709**	0.095	0.058	-0.003	-0.021	0.022	0.104	0.053	0.025	-0.006	-0.005	1.000	
13	0.957**	0.485**	0.385*	0.162	0.235	0.177	-0.013	-0.001	-0.119	0.103	0.696**	0.709**	1.000

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

1. Total fruit yield
2. No. of leaves plant^{-1}
3. No. of branches plant^{-1}
4. Plant height
5. Leaf area
6. Crop dry matter plant^{-1}
7. Relative growth rate
8. Crop growth rate
9. Net assimilation rate
10. Fruit diameter
11. No. of fruits plant^{-1}
12. Weight per fruit
13. Fruits weight plant^{-1}

Table 58 : Matrix of correlation coefficient between fruit yield, growth and yield components at Samaru in mean data.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.267*	1.000											
3	0.359**	0.365**	1.000										
4	0.199	0.368**	0.455**	1.000									
5	0.305**	0.383**	0.540**	0.321**	1.000								
6	0377**	0.623**	0.600**	0.537**	0.559**	1.000							
7	0.002	0.373**	0.268*	0.606**	0.186	0.405**	1.000						
8	0.149	0.559**	0.395**	0.686**	0.303*	0.725**	0.847**	1.000					
9	0.001	0.417**	0.265*	0.557**	0.025	0.544**	0.798**	0.906**	1.000				
10	0.094	-0.004	0.165	0.153	0.027	0.040	-0.040	-0.021	-0.022	1.000			
11	0.418**	0.226*	0.382**	0.599**	0.255*	0.304*	0.561**	0.572**	0.469**	0.092	1.000		
12	0.448**	0.033	-0.082	0.052	0.032	-0.011	-0.003	-0.011	-0.051	0.011	-0.039	1.000	
13	0.862**	0.229*	0.329**	0.163	0.270*	0.354**	-0.089	0.065	-0.070	0.114	0.434**	0.464**	1.000

Df = n-2=(142) ** significant at 1% level of probability * significant at 5% level of probability

1. Total fruit yield
2. No. of leaves plant^{-1}
3. No. of branches plant^{-1}
4. Plant height
5. Leaf area
6. Crop dry matter plant^{-1}
7. Relative growth rate
8. Crop growth rate
9. Net assimilation rate
10. Fruit diameter
11. No. of fruits plant^{-1}
12. Weight per fruit
13. Fruits weight plant^{-1}

In 2011-12 at Samaru, fruit yield significantly and positively correlated with number of leaves per plant (0.485**), number of branches (0.385*), number of fruits per plant (0.695**), weight per fruit (0.709**) and fruits weight per plant (0.957*). Fruit yield did not correlate significantly with the rest of the parameters. The fruit yield also did not correlate with relative growth rate (-0.013), crop growth rate (-0.015) and net assimilation rate (-0.119) being negative.

In the combined mean at Samaru, it revealed that fruit yield significantly and positively correlated with number of leaves (r=0.267*), number of branches (r=0.359**), leaf area (0.305**), crop dry matter (r = 0.377**), number of fruits per plant (r = 0.418*), weight per fruit (r=0.448**) and fruits weight per plant (r = 0.862**). All other parameters did not correlate significantly with fruit yield.

4.7.2 Correlation analysis at Kadawa

The relationship between fruit yield, growth and yield attributes of tomato in 2010-11, 2011-12 and the combined mean in Kadawa is as shown in Tables 59 - 61 respectively.

In 2010-11, there was significant and positive correlation between fruit yield and number of leaves (0.245*), plant height (0.281*), leaf area (r = 0.129*), crop dry matter (0.334*), crop growth rate (0.300*), number of fruit per plant (r=0.923**) and fruit weight per plant (r=0.957**). However, fruit diameter was negatively correlated with fruit yield (-0.202). Also number of leaves, plant height relatively growth rate, crop growth rate net assimilation rate and weight per fruit was not significantly correlated with fruit yield.

Table 59 : Matrix of correlation coefficient between fruit yield, growth and yield components in 2010-11 dry season at Kadawa.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.245*	1.000											
3	0.153	0.219*	1.000										
4	0.281*	0.310*	0.315*	1.000									
5	0.129	0.273	-0.044	0.263*	1.000								
6	0.334*	0.313*	0.168	0.315*	0.532*	1.000							
7	0.112	0.235*	0.104	0.051	-0.191	0.327*	1.000						
8	0.300*	0.125	0.118	0.189	0.116	0.738**	0.702**	1.000					
9	0.174	-0.041	-0.025	0.148	0.096	0.636**	0.545**	0.842**	1.000				
10	-0.202	-0.055	0.093	0.196	0.007	-0.110	-0.071	-0.120	-0.044	1.000			
11	0.923**	0.204	0.094	0.261*	0.887**	0.361*	0.070	0.261*	0.161	-0.204	1.000		
12	0.266*	-0.037	0.015	-0.128	-0.215	-0.012	0.017	-0.040	-0.027	-0.172	0.045	1.000	
13	0.957**	0.197	0.104	0.219	0.175	0.346*	0.048	0.232*	0.134	-0.237*	0.956**	0.306*	1.000

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

1. Total fruit yield
2. No. of leaves plant^{-1}
3. No. of branches plant^{-1}
4. Plant height
5. Leaf area
6. Crop dry matter plant^{-1}
7. Relative growth rate
8. Crop growth rate
9. Net assimilation rate
10. Fruit diameter
11. No. of fruits plant^{-1}
12. Weight per fruit
13. Fruits weight plant^{-1}

Table 60: Matrix of correlation coefficient between fruit yield, growth and yield components in 2011-12 dry season at Kadawa.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.327*	1.000											
3	0.217*	0.124	1.000										
4	0.243*	0.341*	0.215*	1.000									
5	0.171	0.197	0.356*	0.193	1.000								
6	0.467*	0.541**	0.209*	0.354**	0.248*	1.000							
7	-0.011	0.065	-0.217	-0.093	0.143	0.034	1.000						
8	0.259*	0.263*	0.107	0.214*	0.218*	0.588**	0.513**	1.000					
9	0.111	0.081	-0.145	0.066	-0.510**	0.238*	0.374*	0.686**	1.000				
10	0.172	0.136	0.022	0.026	-0.118	0.145	-0.076	0.177	0.163	1.000			
11	0.806**	0.372*	0.224*	0.241*	0.061	0.243*	0.018	0.283*	0.204	0.276*	1.000		
12	0.646**	0.079	0.138	0.099	0.279*	0.108	-0.129	0.101	-0.088	-0.040	0.103	1.000	
13	0.993**	0.327*	0.217*	0.243*	0.171	0.317*	-0.011	0.259*	0.111	0.172	0.806**	0.646**	1.000

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

1. Total fruit yield
2. No. of leaves plant^{-1}
3. No. of branches plant^{-1}
4. Plant height
5. Leaf area
6. Crop dry matter plant^{-1}
7. Relative growth rate
8. Crop growth rate
9. Net assimilation rate
10. Fruit diameter
11. No. of fruits plant^{-1}
12. Weight per fruit
13. Fruits weight plant^{-1}

Table 61: Matrix of correlation coefficient between fruit yield, growth and yield components at Kadawa in mean data.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.000												
2	0.297*	1.000											
3	0.201	0.204	1.000										
4	0.311**	0.205	0.284*	1.000									
5	-0.041	0.218*	0.081	0.039	1.000								
6	0.367**	0.243*	0.256*	0.285**	0.149*	1.000							
7	0.187	0.056	0.030	0.102	-0.256*	0.255*	1.000						
8	0.387**	0.071	0.156	0.293*	-0.199	0.510**	0.723**	1.000					
9	0.303*	-0.054	0.045	0.257*	-0.428**	0.305*	0.620**	0.871**	1.000				
10	-0.071	-0.061	0.039	0.062	0.015	-0.002	-0.123	-0.078	-0.063	1.000			
11	0.722**	0.057	0.143	0.317**	-0.338**	-0.224*	0.368**	0.550**	0.569**	-0.173	1.000		
12	0.426**	0.122	0.093	0.037	0.092	0.098	0.025	0.060	0.012	-0.091	0.076	1.000	
13	0.791**	0.218*	0.119	0.143	0.291*	0.185*	-.105	0.027	-0.090	0.033	0.226*	0.476**	1.000

Df = n-2=(142) ** significant at 1% level of probability * significant at 5% level of probability

1. Total fruit yield
2. No. of leaves plant^{-1}
3. No. of branches plant^{-1}
4. Plant height
5. Leaf area
6. Crop dry matter plant^{-1}
7. Relative growth rate
8. Crop growth rate
9. Net assimilation rate
10. Fruit diameter
11. No. of fruits plant^{-1}
12. Weight per fruit
13. Fruits weight plant^{-1}

In 2011-12, there was significant and positive correlation between fruit yield and number of leaves per plant (r=0.327*), plant height (r=0.243*), number of branches (0.217*), crop dry matter (r=0.467*), crop growth rate (0.259*), number of fruits per plant (r=0.866**), weight per fruit (r=0.646**) and fruits weight per plant (r=0.993**). In the combined mean, significant and positive correlation was obtained between fruit yield and all parameters except number of branches (r=0.201), relative growth rate (r=0.181). Furthermore, non significant relationship was obtained between fruit yield and leaf area (r=-0.041) and fruit diameter (r=0.071). Significant correlation was observed between average weight and fruit weight per plant (r=0.476**) while net assimilation rate (r=-0.428**) and number of fruit per plant (r=0.338**) was significantly and negatively correlated with leaf area.

4.7.3 Path coefficient and percent contribution at Samaru.

The path analysis shows the interrelationship of some tomato growth and yield component with fruit yield at Samaru in 2010-11, 2011-12 and combined is presented in Table 62.

The result in 2010-11 indicated that the highest individual percent contribution to fruit yield was obtained from fruit weight per plant of 20.10% which was followed by 12.76%, 5.13%, 4.69%, 3.27% and 3.01% was from number of fruits per plant, crop dry matter, plant height, leaf area and number of leaves respectively. The highest positive combined contribution to fruit yield ha^{-1} of 20.62% was from number of fruits and fruit weight per plant. However percent contributions of crop dry matter and fruit weight per plant was negative. The percent contribution unaccounted was 11.16%.

At Samaru in 2011-12, it was observed that the individuation percent contribution of 31.9%, 18.72%, 13.4%, 1.84%and 1.47% was from fruit weight, number of fruits, number of leaves,

Table 62 : Percentage contribution of different growth and yield attributes of tomato to fruit yield in 2010-11, 2011-12 and mean data at Samaru.

Variable	**Percent Contribution (%)**		
Individual contribution	**2010-11**	**2011-12**	**Mean**
Number of leaves	3.01	13.42	8.26
Plant height	4.69	1.84	3.27
Leaf area	3.27	8.96	7.11
Crop dry matter	5.13	1.47	3.30
Number of fruits	12.76	18.72	15.74
Fruit weight	20.10	31.90	31.90
Combined Contribution			
Number of leaves via plant height	-11.48	-14.71	-13.09
Number of leaves via Leaf area	0.91	-6.97	-3.03
Number of leaves via Crop dry matter	-2.98	-2.98	5.35
Number of leaves via Number of fruits	3.18	3.18	3.18
Number of leaves via fruits weight	-2.75	-15.74	-9.24
Plant height via Leaf area	1.28	4.68	2.98
Plant height via Crop dry matter	-1.93	-11.81	-6.87
Plant height via Number of fruits	4.30	8.77	6.54
Plant height via fruits weight	3.94	2.48	3.21
Leaf area via Crop dry matter	17.79	20.49	19.14
Leaf area via Number of fruits	3.93	7.05	5.49
Leaf area via fruit weight	9.44	6.59	8.01
Crop dry matter via Number of fruits	-12.91	-12.57	-12.74
Crop dry matter via fruits weight	5.35	6.16	5.755
Number of fruits via fruits weight	20.62	34.00	27.31
Residual	11.16	18.77	15.05
Total	100.00	100.00	100.00

leaf area, plant height and crop dry matter respectively. The combined percent contribution of number fruits and fruit weight had the highest combined percent contribution of 34.0% while the least was obtained from combined percent contribution of number of leaves and fruit weight (-30.74%). The unaccounted variability percent was 18.77%.

The combined mean at Samaru, indicated that the highest individual contribution of 26.42% to yield was made by fruit weight followed by number of fruits (14.74%), number of leaves (8.23%), leaf area (8.11%), crop dry matter (3.309%) and plant height (3.00%). The combined contribution of number of fruit and fruit weight (27.32%) was the highest while the combined contributions of plant height, crop dry matter and plant height plus height plus number of fruits (0.01%) respectively had the lowest. A residual effect of 15.57 was unaccounted for the analysis.

4.7.4 Path coefficient and percent contribution at Kadawa

Table 63 shows the percent contribution of individual and combined contribution of some growth and yield attributes of tomato at Kadawa in 2010-11, 2011-12 and the mean data. In 2010-11, the result indicated that fruit weight had made the highest contribution to fruit yield (22.77%), followed by number of fruits (16.61%) and lowest was plant height (2.00%). The combined percent contribution of number of leaves and fruits weight (30.38%) to fruit yield was the highest while the lowest was found to be combined percent contribution of leaf area and fruit weight (-9.64%). The residual effect of 12.39% was unaccounted for in the analysis.

At Kadawa in 2011-12 dry season, was individual contribution of 20.59% and 15.17% were from fruit weight and number of fruits. The combined contribution of number of

Table 63: Percentage contribution of different growth and yield attributes of tomato to fruit yield in 2010-11, 2011-12 dry seasons and the mean at Kadawa

Variable		**Percent Contribution (%)**	
Individual contribution	**2010-11**	**2011-12**	**Mean**
Number of leaves	6.10	8.31	7.21
Plant height	2.00	2.25	2.13
Leaf area	4.98	2.23	3.61
Crop dry matter	4.40	0.78	2.59
Number of fruits	16.61	15.17	15.89
Fruit weight	22.77	20.59	21.68
Combined Contribution			
Number of leaves via plant height	-2.01	-4.19	-3.10
Number of leaves via Leaf area	0.31	-0.45	-0.07
Number of leaves via Crop dry matter	-0.22	-1.22	0.30
Number of leaves via Number of fruits	-0.71	-1.74	-1.81
Number of leaves via fruit weight	-1.75	1.48	-0.14
Plant height via Leaf area	0.06	-0.55	-0.25
Plant height via Crop dry matter	-0.22	0.34	0.06
Plant height via Number of fruits	5.04	5.70	5.37
Plant height via fruit weight	-1.12	-1.49	-1.31
Leaf area via Crop dry matter	-1.63	-1.46	-1.55
Leaf area via Number of fruits	-8.89	-5.56	-7.23
Leaf area via fruit weight	-6.64	-4.46	-5.55
Crop dry matter via Number of fruits	6.36	6.71	6.53
Crop dry matter via fruit weight	13.82	14.14	13.98
Number of fruits via fruit weight	30.38	34.59	32.48
Residual	12.39	7.38	9.88
Total	100.00	100.00	100.00

fruits and fruit weight (34.59%) was found to be the highest toward fruit yield ha^{-1} while the least percent contribution of the combined contribute to yield ha^{-1} was from leaf area and fruit weight (-4.44%). The unaccounted variability percent was 7.38%. The combine resulted indicated that the highest individual percent contribution of 21.62% was made from fruit weight while the least was obtained from plant height (2.07%). The combined contribution of number of fruits and fruit weight (15.99%) was the highest while the combined contribution of leaf area and crop dry matter (-1.54%) was the lowest. A residual effect of 9.28% was unaccounted in the analysis.

4.7.5 Direct and indirect effect of growth and yield attributes of tomato at Samaru

The direct and indirect effect of different growth and yield component on fruit yield t ha^{-1} in 2010-11 dry seasons is presented in (Table 64). The greatest positive direct contribution to yield was from fruits weight per plant (0.4483) followed by number of fruits per plant (0.2599) and number of leaves (0.1417) while the least positive contribution to fruit yield was from leaf area (0.0515) while the negative direct effect was obtained from crop dry matter (-0.0363). The highest positive indirect effect was from number of fruits via fruits weight $plant^{-1}$(0.3966), followed by number of fruits via plant height (0.2371). The least positive indirect effect to yield was through leaf area via fruit weight (0.0167). All the indirect effect through the crop dry matter was found to be negative. In 2011-12 at Samaru the fruits weight $plant^{-1}$ had the highest direct effect to yield (0.5648), followed by number of fruits (0.4326) and leaf area (0.3600) while number of leaves had the least direct effect on yield (-0.5605). The highest combined indirect effect on yield was through fruit weight via number of fruits (0.3929). The indirect effect of leaf area via number of leaves (-0.3468) made the least contribution. However al the indirect affect of number of leaves were negative.

Table 64: The direct and indirect contribution of growth and yield component to fruit yield in 2010-11, 2011-12 and mean data at Samaru.

Yield Attributes	Effect through						
	Number of leaves	Plant height	Leaf area	Crop dry matter	Number of fruit	Fruits weight	**Total correlated**
				2010-11			
Number of leaves	**0.1417**	0.0474	0.0322	-0.0309	0.1121	0.1666	0.4690
Plant height	0.0808	**0.0831**	0.0169	-0.0257	0.1384	0.2371	0.5305
Leaf area	0.0885	0.0273	**0.0515**	-0.0202	0.0904	0.1455	0.3831
Crop dry matter	0.1207	0.0588	0.0286	**-0.0363**	0.1247	0.1855	0.4821
Number of fruits	0.0611	0.0442	0.0179	-0.0174	**0.2599**	0.3966	0.7623
Fruits weight	0.0527	0.0439	0.0167	-0.0150	0.2299	**0.4483**	0.7765
				2011-12			
Number of leaves	**-0.5605**	0.0420	0.2228	-0.0477	0.2547	0.2742	0.1855
Plant height	-0.1735	**0.1357**	0.1726	-0.0664	0.1021	0.0916	0.2621
Leaf area	-0.3468	0.0651	**0.3600**	-0.0763	0.1535	0.2018	0.3572
Crop dry matter	-0.2209	0.0744	0.2268	**0.1211**	0.1061	0.2132	0.3990
Number of fruits	-0.3300	0.0320	0.1278	-0.0297	**0.4326**	0.3929	0.6256
Fruits weight	-0.2721	0.0220	0.1286	-0.0457	0.3009	**0.5648**	0.6985
				Mean			
Number of leaves	**-0.2094**	0.0447	0.1275	-0.0393	0.1834	0.2204	0.3273
Plant height	-0.0464	**0.1094**	0.0948	-0.0461	0.1203	0.1644	0.3963
Leaf area	-0.1292	0.0462	**0.2058**	-0.0483	0.1220	0.1737	0.3702
Crop dry matter	-0.0501	0.0666	0.1277	**0.0787**	0.1154	0.1994	0.4406
Number of fruits	-0.1345	0.0381	0.0729	-0.0236	**0.3463**	0.3948	0.6940
Fruits weight	-0.1097	0.0330	0.0727	-0.0304	0.2654	**0.5066**	0.7375

Bold = Direct effect

In the combined years at Samaru the highest direct effect of 0.5066 was produced by fruit weight while the least was found to be plant height (-0.2094). The highest combined indirect effect of 0.3463 was accounted by number of fruits via fruit weight while the lowest combined percent contribution was recorded on plant height via fruit weight.

4.7.6 Direct and indirect effect of growth and yield attributes of tomato at Kadawa

The direct and indirect effect of growth and yield attributes on fruit yield at Kadawa 2010-11, 2011-12 and combined mean are presented in Table 65. The result in 2010-11 indicated that fruit weight, number of fruit and crop dry matter showed direct positive effect on fruit yield of 0.8110, 0.2935 and 0.0635 respectively. However, number of leaves, plant height and leaf area indicated negative effect. The highest indirect effect was found in fruit weight via number of fruits crop dry matter, number of leaves, leaf area and plant height with the following values 0.6538, 0.3014, 0.2659, 0.2203 and 0.1972 respectively while the lowest indirect percent contribution was found to be leaf area via number of fruits (-0.1515)

In 2011-12, the greatest direct effect to yield was through fruit weight (0.6752), followed by number of fruits (0.2677), crop dry matter (0.0885) number of leaves (0.0554), plant height (0.0502) and the least direct effect was found to be through leaf area (-0.1495). The least indirect effect to yield was obtained from leaf area and crop dry matter (-0.0808) while the highest was obtained from number of fruits via fruit weight (0.6459).

In the combined mean, fruits weight had the highest direct effect on fruit yield (0.7431) and lowest was evident on leaf area (0.1495). The highest indirect effect to fruit yield was through the number of fruits via fruit weight (0.6499). The indirect effect was the leaf area through number of fruits (-0.0463) made the least contribution.

Table 65: The direct and indirect contribution of growth and yield component to fruit yield in 2010-11, 2011-12 and mean data at Kadawa

Yield Attributes	Number of leaves	Plant height	Leaf area	Crop dry matter	Number of fruits	Fruits weight	**Total correlated**
			Effect through				
			2010-11				
Number of leaves	**-0.0323**	-0.0011	-0.0483	0.0343	0.1093	0.2659	0.3279
Plant height	-0.0110	**-0.0031**	-0.0473	0.0365	0.0709	0.1972	0.2431
Leaf area	-0.0064	-0.0006	**-0.2446**	0.0210	0.1818	0.2203	0.1717
Crop dry matter	-0.0175	-0.0018	-0.0811	**0.0635**	0.1072	0.3014	0.3717
Number of fruits	-0.0120	-0.0007	-0.1515	0.0232	**0.2935**	0.6538	0.8062
Fruits weight	-0.0106	-0.0008	-0.0664	0.0236	0.2366	**0.8110**	0.9934
			2011-12				
Number of leaves	**0.0554**	0.0156	-0.0408	0.0268	0.0547	0.1334	0.2451
Plant height	0.0172	**0.0502**	-0.0394	0.0341	0.0700	0.1484	0.2805
Leaf area	0.0151	0.0132	**-0.1495**	0.0478	0.0845	0.1181	0.1293
Crop dry matter	0.0168	0.0194	-0.0808	**0.0885**	0.0968	0.2338	0.3744
Number of fruits	0.0113	0.0131	-0.0472	0.0320	**0.2677**	0.6459	0.9229
Fruits weight	0.0109	0.0110	-0.0261	0.0306	0.2561	**0.6752**	0.9578
			Mean				
Number of leaves	**0.0116**	0.0073	-0.0446	0.0306	0.0820	0.1997	0.2865
Plant height	0.0031	**0.0236**	-0.0434	0.0353	0.0705	0.1728	0.2618
Leaf area	0.0044	0.0063	**-0.1971**	0.0344	0.1332	0.1692	0.1505
Crop dry matter	-0.0004	0.0088	-0.0810	**0.0760**	0.1020	0.2676	0.3731
Number of fruits	-0.0004	0.0062	-0.0994	0.0276	**0.2806**	0.6499	0.8646
Fruits weight	0.0002	0.0051	-0.0463	0.0271	0.2464	**0.7431**	0.9756

Bold = Direct effect

4.8 Regression Analysis

The polynomial response of the two tomato varieties fruit yield to NPK fertilizer in 2010-11, 2011-12 and combined at Samaru and Kadawa is presented in figures 5-10 respectively. The figures revealed that the responses across the years and combined mean were quadratic as indicated in the equation $\mathbf{Y = a + bx + cx^2}$

Similarly, regression analysis of the two tomato varieties yield against green manure rates is presented in figures 11-16. The result indicated that the yield responses of tomato varieties to green manure were linear in 2010-11, 2011-12 and combined at both locations as shown in the equation. Therefore the optimum was not attained.

$\mathbf{Y = a + bx}$

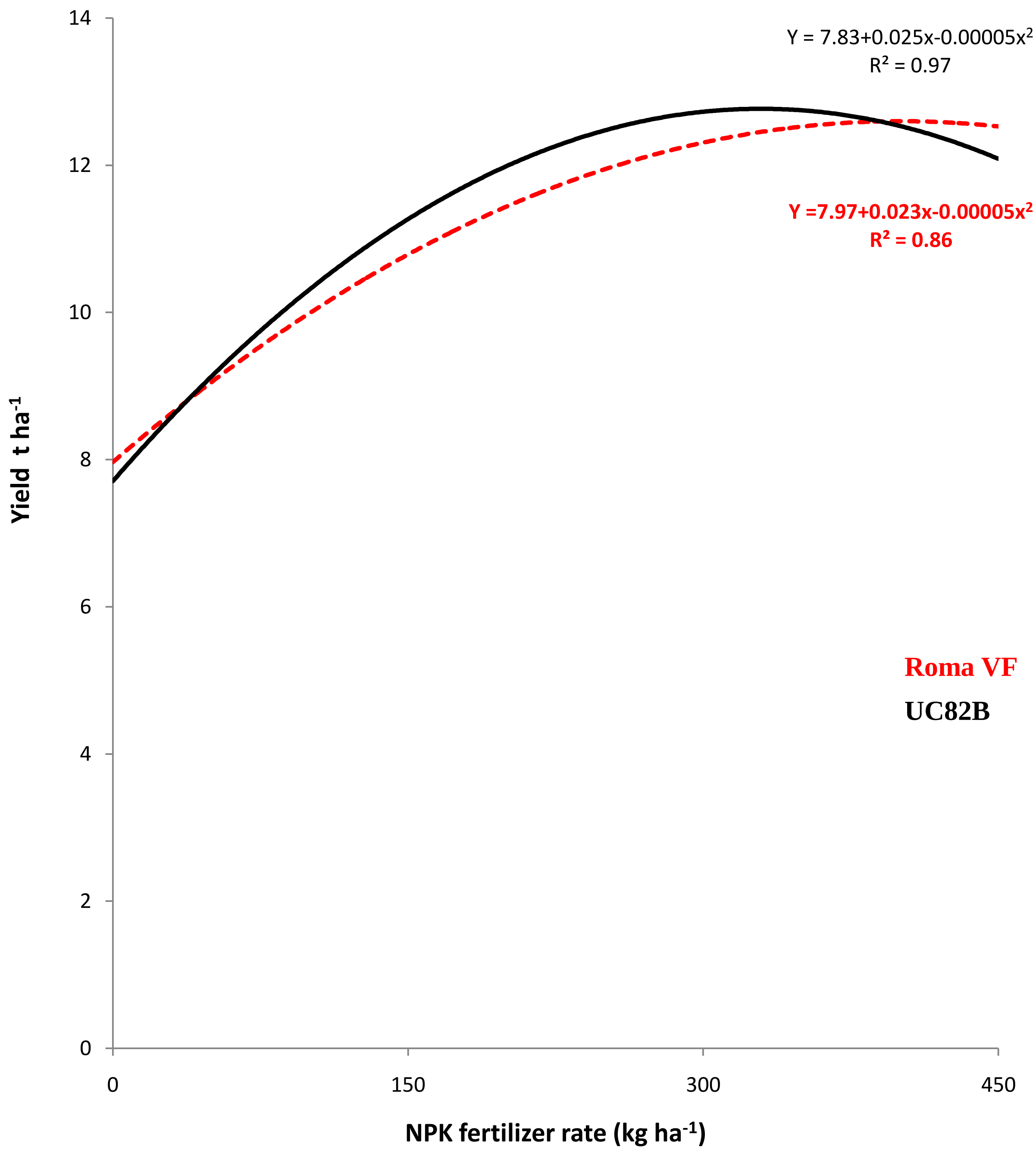

Fig. 5: Regression response of varieties of tomato fruit yield and NPK fertilizer rates at Samaru in 2010-11

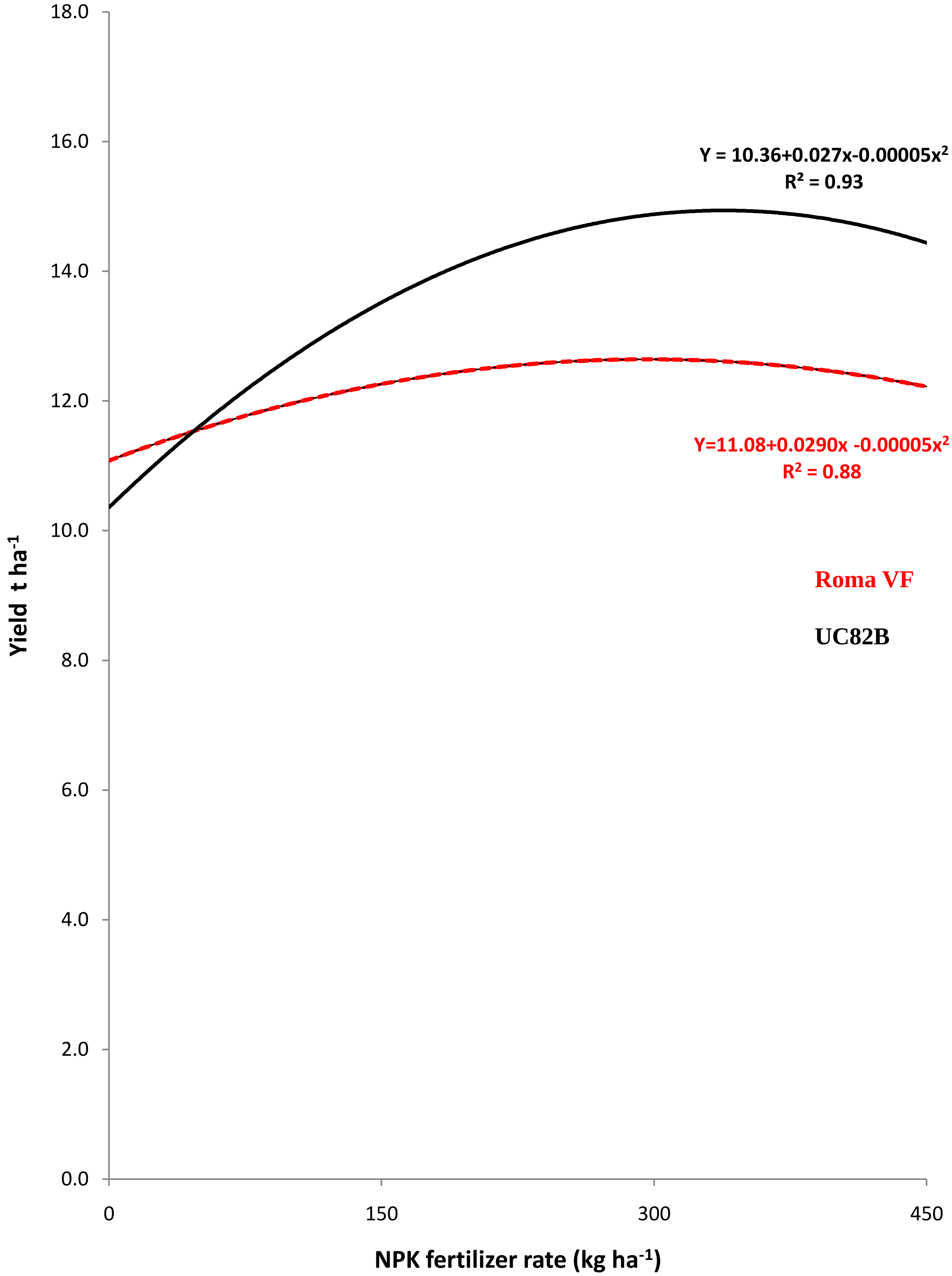

Fig. 6: Regression response of varieties of tomato fruit yield and NPK fertilizer rates at Samaru in 2011-12

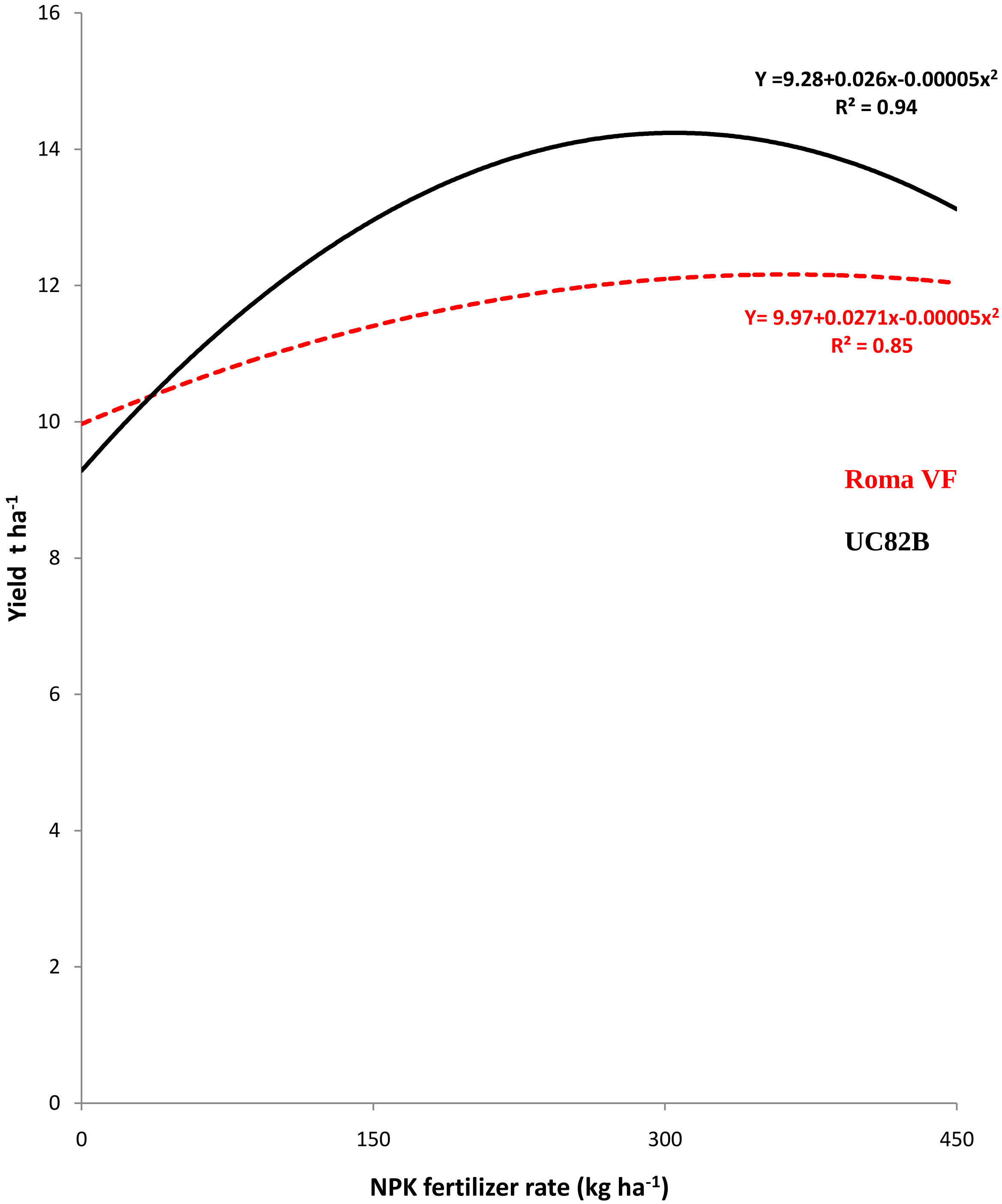

Fig. 7: Regression response of varieties of tomato fruit yield and NPK fertilizer rates at Samaru (Mean)

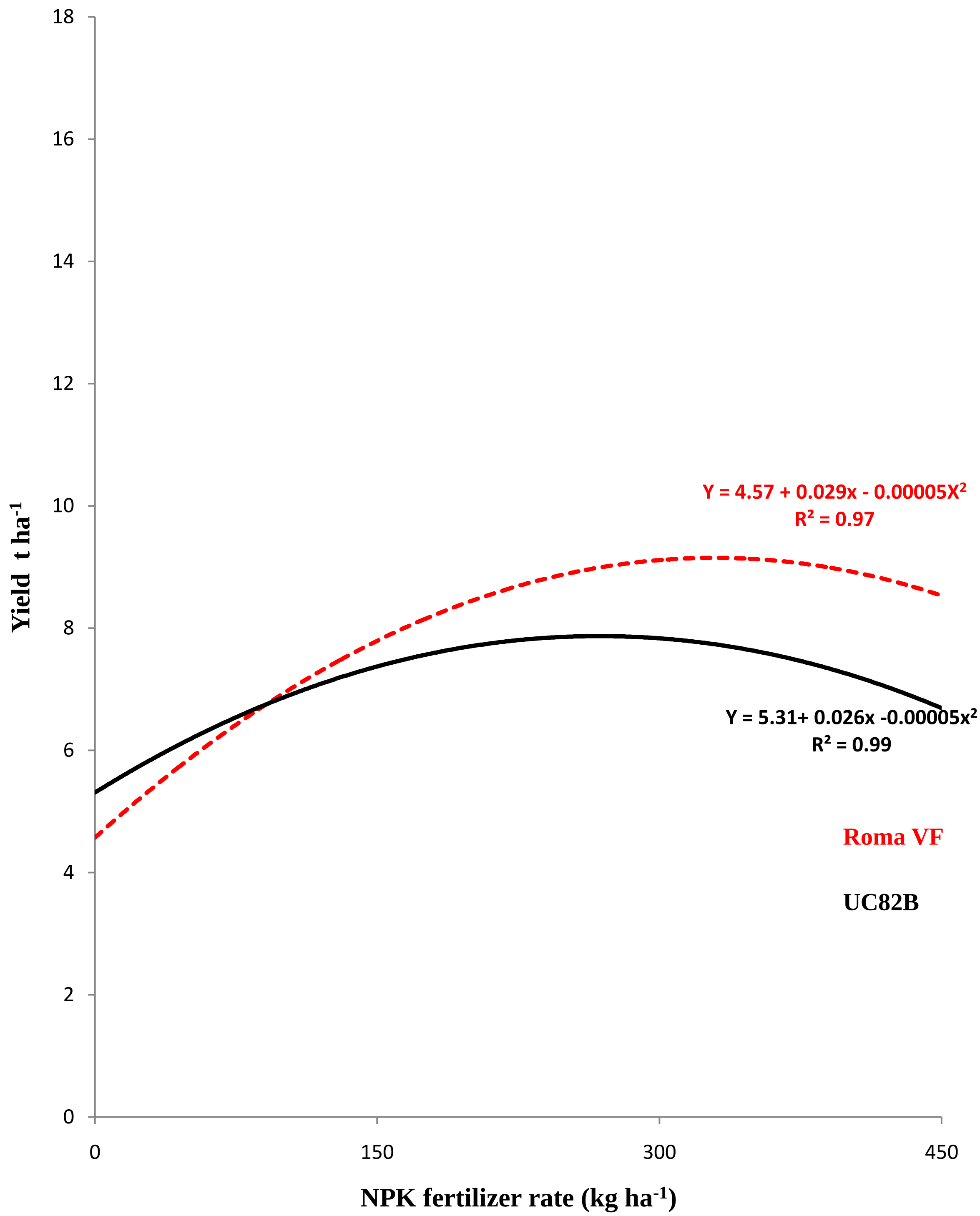

Fig. 8: Regression response of varieties of tomato fruit yield and NPK fertilizer rates at Kadawa in 2010-11

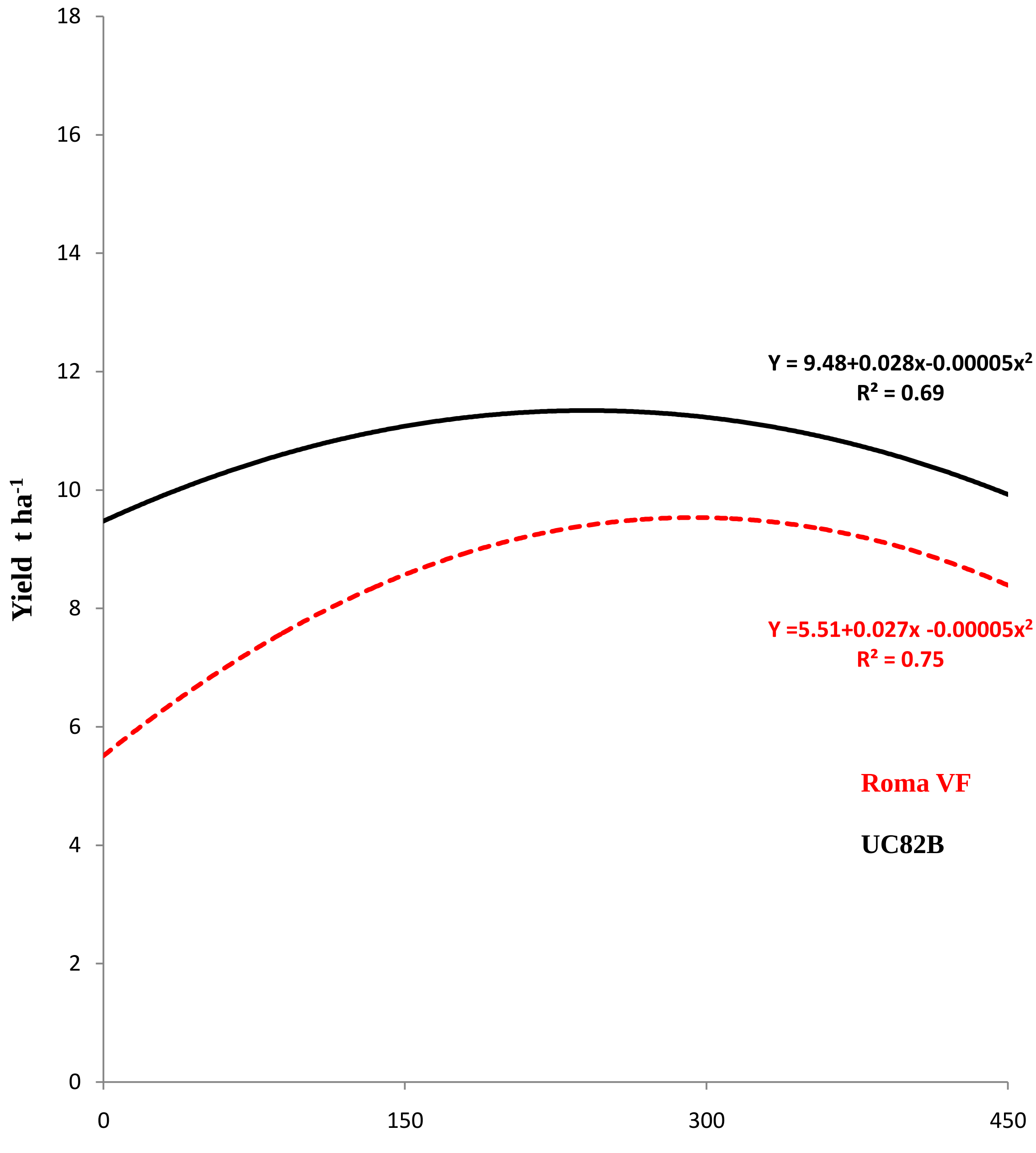

Fig. 9: Regression response of varieties of tomato fruit yield and NPK fertilizer rates at Kadawa in 2011-12

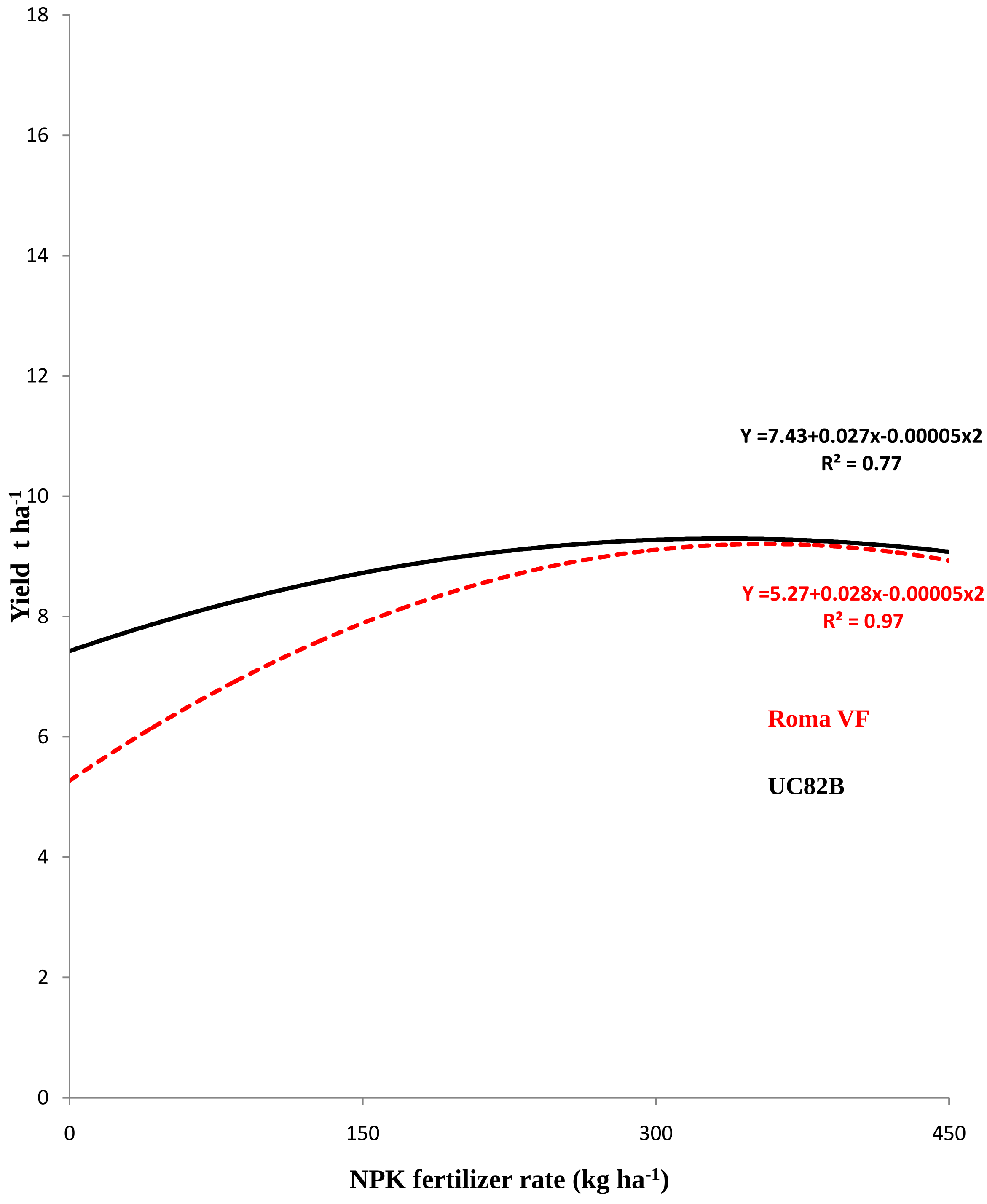

Fig. 10: Regression response of varieties of tomato fruit yield and NPK fertilizer rates at Kadawa (Mean)

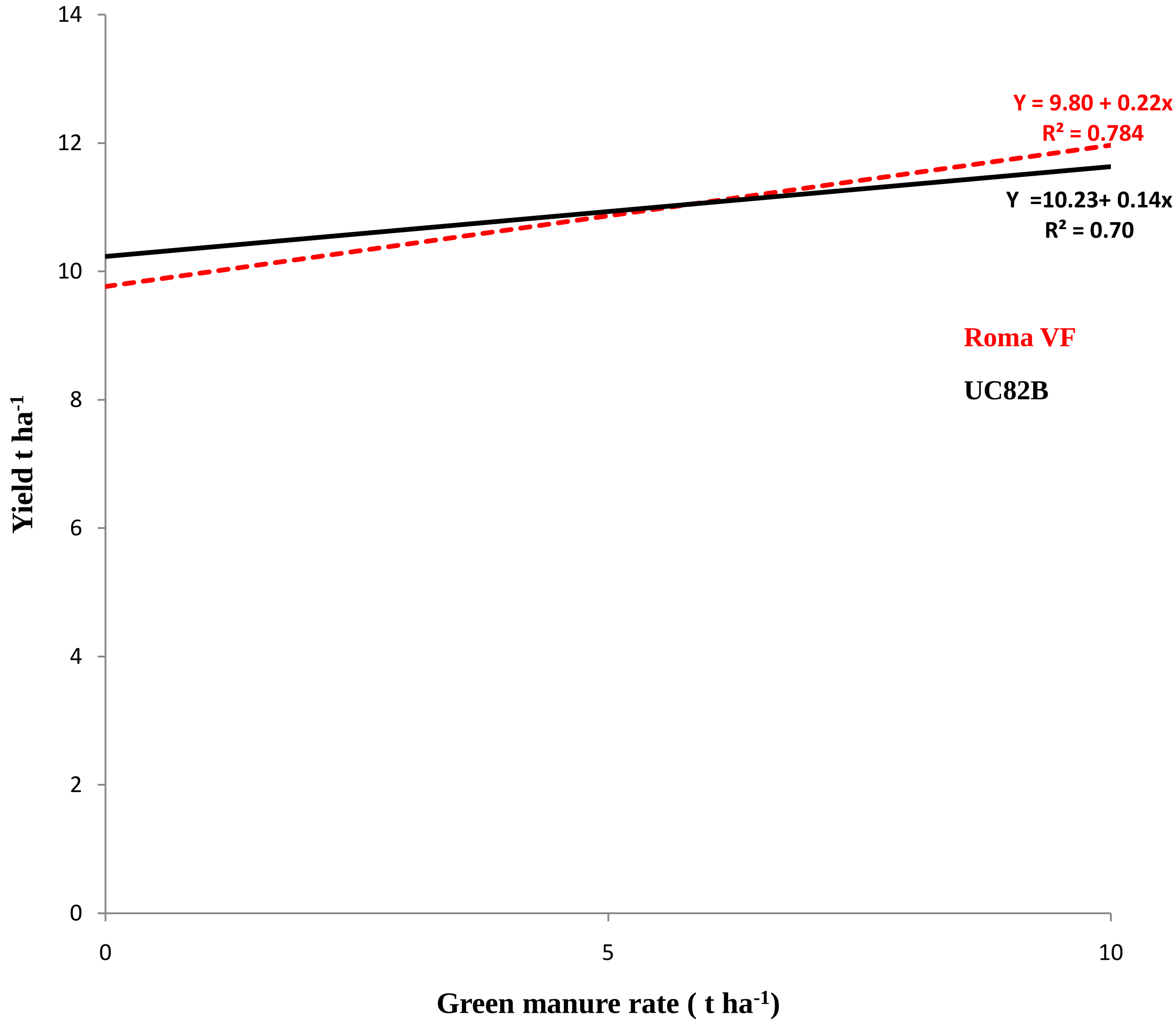

Fig 11. Linear response of two tomato varieties to green manure rate at Samaru in 2010-11

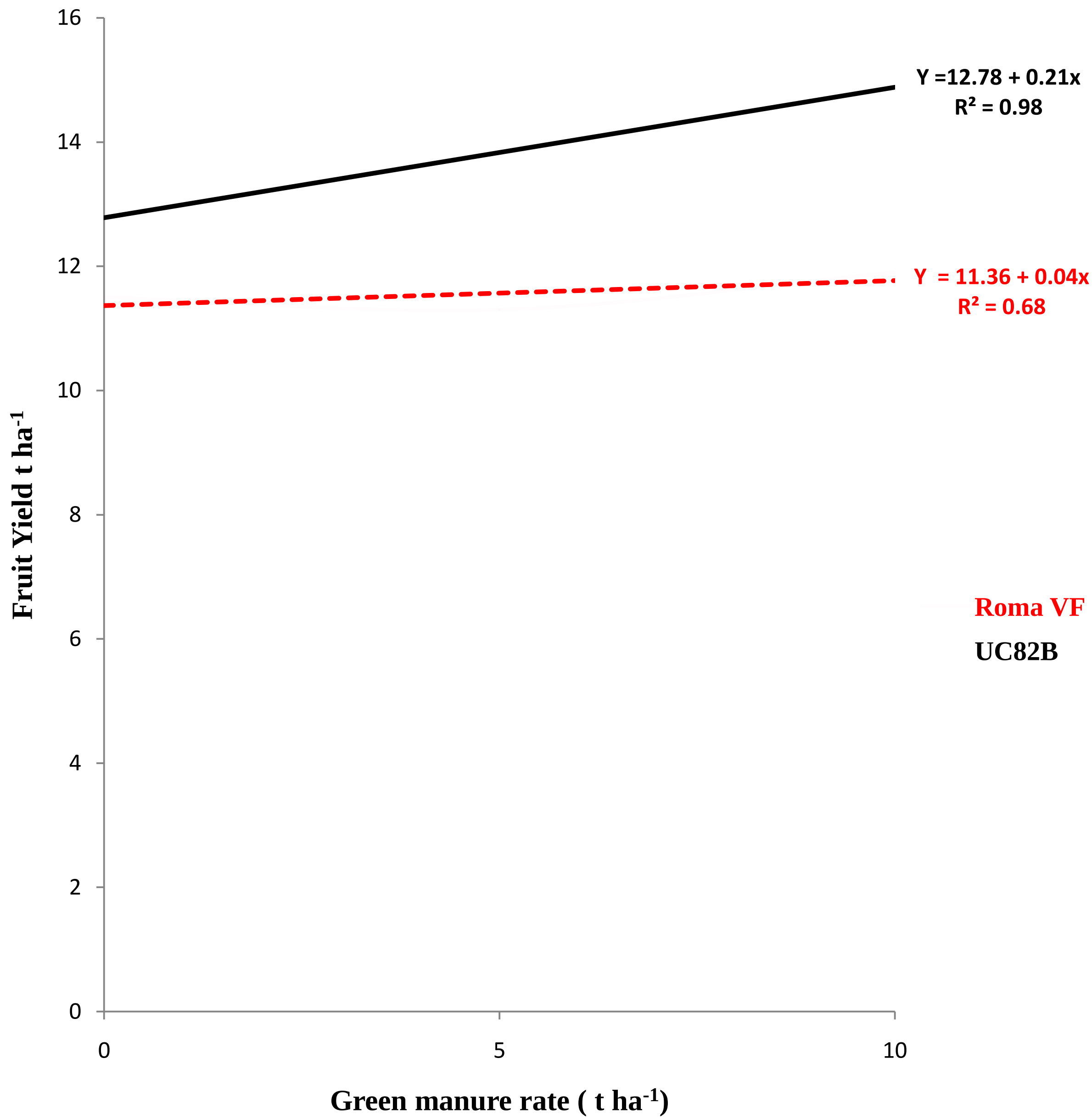

Fig 12. Linear response of two tomato varieties to green manure rate at Samaru in 2011-12

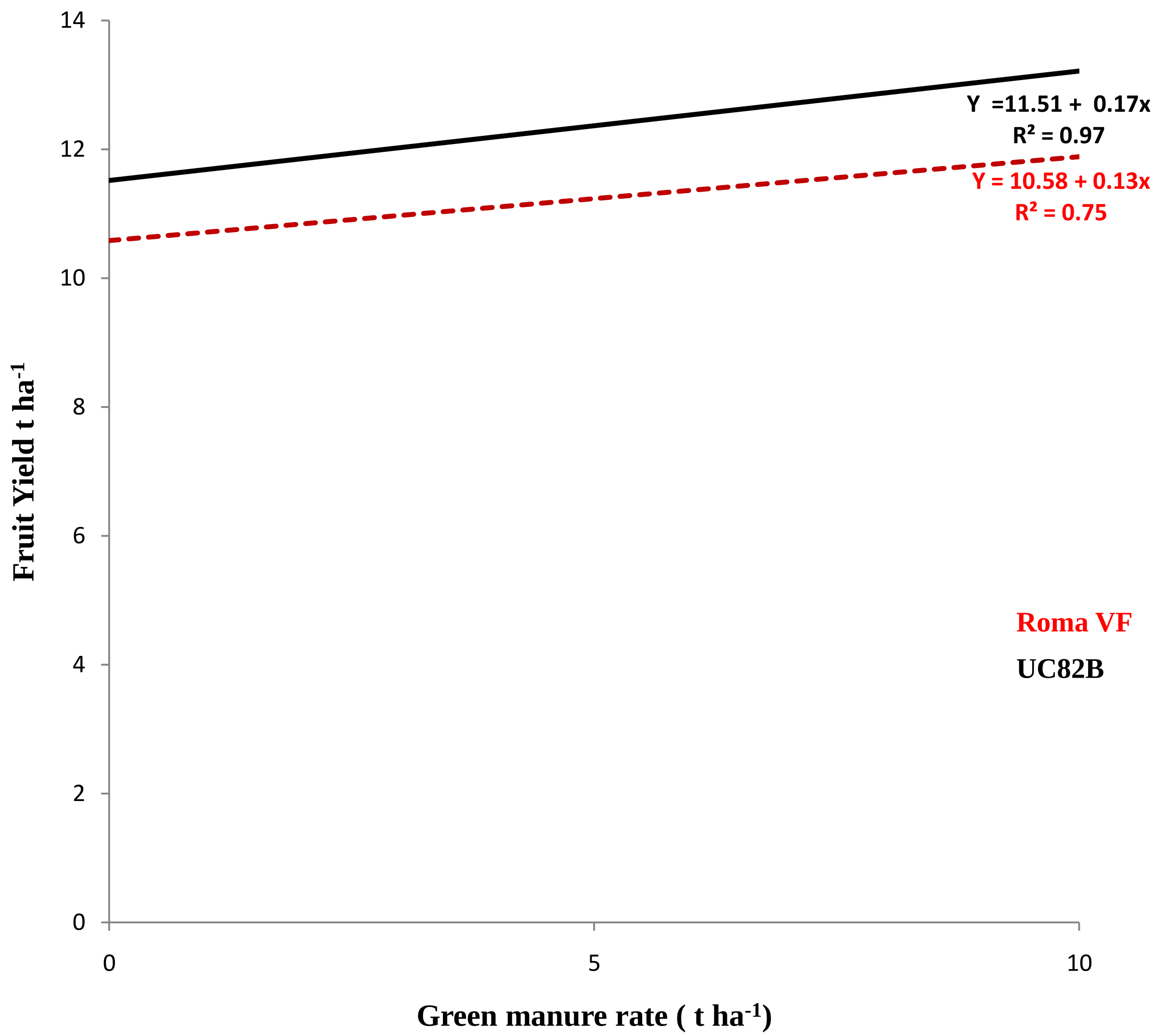

Fig 13. Linear response of two tomato varieties to green manure rate at Samaru (Mean)

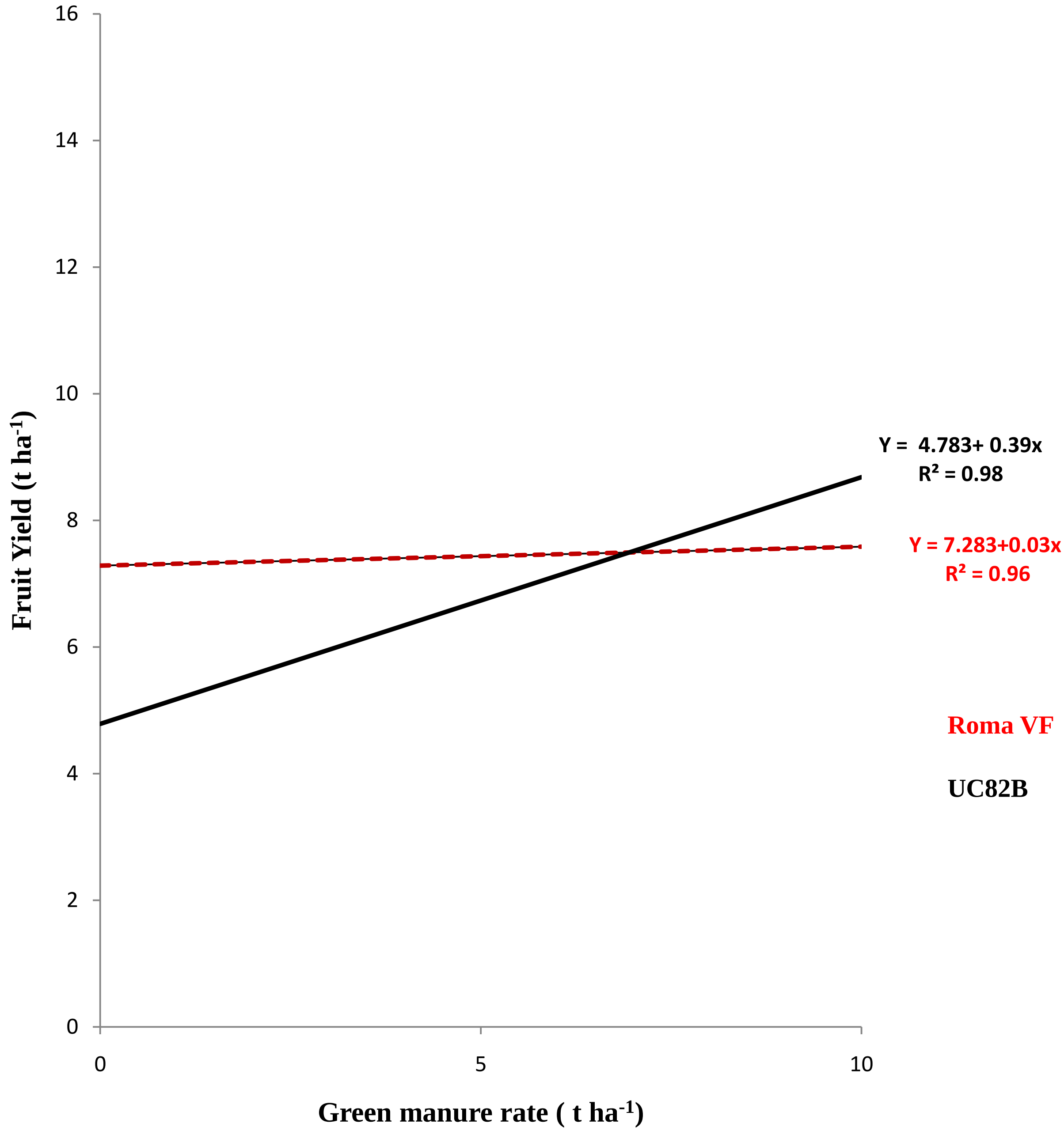

Fig 14. Linear response of two tomato varieties to green manure rate at Kadawa in 2010-11

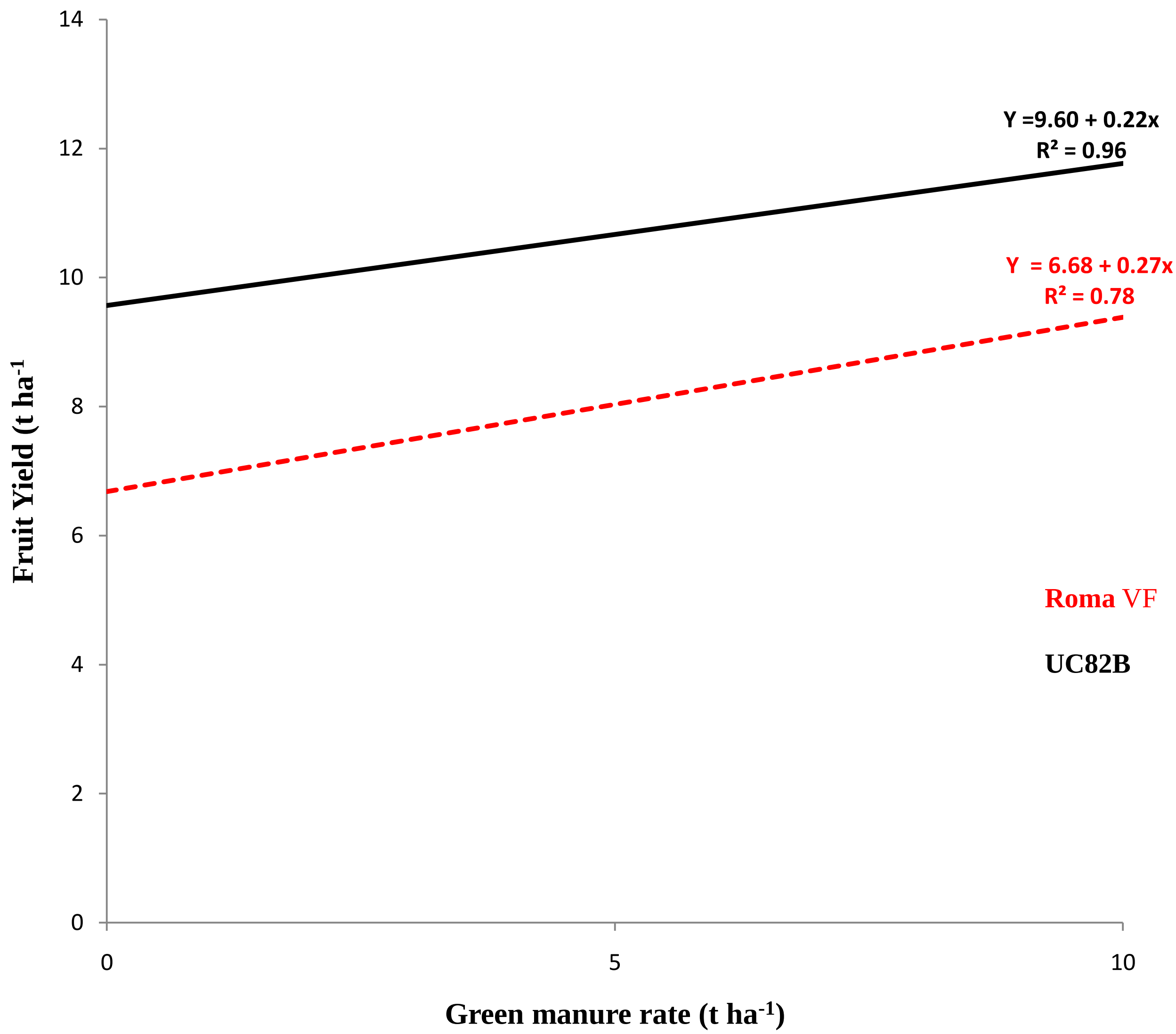

Fig 15. Linear response of two tomato varieties to green manure rate at Kadawa in 2011-12

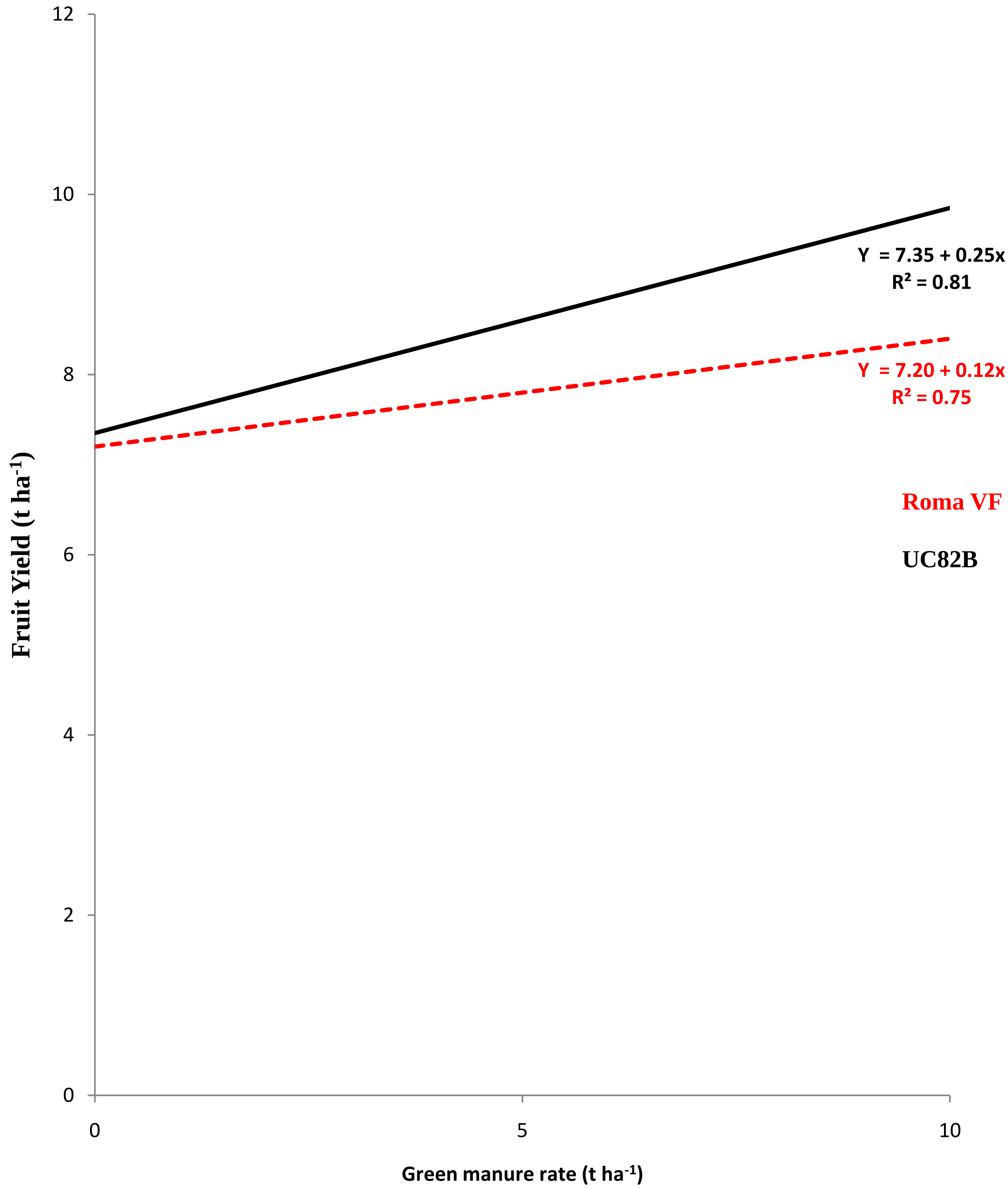

Fig 16. Linear response of two tomato varieties to green manure rate at Kadawa (Mean)

4.9 Partial Economic Analysis of Yield.

4.9.1 Partial economic analysis of yield (Samaru)

Table 66 shows the cost and return analysis on investment of growing tomato using NPK fertilizer and green manure at Samaru. The result showed that non application of NPK fertilizer to either Roma VF or UC82B variety in the production brought profit of ₦19,812.50k and 86k gain per naira invested for Roma VF and profit of ₦15,509.17 and 67k gain per naira invested for UC82B respectively. The production of tomato using 150 kg ha^{-1} combined with 10 t ha^{-1}green manure and tomato variety (UC82B) was the most profitable with ₦59, 475.00 and a profit of ₦1.23k per every naira invested. This was closely followed by UC82B combined given NPK fertilizer at 150 kg ha^{-1} and 10 t ha^{-1} of green manure gave a gross margin of ₦54,577.50k and a profit of ₦1.17k per naira invested. However in this research the production of tomato using 450 kg ha^{-1} NPK fertilizer combined with 5 t ha^{-1} green manure and Roma VF tomato variety brought a loss of ₦10,473.33k where 11k is lost per naira invested.

4.9.2 Partial economic analysis of yield (Kadawa)

The result of gross margin analysis (Table 67) indicate that the highest gross return of ₦70,058.53 and a profit of ₦1.41 per naira invested was achieved by growing UC82B tomato variety at combination of 150 kg ha^{-1} NPK fertilizer and 10tha^{-1} green manure in Kadawa. Similarly, it was followed by producing Roma VF with combination of 150 kg ha^{-1} NPK and 10tha^{-1} green manure applied resulted to ₦58095.83 gross margin and a profit of ₦1.17k per naira invested. The least return of ₦33,452.50k loss was observed from combination of 450kha^{-1} NPK fertilizer with no green manure application and tomato variety UC82B in which 36k was lost per naira invested.

Table 66: Cost benefit and return analysis on investment of growing tomato varieties using NPK fertilizer and green manure at Samaru.

Treatments								
NPK fertilizer (kg ha^{-1})	Green manure (t ha^{-1})	Tomato variety	Total Yield (t ha^{-1})	Average price/basket (₦)	Gross revenue (GR) (₦ ha^{-1})	Total variable cost (TVC) (₦ ha^{-1})	Gross margin (GR-TVC) (₦ ha^{-1})	Gross margin per naira invested ₦
0	0	RomaVF	5.14	500	42862.50	23050	19812.50	0.86
0	5	RomaVF	5.24	500	43667.50	24960	18707.50	0.75
0	10	RomaVF	5.17	500	43117.50	24960	18157.50	0.73
0	0	UC82B	4.63	500	38559.17	23050	15509.17	0.67
0	5	UC82B	5.66	500	47135.83	24960	22175.83	0.89
0	10	UC82B	5.59	500	46623.33	24960	21663.33	0.87
150	0	RomaVF	10.04	500	83673.33	46550	37123.33	0.80
150	5	RomaVF	12.05	500	100375.00	48460	51915.00	1.07
150	10	RomaVF	12.00	500	100020.01	48460	51560.00	1.06
150	0	UC82B	12.14	500	101127.50	46550	54577.50	1.17
150	5	UC82B	11.82	500	98481.67	48460	50021.67	1.03
150	10	UC82B	12.95	500	107935.00	48460	59475.00	1.23
300	0	RomaVF	10.51	500	87557.50	69050	18507.50	0.27
300	5	RomaVF	13.76	500	114680.83	70960	43720.83	0.62
300	10	RomaVF	12.26	500	102140.83	70960	31180.83	0.44
300	0	UC82B	12.28	500	102345.83	69050	33295.83	0.48
300	5	UC82B	13.79	500	114887.50	70960	43927.50	0.62
300	10	UC82B	12.65	500	105405.00	70960	34445.00	0.49
450	0	RomaVF	14.46	500	120489.17	91550	28939.17	0.32
450	5	RomaVF	9.96	500	82986.67	93460	-10473.33	-0.11
450	10	RomaVF	10.94	500	91192.50	93460	-2267.50	-0.02
450	0	UC82B	13.51	500	112610.83	91550	21060.83	0.23
450	5	UC82B	13.66	500	113825.83	93460	20365.83	0.22
450	10	UC82B	17.56	500	146343.33	93460	52883.33	0.57

Calculation of total revenue is based on ₦500 per basket (60 kg) of tomato the prevailing farm gate price at Samaru and environ

Table 67: Cost benefit and return analysis on investment of growing tomato varieties using NPK fertilizer and green manure at Kadawa.

Treatments			Total Yield (t ha^{-1})	Average price/basket (₦)	Gross revenue (GR) (₦ ha^{-1})	Total variable cost (TVC) (₦ ha^{-1})	Gross margin (GR-TVC) (₦ ha^{-1})	Gross margin per naira invested ₦
NPK fertilizer (kg ha^{-1})	Green manure (t ha^{-1})	Tomato variety						
0	0	RomaVF	3.98	500	33181.67	24050	9131.67	0.27
0	5	RomaVF	5.14	500	42850.83	26100	16750.83	0.39
0	10	RomaVF	6.94	500	50311.67	26100	24211.67	0.93
0	0	UC82B	6.63	500	50245.00	24050	26195.00	1.09
0	5	UC82B	4.01	500	33377.50	26100	7277.50	0.28
0	10	UC82B	12.08	500	34009.17	26100	7909.17	0.30
150	0	RomaVF	6.50	500	54155.00	47550	6605.00	0.14
150	5	RomaVF	7.96	500	66301.67	49600	16701.67	0.34
150	10	RomaVF	7.92	500	107695.83	49600	58095.83	1.17
150	0	UC82B	7.03	500	58577.50	47550	11027.50	0.23
150	5	UC82B	10.34	500	86169.17	49600	36569.17	0.74
150	10	UC82B	9.36	500	119658.33	49600	70058.33	1.41
300	0	RomaVF	10.37	500	86384.17	70050	16334.17	0.23
300	5	RomaVF	7.23	500	60251.67	72100	-11848.33	-0.16
300	10	RomaVF	11.02	500	91815.00	72100	19715.00	0.27
300	0	UC82B	10.00	500	83299.17	70050	13249.17	0.19
300	5	UC82B	6.95	500	57938.33	72100	-14161.67	-0.20
300	10	UC82B	7.53	500	62728.33	72100	-9371.67	-0.13
450	0	RomaVF	8.70	500	72504.17	92550	-20045.83	-0.22
450	5	RomaVF	9.23	500	76882.50	94600	-17717.50	-0.19
450	10	RomaVF	8.37	500	69785.83	94600	-24814.17	-0.26
450	0	UC82B	7.09	500	59097.50	92550	-33452.50	-0.36
450	5	UC82B	10.43	500	86917.50	94600	-7682.50	-0.08
450	10	UC82B	12.01	500	100100.00	94600	5500.00	0.06

Calculation of total revenue is based on ₦500 per basket (60 kg) of tomato the prevailing farm gate price at Kadawa and environ

CHAPTER FIVE

5.0 DISCUSSION

5.1 General

Agricultural production depends strongly on the environmental factors. These factors influenced crop growth and modify the genetic potential of plant to use them effectively. Tomato has high yield potential and depends on the varieties and agronomic technologies adopted to enhance the yield potential. The general performance of tomato varieties at both locations was satisfactory, however tomato fruit worm was found as the major pest at both locations. At both locations, the overall performance of tomato plant as exemplified by number of leaves per plant, leaf area index per plant, crop dry matter, crop growth rate, per plant, number of fruits per plant, weight per fruit and fruits weight per plant might be as a result of favourable weather conditions for the crop.

Green manuring is one of the most important ways to influence topsoil. Higher crop growth and yield due to organic fertilizer could be attributed to favorable changes in soil condition which might result in loose soil and enable better root growth. Moreover, positive influence of organic fertilizer might be due to slow and steady availability of nutrients throughout the growing season from organic fertilizer (Maftoun *et al.*, 2004; Amanullah *et al.*, 2006; Tejada *et al.*, 2006). The soil chemical properties that are affected by incorporation of the green manure include the soil pH, soil total N, soil available P and soil exchangeable K, soil organic carbon and soil organic matter were improved.

5.2 Response of Variety

Generally, growth attributes such as number of leaves, plant height, number of branches, crop dry weight, leaf area index and crop growth rate at different sampling periods were found higher in UC82B than Roma VF. The superiority of UC82B to Roma VF on the above mentioned growth and yield characters might be attributed to genetic difference between them. It could be the variety UC82B has better photosynthetic efficiency due to higher leaf area index, higher solar harvesting which resulted to good growth and yield. These findings are in line with earlier reports by Miras *et al.* (2011). Differential performance of variety could be attributed to genetic variability and adaptability during the crop growth period. The reports by Olaniyi *et al*. (2010) indicated that UC82B was higher in the growth attributes of tomato than other varieties evaluated.

The yield components such as number of fruits per plant, fruit weight per plant and total yield ha^{-1} was significant where UC82B proved superior to Roma VF in both locations. This could be attributed to genetic factor as influenced by the favorable environmental factors that allowed the crop to grow vigorously resulting to early fruit setting. These results are not in agreement with the findings of (Law-Ogbomo and Eghavevba, 2008) who reported that UC82B yielded low when compared with other varieties evaluated. Mehta and Asati (2008) and Sharma *et al.* (2009) indicated that early flowering varieties would be beneficial for attaining higher yield of tomato.

Varietal differences in percent soluble solids, titrable acidity, and soluble carbohydrate have been reported in tomato (Abani, 1985). Fruit dry matter and higher fruit titrable acidity of Roma VF was superior to UC82B indicating that less moisture content was attained in Roma VF which is a good character for processing tomato. Fruit quality attributes like fleshiness of tissue and titrable acidity are important processing factor for canning (Oko-Ibom and Asiegbu, 2007). The higher titrable fruit acidity could be variety dependent and may also be due to genetic difference between varieties. Most aspect of tomato fruit quality has been reported to be under genetic control (Hewitt and Carvey, 1987). No significant difference was observed in TSS, crude protein, crude fibre, carbohydrates and percent ash of both varieties. These results obtained are in close conformity to those obtained by (Ereifej *et al.,* 1997, Hamid *et al.,* 2011)

Virtually soil chemical properties were similar for plots tested for soil total nitrogen and soil organic carbon throughout the study period exception of soil exchangeable K and soil C:N. Plot grown with Roma VF had more soil exchangeable K and higher soil C:N than UC82B plots at Samaru. This could be UC82B was more efficient in making used of soil exchangeable K and soil C:N than Roma VF.

5.3 Response to NPK Fertilizer.

In this study, application of 300 kg ha^{-1} NPK fertilizer enhanced growth of two tomato varieties. Tomato growth increased as expressed by the increases observed in crop dry weight, LAI and CGR. These increase in the growth parameters confirmed the importance of N, P and K as a major plant nutrients required for growth processes and development. It has been proven that chemical fertilizer are an essential input in any system in which the aim is to maintain good growth and yield (Rafi, 1996). Ewulo *et al*. (2007) reported that NPK fertilizer increased growth parameters of pepper such as crop dry matter, leaf area and number of branches.

NPK fertilizer application resulted to increase in growth parameters and yield of tomato. The significant yield increase could be attributed to the fact that plant biomass increased with increase in applied nutrient resulting in optimum assimilate production and translocation leading to more flower and fruit production. This result was in conformity with the reports by Nafiu *et al.* (2011) whose reports indicated the wider leaf area was obtained with application of 200 kg NPK ha^{-1} in all the growth stages of egg plant. The result of this present experiment higher leaf area index obtained with increase NPK fertilization showed that adequate supply of nutrient could lead to the production of assimilates and their transportation be enhanced. Similar findings was obtained from Law-Ogbomo and Eghaveuba, (2008), Babajide and Salami (2012), Hussain *et al.* (2012). Also increasing LAI resulting from higher fertilizer rate led to higher dry matter production and fruit yield, because of better utilization of solar radiation which favoured photosynthetic capacity (Gurnah, 1984). The observed delayed in flowering of higher inorganic dose might be attributed to excessive nutrients which prolonged vegetative growth and development. The delay to flowering with NPK application is supported by the findings of Abayomi *et al*. (2012) who reported in delayed in flowering of pepper.

Significant increase obtained on yield attributes such as fruits weight per plant after application of fertilizer followed the pattern of increases in NPK rates. This was an indication of improved soil fertility brought by NPK treatments as explained by Brady (1987) that the availability of nitrogen, phosphorus and potassium enhanced growth and yield of plant. This could led to higher assimilate production to the fruit yield, number of fruits and heavier fruit yield in NPK treated plots than in the control treatment.

Total soluble solids (TSS ^{0}Brix) content of the fruit varied due to NPK rates. It ranged from 3.5 to 6.7. The highest TSS was recorded from fruits which were produced with 450 kg ha^{-1} whereas the lowest was found in the control treatment at both locations. Puspha (2004), Salam *et al*. (2010) obtained higher total soluble solid with 100% recommendation dose of NPK with biofertilzer. This result confirmed the report of Beckles, (2012) who reported that nitrogen, phosphorus and potassium are critical for crop yield and fruit quality of tomato. Also (Chapagain *et al.,* 2003; Sainju *et al.,* 2003; Benard *et al.*, 2009) reported that tomato genotypes affect the responses to varying chemical fertilizer rate on fruit TSS. Although some studies pointed to an inverse relationship between soil nutrients and fruit TSS (Elamin and Al-Wahaibi, 2005; Parisi *et al*., 2006) and sugar accumulation (along with acids) may determine aroma intensity of tomato (Causse *et al*., 2002).

NPK fertilizer application consistently effect on fruit carbohydrate content and crude fibre content of fruit at Samaru. The significant decreases observed in carbohydrate and crude fibre content may probably be adequate nutrients availability to the fruits pulp development which might translate to less fibrous formation. This result is similar to the findings of Salam *et al*. (2010) whose reports revealed that pulp weight in tomato fruit was increased by NPK fertilization.

The significant difference noted among the NPK rates on fruit acidity in 2010-11 at both locations. Acidity is an important fruit quality character of tomato for canning and is an attribute of shelf life of fruits. Puspha (2004) obtained the highest titrable acidity of tomato fruit under the recommended dose of NPK bio-fertilizer.

Agronomic efficiency for both varieties was higher at 150 kg ha^{-1} NPK fertilizer and further increase of NPK reduced agronomic nutrient efficiency of tomato varieties at both locations. This implies that as the nutrient supply increases, incremental yield gain becomes smaller because yield determinants other than nutrients become more limiting as the yield potential of the crop is approached. This finding was similarly portrayed quadratic regression of this study both of which indicated that increasing nutrient elements increased the performance, efficiency and finally reaches asymptote line. Raeesi and Khajehpour (1992) and Abdolghayoom *et al*. (2012) reported similar findings that the decrease in fertilizer efficiency with the increase in N level.

Significant increase was observed in soil pH after NPK fertilization which could be attributed to oxidation of N nutrient of the compound fertilizer where conversion N to ammonium produces H^+ that increases the soil pH during reduction reaction (Yusuf *et al*., 2007). NPK fertilizer had significant influenced soil total N and soil organic carbon. This might be an indication that NPK fertilizer application had contributed significantly in increasing soil N. This result is in line with the findings of Ayeni and Adetunji (2010) who observed significant increase in soil N when soil was amended with inorganic NPK fertilizer. Also higher application of NPK fertilizer increases soil organic carbon (SOC). This increase in soil organic carbon might be due to the fact that NPK enhance microbial decomposition of plant residue (Pikul *et al.*, 2008; Poirier *et al*., 2009). Application of 300 kg ha^{-1} NPK produces significantly higher SOC and SOM at Kadawa. Soil organic carbon is an index of sustainable land management (Woomer, *et al*., 1994; Nandwa, 2003) and is critical in determining response to N and P fertilization.

5.4 Response to green manure.

The organic fertilizer takes the place of inorganic fertilizer in sustainable agriculture. The technology of using green manure is one of the most environmental friendly agricultural technologies which could provide better condition of the soil by improving the soil physical and chemical properties, soil fertility and soil micro flora (Seo *et al*., 2000b, Aksoy, 2001, Chowdhury, 2004).

In this study, tomato responded to green manure rates produces a better growth as indicated by leaf area index, and crop dry matter crop growth rate, relative growth rate and net assimilation rate. Higher crop growth and yield due to organic fertilizer could be attributed to favorable changes in soil condition which might result in loose soil and enable better root growth. Moreover, positive influence of organic fertilizer might be due to slow and steady availability of nutrients throughout the growing season from organic fertilizer (Maftoun *et al.*, 2004; Amanullah *et al.*, 2006; Tejada *et al*., 2006). The growth response of tomato to green manure relative to control in this trial could also be attributed to increased amount of nitrogen content of the legume (34.2-37.3 g kg^{-1}) and quality of phosphorus and potassium as well as other nutrients derived from decomposition of the incorporated green manure as shown in (Table 2). This is because the amount of nitrogen available from legume depends amongst other factors, on the amount of the total biomass incorporated as reported by Sullivan (2003), Liu *et al.* (2007), and Tonfack *et al.* (2009). Also Ogunwole *et al*. (2010) attributed that the increase in soil N to the quality (i.e Nutrient composition) of *Centrosema pascuorum* and *Parkia biglobosa* which were incorporated. It was further asserted that high total soil nitrogen in most cases means a small C:N ratio, which is one indication of the rate of decomposition in the soil. Similarly Abassi *et al*. (2009) and Sharma and Behera, (2009) observed that significant increase in soil nutrients after legumes incorporation.

Fruit weight, total fruit yield, fruit dry matter and fruit acidity were increased by green manure application. The implication of the results was that incorporation of green manure at 10 t ha^{-1} increased soil nutrients and mineralized N from decomposed incorporated materials. Also this could be attributed to the ability of green manure to supply essential nutrients and micronutrients for fruit quality. Aguyoh *et al*. (2010) reported that green manure serve as source of slow-release nutrients; therefore contribute to greater efficiency of nutrient utilization. Incorporation of Lablab as green manure was considered as important and beneficial to soil in terms of increased soil total N and organic carbon. These benefits could be attributed to N fixation of rhizobia in root nodules before incorporation. Similarly Abbasi *et al*. (2009) and Sharma and Behera (2009) observed significantly increase in soil total N after incorporation of legumes. These results was similar with the work of (Thomas *et al.,* 2012) who reported that when legumes are used as green manure they fix atmosphere N and green manure can be used as alternative to mineral fertilizer particularly to sustenance farmers whose resource base is small.

Agronomic efficiency for both varieties was higher at 10 t ha^{-1} green manure at both locations. This might be adequate availability of nutrients and slow release which effect yield output of variety. According to evaluation of Crawell and Godwin (1984), crop yield increased with increasing fertilizer consumption.

Reduction of soil pH observed after legume incorporation could be attributed to the development of biomass crop residues released organic acids which probably might be the caused the pH depression (Ogunwole *et al.,* 2010). It has also be reported that legumes may take up higher amount of base cations and in the process of balancing internal charges releases H^+ ion into rhizosphere that cause soil to be acidic (Tang *et al.,* 2001; Dakora and Phillips, 2002; Cheng *et al*., 2004, Adeboye *et al*., 2005b). Odunze (2003), Sharma and Behera (2009) observed significant improvement in soil organic carbon after incorporation of legumes.

This result also revealed low C:N ratio (9-18:1) of lablab incorporated legumes. This is an indication that better quality material were decomposed very fast because of the low C:N ratio which facilitate the quick release of mineralized N. Ogunwole *et al.* (2010) attributed the increase in soil total N to the quality of material incorporated and it was further asserted that higher total soil N in most cases means small C:N ratio, which is one indication of the rate of decomposition in the soil. In this experiment, the observed improvement of soil organic carbon after incorporation of lablab, could also be attributed to quick decomposition of incorporated green manure because of low C:N ratio.

5.5 Interactions

5.5.1 NPK and variety interaction

NPK and variety interaction on number of leaves number of branches and leaf area index revealed that addition of NPK fertilizer increased those LAI in both varieties. This could be attributed to the fact that tomato requires large amount NPK and the important role played by these nutrients for growth and development through increase in meristematic and physiological activities of the crop.

Significant variety and NPK fertilizer interaction on soil pH showed that the plots that received 300 or 450 kg ha^{-1} NPK had a low soil pH value which means higher NPK rate produce acids than the control rate. This control be attributed to the process of mineralization of N that resulted to production of H^+ that decrease the soil pH during reduction action as reported by Yusuf *et al*. (2007). The implication of this is higher NPK fertilizer can increase soil acidity meaning that nutrients availability may be hindered. According to Marinari *et al*. (2006) reported that slight acidic (6.1 – 6.5) is optimal pH range for most crops. Similar authors consider soil pH as one of the most important indicator of soil fertility because it affects plant nutrients in the soil (Kisetu e*t al*., 2013)

5.5.2 Green manure and variety interaction

The significant interaction between green manure and variety in CGR 7-9 WAT at Samaru revealed that the incorporation of green manure from 5-10 t ha^{-1} had produced higher CGR in the period of 7-9 WAT than in the control plots. UC82B proved superior over Roma VF on CGR 7-9 WAT. Similarly significant interaction was observed on weight per fruit, the result indicated that increased green manure increases fruit weight, on the other hand, Roma VF had produce taller plants than UC82B but UC82B proved superiors over Roma VF on CGR 7-9 WAT and weight per fruit. The interplay of superiority between the varieties might probably be genetic and quality of green manure applied for release of nutrients Babajide and Salami (2012).

5.5.3 NPK and green manure interaction

Significant NPK and green manure interaction on plant height, LAI, NAR, crude protein, days to first flower production and marketable yield was observed in this experiment. The use of

150 kg ha^{-1} NPK fertilizer and 10 t ha^{-1} green manure produced higher marketable and total fresh fruit yield but comparable to combined use of 10 t ha^{-1} of green manure and applied 300 kg ha^{-1} NPK fertilizer. This clearly demonstrated that with minimal NPK use increase fruit yield tomato can be obtained at higher green manure rate. This could be because of green manure from legumes were more qualitative and made available nutrients for leaf expansion. Significant NPK and green manure interaction on fruit dry matter was obtained at 10 t ha^{-1} of green manure and 300 kg ha^{-1} of NPK fertilizer. This could be attributed to increase availability of nutrients in the soil, water holding capacity and improved soil conditions. Sharma and Behera, (2009) observed that significant increase in soil nutrients after legumes incorporation.

5.6 Decomposition Pattern

Generally, there was a rapid mass loss from the litter bag during the first two weeks on the plot treated with inorganic fertilizer when compared with control treatments in both locations. By the end of incubation at both locations application of 450 kg ha^{-1} NPK had loss about 95% of the mass of the green manure buried in plots treated with higher rate had been decomposed.

The rate of decomposition per day increases with increase in NPK fertilizer rates, the probable reason might be connected to N availability and the quality of the green manure material used (low C:N ratio, polyphenol and lignin concentration) may reduced or enhanced decomposition dynamics. Various studies have established that high lignin, high polyphenol content and high C:N ratios in leaves tend to slow down litter decomposition and nutrient release (Semwal *et al*., 2005; Upadhanya *et al*., 2012; Dhanya *et al*., 2013). It is possible to attribute faster decomposition in those treated with inorganic fertilizer, residue that had N content of 2%

decompose faster. This suggests that chemical fertilizer favoured the decomposition process. This observation is in conformity with Makaza and Shoko (2013).

Also the negative effects of low quality organic material (Giller and Watson, 1991) explained in term of nutrient immobilization because of microorganisms are active in organic matter decomposition (e.g. bacterial & fungi) also obtained their nutrient requirement from the decomposing organic matter. Varying the NPK fertilizer levels affected the decomposition rate. Brady (1984) conforms this findings that nitrate availability and narrow C:N enhanced microbial activities hence materials are decomposed rapidly. This might be due to the presence of inorganic fertilizer which increases microbial activity since N was not limiting. However, it suggests the level of mass decomposition of plant residues is a function of integrated effects of chemical characteristics of the residue and the field conditions (Moniruzzaman *et al*., 2003).

5.7 Regression Analysis

5.7.1 Regression analysis on NPK fertilizer

The association of NPK rate with fruit yield was quadratic in both varieties and different optimum rate of NPK for fruit was attained. In combined data at Samaru; Roma VF (270 kg ha^{-1}), UC82B (260.1 kg ha^{-1}) while at Kadawa; Roma VF (280.1 kg ha^{-1}), UC82B (270.2 kg ha^{-1}).

5.7.2 Regression analysis on green manure

From the result of the regression analysis fruit yield was generally maximized at green manure rates. Therefore, the fruit yield had a linear response when regressed with green manure rate at both locations.

5.8 Correlation and Path Coefficient Analysis

The significant positive correlation observed between yield and growth and yield characters have identified their significance as yield determination factors at both locations. This is expected 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), Sigh 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 for tomato fruit yield is not a unitary character but depends on the development of various characters. In both locations, over all observations of the path coefficient analysis shows that fruit weight per plant, numbers of fruits per plant, plant dry weight, leaf area and number of leaves per plant are the most important traits. Similar results supported by the findings of Dudi and Kalloo (2002) for direct effect of average fruit weight; Bhutani *et al*. (1989) for number of fruits par plant and Nandan and Asati (2008).

The yield component used for the analysis exhibited highest direct effect throughout the years of study and the combined. The low residual values obtained in study signify that the major characters contributing to the fruit yield of tomato were considered. It was observed that only 11.2%, 18.8% and 15.1% at Samaru while at Kadawa 12.4%, 7.4% and 9.3% of the variability remain unexploited in 2010-11, 2011-12 and their mean respectively.

5.9. Cost benefit analysis

In this study, it was indicated that regardless of variety, application of NPK fertilizer up to 300 kg ha^{-1} and 10 t ha^{-1} of green manure increased the biological yield. The economic analysis of tomato production using 150 kg ha^{-1} NPK fertilizer and 10 t ha^{-1} green manure recorded in most cases gave highest gross margin and profit per naira (₦) invested. The lowest gross margin came from highest combination of NPK fertilizer and green manure rates. This might be an indication of higher fertilizer rates could be responsible to favoured vegetative growth that may significantly affect the reproductive growth and development. Therefore the fruits produced might not be bountiful enough to upset the cost of production.

CHAPTER SIX

6.0 Summary and Conclusion

Field experiments were conducted in 2010-2011 and 2011-2012 dry seasons at irrigation farms of the Institute for Agricultural Research, Samaru and Kadawa to assess the response of tomato varieties to NPK fertilizer and green manure rates. Treatments consisted of two tomato varieties (Roma VF and UC82B), four rate of NPK 15-15-15 fertilizer (0, 150, 300 and 450 kg ha^{-1}) and three rate of green manure (0, 5 and 10 t ha^{-1}), laid in a split-plot design with three replications. The combination of variety and NPK fertilizer rates were assigned to main plots and green manure to the subplots. Decomposition study was conducted using litter bag method in the field to determine fodder decomposition rate applied as green manure.

The result at both locations showed varieties differed significantly on growth parameters such as higher number of leaves, number of branches, leaf area index, crop growth rate, net assimilation rate, and yield attribute such as weight per fruit, fruits weight per plant, marketable yield and total fruit yield where UC82B performed better than Roma VF and also attain anthesis early while Roma VF had wider fruits, fruit dry matter and fruit acidity than UC82B. The soil chemical properties were similar except soil exchangeable K and C:N which was not consistent in the two locations.

Application of NPK fertilizer significantly increased growth parameters such as number of leaves, number of branches, plant height leaf area index, fresh crop, dry weight crop growth rate and net assimilation rate and days to flowering. Yield attributes such as fruit diameter, number of fruits per plant, fruits weight per plant, marketable, total fresh yield and nonmarketable yield were significantly increased by NPK fertilization. Also total soluble solids, ash content and crude protein were enhanced by NPK while carbohydrate, crude fibre, was significantly reduced by NPK application. However NPK fertilizer application increases soil pH, soil P, soil K and reduced soil C:N ratio soil organic carbon and soil organic matter.

At both locations, incorporation of green manure enhanced most growth parameters such as number of branches, plant height, and leaf area index, crop dry matter, relative growth rate and yield parameters such as fruit weight per plant, fruit number per plant, marketable fruit and yield total fruit yield as well as total soluble solids, carbohydrate, crude fibre and crude protein.

Interaction between NPK fertilizer and green manure rates on marketable yield and total fruit yield indicated that the combined application of 10 t ha^{-1} of green manure and 150 kg NPK ha^{-1} was found suitable for maximum fruit yield though at par with 300 kg ha^{-1}NPK fertilizer. The combination of 150 kg ha^{-1} of NPK fertilizer and 10 t ha-^{1} of green manure will save about 50% when compared with 300 kg ha^{-1} NPK fertilizer rate alone.

At both locations, agronomic efficiency was higher at the application of 150 kg ha^{-1} NPK fertilizer and decreased with increase application of fertilizer for both varieties. On the other hand, the agronomic efficiency using green manure at 10 t ha^{-1} gave the best. Decomposition of lablab fodder applied as green manure was fast with the application of 450 kg ha^{-1} and it took 11 days to reach 50% decomposition of fodder.

There was significant and positive correlation between total fruit yield and number of leaves, crop dry matter, number of fruits and fruits weight per plant. These were correlated positively and significant among themselves. The partitioning of the total correlation into direct and indirect contribution showed that most of growth and yield components made their greatest contributions to yield individually e.g. plant height, leaf area index, crop dry matter, number of fruit and fruit weight. The path analysis between growth and yield components showed that the greatest indirect contribution to total fruit yield was via fruit weight per plant. The residual effect determines how best the causal variable account for the variability of depend variable total fruit yield. The low residual effect obtained signifies that the major characters contributing to yield were considered.

Regression of total fruit yield to various treatments indicated that NPK fertilizer response was quadratic in all the location and years of study while green manure response was linear. The optimum for NPK fertilizer was calculated based the variety in combined data and the location. at Samaru, Roma VF 260, 280 and 270 kg ha^{-1} while UC82B optimum were 250, 270 and 260 kg ha^{-1} NPK fertilizer in 2010-11 2011-12 and combined; at Kadawa the optimum for Roma VF were 290, 270 and 280 kg ha^{-1} while UC82B were 260, 280 and 270 kg ha^{-1} NPK fertilizer in 2010-11, 2011-12 and the combined**.**

Partial economic analysis of tomato production in Samaru and Kadawa revealed that application of 150 kg ha^{-1} and 10 t ha^{-1} with any of the two varieties gave the highest gross margin as well as gross margin per naira (₦) invested.

Based on the result obtained from this study, one can conclude to the following that:

- The variety UC82B was superior to Roma VF in most growth and yield attributes while Roma VF produced more fruit dry matter and higher fruit acidity than UC82B
- Combined application of 150 kg ha^{-1} NPK fertilizer and 10 t ha^{-1} green manure gave best fruit yield but economically, fruit yield was best at the combination of 150 kg NPK fertilizer and 10 t ha^{-1}green manure in terms of profitability.
- Agronomic efficiency was higher using 150 kg ha^{-1} for the varieties at both locations

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Appendix I: Samaru Meteorological Observation for 2010-2011 and 2010-2011 dry seasons.

	2010-2011				2011-2012			
Month	RH (%)	T^0 max	T^0 min	Sunshine(hrs)	RH (%)	T^0 max	T^0 min	Sunshine(hrs)
Oct2010					**Oct2011**			
1-10	73.5	33.5	20.3	6.1	78.5	32.6	21.2	6.6
11-20	69.5	35.1	18.9	6.0	76.4	33.3	20.7	6.8
21-31	50	34.7	14.8	7.7	64.8	32.4	20.1	6.2
Nov					**Nov**			
1 – 10	15.7	34.5	12.2	8.9	40.5	31.8	17.1	8.3
11 – 20	13.6	32.9	11.7	8.7	29.1	35.2	15.9	8.8
21 – 30	14.4	31.7	12	8.6	17.8	34	15.7	9.0
Dec.					**Dec.**			
1 – 10	17.7	32	13.2	7.6	19.2	32.2	13.3	8.8
11 – 20	73.5	33.5	20.3	6.2	16.5	32.7	13.3	8.8
21 – 31	69.5	35.1	18.9	6.0	16.9	30.7	11.4	8.4
Jan 2011					**Jan 2012**			
1 – 10	20.7	28.1	13.1	5.9	18.8	29.6	12.3	8.5
11 – 20	20.3	27.5	11.6	7.9	17.5	29.7	12.2	6.9
21 – 31	11.9	34.7	14.6	9.3	14.3	36.4	14.3	8.7
Feb					**Feb**			
1 – 10	21.3	35.5	17.2	7.3	11.1	35.1	15.6	7.6
11 – 20	15.4	37.6	17.4	8.6	16.4	37.5	16.7	7.4
21 – 28	25.5	36.0	20.9	6.1	18.2	36.8	18.0	5.9
March					**March**			
1 – 10	11.3	38.5	19.5	7.1	14.1	37.3	18.2	7.7
11 – 20	15.6	38.6	19.4	8.3	8.8	35.1	19.5	3.9
21 – 31	12.5	38.9	19.9	6.2	4.7	36.9	19.1	6.5
April					**April**			
1 – 10	20.7	28.1	13.1	5.0	48.8	39.8	23.4	7.2
11 – 20	20.3	27.5	11.6	7.9	54.6	38.3	22.8	6.7
21 – 30	11.9	34.7	14.6	9.3	52.6	39.0	23.2	7.8

Source: IAR Meteorological Unit, IAR/ABU, Zaria.

Appendix II: Kadawa Meteorological Observation for 2010-2011and 2011-2012 dry seasons.

	2010-2011				2011-2012			
Month	RH (%)	T^0 max	T^0 min	Sunshine(hrs)	RH (%)	T^0 max	T^0 min	Sunshine(hrs)
Oct2010					**Oct2011**			
1-10	29.9	34.6	20.3	8.9	35.4	29.0	21.9	10.6
11-20	37.0	32.9	19.6	9.6	29.8	28.6	22.7	9.8
21-31	32.8	34.7	20.7	10.1	29.8	29.9	22.3	8.8
Nov					**Nov**			
1 – 10	35.2	36.2	19.0	10.8	24.2	35.4	17.3	10.6
11 – 20	27.7	36.0	18.7	10.1	22.5	34.8	16.3	9.7
21 – 30	23.6	34.4	17.0	10.6	20.9	32.4	15.7	10.2
Dec.					**Dec.**			
1 – 10	28.2	32.0	15.1	10.3	24.4	31.1	15.8	9.5
11 – 20	26.4	31.5	14.8	10.4	29.5	28.3	13.7	8.3
21 – 31	31.0	29.6	13.5	9.3	39.0	29.8	14.9	8.9
Jan 2011					**Jan 2012**			
1 – 10	39.5	29.0	18.9	8.7	45.4	28.0	13.6	9.5
11 – 20	28.9	30.1	1.6.5	9.8	37.6	28.8	12.9	8.2
21 – 31	28.0	32.6	20.5	9.5	36.0	35.2	16.2	10.0
Feb					**Feb**			
1 – 10	29.5	35.1	18.6	9.4	38.8	33.5	17.4	9.5
11 – 20	27.6	37.7	19.8	8.9	33.8	36.8	19.2	8.2
21 – 28	20.2	36.3	21.6	7.1	22.3	37.3	20.6	6.8
March					**March**			
1 – 10	28.2	39.1	22.1	8.3	25.9	38.1	20.2	9.1
11 – 20	35.2	38.9	20.8	10.0	25.7	34.8	21.7	7.1
21 – 31	42.3	39.9	21.6	8.6	24.1	37.4	21.5	7.7
April					**April**			
1 – 10	47.5	38.2	22.6	7.4	51.2	41.7	26.5	8.1
11 – 20	30.5	41.4	22.4	9.8	52.5	40.7	26.7	6.2
21 – 30	51.7	40.6	25.1	9.2	43.6	41.5	25.3	8.6

Source: IAR Meteorological Unit, IAR/ABU, Zaria.

Appendix III: Field Experimental Layout (split plot design) at Samaru and Kadawa in 2010-11 and 2011-12 dry seasons

V^1N^0	V^2N^2	V^1N^1	V^1N^2	V^2N^3	V^2N^0	V^1N^3	V^2N^1	
G5	G5	G10	G5	G5	G0	G10	G0	
G10	G0	G5	G10	G0	G5	G0	G5	**REP I**
G0	G10	G0	G0	G10	G10	G5	G10	

V^1N^0	V^1N^1	V^1N^3	V^1N^2	V^2N^1	V^2N^2	V^2N^0	V^2N^3	
G5	G5	G10	G5	G0	G5	G5	G0	
G10	G0	G5	G10	G5	G10	G0	G5	**REP II**
G0	G10	G0	G0	G10	G0	G10	G10	

V^2N^3	V^1N^1	V^2N^1	V^1N^2	V^1N^3	V^2N^0	V^1N^0	V^2N^2	
G0	G10	G5	G5	G10	G5	G0	G0	
G5	G0	G10	G0	G5	G10	G10	G5	**REP III**
G10	G5	G0	G10	G0	G0	G5	G10	

V^1 = Roma VF, V^2 = UC82B, N^0 =0 NPK fertilizer, N^1= 150 kg ha^{-1}, N^2 = 300 kg ha^{-1} N^3 = 450 kg ha^{-1}
G0 = 0 Green manure, G5 = 5 t ha^{-1}, G10 = 10 t ha^{-1} green manure

BIOGRAPHY

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