GROWTH AND YIELD OF TOMATO (*Solanum lycopersicum* (L.) Kart) AS INFLUENCED BY FERTILISERS AND LIGHT INTENSITY

BY

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ABSTRACT

Tomato is a source of dietary lycopene but its Fruit Yield (FY) is low due to declining Soil Fertility (SF), and Light Intensity (LI) affects its growth. Farmers rely on mineral fertilisers to improve SF, which could be scarce. Organic Fertilisers (OF) improve SF, while regulation of LI could be deployed to improve FY. However, there is insufficient information on application of OF and LI regulation in tomato production. Therefore, effects of OF and LI regulation on growth and yield of tomato were investigated.

In pots, commercially produced OF (I, II, III) at 60 (T1, T2, T3) and at 120 kg N/ha (T4, T5, T6), urea (60 kg N/ha)+single super phosphate (35 kg P_2O_5)+murate of potash (30 kg K_2O/ha) (T7) and urea (60 kg N/ha) (T8) were mixed with 10 kg soil arranged in Completely Randomised Design-CRD in four replicates. Unamended soil served as control (T9). Seedlings of Tomato Varieties-TV: Ibadan Local (IL), UC82B and Roma VF (RVF) were transplanted into pots. On the field (40,000 plants/ha), the treatments were arranged in Randomised Complete Block Design (RCBD) in triplicate. In another experiment, TV were transplanted into pots (CRD, R=5) and field (RCBD, R=3) and placed under different LI: [897.89 (L1, control), 673.70 (L2) and 450.44 (L3) Lux] for two weeks at vegetative (G1), flowering (G2), 50% fruiting (G3) and fruit maturity (G4) stages. The Plant Height-PH (cm), Leaf Area-LA (cm^2) and FY were assessed. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05.}$

Fertilisers, TV and their interactions significantly affected PH, LA and FY. The PH, LA and FY (g/plant) ranged from 58.9±2.5 (T9) to 81.1±3.2 (T4), 245.1±6.5 (T9) to 467.2±8.4 (T3) and 8.7±1.1t/ha (T9) to 13.2±1.5t/ha (T4), respectively across TV. The IL had the highest PH (80.8±3.1), LA (471.6±11.5) and FY (13.8±1.5t/ha) in T4. On the field, UC82B had the highest PH (88.0±5.4) in T3 similar to IL (85.65±5.2) under T1 but least in IL (62.0±4.5) in T9. The IL had highest LA (510.1±13.0) in T4 but least (357.5±10.2) in UC82B under T9. The UC82B in T4 had the highest FY (21.4±3.5t/ha), while IL (11.8±2.2t/ha) had the least in T9. The IL at G3 had significantly the highest PH (68.3±4.5) under L3 but least in UC82B at G3 under L3 (60.5±4.0). The LA (487.4±10.4) of UC82B and RVF (458.2±9.5) at G3 under L3 were similar but significantly higher than IL (330.5±8.0) at G3 under L3. The FY (23.8±2.5g/plant) of UC82B at G1 under L2 was significantly higher than IL

(22.1±2.2g/plant) under L2. The highest PH was obtained from IL at G3 under L2 (81.4±4.8), while least was from RVF at G3 under L2 (65.5±4.5). The LA of UC82B (387.4±12.8) was significantly higher than IL (315.4±10.5) and RVF (302.5±10.2) under L3 at G3. The FY of UC82B (25.8±2.3t/ha) was significantly higher than RVF (10.9±1.8t/ha) at G1 under L2.

Commercially produced organic fertiliser I applied at 120 kg N/ha and light intensity at 673.70 Lux during vegetative stage improved growth and fruit yield of tomato variety UC82B.

Keywords: Tomato varieties, Commercial organic fertiliser, Light regulation, Tomato phenological stages

Word count: 497

CERTIFICATION

I certify that this study was carried out under my supervision by Epiphania Ayangbolagun ILUPEJU, at the Department of Crop Protection and Environmental Biology, University of Ibadan, Nigeria.

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DEDICATION

This project work is dedicated to God Almighty and to my lovely children AnuOluwa and Oluwatobiloba Akanbi.

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CHAPTER 1

Introduction

Tomato (*Solanum lycopersicum* (L. Kart) is an annual plant and a member of the Solanaceae family. Tomato is usually cultivated as vegetable in the world and identified to contain minerals and vitamins (Wilcox *et al*., 2003). It is known to originate from the high areas of Central and South America (Gould, 1983). Total world tomato production in 2014 amounted to 170,750 million metric tons (FAOSTAT, 2014). In Nigeria, tomato fruit has been the most commonly eaten fruit vegetable in the diet (after pepper), and generally cultivated under irrigation or rain fed conditions (Kirimi *et al*., 2011).

Tomato fruit is a good source of secondary metabolites and essential nutrients to the health, for example lycopene, β-carotene, vitamins C and E, potassium and flavonoids (Agele *et al*., 2002). Dry matter comprises of sugars, organic acids, minerals, primarily nitrogen, phosphorus and potassium, and nutritionally significant vitamins and anti-oxidant including folates and lycopene. Tomato fruits have a large overall soluble strong content, which adds to their industrial significance (Kader, 1977). In tomato fruit, the principal components essential for their nutritional value are ascorbic acid (vitamin C), lycopene and potassium. Lycopene content has positive impacts on human health, and it is the pigment that is responsible for the colour in tomato fruits and other vegetables like watermelon, carrots and papaya. Also found in tomato fruit are β-carotene, flavonoids and phenolic acids which are secondary plant metabolites that determine the appearance and taste of the tomato fruit (Yahia and Brecht, 2012).

The quality and amount of significant phytochemicals in tomato fruit is dependent on varieties / genotypes (Binoy *et al*., 2004), soil nutrient concentrations, temperature, light intensity, fruit-leaf ratio, season (early or late), fruit size, nutrient sources and or quantity, storage and handling techniques, has powerful influence on dietary attributes of vegetables and fruits (Abushita *et al*., 1997). Among the climatic conditions mentioned, light intensity is a main factor in production of crop because of its responsibility in photosynthesis. Therefore, it is essential to cultivate plants with moderate light to improve optimum efficiency (Odeleye *et al*., 2001). Higher light intensity leads to production of more sugars and vitamin C, but inhibiting the development of beta-carotene that protects chlorophyll

from photo bleaching (Gross, 1991). A correlation has also been known between intensity of light and lycopene destruction and accumulation. Similarly, the ripening stages of tomato fruit may influence the content of its lycopene and other compounds. Highest lycopene content is discovered in ripe fruit compared to other ripening stages (Gross, 1987). In the process of ripening, tomato lycopene content was reported to increase sharply from the pink stage onward (Garcia and Barrett, 2006).

Fruit yield and dietary quality for example, the antioxidant content of tomatoes, are also affected by soil fertility. Appropriate use of fertilisers, either organic or inorganic, could improve the yield and nutrient content of tomato. However, inorganic fertilisers are generally scarce and always costly for low-income, small-scale farmers in Nigeria (Togun *et al*., 2003). Therefore, the enhancement of soil fertility in subsistence farming is completely dependent on locally available resources such as chicken manure, cattle and pig manure, slurry, compost, cereal and legumes (Adediran *et al*., 2003). However, combined use of organic and inorganic fertilisers is sometimes suggested for tropical planting (Ipimoroti *et al*., 2002). Using non conventional fertilisers also impacts accessibility of nutrients and the effectiveness of nutrient use of the plant (Akanbi *et al*., 2007).

Cultural practices associated with tomato growth and fruit lycopene have been investigated, but the findings are not conclusive. The situation is worse in developing country such as Nigeria, where there is insufficient information on the application of the organic fertiliser and light intensity regulations to the production of tomatoes. For this reason, it difficult to define the optimal development condition to maximize the synthesis and accumulation of lycopene, vitamins C and E and phenols in tomato fruit. To have more information it would be of interest to give an insight on how agronomic and environmental factors affecting the build up of these valuable compounds during period of fruiting. The research was therefore conducted in the derived savannah and tropical rainforest transition area to (1) investigate the effects of different commercially produced organic fertilisers, rates and forms of application on six ripening phases of different tomato varieties and (2) determine the effects of different light intensity imposed at various phenological stages on growth, fruit yield, phytochemicals and phytonutrient compositions in tomato fruits.

The research objectives were to:

i. investigate the effect of fertilisers on growth and development, fruit yield and phytochemical compositions of three tomato varieties;

ii evaluate effect of planting seasons and forms of fertiliser applications on growth, fruit yield, and phytochemical compositions of UC82B variety at six ripening stages

iii determine dry matter partitioning, fruit yield and phytochemical components of tomato varieties to different light intensities at various phenological stages

CHAPTER 2

LITERATURE REVIEW

2.1. Origin, varieties and botanical description of tomatoes

Tomato (*Solanum lycopersicum* (L.) Kart) is an edible plant with the typical red fruit it bears. It is an annual crop belonging to the Solanaceae group. Originating from South America, tomato has spread throughout the globe since the colonization of the Americas and different cultivars are extensively grown. Tomato fruits are eaten in different ways such as raw and in different meals. Tomato is a fruit, but regarded as vegetable for cooking reasons. Tomato is rich in lycopene which has beneficial impact on health. Tomato varieties are approximately split into several classifications, depending on the form and size of the fruit. Indeterminate tomato bears fruit as environmental conditions are favourable. Determinate types are chosen by business growers who would like to harvest the whole crop once or by domestic growers concerned in canning.

Tomato crops are vines with a sequence of stem branching, with the terminal bud at the apex where it is growing. The vines are typically pubescent and this facilitates the vining process wherever the plant touches the soil. Tomato plants have compound leaves, strange leaves pinnate, that has five leaflets on petioles (Acquaah, 2002). On the apical meristem its flowers appear with yellow corolla, which were bear together in a cyme of three to 12 cm. The fruit is categorized as a true berry with pericarp walls and hollow spaces, called a locular cavity filled with seeds and moisture.

2.2. Economic and dietary significance of tomatoes

Tomato is an excellent source of abundant secondary metabolites and nutrients including flavonoids, chlorophyll, lycopene, folate, potassium, vitamins C and E (Wilcox *et al*., 2003) which are essential to human health. Chlorophyll and lycopene are essential in photosynthetic reactions which are produced in chloroplasts and particularly chromoplasts in plastids with the highest accumulation. Carotenoids function as photoprotectants substances because of its capacity to neutralize harmful by-products of photooxidation (Clinton, 1998). Tomatoes and tomato products can be considered nutritious foods because they are low in

fat and calories and cholesterol-free, a good source of dietary fibre, vitamins A and C, β-carotene, potassium and lycopene (Yahia and Brecht, 2012) and its products are considered safe. The advantages of tomato fruit and their products have risen significantly on health due to its dietary (Giovannucci, 1995). An organic antioxidant for the prevention of cancer and heart disease (Shi and Le Mguer, 2000) was the main pigment responsible for the deep red colours in the tomato fruit and its products.

2.3: The nature and function of lycopene

Lycopene has been shown as the most antioxidant produced by the carotenoids pathway (Di Mascio *et al*., 1989). The lycopene structure has a very big molecule, $C_{40}H_{56}$, with a deep red colour. This deep red colour of lycopene provides colour to a lot of red fruits, including pepper, grapefruit, guava, watermelon, papaya, apricots and others (Conrad *et al*., 2007). Lycopene is highly sensitive to heat and degree of brightness and is easily degraded if not protected in its occurrence. Research on lycopene processing warn and advised a range of precautions from low to gold light to freezing temperature to prevent degradation during extraction or storage (Barua and Furr, 1992). The lycopene in tomato however, is very stable and boiling at 80°C for 10 hours had no effect on lycopene, but lycopene boils down only by 10% at 100°C (Zanoni *et al*., 1999).

2.4: Tomatoes as a lycopene source

Consumption of tomatoes is generalized and on a massive scale. Tomatoes have one of the highest concentrations of lycopene level of any fruit and definitely the highest concentration among common fruits and vegetables. The primary source of nutritional lycopene consumption globally (Stahl and Sies, 1996) is fresh tomato and its products. Fresh tomato alone accounted for 50 percent total lycopene consumption globally (Rao *et al*., 1998). The normal consumption of lycopene in the UK, Spain, Ireland and France (Olmedilla *et al*., 2001) was 3.5 mg/day in 1997. The availability of lycopene in tomatoes depends mostly on the handling methods with food product taken with it. Boiling tomatoes disrupt the cells and allow lycopene out of the cells, making it more easily available for intestinal absorption. In addition, as lycopene is extremely lipophilic, low fat intake by products from tomato will end up in lower uptake than high fat intake (Gartner *et al*., 1997). Different types of

nutritional fibre decrease bioavailability of lycopene while eaten simultaneously (Reidl *et al*., 1999). In fact, benefits from lycopene are realized even more from processed tomato products. Therefore, some evidence suggests that processing of tomatoes improves the health benefit by both concentrating lycopene and altering it to a more useful form.

2.5: Factors affecting the carotenoid contents of fruit and vegetables

Carotenoid concentration in fruits and vegetables can be affected by several factors. The product type, cultivar or variety, climatic condition, geographical location, maturation and stages of ripening, temperature during ripening, exposure to light, harvesting and post-harvest handling techniques (like the temperature during storage, natural/controlled atmospheres, processing and agro-technological condition and procedure analysis in several variables which can vary the concentration of carotenoids in fruits and vegetables (Solovchenko *et al*., 2006). Within tomatoes, lycopene concentrations differ according to the variety, ripeness processing as well as the growing conditions. During ripening process of tomato, chloroplasts undergo transformation to chromoplasts, which hold the lycopene (Kirk and Tilney-Bassett, 1978).

2.6: Tomato variety and its nutritional components

Tomato growth and yield are determined by varietal differences. Sajjan *et al*., (2002) recorded that, physiological parameters of crop including height of the plant, number of leaf, leaf area, secondary branches and fruit production were affected by hereditary traits from various varieties. Ibrahim *et al*., (2000) observed variations in crop growth indices are usually ascribed to their genetic composition. Odeleye and Odeleye (2001) observed physiological characteristic, yield and its constituents varied with plant cultivars and suggested that growers should choose the most successful genotypes in their breeding systems. The variations in photosynthetic activities between the growth characters of the crop genotypes in leaves were defined by Ray and Sinclair (1997) which include internal factors or differences in high distribution on leaf surface of the crop canopy, arrangements of the leafs, chlorophyll content differentiations, photosynthetic enzymes activity, and variations within conductivity of stomata. Zaki (1999) ascribed plant cultivar yield differences to stomata conductance and genotypic variations in the partitioning of

photosynthetic materials into economic yield. Clark *et al*. (1997) reported that the genotypic variations in components of yield may be due to differences in hereditary structure, nutrient levels and characteristics, mineral concentration and capacity to transport photosynthetic elements within the plants.

Tomato fruit lycopene and secondary plant metabolites activities were found to be different significantly among genotypes. Types of product can influence type and quantities of carotenoids, although varietal variations can mostly be attributed to quantitative differences. In a report, various tomato varieties were found to contain greater amount of flavonoids, primarily as quercetin (Crozier *et al*., 1997). Paksoy and Acar (2009) evaluated response of different tomato cultivars to organic fertilisers. He reported that crop variety varied as regards their growth, fruit yield and quality when subjected to similar growing condition. In this report, fruit quantity and quality varied among the ten tomato varieties tested.

Agele *et al*. (2008) assessed some tomato cultivars in their response (SAMTOM, Ibadan local and Roma VF) to growth, yield and nitrogen effectiveness when cultivated using inorganic and organic manure fertilisers. Significant greater amount of dry weights and root fresh weights and biomass of shoot were developed by tomato plants cultivated on the plots where nitrogen, phosphorus, potassium and poultry droppings were applied on untreated soil. Higher Nitrogen applications and fruit production utilization have been reported for Roma VF. Olaniyi *et al*. (2009) evaluated growth parameters, fruit yield and superiority in seven tomato cultivars in a Guinea Savannah region of South West Nigeria observed variability in the performance of tested cultivars in response to fruit yield and dietary compositions. Those variations found were ascribed to variations in assimilate partitioning of different cultivars.

The choice of variety depends on local conditions and the use for which the crop is grown. Farmers prefer improved varieties because of their superior qualities (Adebo and Olaoye, 2010). In another research, six watermelon varieties (crimson sweet, jubilee, sugar baby, charleston gray, green gold and ice box) were evaluated for their growth, fruit yield and nutritional composition by Karung *et al*. (2000). The report indicated significant variation in

all the traits assessed. It was concluded that crop varietal performance under certain ecological conditions could depend on cultural practices and environmental factors.

2.7 Fertiliser utilization and crop performance

2.7.1. Fertiliser as a factor in crop production

Declining soil fertility is the main factor accountable for decline in production of fruit and vegetable crops in Nigeria. Soil fertility could be enhanced by mineral and non mineral fertiliser applications. However, application of any type of fertilisers depends on a number of factors for instance soil nature, nature of crop, reason for production and environmental conditions of the area (Akanbi *et al*., 2010). Soils in most areas where tomato is growing in Nigeria are predominantly sandy which are regarded to be little in nutrient and low water holding capacity which resulted in stunted plant growth, poor bloom or fruit production and low quality produce (Akanbi *et al*., 2010). If soil is properly prepared and maintained, farmers will take pleasure in these opportunities despite the fact that possible negative factors will be improved. These produce a healthy soil for which many crops flourish (Ismail, *et al*., 2005).

Soil fertility in subsistence farming is dependent on locally available resources through composting. Compositing is a natural mechanism through which microbes turn organic plant substances into soil-like dark compost. On the forest floor, the leaves that dropped follow the same method that produces the dark humus deposit. Composting is an easy way of recycling food remnants at home and various farm wastes to produce organic fertiliser, as soil amendment for the field and horticultural crops (Park *et al*., 2002). Application of fertilisers improved agricultural produce for the farmers. This will improve farmers' rights that do not lead to fertiliser usage in many developing countries, which have little priority for the subsistence sectors. It is particularly important for farmers to use organic fertilisers (FAO, 2006).

2.7.2 Influence of mineral fertiliser on fruit yield and quality parameters

Fertiliser application had been reported to promote plant growth and development. Several researchers had observed an improvement in the vegetative growth with application of

fertilisers. Quality of the crop produced shows contrary opinion on the role of fertiliser. Stefano *et al*. (2004) reported fertiliser amendment produced good fruit that was acceptable by consumers. The size of the fruit, colour and firmness could be influenced by the types and levels of nutrients applied (Drake and Fellman 1987). In another article, application of mineral fertilisers profited eggplant fruit set and generally boosted onion and eggplant size characters more than non-fertilized plants (Asiegbu and Uzo, 1984). Growth, yield and flavour size of the onion bulbs are genotypic dependent characteristics. In general, by the application of fertilisers this could be changed by agricultural practices (Mahanthesh *et al*., 2008). Conclusions in most research works have suggested that crops can only demonstrate their ability if they are fed sufficiently with fertiliser and nutrient requirement. Size of the fruit and nutritional composition are the most important requirements for vegetables and fresh fruit. This has been stated of tomatoes to be strongly associated with the levels of nitrogen nutrient required in plant use for the duration of cell mitotic development, cell enlargement and fertilization, (Jullien *et al*., 2001). Likewise, the accessibility of N might influence the functions of the fruit sink and it plays a role in controlling accumulation of carbohydrates (Gyllaspy *et al*., 1993). The quantity, weight and chemical constituents of fruit such as tomatoes are determined through these activities. These variables were extremely essential in quality assessment, size and chemical characteristics in fruit (Joubes and Chevalier, 2000).

Nitrogen (N) is one of the macro nutrients needed by crops. Nitrogen is taken up by plant as inorganic ions (Sandoval-Villa *et al*., 1999) (NH_4^+ or NO_3^-). Gao *et al*. (1996) stated that the quality of its fruits is improved by using high NH_4^+ and low NO_3 levels. The synthesis of secondary metabolites comprises inadequate information concerning the influence of N form (Brandt and Molgaard, 2001). In line with "hypothesis of carbon-nitrogen balance, when N is ready to use, crops produce particularly high nitrogen concentration (for instance proteins), while in restricted availability of nitrogen, the metabolism of secondary metabolites including phenols and terpenoids, such as starch, non-N, and cellulose is shifted more toward carbon composition (Jeffrey *et al*., 2009). Due to comparative changes in mineral element discharge from distinct fertilisers, different Carbon / Nitrogen ratios in plants may result in a variation in secondary metabolites production (Brandt and Molgaard, 2001).

2.7.3 Influence of organic fertiliser on crop development, fruit yield and quality

The society has become more worried with the ecological harm done by farming operations, in particular with regard to adverse health effects arising through utilization of synthetic chemicals (Van der Berge *et al*., 2000). Different methods of farming substitute were developed in which organic farming had been established and licensed throughout the world (Adediran *et al*., 2003). Organic farming is regarded to be deficient mineral fertilisers with pesticides plus regular use of organic fertiliser as a source nutrient to plant (Adediran *et al*., 2003). Accepting of fruits may be affected through the nutrients engaged during its production. Organic fertiliser increases soil physical, chemical and biological situation of the soils, which improves growing of crop surroundings and culminates by increasing economic efficiency of the plant parts (Akanbi and Togun, 2002).

Non conventional fertiliser provides a natural process to enhance soil nutrients (Adenawoola, 2005). Organic fertilisers including compost and manure contain higher ratio among organic matter and nutrient value (Adeniyan, 2005). Subsequently, soil is the foundation for sustainable food production management, with a substantial increase in soil efficiency during the utilization of organic fertilisers in organic food production (Neeson, 2004). In organic cultivation, compost, green manures and their extracts are applied in different forms to enhance fertility of the soil and to combat pests and diseases (Barker and Bryson, 2006). Organic droppings and composts had been discovered by stimulating competing micro-organisms to have a direct anti disease effect and increasing crop disease resistance (Ghorbani *et al*., 2006). Utilization of fertilisers and droppings improved fertility in the soil and therefore enhance crop yields (Sandeen *et al*., 2003).

Many research activities undertaken indicated positive effect of organic wastes on soil fertility. Pandey *et al*. (2006) discovered that, use of manure and soil (1:1 volume ratio) had vigorous plants with the largest ratio solid phase and gave highest height of plant and dry matter than carbonized rice husk and soil (1:3) with peat and soil (1:3) in pepper and tomato. Allen *et al*. (1997) observed that application of rape seed cake cucumber produced good quality fruit than bark compost because of slow release of nitrogen. Upendra *et al*. (2001) also noted that the residue of vetch hairy (Vicia villosa Roth) (100 g /plant)

efficiently improved leaf dry weight, nutrient uptake and total dry weight of tomato (4.4 to 7.9 g /plant) as mineral fertilisers improved tomato fruit yield.

Combination of compost with NPK showed a greater yield of tomato fruit (35.27 tons per hectare) in polyhouse with a medium cost. The interactions among growing conditions and various nutrient sources were non-significant with regard to tomato production, yield and nutritional value (Shiraghings, 2010). Basavaraja *et al*. (2003) suggested that irrespective of growing conditions, the plant that received 50 percent FYM + Azospirillum root dipping + 50 percent RDF + 50 percent compost had significantly higher fruit yield (21.49 t/ha) in capsicum. It was suggested that this could be attributed to a substantial rise in stem height (59.49 cm), fruit / plant (3.99) and yield / plant (7.76 kg). In the RDF + FYM treatment the least yield (17.36 t/ha) was observed. The use of vermicompost rendered better performance in respect of all round mulberry plant growth in the lateritic soil of South West Bengal (Chakraborty *et al*., 2008). The main distinctive character of vermicompost is that it has ability of converting multiple organic refuses to earthworms, but some of the nutrients are tampered in the form that will make them readily available for use by the crops.

2.7.4 Organic fertilisers and crop quality

Influence of fertilisers on physicochemical properties of plants residues on the nutrient uptake are constituents of major organic compounds that latter increases the content in crops (Pan *et al*., 1995). Various agrochemical and biochemical research indicated that fertiliser is one of the most efficient and quick acting factors of variations in plant chemical composition and higher crop quality. By improving the supply of plants with particular nutrient, the biochemical processes that make use of the nutrient are favoured. It follows directly from this that inadequate supply of nutrients appreciable growth cannot takes place and that plants must remain stunted and relatively under developed when essential nutrients are deficient. Apparently, when nutrients are deficient, leaves will contain relatively little chlorophyll and thus reduced photosynthetic capacity. In response to increase in biomass, non conventional production is required to offer excellent quality, safe from pesticide residues and improve nutrients. (Montagu and Goh, 1990), observed improved quality of organic vegetables than inorganic vegetables for example, carrots with better carotene

(greater than12 %), vitamin C content (greater than 11percent), a reduced amount of nitrate in celeriac, excellent flavour, colour and betanine in beetroot. Hsieh-ChingFang and Hsu-Kuonan (1994) indicated quality fruit of sweet pepper fruit enhanced through organic treatment than inorganic fertilisers.

Lampkin (1990) noted that vegetables produced under the organic production had a taste. Perry and Mcintosh (1991) also discovered variations in taste of different organically produced or biodynamically manufactured tomato and potato, respectively. Again, Liu *et al*. 2009 discovered reduced acidity, greater sugar and lycopene content in tomatoes cultivated organically, while Abbasi (2009) indicated that vermicompost was used alone at 5 t/ha or in conjunction with the suggested quantity of fertilisers and farm yard manure, enhanced fruit yield and quality parameters.

2.7.5 Influence of fertiliser on fruit parameters

The production of seed in any plant could be optimal when all the necessary growth factors at hand are present. From the work of Olaniyan *et al*. (2006), the capacity of a crop to show signs of its hereditary potential for the production of seed depends on the available nutrients during the formation of seed. It shows that the procedures engaged in the production of seed under a low nutrient system would be extremely influenced. This can point out the variations found in the amount of tomato plants cultivated with different fertilisers. The plant that received NPK produced the good seed in terms of quality and quantity which shows the nutrients contained in NPK are adequate to produce high-quality seeds. Olaniyan *et al*. (2005) stated that fertiliser application usually increased production of fruit in *S. macrocarpon* and plants without fertiliser yielded fruits that were smaller in number and fewer with many unfilled seeds.

Nutrient stress has been reported in another research to have adverse effect on physicochemical characteristics of eggplants fruit. When an appropriate quantity of fertiliser is applied, the mobilization of nutrients in fruit is improved. Also, rate of nitrogen intake depends on the quantity of photosynthate supplied to the root system. The assimilate supply, in turn, depends on the production of photosynthate and its use by shooting processes. All of these are influenced by the supply of nutrients. In this research, poor fruit qualities

connected with low N fertiliser rates could be attributed to inadequate N supply needed for fruiting. This is correlated with the reports by Pan *et al*. (1995). In both reports, elemental and proximate composition of plant fruits and seed were discovered to be low with poor nutrition. More so, eggplant exposed to high nutrition has been documented to have a stronger sink for assimilate in eggplant fruit harvested. This invariability had positive influence on dry matter partitioning into fruits (Savvas and Lenz, 2000).

The use of organic fertilisers could help to ameliorate and control crop diseases. In the research work of Siddiqui and Akhtar (2007) the influence of arbuscular mycorrhizal and organic manure for example (cattle dung, goat dung and poultry droppings) alone, as well as in combinations on the reproduction of the nematode Meloidogyne incognita and on growth and loss of water in tomato were recorded. The addition of organic fertiliser enhanced growth and fruit yield in tomato reduced the rate of water loss and effect of nematode.

2.7.6 Integration of organic and inorganic fertilisers in crop production

The integration of a small quantity of conventional fertiliser and non conventional fertiliser available on farms provides an approach to satisfy the nutrient needed by plants. It reduces leaching of the nutrient, especially on poor sandy soils and later on groundwater contamination (Manna *et al*. (1999). It makes application of available organic materials and reduced application of expensive conventional fertilisers (Ghosh *et al*., 2004). Supplying organic products to farms, including application of farm yard manure and crop residues compost, is probably inadequate to resolve soil nutrient deficiency.

Sutapradia *et al*. (1979) noted that the effect on tomato growth from combinations of droppings and NPK (complex fertilizer, 15:15:15). The study revealed that a mixture of 30 tonnes per hectare of droppings and 100 kilogram per hectare of NPK provided the highest yield in tomato. Thomas *et al*. (1995) reported greater production on physiological parameters with yield components of tomato attributed to the use farm manure mixed with recommended rate of mineral fertilisers more than sole application. Uddin *et al*. (2009) discovered that in potato, use of 80 kg nitrogen by poultry droppings plus 80 kilogram of nitrogen ammonium sulphate produced higher stem height (33.15 cm), plant shoots (4.66)

per plant, number of leaves (48.40), fresh weight, dry matter (14.13 %), weight of fresh tuber (131.83 %), tuber dry matter (16.87 %), protein (2.12 %), carbohydrates (12.42 %), starch (15.97 %) and phosphorus (0.282 %) and marketable yield (121.48 % per hectare). Jigme (2019) discovered the use of poultry manure at 25 tonnes per hectare along with inorganic fertiliser improved spring broccoli yields, peppers, cauliflower, eggplant and tomatoes compared to inorganic control. Utilization of farmyard + poultry droppings at 5 tonnes per hectare each, supplemented by 50 kilogram N per hectare, resulted in greater yields of pepper fruit relative to mineral fertilisers (Aliyu, 2002). Ribeiro *et al*. (2000) noted that pepper yield was enhanced by conventional augmented soil than inorganic fertilisers under field condition. But dry matter had improved by increased vermicompost (600 g) and dry matter of root (400 g) in screen house condition. Sharu and Meerabai (2001) discovered a greater yield of pepper fruit yield was achieved with 50 per cent poultry droppings and 50 percent of inorganic nitrogen.

In another development the use of neem cake at application rate of 2 tonnes per hectare combined with 75 % recommended nitrogen had a the greatest dry pod yield (4.078 gram), dry plant weight (141.67 gram), uptake of nitrogen (168.4 3 kilogram per hectare) and the uptake of potassium (176.80 kilogram per hectare) whereas, poultry manure at 10 tonnes per hectare in combination with 75 % recommended nitrogen fertilisers resulted in the highest P uptake (42.17 kilogram per hectare) in paprika plant (Hari *et al*., 2006). Abumere *et al*., 2019 reported inorganic fertiliser at 20 gram/plant, goat dung fertiliser and chicken manure (50 gram/plant each) along with modification of soil had positive impacts on pepper performances.

Vijaya. (2011) reported significant variations in the physiological parameters on the height of the plant, plant girth, leaves per plant, primary and secondary branches due to the use of various rates of organic manure, mineral fertiliser and biofertilisers on eggplant. Also, Shehata *et al*., 2012 noted the response of NPK + poultry dung + compost at a rate of 1/3 + 1/3 + 1/3) enhanced plant height, leaf number and stems as well as their fresh weight, total fruit yield, flesh thickness and increase in concentration of N, P and K inside sweet pepper leaf with stem. This is similar to the observation of Ghoname and Shafeek (2005) on tomato.

During green house experiment conducted by Heeb *et al*. (2006) on tomato plants to test effect of fertilization types and level of applications as affected yield, dietary quality and fruit taste. At the end of the final harvest, yields of green tomatoes in the organic treatment with extra sulphur were related. This was because organic fertilisers released nutrients slowly than mineral fertilisers, resulting in decreased S and P concentrations in the leaves, which reduced growth and yield in the non conventional treatments. Adequate nutrient supply was found to be sufficient for the production of tomatoes to produce high yields and good taste.

In another research, investigations were carried out to see the impact of conventional and non conventional fertilisers on tomatoes. Recommended doses of nitrogen, phosphorus and potassium together through farmyard manure and vermicompost at 250 and 12.5q per hectare was discovered to be more useful on the yield / plant, earnings / hectare, fruits / plants, mean fruit weight, fruits / clusters and total soluble solid content. However, there was no combined influenced of nitrogen, phosphorus, potassium, farm yard manure and vermicompost on vine length and pericarp width. Vermicompost together with nitrogen, phosphorus and potassium could lead to early flowering, while early harvesting resulted through vermin compost applications and P (Shukla *et al*., 2006).

In Nigeria, yield and quality of tomatoes cultivated with conventional and non conventional fertilisers were investigated by Taiwo *et al*. (2007). The compost fertiliser (CBF) was made from the corn stover and cassava peels as well as from poultry droppings was used at 5 Mt. ha^{-1} and combined with N: P: K (20:10:10) and 0, 30, 60 and 60 kg. The use of CBF only enhanced the produce by 145 % than unamended and was significantly greater than other treatments. The study proposed significantly greater efficiency of the tomato plant and improved soil fertility maintenance with the use of CBF. Again, recommended rates for sustainable tomato production have been observed to combine organic fertilisers with synthetic fertilisers for production of tomato.

Ojeniyi *et al*. (2007) have examined the value of mixing crop and animal waste to achieve an adequate quantity of organic manure for tomato crops production. The studies investigated the influence of NPK fertiliser on leaf nitrogen, phosphorus and potassium

levels on physiological parameters and fruit yield of tomato, along with spent grain, ground cocoa husk, cattle dung, poultry droppings and goat dung. Fruit yields given by organic sources were 268 percent higher than what was obtained with NPK fertiliser. This was ascribed to slow releases of nutrients from non conventional fertiliser which makes the nutrients accessible to plants for better use. Effects of distinct types of fertilisers and application methods on tomato yields and inorganic nutrient content were investigated (Nakano and Uehara, 2007).

Soil microbial community structure and tomato crop yield could also be improved through the use different type of fertilisers. This was ascertain in the research work of Gabriel Maltais *et al*., 2007 on the impact of cover crops, compost and manure amendments on soil microbial population structure in tomato production systems. The crop yield and microbial population structure was significantly under integration of organic and inorganic fertilisers. Tamaki *et al*., 2002 reported effects of soil amendment method using filter cake (fermented organic waste from the sugar mills factory) and poultry droppings in combination with different forms of nitrogen fertilisers and the application of calcium chloride on fresh fruit, seed yield of processing tomato variety X6048. The report revealed that soil treated with 50 % organic fertilisers and 50 % of recommended amount of nitrate-based nitrogen fertiliser gave the highest fresh fruit and seed yield.

Influence of non conventional fertiliser, mineral fertilisers and compost extracts on health of the crop, productivity and durability of tomato were tested with different fertilisers: cattle dung, sheep dung and chicken droppings, farm yard waste, home waste with mineral fertilisers of urea and superphosphate and their different combinations (Ghorbani *et al*., 2008). It was observed that amended with chicken droppings reduced disease incidence, as shown by 80 % healthy tomato compared to other fertilisers. However, non conventional fertilisers applied had lesser yield than mineral fertilisers. Sheep manure and mineral fertilisers led to the highest total yield of tomato. Saleable yield was highest in chicken droppings of 16 tonnes per hectare, and lowest in mineral fertiliser of 7 tonnes per hectare, 6 weeks after storage. The influence of aqueous extract on either crop health or tomato yield was not significant and the results were not consistent. The compost made from chicken

droppings as a result appears to show environmental potential substitute to conventional fertilisers.

Integrated use of conventional and non conventional fertilisers could boost farmers' returns. Researches were conducted as an on-farm trial to evaluate the influence of various fertilisers on the efficiency in terms of growth, produce and tomato profitability. The experimentation consisted of five treatments: control, compost manure, cured poultry dropping, conventional fertiliser (NPK 15:15:15) and combination of 20 tonnes per hectare of organic fertiliser (compost mixture and chicken droppings) and 100 kilograms per hectare of NPK minerals fertiliser (organomineral fertilisers). Results showed that crop vegetative parameters, days to 50 percent flowering and fruit yield were affected by applied fertilisers. The best possible fruit yield (27.30 t/ha) produced from combination of organic and inorganic fertiliser treatment based on revenue (N1, 187,550.00), gross margin (N1, 090611.50), net farm profit (N1, 077892.65) and Benefit-cost ratio (10.83) were the greatest among the treatments (Lin *et al*, (2003).

2.7.7 Fertilisers types and phytonutrient components of tomato fruit

Tomatoes are cultivated by means of both mineral and non synthetic fertilisers. The nutritional quality of organic and inorganic grown plants has been compared mainly in terms of macronutrients, vitamins, and minerals. Woese *et al*., 1997) analyzed the observations of more than 150 researches, and it was found that the nutritional value of these items was inconsistent. In some experiments, secondary metabolites (e.g. antioxidants) are compared for mineral and non-conventional grown food. In recent times, in three varieties of organically and inorganically cultivated strawberries, Hakkinen and Torronen (2000) compared the phenolic contents. The findings shows that, there were lower phenolic levels in inorganic than variety grown under organic environments, but its phenolic value for the other two varieties was not significantly different. Compared with inorganic methods (412 mg per 100 gram), Asami *et al*. (2003) reported significantly higher total phenolics in organically grown marionberries (620 mg per 100 gram of fresh weight). The Golden delicious phenol (mainly flavonol) was 19 percent greater than in apples grown using conventional farming (Weibel *et al*., 2000).

2.7.8 Fertiliser forms and crop performance

Taking into consideration, crop and soil constraints and duration of the growing season, fertiliser must be applied in smaller amounts in synchrony with plant demand. In the recent situation, crop production is questioned in a way that the production benefits are maximized and adverse effects of water and nutrients were reduced. The mixture of nutrients and water is a requirement for improved yields and efficient production. An essential way to improve the good organization of the nutrients is also the method of application of fertilisers. Fertigation allows sufficient supplying of the nutrients and water regular distribution in order to meet the demand for plant nutrients (Narda and Chawla, 2002).

Various forms of nitrogen affected yield, quality and tomato taste in non-conventional and conventional fertilisers. Tomato plants were grown for 10 weeks in the screen house and supplemented with two non-conventional fertilisers or three various standard nutrient mineral solutions, with a ratio 4:1 or 1:4 (NO_3^- : NH_4^+). In order to copy the nutrient supply of organic production systems, ammonium inorganic fertilisers have been combined with two chloride levels as the dominant N source. Significant higher scores were obtained in terms of sweetness, acidity, taste and acceptance in organically cultivated tomatoes and ammonium-dominated tomatoes. As an improved sample of tomato fruit, tomato plants with small quantity of nitrogen, including ammonia and nitrogen, should also be recommended (Heeb *et al*., 2005). Fertigation also ensures large reserves of fertiliser use and eliminates losses of discharge (Mmolawa & Or, 2000). Water is widely used, optimal splitting of fertiliser increases crop yield quality and quantity compared to standard practice, and Hebbar *et al*., 2004 noted greater yields of tomatoes through fertilization compared irrigation banded and furrowed and banded and irrigated trickles. Previous tomato surveys showed 16 % rise in yield with drip irrigation over the furrow technique when 60 per cent of N and K fertilisers were applied pre-planted (Locascio *et al*., 1997) and enhanced nutrient movement of soil phosphorus and potassium in the drip root field fertigation (Hebbar *et al*., 2004).

2.8 Effects of season on the major antioxidant components of tomatoes

Little researchers investigated seasonal fluctuations of nutrient especially the phytonutrient content of tomato. Vanderslice *et al*., 1990) recorded variations in season tomato ascorbic acid substance, with greater concentrations at summer than in spring. In mature green stage, greenhouse grown tomato shows seasonal variations in content of vitamin C and directly correlated to differences in temperature (Liptay *et al*., 1986). There were significant variations in the quercetin levels of cherry tomatoes cultivated during different periods of the year with respect to phytochemicals, but there were no definite seasonal patterns (Stewart *et al*., 2000).

2.9 Tomato fruit maturity, ripening stages and nutritional quality

The method of ripening is the most important thing influencing fruit and vegetables carotenoid material. In just a few days, some crops carotenoid content may increase as a result of maturation, from nothing to elevated concentrations (Carrillo-Lopez and Yahia, 2010). The qualities in carotenoids are increased through metabolic activities of ethylene. For the ripening period in mangoes the carotenoid content increases gradually (V'azquez-Caicedo *et al*., 2005) for the period of the maturation. The development of the quality of carotenoids resulted from ethylene metabolism. Related results were recorded for a number of fruit and other vegetables like apricots (Dragovic-Uzelac *et al*., 2007). Immature pepper (*Capsicum spp*.) fruit usually had reduced concentrations of lutein and xeaxanthin compared to mature, coloured fruit (Lee and others 2005a). In tomato, lycopene carotenoids increase significantly during plant maturation and ripening (Carrillo-Lopez and Yahia. 2010), and the amount of carotenoid accumulation depends on various factors, such as temperature and light intensity (Von Elbe *et al*., 1996). Nonetheless, exceptions include, for instance, Xu *et al*., 2005 discovered the carotenoid content of three varieties of date reduced for the period of maturation with highest at matured level and lowest at the ripeness.

Chlorophylls content frequently disappearing during maturation, chloroplasts is degraded and converted into chromoplasts, while carotenoids synthesized and appeared. Unripe green fruits commonly contained chloroplasts carotenoid, and when it is ripe, chromoplasts build up and carotenoids produced in a larger scale, which was not similar to the one present in

the chloroplasts. In the process of maturation, many genes "turn on," including those related to carotenoids biosynthesis or degradation of chlorophyll, lead to increased accumulation or an enhanced carotenoid appearance, (later, chlorophyll disappearances and the emergence of carotenoids). Those enzymes are found, including ripening-specific phytoene synthesis inside tomatoes (Fray and Grierson. 1993). For fruits such as tomatoes, where selective breeding tomatoes containing increased quantities of plant synthase are developed by the introduction, molecular genetic manipulation was used.

The yield and quality factors of tomato (flavour, colour, soluble solids and nutritional importance) could be influenced by cultivar, climate, storage conditions, fruits maturity and cultivation techniques (Gould, 1983). Differences in the ripening of tomato fruit happen in the plastids after chlorophyll has disappeared. Chlorophyll and carotenoids are the two main pigment groups found in tomato fruit. The most significant change during maturation is the significant increase in fruit carotenoid levels. Chlorophyll decreases during the ripening process while the fruit is producing carotenoids, particularly lycopene (Liu *et al*., 2009). Brandt *et al*., 2001 reported that glasshouses tomato have reduced lycopene content compared to field grown crops at various harvesting times. As proposed by Ilupeju *et al*., 2015, there is a significant distinction in the quantity of lycopene in different cultivars. Light intensity has influence on carotenoid biosynthesis and growth of fruit colour (Shiraghinge *et al*., 2010).

Ascorbic acid and total soluble solids (TSS) contents are frequently regarded to determine the characteristics of the fruit in tomato. In general, soluble solids are sugars like glucose, fructose and sucrose. In tomato fruits, organic acids with sugars make a major contribution to the taste of the fruit. Most flavour changes may be caused by differences in the sugar content and fruit acid content. Olaniyi *et al*., 2006 observed basic fundamental differences in acidity between tomato cultivars. Even though the cultivar has a powerful impact on the characteristics of quality determinants, the ecosystem in which it grows also has an important effect on quality characteristics (Purseglove *et al*., 1986). In the research carried out by Akpapunam. (1981) vitamin c content reduces with ripening therefore inconsistent results might have been attributed to variations in ripeness at period of analysis.

Fruit size and composition are major quality parameters for fresh fruit vegetables. These are regulated genetically and environmentally through the use of successive stages of fruit growth and reported to be related positively to the amount of nutrients available for the fertilization period, the cell mitotic activity and cell expansion available to plants (Jullien, 2001). Furthermore, the nutrients availability could influence the function of the crop sink (Bergervoet *et al*., 1996) and this has been found to play a part in controlling accumulation of carbohydrate in tomato (Gyllaspy *et al*., 1993). The amount, size and chemical elements of berries, plant seeds could be determined by this operation (Joubes and Chevalier, 2000). In fact, both cell numbers and size lead to fruit size control (Asiegbu, 1991) and in some species small fruit can be linked to low cell (Jullien, 2001). The cells number, individual cell size and nucleus DNA content are relevant factors when assessing fruit size variations in genetic and phenotypic. As demonstrated by many research works the amount of fruit cell DNA depends to some extent on the available nitrogen. Hence, in fruit with sufficient amount of N, the numbers and size of cells are bound to be high. In tomato Errebhi and Wilcox (1990) indicated reduced yield and quality of fruit with nutrient deficiency. This was attributed to low meristematic cell activities, and hence, lower number of cells observed in plant nourished with low N levels.

2.10 Light intensity and crop performance

The intensity of light or abundance refers to an overall amount of sunlight received by crops. It could be defined as the level of intensity that a plant is exposed to. The definition of light intensity does not consider colour or wavelength, in comparison to light quality. The amount of intensity of light is generally measured by means of lux unit (lx) and the foot candle (fc). Maximum light intensity means that it is brighter than low light levels. Partial sun and partial shadow, open, or dense shade are some of the words with brightness. Depending on adaptation, crops with different intergrades in between can be categorized as sun plants and shade plants.

2.10.1 Factors influencing the intensity of light received by crops

Light intensity changes with the time of the day, place, season, climate and distance from the equator. It rises steadily from sunrise to mid-day and then slowly reduces towards the

end of the day; the sun is elevated for the period of summer, fair in the spring and fall, and low for the duration of winter. Highest amount of intensity occurs at the surface of the earth and is decreasing steadily with increasing distance from the equator to the southern and northern poles. Dust particles, ambient water vapour, land slope and elevation are affected by intensity of light (Edmond *et al*. 1978).

At this particular point in the year, the distance from the moon to the earth surface varies and it is close in January (about 147 million km). This produces a small amount of light and heats on the earth. In the same way, many variables can influence internal light. The natural light that could enter a house in research by Manaker (1981) is determined by the position of doors or window phrases that reflect light, the nature of overhanging shrubs and trees and roofs, window screens and awnings and the tinting and neatness of the glass. A grey glass bottle makes transmission of light of 41% while the glass can be cleaned up to 89%. The quantity of light, either artificial or natural, could be further influenced by surface textures, curtains and blinds, reflectance from wall coverings, furniture, and other furnishings in the interior of a building.

In addition, the leaves differ in the amount of light received on a single plant. The intensity of incoming light incident to a leaf declines as sunlight passes across the canopy downwards. Leaves in the top part of the canopy appear to shade and redirect light away from the bottom. Slightly vertical leaves of plants (e.g. erectophyll type) allow additional light to flow and support a large planting population in comparison to crops with droplets (planophyll type) (Chapman and Carter 1976). Line cultivation and appropriate spacing can also reduce interplant shading.

2.10.2 Light attributes and crop performance

The light attributes that has marked influence on crop performance are intensity, duration and quality. Light is an essential requirement towards development and growth of plants. Nevertheless, various crops have maximum necessities with both inadequate and too much intensity is harmful. Increasing intensity of light, subjected to physiological limits, enhances photosynthesis and reduces the time needed for the plant every day (Manaker, 1981). Insufficient intensity of light tends to decrease growth and yield for the reason that little

quantity of sunlight limits the rate photosynthesis. The plant drops below the compensation level, under a minimum intensity. Photosynthesis decreases or stops during continued respiration. Compensation is the metabolic level where rate of photosynthesis and the degree of respiration were equivalent therefore leaves do not lose or gain dry matter.

Chapman and Carter (1976) describe etiolation as a structural characteristic of negative impact of insufficient light, it develops white, stems are spindly, leaves are not completely developed, elongated internodes and roots system are stunted as follows. In the same way, too much light intensity must be prevented. It may leads to scorching the leaves and decrease yield of crop. Edmond *et al*. (1978) explain the following three things: (1) decrease the absorption rate and the photosynthetic level when the amount of chlorophyll is reduced (2) Excess intensity of light increased the temperature of the leaves that causes quick water loss and transpiration. The guard cells lose turgid, the stomata temporarily or permanently close while slowing down the rate of carbon dioxide diffusion into the leaves. Photosynthesis level reduces during continued respiration and results in low carbohydrate availability for growth and development; (3) the enzyme system that moves sugar to starch inactivates the higher leaf temperature. Sugars are increasing and photosynthesis rates are slowing down.

2.10.3 Effects of light intensity on crop performance and fruit yield

Vegetable plants are economically important and are now widely grown throughout the world, not only through cultivation on the field, but also through the preservation of farming. Plants such as rice and maize are very prone to negative environmental circumstances that will have a minor influence on growth and yield. To improve ecological conditions in higher-quality production of vegetables and high-yield, this involves research sequences on the connection of environmental variables such as crop fertility, intensity of light, temperature of air, relative humidity and concentration of CO_2. Alongside the environmental variables, soil fertility and light intensity, particularly the tropical protected area, are seen as the key variables for plant performance.

Tomato growth and yield are associated to the quantity of light obtained during the time of cultivation. (Challa and Bakker, 1998). A theoretical light-use efficiency of 1.0 gram MJ-1

of dry mass of global radiation outside of the greenhouse was estimated for the crop, equivalent to 3.1 gram MJ-1dry mass of the photosynthetically active radiation (PAR) (Challa and Bakker, 1998). The lower level of intensity of light, in the tropical limit defined summer as 8.4MJ $m^{-2}day^{-1}$ (FAO 1990), is not capable of keeping the plants alive. This tropical boundary was verified in Southern Brazil, where there were losses in tomato plants dry matter when energy levels dropped under this limit (Andriolo *et al*., 1998). On the basis of idea, intensity of light levels throughout the year was used as the principal variable to recognize area or else season appropriate for horticultural plants (Buriol *et al*., 2000). From the opposite side, the research reveals decreased volume of information which means that these plants are limited to an absolute limit of radiation from the sun. The effect of photosynthesis and respiration of high temperatures are mainly due to environmental restrictions on plant growth in summer (Lapuerta, 1995). This statement is not clear if either solar radiation could be used alone just to assess crop performance or whether combinations with many other environmental factors, in particular air temperature, should be regarded. Even though the temperature of the atmosphere is connected to intensity of light, this connection is not continuous and may demonstrate differences in different season and/or locations

The intensity of light on the comparative growth rate of tomato has been determined quantitatively (Challa and Bakker, 1998). It was found that the rate of growth, in form of gain in dry weight increased steadily as light intensity was increased from 0.1 to full daylight. As full daylight intensity was approached, however, there was a definite tapering off of the response to additional light. A unit leaf surface assimilation rate was linear to the light intensity logarithm. For young tomato plants, relative growth in dry weight was linked to the light intensity logarithm. The answer to growing light increases at low light intensity was greatest tapering off towards very little response to increments as the full day light intensity was approached (Ayeni *et al*, (1997).

The intensity of light required highest rate of photosynthesis is quite depending on the different conditions of the tomato varieties and the ambient circumstances. The photosynthesis requirement cannot be satisfied by too low light intensity, which resulted in insufficient image synthesis, which has an important influence on growth, yield and

production of vegetables. In comparison, a decrease in photochemical activity known as photo inhibition can cause too high light intensity (Xiaoyu *et al*., 2012). In general, light-dependent photosynthesis reactions produce ATP and NADPH above that consumed by dark carbon metabolism (Demmig-Adams. and Adams, 2000) reactions. On the other hand, when environmental conditions were not in support of carbon fixation, yet soft or reasonable light can grow to be dangerous (Gerotto, 2011).

There has been more application of sunlight and temperatures to improve fruit and vegetable carotenoid biosynthesis, compared with the adjacent farm that used Agrochemical, both of which were harvested at same maturity stage (Young and Britton 1990), carotenoid contents were considerably greater in kale leaves harvested from organic farming. Carotene, lutein and entire carotenoids in the winter were significantly higher than in the summer of 'Manteiga,' which can be caused by more severe leaf carotenoid destruction at higher temperatures and sunlight, but the content of neoxanthine in the cultivar of 'Tronchuda' was considerably higher in the summer.

The amount of intercepted light intensity determines assimilate partitioning (Ho, 1996) and tomato yield (Newton *et al*., 1999). Partitioning of assimilates is affected by temperature among plant and generative sections (Adams *et al*., 2001). Influence of temperature is likely to affect the rate of growth, fruit setting and abortion (Heuvelink, 1995). It is not directly affected. At higher temperatures, trusses appear faster, producing more fruit at higher temperatures (Adams *et al*., 2001).

CHAPTER 3

MATERIALS AND METHODS

3.1. Experimental site

This research work was investigated at the experimental site of Ladoke Akintola University of Technology, Ogbomoso, between 2012 and 2014 and Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria.

Ogbomoso lies on latitude $8^0$10' N and $4^{0'}$ 10' E within the derived savannah agroecological zone of Nigeria. The area had a bimodal rainfall pattern of April-July and September-November. The mean daily maximum and minimum temperatures of the area were 33^{o}C and 20^{o}C, respectively. Mixed cropping is major pattern in the area and the soil of the study centre is classified as Olorunda series (Smyth and Montgomery, 1962). Most prominent food crops cultivated in the area are maize, cassava, guinea corn, and vegetables like pepper, okra, tomato, green vegetable and fluted pumpkin among others etc. Prominent weed species at the site during the study included; *Euphorbia heterophylla*, *Amaranthus spinosis*, *Boerhivia sp*, *Commelina sp*, *Imperata cylindrical* and *Tithonia diversifolia*.

University of Ibadan, Ibadan, Nigeria lies on latitudes of 7^0 33' N and 30^0 56' E. It lies within tropical rainforest transition zone and it belongs to Egbeda series (Smyth and Montgomery, 1962). The monthly rainfall distribution pattern for Ibadan is bimodal, with peak in June and September. Major crops are maize, cassava, yam and vegetables such as pepper, tomato, okra, green vegetable and fluted pumpkin plant. The site used for the experiment had been under guinea grass fallow for three years before use. The ground is moderately drained, ferruginous soil with a sandy loam feel. The experimental location is in Fig. 3.1.

3.2. Experimental Materials

3.2. 1. Crop variety: Three varieties of tomato were used for the study: Ibadan local, UC82B and Roma VF.

Ibadan local: This is an indeterminate tomato variety which is adapted to Southwest Nigeria. The fruit is characterized by big to medium size fruit with 4-6 grooves, roundish, high moisture content, high vitamin A and C, lycopene and carotenoids. Farmer's prefer the choice of this variety because of its high yielding ability of about 20 t ha^{-1} and its resistance to prevailing pest and diseases (NIHORT, 1986). The fruits used were obtained from "Arada" open market in Ogbomoso. Thereafter the seeds were extracted, air dried and stored in an airtight plastic bottles.

UC82B and Roma VF. These two varieties are tomato cultivars grown, consumed and adapted to the majority of agro-ecological areas in Nigeria. They are the determinate type, being cultivated, consumed and adapted nearly everywhere in Nigeria. The fruit is oblong, fleshy, light yellow to orange in colour at maturity. They have high resistance to cracking, rotten and diseases (especially bacterial wilt) in the savannah zone of Nigeria. The fruits are medium sized, and have long shelf-life under cool temperature condition. The fruit yields of the two varieties are on the average 25-30 tonnes per hectare. The fruit were high in lycopene and carotenoid (Akanbi, 2010). The seeds were obtained from 'Seed Project Co Ltd, Kano and stored in the refrigerator till when used.

3.2. 2. Types and sources of organic fertilisers

Three types of organic fertilisers were used: commercially produced organic fertiliser I (Pacesetter Organic Fertiliser), Sunshine Organic Fertiliser (II) and Alesinloye grade A Organic Fertiliser (III). Pacesetter organic fertiliser is produced by Oyo State Government fertiliser factory Bodija, Ibadan while the Sunshine fertiliser was obtained from Waste to wealth factory owned by Ondo State Government, Akure. Aleshinloye Organic fertiliser is a product of an Organic fertiliser factory at Aleshinloye market, Oyo State. Preceding the utilization of the organic fertilisers, Samples were collected on each fertiliser and analyses were carried on nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc and copper at Institutes of Agriculture, Research and Training, Moor Plantation, Ibadan, following standard procedure. Nutrient contents were used to determine the equivalent quantity of each fertiliser material that was applied to meet the recommended rate for the test crop.

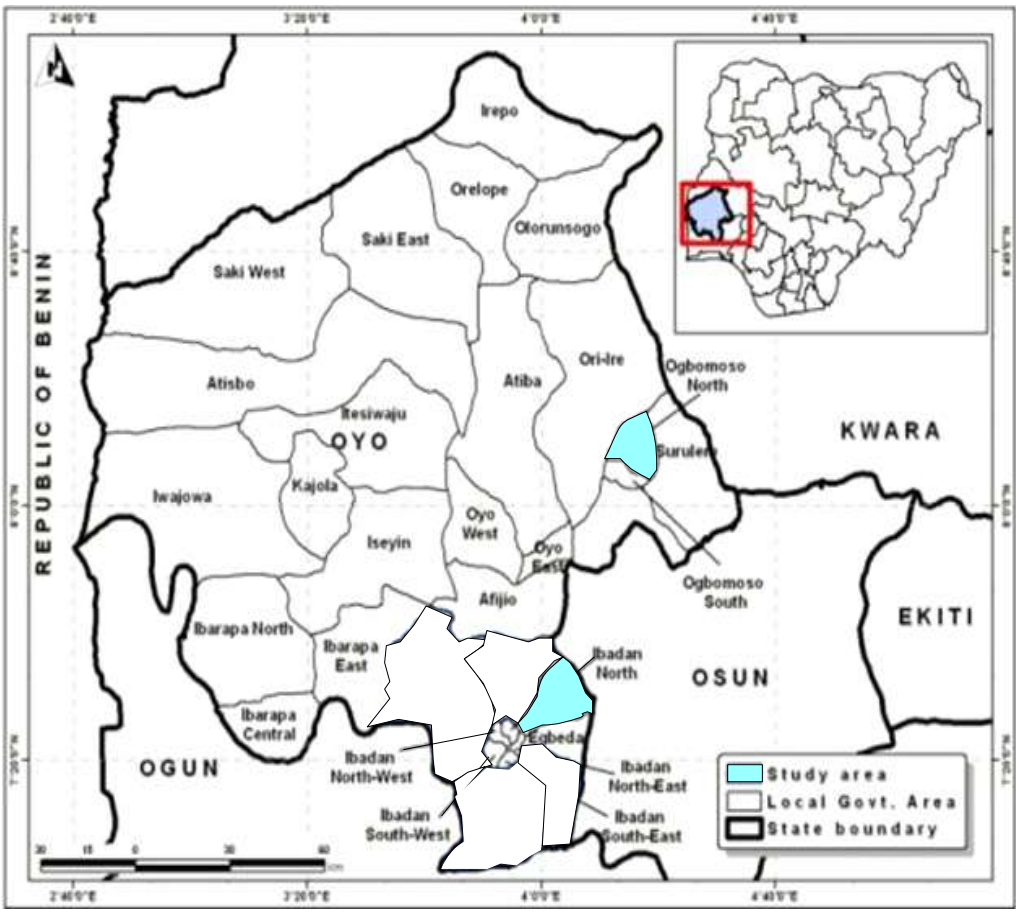


Figure 3.1: Map of Oyo State showing experimental locations

3.2. 3. Mineral fertiliser:

Three mineral fertilisers used were: urea (46% Nitrogen) as a source of nitrogen, Single Super Phosphate (SSP) (18%, P_2O_5) for Phosphorus and Muriate of Potash (MOP) (60%, K_2O) for potassium.

3.3. Soil sampling and analysis

Pre-cropping soil samples were taken at a depth of 0-15 cm for chemical and physical analyses. The samples were bulked to form a composite sample. The samples were air-dried, crushed and sieved through 2 mm mesh for determination of particle size, pH, total nitrogen, organic carbon %, available phosphorus, iron, copper, zinc and exchangeable cations. These analyses were carried out at the Soil laboratory in the Institutes of Agriculture, Research and Training, Moor Planting, Ibadan, IAR&T following IITA (1979) soil analytical procedure.

3.4. Nursery operation

The seeds of the three tomato varieties were sown in the nursery bed that contained 1volume of top soil and 3 volume compost proportions (Akanbi *et al*., 2002). The seeds of the three tomato varieties were sown into 1mx3m bed by drilling method and then covered lightly with dry palm fronds to reduce the rate of water evaporation. The nursery was watered at two days interval.

3.5. Experiment 1: Effect of fertilisers on growth, fruit yield and phytonutrient content of tomato varieties

Pot and field experiments were conducted at the Agronomy Department green house and Teaching and Research Farm, LAUTECH, Ogbomoso, between January and April and May and August 2012, respectively.

3.5.1 Pot experimentation: The top soil for the pot experiment was gathered from plots that were later used for field experiments. Polythene bags used were measuring 45 cm x 30 cm. Individual bag was filled with 10 kg soil and perforated at the base and plugged cotton wool and placed on the saucepan to collect the leachates. The factorial combinations of three varieties, nine fertiliser treatments gave 27 treatment combinations and 3 polythene bags per

treatment per replicate, making a total of 324 polythene bags. The polythene bags were arranged in a completely randomized design in four replications.

Treatments

Treatments consisted of tomato varieties (Ibadan local, UC82B and Roma VF) and nine fertiliser treatments as listed below:

T1 - 60 kg N/ha Commercially Produced Organic Fertiliser (CPOF I)

T2 - 60 kg N/ha Commercially Produced Organic Fertiliser (CPOF II)

T3 - 60 kg N/ha Commercially Produced Organic Fertiliser (CPOF III)

T4 - 120kg N/ha CPOF I

T5 - 120 kg N/ha CPOF II

T6 - 120 kg N/ha CPOF III

T7 - 60 kg N/ha Urea+35 kgP_2O_5/ha SSP+ 30 kgK_2O/ha MOP

T8 - 60 kg N/ha Urea

T9 - No fertiliser treatment (control)

3.5.1.1 Experimental Set up

The organic fertiliser treatments was applied and mixed one week before transplanting to permit sufficient time for mineralization of the applied materials, while urea and other mineral fertilisers were applied two weeks after transplanting (Akanbi *et al*., 2003). Four weeks after sowing, seedlings were transplanted one seedling per polythene pots. Watering was done immediately and thereafter as needed. Supplying of missing stands was done, where necessary at one week after transplanting (WAT).

3.5.1.2 Data collection

Collections of data started at 4 WAT and continue fortnightly till the plant maturity. Growth, yield components as well as fruit phytochemicals composition were assessed on the selected middle plants for data taken.

3.5.1.2.1 Growth and yield components:

Growth Parameters: The measurements were taken at four, six and eight Weeks After Transplanting (WAT)

a. **Plant height:** The plant height (cm) was measured from the tip of the main plant to the base at ground level.

b. **Stem girth:** The circumferences of the stems were measured 10 centimetres above ground level on the stem with a measuring tape.

c. **Number of leaves:** This was obtained by counting fully opened green leaves /plants at each sampling period.

d. **Number of branches:** Branches on the main stem were numbered as branches per plant.

e. **Leaf area /plant (cm^2):** This was obtained as described by Togun *et al*. (2003). Leaf length multiplied by the width of the leaf. It is L x B x 0.68

3.5.1.2.2. Components of yield: At flowering, the following reproductive parameters were taken from the tagged plants:

i. **Days to 50% flowering:** This was obtained by counting days from transplanting to when half of the total experimental area carried open flowers.

ii. **Number of open flowers / plant:** This was obtained by counting total number of opened flower/plant at each sampling period and double counting was avoided by marking the stalk of the already counted flowers with permanent marker.

iii. **Fruits produced / plant:** The total fruits number produced were taken per plant and recorded for each plant.

iv. **Percent fruit set:** This was calculated as described by Katung *et al*.(1996):

$$\% \text{ fruit set} = \frac{\text{Fruits produced /plant}}{\text{Flowers produced /plant}} \times \frac{100}{1}$$

v. **Marketable fruits:** The total number of marketable fruits from total harvested fruit /plant were counted and recorded.

3.5.1.2.3. Plant dry matter yield: Determination of dry matter accumulation and partitioning, one plant per treatment was uprooted at the onset of flowering and it was separated into root and shoot. Soil that adhered to the roots was removed by rinsing the roots under running tap, fresh weight was taken and surface water allowed to dry up. The plant materials were dried to a constant weight at 80^{o}C.

3.5.1.2.4 Determination of plant tissue nutrient contents and uptake: Three leaves per plant were picked at 7 WAT (Tandon, 1995), for the determination of the nitrogen, phosphorus, potassium, iron, copper and zinc content of the leaves. At 80^{o}C, the leaves were oven-dried to a constant weight, ground in a Willey mill to decrease the sample to a fineness acceptable size. For chemical analysis, the ground samples were contained in air tightened plastic containers, total nitrogen was achieved by digesting 0.5 gram of dry leaf samples with 68% H_2SO_4 in the kjeldahl digestive unit until the sample was colourless and titrated in 0.1 N H_2SO_4 (Tandon, 1995) using selenium and sodium as a catalyst. Total nitrogen was measured by steam distillation through excess NaOH from the digest. The phosphorus, potassium, iron, Copper and Zinc plant tissue content were achieved through ashing 0.2 gram of the plant samples in the muffle furnace at 600^{0} C for 3 hours. After ashing the sample was cooled and dissolved in 1N Hydrochloric acid, and the solution was passed through filter paper to 50 ml volumetric flask and was filled with distilled water to the measurement. From the digest, the concentration of P was calculated using a spectrophotometer by the vanadomolybdate yellow calorimetry technique. Potassium was measured by the use of a flame-photometer (Cornin Model 400) while atomic absorption spectrophotometer (Perken Elmer AAS -300) calculated micronutrient (Fe, Cu, Zn). Accumulated nutrient in the plant was calculated through the method described by Ombo (1974) and used by Akanbi (2002):

Nutrient uptake = % Tissue nutrient content x sample dry weight (g)

3.5.1.2.5 Phytochemical Parameters: Determination of fruit proximate, elemental, lycopene and other phytonutrient contents. For the determination of these parameters, 12

fruits were chosen randomly at the fruiting period (i.e. 11-12 WAT or 2-3 weeks after first flowering) per procedure (AVRDC, 2005).

a. Fruit Proximate analysis. According to the association of analytical chemist (1995) methods, the moisture content, ash, crude fat, crude protein and crude fibre were determined. Crude fat was measured by an exhaustive sample extraction by the use of an anhydrous diethyl ether as the solvent in a Soxhlet apparatus. The determination of crude protein was achieved through Kjeldhal nitrogen assay (N x 6.25). Crude fibre was estimated through loss of weight on dried residue ignition followed by the digestion of fat-free samples in 1.25 % each of sulfuric acid and sodium hydroxide solutions under different conditions (AOAC, 1998). Using hand refractometer, the total soluble solid (TSS) was determined (Adebooye *et al*., 2006). The carbohydrates content was measured by differences while calorific values were obtained by summing the mean combined values for protein, fat and carbohydrate, respectively.

b. Determination of Fruit Mineral Contacts. After first wet washing as stated by Onwuliri and Anekwe (1992) the atomic absorption spectrophotometer was used to determine the following nutrient content, (Model No.AA- 6400) potassium, calcium, copper, iron, magnesium and zinc. Colorimetric phosphorus was analyzed with the help of potassium-dihydrogen phosphates as a technique (UV-visible spectrophotometer, Model No: U V-1600).

c. Determination of fruit lycopene, phenols, vitamins A, C and E contents

i. Lycopene estimation. The lycopene content in tomato extract was determined through the use of a colorimetric technique that Rao and others (1998) validated with HPLC to ensure the quality of being specific adequately in the measurement of lycopene. Lycopene was extracted with hexane: methanol: acetone at a volume ratio of 2:1:1 within 1 hour. Absorbance of the extract at 502 nm was measured using UV /vis against the blank extract solvent. Lycopene concentration was estimated through the extinction coefficient (E percent) of 3150 Chang and others 2006.

ii. Determination of Vitamin A. Vitamin A was estimated with the aid of a spectrophotometer (AOAC 1998) (Muchoki *et al*., 2007).

iii. Determination of Vitamin C (Ascorbic acid). According to the method of AOAC (2005) ascorbic acid was measured. To measure ascorbic acid, 10 cm^3 tomato juice sample was mixed with the 20cc distilled water and then 2cc from one-percent (1%) soluble starch was added. Then ascorbic was determined by titration of 10 ml filtrated juice which contained Potassium iodide (KI). In fact, it was based on mg ascorbic acid per 100 g FW.

iv. Determination of Vitamin E. Vitamin C was determined by the method of Cerretani *et al*. (2010). 1 gram of the original sample was weighed, macerated with 20mls of n-hexane in a test tube for 10 minutes and centrifuged for 10 minutes. The solution was filtered, 3ml of the filtrate was poured in duplicates into a dry test tube, and evaporated in a boiling water bath to dryness. Following this, 2mls of 0.5N potassium alcoholic hydroxide was added and boiled in a water bath for 30 minutes. Then 3mls of n-hexane was applied, and vigorously shaken. Then-hexane was moved and evaporated to dryness into another set of test tubes. To the residue, 2ml of ethanol was added. Another quantity was applied to ethanol, 1ml of 0.2 per cent ferric chloride. Afterwards, 1ml of 0.5% 1 1-dipyridyl in ethanol was added followed by the addition of 1ml of ethanol to make it up to 5mls. The solution was diluted and absorbance was taken against the blank at 520 nm.

vi. **Total phenols:** The total phenol was estimated with reagent Folin-Ciocalteu (Singleton and Rossi, 1965). Results of fresh weight and dry weight were described as catechin (mg/100 g), respectively.

vii. **Total flavonoids:** The total flavonoids content in tomato extracts was determined by modified colorimetric method (Dewanto and others 2002). Both the methanolic extract (25µL) and (+) catechin solutions were diluted in 1.25mL DI water and 75 µL 5 percent NaN_{O2} solution, respectively, and then allowed to mix for 6 min. After that, 150 µL of 10% $AlCl_3$ solution were added and mixed for 5 min. A further 0.5 mL of 1M NaOH was added and

the total volume was made up to 2.5 mL with DI water. Sample absorbance was measured at 510 nm against a prepared blank using UV/vis.

viii. **β-carotene content:** β-carotene was extracted and analyzed according to the procedure Kurilich *et al*. (1999) published. The absorbance was recorded at 450 nm for β-carotene.

ix. **Moisture content (%):** The moisture content was evaluated according to the following equation and the method: (Singleton and other 1999)

$$\textbf{Moisture content } (\%) = \frac{\text{the difference in weight between fresh and dried sample}}{\text{the fresh weight of sample}}$$

xi. **Determination of sugar and acid concentration:** Sucrose, D-glucose, D – fructose, and concentrations of citric and malic acids were calculated by enzymatic test kits measuring NADH or NADPH formation at 340 nm, based on the protocol mentioned in the kits. The sugar: acid ratio was determined individually, taking into account the molar concentration of each compound. Consequently, the sugar value is the sum of the concentrations of glucose, fructose, and sucrose and the acid value is the sum of the concentrations of citric acid and malic acid (AOAC; 1998).

3.5.1.3. Statistical analysis

Analysis of variance was performed on the data and significant means were separated using Duncan‘s Multiple range test ($P \leq 0.05$).

3.5.2 Field experiment

3.5.2.1: Experimental site, design and management: This research work was conducted at Ladoke Akintola University of Technology, Ogbomoso experimental fields between May and August, 2012. The site characteristics were as described in section 3.1. Experimental plot was ploughed and harrowed before the research work commences. Soil samples were taken and analyzed before cultivation as defined in Section 3.3. The gross experimental area was 82 m x 43 m (3526 m^2). This was divided into three replicates each measured 26 m x 13 m (338 m^2). A replicate was divided into 30 plots each 2 m x 3 m (6 m^2), 2 m gaps separated the replicates while the plots were demarcated by 1 m gap (Fig. 3.2). Individual plot contained 35 plants spaced out at 50 cm x 50 cm. The experimental design was randomized

complete block design and the layout in the open field condition is as shown in Figure 3.2. Treatments and crop management were as reported under pot experiment and they were replicated 3 times. Nursery operations and transplanting were as in the pot trial. Supplying of missing stands was done a week after transplanting to achieve uniform planting density per plot. Individual crop was staked with 0.5 - 1m stake at 3 - 4 WAT. Weed management was achieved by hoeing at 2, 6 and 10 WAT to ensure minimal weed interference on the plots.

3.5.2.2 Data collection

3.5.2.2.1. Growth parameters: Three plants were randomly chosen from the inside competitive plants for the assessment. Measurements were taken at 4, 6 and 8 WAT for:

i. **Plant height:** The plant height (cm) was measured from the tip of the main plant to the base at ground level.

ii. **Stem girth (cm):** The circumferences of the stems were measured 10 centimetres above ground level on the stem with a measuring tape.

iii. **Leaves/plant:** This was obtained by counting opened green leaves / plants at each sampling period.

iv. **Number of branches:** Branches on the main stem were numbered and counted as branches per plant.

v. **Leaf area /plant (cm^2):** This was obtained as described by Togun *et al*. (2003). Leaf length multiplied by the width of the leaf. It is L x B x 0.68

vi. Plant Dry matter: Determination of dry matter accumulation and partitioning, one plant per treatment was uprooted at the onset of flowering and it was separated into root and shoot. Soil that adhered to the roots was rinsed under running tap, allow the surface water to dry up, fresh weight was taken. The plant materials were dried to a constant weight at 80^oC.

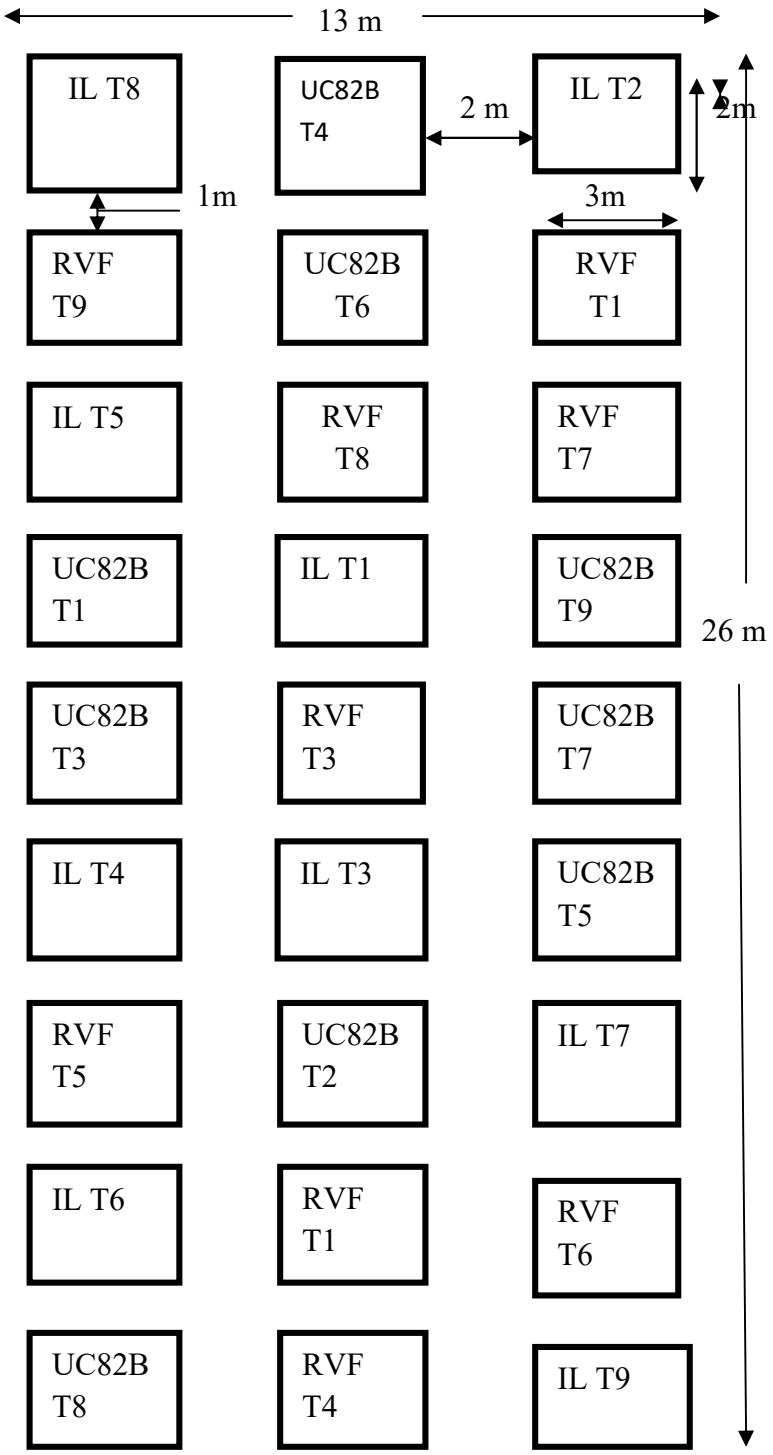


Fig. 3.2: Field experimental layout involving factorial combination of three tomato varieties (Ibadan local (IL), UC82B and Roma VF (RVF) and nine fertiliser treatments

Leaf Area Index (LAI): This is leaf area per unit of land

$$LAI = \frac{LA}{P}$$

Where LA is leaf area and P is the land area occupied Hunt (1982)

Crop Growth Rate: This was calculated by the method of Hunt (1982)

The unit is expressed as $g/m^2/day$.

$$Crop\ growth\ rate\ (_{1-2}\overline{C}) = \frac{1}{p} x \frac{W_2 - W_1}{(t_2 - t_1)}\ (Hunt, 1978)$$

Where W1 and W2 are dry weights of crops harvested from equal (but separate) areas of ground P, time 1 (T1) and 2 (T2)

Relative Growth Rate: It measures the rate of growth per unit dry matter.

$$\text{Re}lative\ \ growth\ \ rate\ \ (_{1-2}\overline{R}) = \frac{\log_e w_2 - \log_e w_1}{(t_2 - t_1)} (Hunt, 1982)$$

Net Assimilation Rate: It is the net gain in weight per unit leaf area

$$Net\ assimilation\ ratio\ (NAR) = \frac{W_2 - W_1}{(t_2 - t_1)} x \frac{Log_e\ A_2 - Log_e A_1}{LA_2 - LA_1}\ \ (Hunt, 1982)$$

Where: W_1 = Weight of previous harvested crop;

W_2 = Weight of current harvested crop; (g)

P = P is the land area occupied (m^2)

t_1 = Time of harvested biomass yield $W_{1\ (day)}$

t_2 = Time of harvested biomass yield $W_{2;\ (day)}$

LA_1 = Leaf area at previous harvested date and (cm^2)

LA_2 = Leaf area at current harvested date. (cm^2)

3.5.2.2.2. Yield parameters: Records were taken on the following reproductive parameters from the tagged plants;

i. **Days to 50% flowering:** It was obtained by counting number of days from the transplanting day to when 50% of the total plants in a plot carried open flowers.

ii. **Number of opened flowers / plant**: It was obtained by counting opened flowers per plant at each sampling time. Double counting was avoided by using a permanent marker to mark already counted flowers.

iii. **Fruits per plant:** The total number of fruit harvested from each plant was counted recorded.

iv. **Percent fruit set**. This was calculated as follows (Katung *et al*., 1996):

$$\% = \frac{\text{Number of fruits produced /plant}}{\text{Number of flowers produced /plant}} \times \frac{100}{1}$$

v. **Number of marketable fruits**: The total marketable fruits were obtained from the total number of healthy fruit harvested per plant.

vi. **Fruit weight / plant:** This is the weight of all total harvested fruits taken from the tagged plant and the mean was calculated and recorded as fruit weight /plant

3.5.2.1.3. Statistical analysis

Analysis of variance was performed on the data and significant means were separated using Duncan‘s Multiple range test ($P \leq 0.05$).

3.6 Residual Experiment: Residual effect of fertilisers on yield components, fruit yield, fruit lycopene, and proximate composition

The field experiment on residual effect was carried out between September and November, 2013 to find out residual effects of the applied treatments on the same plot. The plots were re-established with minimal disturbance. Each plot identity was maintained that is, no application of additional fertiliser. The nursery and transplanting operation, field establishment, plot layout and experimental design were all carried out as explained under the main field experiment.

3.6.1 Field preparation and re-establishment

The plots were re-established and manually cleared to ensure minimal soil disturbance on which tomato plant was transplanted. Each plot were kept weed free through normal hoeing as required.

3.6.2 Data collected:

a. Components of yield and Fruit yield (3.5.2.1.2).

b. Fruit proximate and elemental compositions following the procedure described in pot experiment (3.5.1.2.4b).

c. Pyhtonutrients e.g Fruit K, Vitamin A and C and Lycopene content following the procedure described in pot experiment (3.5.1.2.4c).

3.6.3 Statistical analysis

As described in the main field experiment, data were subjected to analysis of variance (ANOVA) and means separated by DMRT (P=0.05).

3.7. Experiment 2: Effect of season and fertiliser forms, on growth, fruit yield, fruit phytochemicals parameters of UC82B variety at six different ripening stages for two planting seasons

3.7.1 Experimental procedure and treatments

Two field experiments were carried out at teaching and research farm, LAUTECH, Ogbomoso. The experimental location was about 5 km from the plot used for the experiment 1. The experiment was done in both early and late planting season of 2013. Before the commencement of the experiment, the land was ploughed and demarcated based on the number of treatments and replicates. Commercially produced organic fertiliser I and the best rate (120 kg N/ha) that enhanced optimum fruit yield in experiment 1 was formulated into four forms (Residue, Pelletized, Shredded and liquid) on the best tomato variety (UC82B) from experiment 1.

3.7.2 Procedure and crop management

Total experimental area was 14 m x 14 m (196 m^2). Plot size was 2 m x 2 m, each plot contained 25 plants / plot spaced out at 50 cm x 50 cm. The experimental design was randomized complete block design with four replications (Fig. 3.3). The weeds and insect pest were properly managed as in the experiment 1.

3.7.3 Preparation of the fertiliser forms

The commercially produced organic fertiliser I was sieved with 2mm mesh. After sieving, the shaft part of it served as the residue form while the sieved fertiliser was the shredded form. Out of the sieved organic fertiliser, 25 kg were missed with 100 g of the prepared starch to make it stick together during pelletization. Liquid form was prepared by mixing five litre of water to five kilogram of the sieved organic fertiliser.

3.7.4 Data Collection

3.7.4.1 Growth parameters: Plant height, stem girth and leaf area were collected as in experiment (3.5.2. 1).

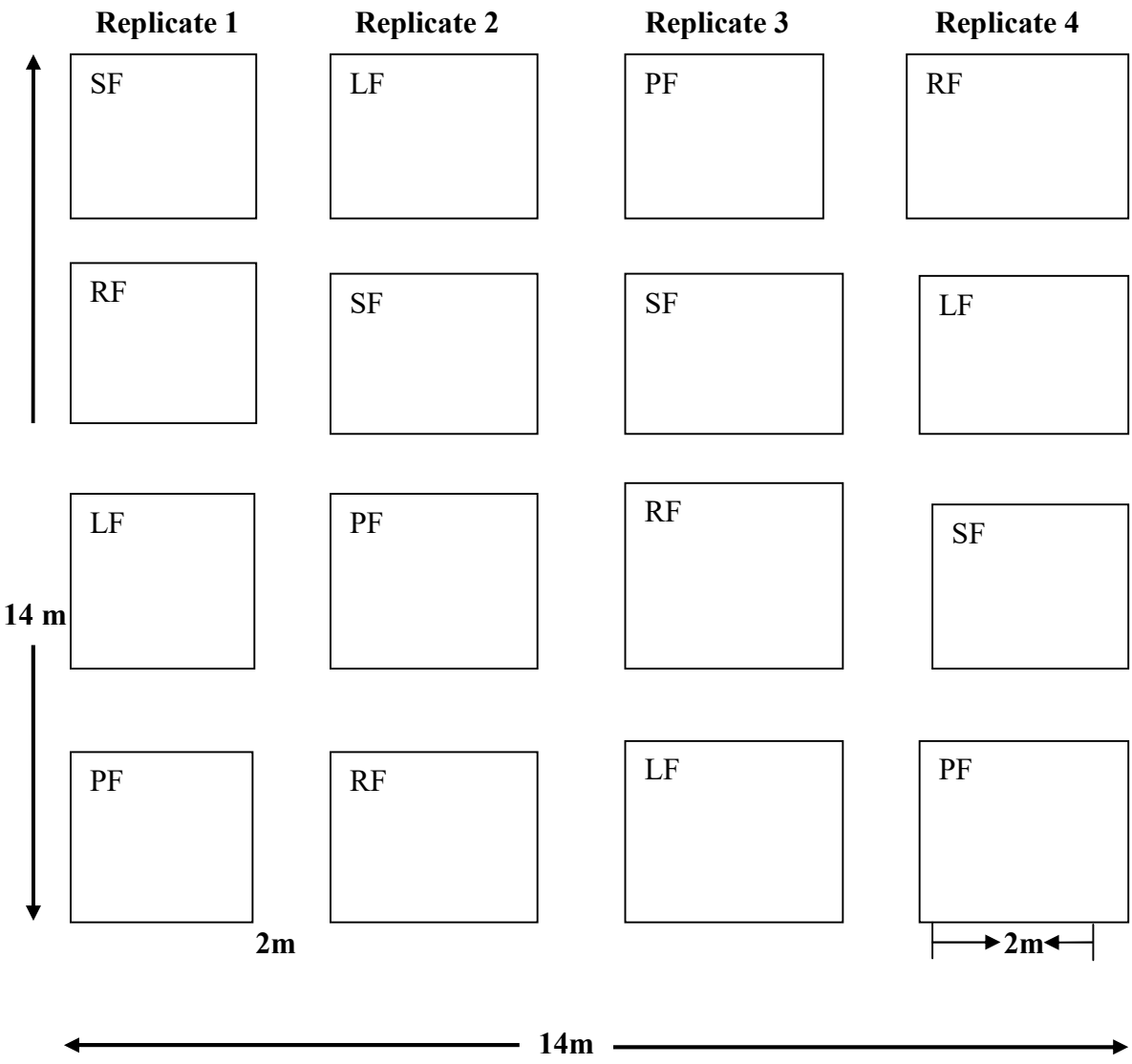


Fig.3.3. Field experimental layout involving four forms of application of commercially produced organic fertiliser I and UC82B variety. RF: Residue form, SF: Shredded form, PF: Pelletized form and LF: Liquid form.

Fruit yield: This was obtained as explained in experiment 1 (3.5.2.1.2. iii).

3.7.4.2 Phytochemicals and nutrients analyses: These analyses were carried out at six different fruit ripening stages (Yamaguchi, 1983).The ripening stages:

B1: Mature green: (Fruits are mature, fully dark green to light)

B2: Breaker stage: (Yellow or pink colour appearance first, but not more than 10%)

B3: Turning stage: (Yellow or pink colour appearance between 10 to 30%)

B4: Pink stage: (Pink or red colour appearance ranges between 30 to 60%)

B5: Light red stage: (Red colour more than 60% but less than 90%)

B6: Deep red stage: (Red colour exceeds 90%)

At each harvesting time, six fruits from each ripening stage were harvested. They were analysed for lycopene, flavonoids, β-carotene, vitamins C and E; soluble solid, dry matter, crude fibre, crude protein, sugar and acid contents as well as Phytonutrients. All the analyses were done as explained in experiment 1 (3.5.1.2.4). The experimental layout is shown in fig. 3.3.

3.7.4.3 Data analysis: Analysis of variance was performed on the data following the procedure of Gomez and Gomez (1991) with SAS and significant means were separated using Duncan‘s Multiple range test ($P \leq 0.05$).

3.8. Experiment 3: Response of tomato varieties to different light intensities at four phenological stages on dry matter partitioning, fruit yield and phytochemicals compositions

This experiment consisted of pot and field trials. They were both conducted at the University of Ibadan, Ibadan, Nigeria. Pot experiment was done between April and July, 2014 in the University of Ibadan at the Crop Garden of Department of Crop Protection and Environmental Biology and field experiment between August and November, 2014 at the University of Ibadan Teaching and Research Farm.

3.8.1. Treatments and Experimental layout

The experiment consisted of three tomato varieties (used in experiment 1) and three light intensities applied at four phenological stages as shown below:

Tomato varieties were: IL = Ibadan local, UC82B and RVF = Roma FV

The 3 light intensities were:

L1 = 897.89 Lux light intensity

L2 = 673.70 Lux light intensity

L3 = 450.44 Lux light intensity

The four phenological stages are:

G1 = Active vegetative stage

G2 = Onset of flowering

G3 = 50% fruiting

G4 = Fruit physiological maturity

3.8.2. Experimental Design

The experiment was a split- split- plot design with tomato varieties as the main plot factor, phenological stages as sub plots and light intensity as the sub - sub plot factors.

3.8.3. Construction of cages: For the pot experiment, cages for light intensity regulation were made of 5 cm x 5 cm wood, with inner dimensions 1.8 mm x 1.2 mm x 1.3 mm (Odeleye *et al*., 2001). The frames made from wood were enclosed through Synthetic, green 1 mm mesh net single or double layer for light reduction into different light intensities. The ones with a single layer net reduced the light by 25% (L2) while L3 was achieved by covering the cages with a double layer net and reduced light intensity by 50%. The plants that were fully exposed (without cage covering) was 100% light intensity (L1). The amounts of light within and outside the cages were measured by the use of a light meter Model 4555 type C.

3.8.4. Crop establishment and management: One hundred and eighty (180) polythene bags (10 kg soil capacity) were packed with 10 kilogram sterilized top soil obtained by heating the top soil gathered inside Crop Garden of Crop Protection and Environmental Biology in a drum. After heating, soil samples were collected and analyses were done as explained in section 3.3. At four (4) weeks, vigorous seedlings of already raised tomato in the nursery were transplanted into each polythene bag. The bags were arranged in a randomized complete block design. The light regimes were imposed for two weeks on each tomato variety at each of the phenological stages. The crops were irrigated as required and weeding was done to minimize the effect of weed interference at 2, 4 and 6 weeks after transplanting.

3.8.5. Data collection

Data collection commenced immediately after removal of the cage (Odeleye, 2001) and continued till the end of the experiment at an interval of two weeks. At fruit maturity, tomato fruits were picked at each phenological stage to look at the influence of various intensities of light on the fruit yield, proximate and phytochemicals compositions. At each sampling time, three plants per treatment were assessed for the following parameters:

At each sampling time, three plants per treatment were assessed for the following parameters:

i. **Growth parameters**: Stem height, leaves /plant and leaf area were all determined as explained under experiment 1(3.2.1.2.1).

ii. **Dry matter determination**: At harvesting, each plant was partitioned into the shoot and root for fresh and dry matter yields. The dry matter yields were determined after oven drying the samples to a constant weight at 80^{o}C for 48 hours.

iii. **Leaf chlorophyll content**: The leaf chlorophyll concentration was determined by the use of Chlorophyll meter SPAD-502 Plus Konical MINOLTA SENSING 20003268.

iv. **Components of yield**: At harvesting, data were taken on a flowers/plant, fruit/plant, percent fruit set, mean fruit weight, total fruit yield (t ha^{-1}) as explained in experiment 1 (3.5.1.2.2).

v. **Phytochemicals parameters**: Fruit proximate, elemental and lycopene compositions were also determined as explained in experiment 1(3.5.1.2.4).

3.8.6. Data analysis: Analysis of variance was carried out on data collected. Means were separated by Duncan Multiple Range Test (DMRT) at 5% level of probability.

3.8.7. Field experiment: Study site: University of Ibadan, Ibadan, Teaching and Research Garden.

Field preparation: Experimental site was ploughed twice and harrowed before partitioned into plots based on the number of treatments, and replicated three times.

3.8.7.1 Treatments and Treatment application: This consisted of 3 varieties of tomato, different light regimes and phenological stages as reported under pot experiment. The experimental design was split-split plot design. Tomato varieties were the main plots, light intensity the sub plots and phenological stages the sub-sub plots. The treatments were applied as described under pot experiment.

3.8.7.2. Field layout: The field arrangement consisted of three main plots, nine sub-plots and thirty six sub-sub plots per replicate. Experimental plot was 24.5 meter x 20.5 meter; each main plot was 7.5 meter x 5.5 meter, while sub sub-plots were 1.5 meter x 1.5 meter. The main plot was separated by 2 meter gaps, while sub sub-plots had 1 meter gaps to demarcate them. The plants were spaced at 50 cm x 50 cm to give 16 plants per sub sub-plot

(bed). A bed of 1.5 m x 1.5 m constituted of sub sub-plots and it was manually prepared using hoe before transplanting (Fig 3.4).

3.8.7.3. Construction of cages for the field trail: For the field trial, cages were made of 5cm x 5 cm wood, with inner dimension of 1.0mm x 1.2mm x 1.0mm (Odeleye *et al*., 2001). To reduce the intensity of light, the wooden frames were enclosed with single or double layers of synthetic green 1 m mesh net. The ones with a single layer net reduced the light by 25% (L2) and while L3 was achieved by covering the cages with double layers of net and it reduced the light by 50%. The plants that were fully exposed (without cage covering) have 100% light intensity (L1). The light meter Model 4555 model C (Megatron, England) was measured in and outside of the cage.

3.8.7.4 Crop establishment and maintenance: Four (4) weeks tomato seedlings from the nursery were transplanted into the appropriate bed. Supplying was done 1 week after transplanting (WAT). The use of fungicide (Benlate) at 1 kilogram/per hectare and nematicide 0.5 kilogram /ha were done to prevent diseases. The insect pests were controlled using cypermethrine at 40 ml per 20 litre of water, using a knapsack sprayer.

The individual crop stand was staked at 3-4 weeks after transplanting by using 0.5 – 1 m stake. Weed clearing was done at 2, 6 and 10 weeks to maintain a weed free plot. The light intensity treatments were imposed on tomato plants at different phenological stages as explained in pot trial. The best fertiliser types in experiment 1, and the rate 120 kg N/ha of commercially produced organic fertiliser I, in a pelletized form based on the result of experiment two were used for this trial.

3.8.7.5 Data collection and Analyses:

Data collection and analysis were as explained under pot trial. The treated seedlings were removed from the cage after two weeks. Data collection commenced immediately after expiration of the treatment and continued fortnightly. At each sampling, three plants per treatment were assessed.

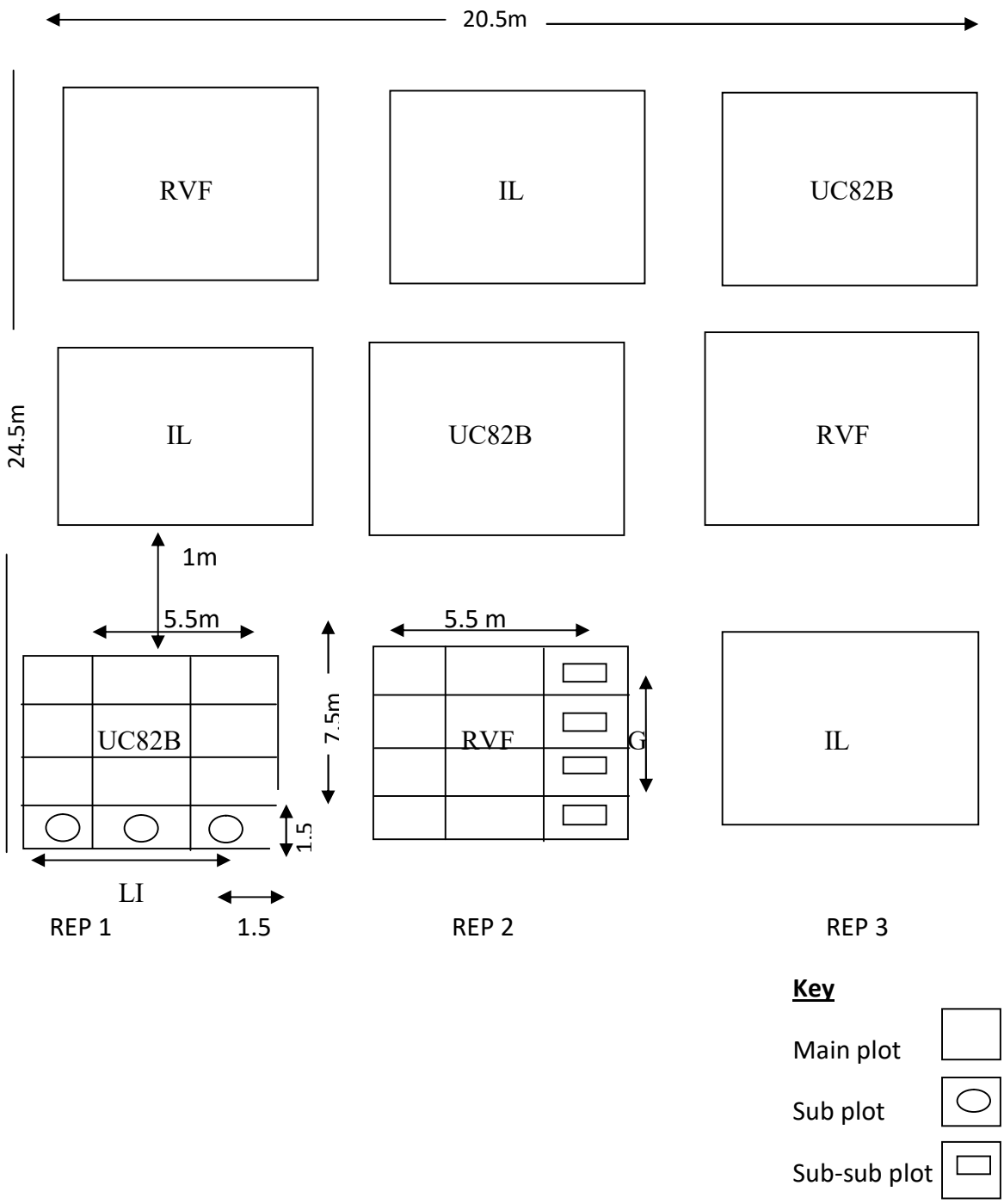


Fig.3.4: Field experimental layout for tomato varieties (main plot), four Phenological Stages (G) (sub plot) and three different light intensities (LI) (sub-sub plot) in split-split plot design replicated three times.

Data analyses: Analysis of variance was carried out on the data collected. The Duncan Multiple Range Test (DMRT) conducted at 5% significance was used for comparison of various treatments means.

CHAPTER 4

RESULTS

4.1 Experiment 1. (Pot experiment) Effect of fertilisers on growth, fruit yield and quality of three tomato varieties grown in the pots

4.1.1 Pre-cropping chemical and physical properties of the soil used for the experiments

The results of pre-cropping chemical and physical characteristics of the soils used for the research are shown in the Table 4.1. It was revealed that Ogbomoso soils in the year 2012 and year 2013 were low in essential minerals such as total nitrogen (1.2 and 0.18 g kg^{-1}), P (10.7 and 11.1 mg kg^{-1}), K (0.47 and 0.55 c mol kg^{-1}), organic carbon (1.3 and 1.2 g kg^{-1}) and organic matter (2.1 and 1.9 g kg^{-1}). The soils were slightly acidic and low in exchangeable cations. Analysis of the essential nutrients in Ibadan soils during 2014 showed that, total nitrogen contents (1.2 g kg^{-1}), P (10.2 mg kg^{-1}), K (0.5 c mol kg^{-1}), organic carbon (1.1 g kg^{-1}) and organic matter (2.1 g kg^{-1}) as shown in Table 4.1.

The analysed commercially produced organic fertilisers used for the study revealed that, the essential nutrients in (CPOF I, CPOF II and CPOF III) fertilisers varied in the nutrient concentrations such as total nitrogen (3.0, 3.5, 2.5 and 2.1 g kg^{-1}), available P (1.4, 2.0, 1.8 and 1.5 mg kg^{-1}), K (0.63, 0.6, 0.5 and 0.55 mg kg^{-1}), respectively. Pb and Se were not detected, Table 4.2.

4.1.2 Influence of fertilisers on some selected vegetative parameters of three tomato varieties

The response of three tomato varieties to different fertilisers showed significant differences at 6 and 8 Weeks After Transplanting (WAT) on the plant height. The Ibadan local consistently produced the highest plant height at 4, 6 and 8 WAT (33.40 cm), (56.9 cm) and (78.5 cm), however, those of UC82B and Roma VF varieties were similar and lowest. Fertilisers significantly affected each sampling period. At 4 WAT, the plant treated with 60 kg N/ha CPOF II (T2) recorded the highest plant height (31.7 cm) while untreated (T9) had the lowest (22.2 cm). At 6 WAT, application of 120 kg N/ha CPOF II (T5) gave higher plant

Table 4.1: Pre – cropping chemical and physical properties of soils used for the study at Ogbomoso and Ibadan

Properties	Ogbomoso		Ibadan
	2012	2013	2014
pH	6.9	5.20	5.6
Silt (g kg^{-1})	62.40	62.70	61.5
Clay(g kg^{-1})	7.70	8.40	10.5
Sand (g kg^{-1})	29.60	29.60	41.7
Organic Carbon (g kg^{-1})	1.3	1.2	1.1
Organic Matter (g kg^{-1})	2.1	1.9	2.1
Total Nitrogen (g kg^{-1})	0.19	0.19	0.18
Available P (mg kg^{-1})	10.7	11.1	10.1
Exchangeable cations (cmol kg^{-1})			
K	0.5	0.6	0.5
Na	0.3	0.4	0.4
Ca	3.1	0.3	0.4
Mg	1.0	0.1	0.7
Extractable micronutrients (mg kg^{-1})	0.3	0.3	0.3
Cu	1.3	1.0	1.1
Fe	11.9	12.5	11.5
Zn	3.4	4.5	21.2
ECEC (cmol g kg^{-1})	5.2	4.2	4.1
Based saturation (g kg^{-1})	95.0	90.9	91.6
Textural class	Loamy-sand	Sandy loam	Loamy-sand

height (60.5 cm) than the control (38.7 cm) T9. At 8 WAT, 120 kg N/ha CPOF I (T4) had highest plant height (81.1cm) but lowest in control plants (58.9 cm) (T9).

The effect of varieties and fertilisers significantly influenced tomato plant height at each sampling period (Table 4.3). Amendment with 120 kg N/ha CPOF I (T4) gave the tallest plant (80.8 cm). This was similar to Ibadan local treated with 120 kg N/ha CPOF I(T4), 60 kg N/ha Urea+35 kg P_2O_5/ha SSP+30 kg K_2O/ha MOP (T7), and Roma VF treated 120 kg N/ha CPOF II (T5) while Ibadan local control, UC82B control and Roma VF control had the shortest (Table 4.4).

The effect of the varieties and fertilisers were significantly observed at 6 and 8 WAT. At 6 WAT, UC82B recorded the most robust stem girth while Ibadan local had the least stem girth. Again at 6 and 8 WAT, the girth of the UC82B and Roma VF were similar. Application of fertilisers also influenced tomato stem girth ($P \leq 0.05$). It was observed that at 8 WAT, 120 kg N/ha CPOF I (T4) (4.1 cm) stem girth was widest, while control had the least (2.6 cm) (T9). It was also found that at this age, stem girth of plants treated with 60 kg N/ha CPOF II (T2), 60 kg N/ha Urea+35 kg P_2O_5/ha SSP+30 kg K_2O/ha MOP (T7), 120 kg N/ha CPOF II (T5) and 120 kg N/ha CPOF III (T6) were similar (Table 4.5).

The varietal effect significantly influenced ($P \leq 0.05$) the number of branches at 4 and 6 WAT. At 6 WAT, the Ibadan local had the highest number (6.71) of branches/plant, but the lowest was (4.63) in UC82B. Fertiliser application influenced a number of branches at 4 – 8 WAT. At 4 WAT, 120 kg N/ha CPOF III (T6) had the highest value (3.0) but 60 kg N /ha Urea (T8) recorded the lowest (1.6) number of branches. The plot supplied with 60 kg N/ha CPOF (T3) (8.3) recorded the highest number of branches, while 60 kg N/ha CPOF II (T2) had the least (5.4). At 8 WAT, 120 kg N/ha CPOF I (T4) significantly had most branches as compared to 60 kg N/ha CPOF III (T3), while untreated (T9) plants were the least (7.3) (Table 4.6).

The varietal effect on the leaves/plant significantly affected the tomatoes at 4, 6 and 8 WAT (Table 4.6). At 4, 6 and 8 WAT, Ibadan local consistently produced a higher number of leaves/plant than UC82B. However, the values recorded for Ibadan local were similar to Roma VF. At 8 WAT, the plants treated with 60 kg N/ha Urea (T8),

Table 4.2: Chemical characteristics of the commercially produced organic fertilisers used for the experiment

Properties	CPOF I	CPOF II	CPOF III
P^h	5.5	5.52	5.46
Total N (g kg^{-1})	3.0	3.5	2.5
P (g kg^{-1})	1.4	2.0	1.8
K (g kg^{-1})	0.63	0.6	0.5
Mg (g kg^{-1})	1.47	1.2	1.2
Zn (mg kg^{-1})	1.25	1.33	1.13
Cu (mg kg^{-1})	3.4	3.5	2.95
Pb (mg kg^{-1})	ND	ND	ND
Se (mg kg^{-1})	ND	ND	ND

*All determinations were on dry weight basis. ND- not detected, Commercially Produced Organic Fertiliser CPOF I (Pacesetter Organic fertiliser), Commercially Produced Organic Fertiliser CPOF II (Sunshine Organic Fertiliser), Commercially Produced Organic Fertiliser CPOF III (Alesinloye Organic Fertiliser).

Table 4.3: Effect of fertilisers on plant height (cm) of three tomato varieties grown in Ogbomoso during the 2012 trial

	Weeks after Transplanting		
Treatments	**4**	**6**	**8**
TV			
Ibadan local	33.40a	56.90a	78.50a
UC82B	28.50a	45.20b	64.70b
Roma VF	28.20a	48.20b	63.20b
Fertiliser (F)			
T1	23.20b	49.90b	78.35a
T2	31.70a	56.30a	78.20a
T3	29.00a	54.40a	69.90b
T4	28.40a	59.50a	81.10a
T5	25.60ab	60.50a	68.60b
T6	28.40a	58.30a	75.00a
T7	28.60a	56.50a	72.80a
T8	23.50c	53.20a	67.70b
T9	22.20b	38.70c	58.90c
Interaction:	ns	ns	ns
TV x F			

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

60 kg N/ha Urea+35 kg P_2O_5/ha SSP+30 kg K_2O/ha MOP (T7) and 120 kg N/ha CPOF I (T4) gave a better number of leaves than control T9. It is important to note that values obtained for all fertiliser applications were higher than those of unfertilized plants (Tables 4.7). The leaf surface of tomato varieties was significantly influenced by different fertilisers. Roma VF had the largest leaf area/plant (383.6 and 375.4 cm^2) at 4 and 6 WAT, respectively, while the smallest (323.4 and 323.2 cm^2/plant) was observed in UC82B variety. At 8 WAT, Ibadan local produced the largest leaf area/plant. The leaf area/plant of Ibadan local at 8 WAT was similar to that of Roma VF. The leaf area was affected significantly by fertilisers at 6 and 8 WAT. At 6 and 8 WAT, 120 kg N/ha CPOF I (T4) treatment had the highest values, while untreated plants were the least (T9). The leaf areas of all fertilized plants were better than control (T9) (Table 4.8).

4.1.3 Influence of fertilisers on components of yield and fruit yield of three tomato varieties grown in pots

There was a significant effect from the days of transplanting to 50% flowering on the number of flowers, fruits/plants and percentage fruit set. The Ibadan local variety flowered at 56 days (i.e. 9.5 days lesser), but Roma VF flowered at 60.60 days while UC82B flowered at 65.30 days after sowing. For the number of flowers/plant, Ibadan local produced 20.5 flowers/plant, but more than UC82B and Roma VF varieties. The fruits number produced/plant and percentage fruit set performances were similar even considering varietal differences. For the two parameters, Ibadan local performed better than the other two varieties. The percentage of fruit set in Ibadan local variety was significantly higher than UC82B and Roma VF varieties (Table 4.9).

Days to 50% flowering ranged from 55.5 days in untreated (T9) plants to 63.4 days in treated plants. The plants treated with 120 kg N/ha CPOF III (T6) flowered earlier than all other treated plants. All treated plants produced higher number of flowers than untreated plant T9. The number of fruits/plant varied from 10.5 in the untreated plot (T9) to 14.2 in 60 kg N/ha CPOF II (T4) and 120 kg N/ha CPOF II OF (T5) of treated. The number of fruits/plant treated with 60 kg N/ha CPOF II (T2), 60 kg N/ha CPOF III (T3), 120 kg N/ha CPOF I (T4), 120 kg N/ha CPOF II (T5), 120 kg N/ha CPOF III (T6) and 60 kg N/ha

Table 4.4: Effect of variety and fertilisers on plant height (cm) of three tomato varieties grown in pot

Fertiliser	Tomato varieties		
	Ibadan local	UC82B	Roma VF
T1	73.36c	68.72c	69.28c
T2	76.25ab	70.26b	76.38b
T3	79.91a	71.38b	77.66b
T4	80.8a	76.61a	76.35b
T5	76.71ab	74.68ab	79.72a
T6	75.62ab	76.72a	78.29ab
T7	79.42ab	74.52ab	31ab
T8	78.10ab	74.65ab	75.91b
T9	66.75d	60.27d	65.40d

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$).T1=60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.5: Effect of fertilisers on stem girth (cm) of three tomato varieties grown in pots

Treatments	Week after transplanting		
	4	6	8
TV			
Ibadan local	2.10a	2.60b	2.90b
UC82B	1.80a	3.20a	3.60a
Roma VF	1.80a	3.00a	3.60a
Fertiliser (F)			
T1	2.00ab	2.90ab	3.00b
T2	2.00ab	3.20a	3.40ab
T3	2.10ab	3.00a	3.20b
T4	2.30a	3.60a	4.10a
T5	2.60a	3.20a	3.90a
T6	2.40a	3.40a	4.00a
T7	2.40a	3.20a	4.00a
T8	1.70b	2.90ab	3.20b
T9	1.80b	2.40b	2.60b
Interaction:			
TV x F	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.6: Effect of fertilisers on the number of branches of three tomato varieties grown in pots at 4, 6, and 8 WAT

Treatments	Weeks after transplanting		
	4	6	8
TV			
Ibadan local	2.30a	6.71a	8.71a
UC82B	2.00b	4.63b	7.61a
Roma VF	2.01a	5.81a	8.00a
Fertiliser (F)			
T1	2.70bc	6.32cd	9.10b
T2	1.70d	5.40d	8.90bc
T3	2.99b	8.30a	10.32a
T4	2.98b	7.00ab	10.41a
T5	2.50bc	6.42bc	10.20ab
T6	3.00ab	6.51bc	9.99abc
T7	2.96b	6.71bc	10.21a
T8	1.60d	6.71bc	8.70bc
T9	3.00ab	6.51bc	9.99abc
Interaction:			
TV x F	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.7: Effect of fertilisers on the number of leaves /plant of three tomato varieties grown in pots

Treatments	Weeks after transplanting		
	4	6	8
TV			
Ibadan local	23.45a	51.98a	73.70a
UC82B	16.20b	37.21c	60.21b
Roma VF	19.63a	48.98b	70.41a
Fertiliser (F)			
T1	20.67ab	42.24ab	64.18a
T2	18.00b	33.65b	60.23b
T3	22.13ab	42.23ab	69.00a
T4	26.22a	48.73a	68.34a
T5	20.24ab	42.03ab	64.56a
T6	22.45ab	43.28ab	66.34a
T7	21.45ab	43.98ab	68.69a
T8	19.21ab	40.23ab	68.77a
T9	17.45b	39.21ab	51.70c
Interaction:			
TV x F	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60 kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.8: Effect of fertilisers on leaf area /plant (cm^2) of three tomato varieties grown in the pot

	Weeks after transplanting		
Treatments	**4**	**6**	**8**
VT			
Ibadan local	365.7a	343.6ab	344.2a
UC82B	323.4b	323.2b	236.6b
Roma VF	383.6a	375.4a	327.1ab
Fertiliser (F)			
T1	323.7a	343.5bc	451.5ab
T2	351.8a	333.8bc	389.2b
T3	383.8a	361.5b	467.2a
T4	393.8a	343.6bc	375.2c
T5	398.3a	343.6bc	375.2c
T6	364.6a	256.4c	385.5a
T7	356.9a	369.6b	462.7a
T8	377.5a	345.7bc	443.5ab
T9	353.9a	212.8c	245.1c
Interaction:			
TV x F	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Urea+35 kg P_2O_5/ha SSP+30 kgK_2O/ha MOP (T7) exhibited a significantly higher number of fruits than those obtained from control (T9), 60 kg N/ha urea (T8) and 60 kg N/ha CPOF I (T1). In the 60 kg N/ha Urea (T8) fertiliser, the lowest percentage fruit set of 53.5 percent was observed, and the highest was 60 kg N/ha CPOF III (T3) (65.1 percent). The interactive effect of variety and fertilisers were not significant on all the yield components (Table 4.9).

The application of different fertilisers affected fruit/plant weight as well as the marketability of fruit/plant. Roma VF produced the highest number of marketable fruits/plant (10.1), but lowest in Ibadan local (8.9). The marketable fruits/plant of Roma VF was significantly similar to UC82B. Ibadan local had the highest fruit weight/plant, while UC82B had the lowest value. The effects of fertilisers on the marketability of fruits/plant were significantly influenced. The marketable fruits yield ranged from 6.7/plant in untreated T9 to 10.7/plant in 60 kg N/ha CPOF III (T3) fertiliser. Again, the 60 kg N/ha CPOF II (T2), 60 kg N/ha Urea+35kg P_2O_5/ha SSP+30kg K_2O/ha MOP (T7), 120 kg N/ha CPOF I (T4) and 120 kg N/ha CPOF II (T5) treatments were identical (Table 4.10).

The effect of fertilisers on fruit dry matter and fruit yields (g/plant) of three tomato varieties are presented in Table 4.10. The findings showed that there was no significant difference among the three tomato varieties tested. The Ibadan local had the highest fruit yield (12.9 g/plant) but statistically similar to UC82B while Roma VF had the lowest (10.9 t ha^{-1}) fruit yield. The effect of fertilisers on fruit dry matter of the fruit showed that 60 kg N/ha CPOF II (T3) had the highest fruit dry matter (91.0 g) while untreated (T9) plant had the lowest (76.2 g) fruit dry matter. However, treatments 120 kg N/ha CPOF I (T4) and 120 kg N/ha CPOF II (T5) significantly produced the highest fruit yield (13.2 g/plant) and (12.2 g/plant) but untreated plants had significantly lowest (8.7 g/plant) (Table 4.10). Interactive effect of variety and fertilisers on fruit yield were higher in Ibadan local treated 120 kg N/ha CPOF I (T4) (13.8 g/plant) while UC82B control (8.3 g/plant) had the least (T9) (Table 4.11).

Table 4.9: Effects of fertilisers on yield components of three tomato varieties grown in the pot

Treatments	Days to 50% flowering	No. of flowers/ Plant	No. of fruits/ Plant	Percentage Fruit set (%)
TV				
Ibadan local	57.30c	20.50a	14.10a	68.80a
UC82B	65.30a	18.20b	10.20b	56.00b
Roma VF	60.60b	18.60b	10.80b	58.10a
Fertiliser (F)				
T1	59.40b	22.7a	12.3b	62.2a
T2	60.60ab	19.8bc	12.4b	62.6a
T3	61.30ab	21.8ab	14.2a	65.1a
T4	60.60ab	21.4ab	13.0ab	60.7b
T5	62.30a	22.9a	14.2a	62.0a
T6	62.10a	23.6a	12.8ab	54.2b
T7	63.40a	22.7a	13.1ab	57.7ab
T8	60.80ab	21.3b	11.4bc	53.5b
T9	55.50c	18.6c	10.5c	56.5ab
Interaction:				
TV x F	ns	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.10: Effect of fertilisers on fruit parameters of three tomato varieties grown in pots

Treatments	Number of marketable fruit/plant	Weight of fruit /plant (g)	Fruit dry matter (g)	Fruit yield (g/plant)
TV				
Ibadan local	8.90b	596.87a	65.10a	12.90a
UC82B	9.59ab	489.56c	68.23a	11.20a
Roma VF	10.10a	526.17b	70.40a	10.90b
Fertiliser (F)				
T1	9.40b	502.34b	90.00ab	10.20b
T2	9.80ab	512.45bc	91.00a	10.20b
T3	10.80a	564.78a	88.80ab	10.40b
T4	10.70a	592.74a	88.12ab	13.20a
T5	9.90ab	589.78a	88.12ab	12.20a
T6	9.50b	528.78ab	90.14ab	11.80ab
T7	10.60a	549.60a	89.21ab	12.10ab
T8	9.50b	482.79c	78.32b	9.40c
T9	6.70c	434.56d	76.21b	8.70c
Interaction:				
TV x F	ns	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.11: Effect of fertilisers on fruit yield (g /plant) of three tomato varieties grown in pot

Fertilisers	Tomato Variety		
	Ibadan local	UC82B	Roma VF
T1	10.65c	11.67b	10.35c
T2	10.75c	11.81b	11.61ab
T3	11.68b	10.55c	10.39c
T4	13.83a	12.28a	12.61a
T5	10.57b	11.39b	10.71c
T6	10.45b	11.91b	11.40b
T7	12.27ab	12.24a	11.85ab
T8	10.51c	9.80d	9.80d
T9	8.80d	8.30e	8.80e

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

4.1.4 Influence of fertilisers on fruit phytochemicals composition of three tomato varieties grown in pots

The fruit crude protein and fruit ether extract in the tomato varieties indicate no significant difference, but are statistically compared to fruit crude fibre. The crude protein (0.67 g kg^{-1}) in UC82B and Ibadan local (0.70 g kg^{-1}) were not significantly different. However, Roma VF produced the highest crude protein. For the ether extract, it was revealed that UC82B had the highest (2.81 and 4.23 g kg^{-1}), followed by Roma VF (2.34 and 3.99 g kg^{-1}) while Ibadan local had the lowest (1.62 and 3.65 g kg^{-1}). The crude protein varied from 0.81 g kg^{-1} in 120 kg N/ha CPOF II (T8) to 0.69 g kg^{-1} in untreated plants T9. The values obtained with 60 kg N/ha CPOF III (T3) to 120 kg N/ha CPOF III (T6) were similar to that of 120 kg N/ha CPOF II (T5). The highest crude fibre (1.48 g kg^{-1}) were recorded in treatments 60 kg N/ha CPOF III (T3) and 120 kg N/ha CPOF I (T4), while untreated (T9) plants gave the lowest (1.20 g kg^{-1}). The ether extracts ranged from 1.81 g kg^{-1} in control (T9) to (2.80 g kg^{-1}) in 120 kg N/ha CPOF I (T4) treatment. The combinations of tomato varieties and fertilisers were not significantly different on all the selected phytochemicals composition of tomato varieties (Table 4.12).

4.2. Field Experiment. Influence of fertilisers on growth, dry matter partitioning, fruit yield and phytochemicals composition of three tomato varieties grown under field conditions

4.2.1. Growth parameters at 4, 6 and 8 WAT

Influence of fertilisers on plant height of three tomato varieties is as shown in Table 4.13. It was observed that Ibadan local significantly had tallest plant height over Roma VF and UC82B varieties, but Roma VF was not significantly different from Ibadan local. Fertilisers also had effects on tomato height at 4, 6 and 8 WAT. Application of 60 kg N/ha CPOF III (T3) had the highest plant height (37.8 cm) while non treated plants (T9) had the shortest height (29.2 cm). At 6 WAT, treatment with 60 kg N/ha CPOF III (T3) had the highest height but comparable to treatments 60 kg N/ha CPOF I (T1) and 60 kg N/ha Urea+35 kgP_2O_5/ha SSP+30 kgK_2O/ha MOP (T7) although control was the lowest height of the plant. Likewise, at 8 WAT, 60 kg N/ha CPOF II (T2) treated plants had the highest plant height while untreated (T9) plants had the shortest (Table 4.13).

Table 4.12: Effect of fertilisers on fruit phytochemicals composition in the three tomato varieties

Treatment	Crude protein	Crude fibre	Ether extract	Carbohydrate
	⟶	g kg^{-1}	⟵	
TV				
Ibadan local	0.70b	1.23a	1.62b	3.65c
UC82B	0.67b	1.12a	2.81a	4.23a
Roma VF	0.81a	1.31a	2.34a	3.99b
Fertiliser (F)				
T1	0.72bc	1.28b	2.14a	3.82abc
T2	0.72bc	1.40a	2.18a	3.75abc
T3	0.79ab	1.42a	2.16a	3.77ab
T4	0.80a	1.42a	2.80a	3.69ab
T5	0.81a	1.32b	2.11ab	3.60bc
T6	0.78b	1.30b	2.24a	4.12a
T7	0.80a	1.29b	2.46a	3.79abc
T8	0.70c	1.34b	2.32a	3.90abc
T9	0.69d	1.20b	1.81b	3.89c
Interaction:				
TV x F	ns	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Treatment 60 kg N/ha CPOF III (T3) to UC82B had significantly the highest plant height and was similar to Ibadan local fertilized with 60 kg N/ha urea (T8). Ibadan local treated with 60 kg N/ha CPOF I (T1), 120 kg N/ha CPOF II (T5) and 120 kg N/ha CPOF III (T6), while Ibadan local control (T9) had the lowest (Table 4.14). Table 4.15 presented the effect of different fertilisers on stem girth of three tomato varieties. Roma VF had wider stem girth than the other two varieties at 4, 6 and 8 WAT while UC82B had the thinnest stem girth. Fertilisers also had a significant effect on stem girth.

Treatment 60 kg N/ha CPOF III (T3) showed the highest stem girth, while 60 kg N/ha CPOF II (T3) gave the smallest girth. At 6 WAT, 60 kg N/ha CPOF I (T1) had significantly higher stem girth than the control (T9). Likewise, at 8 WAT, treatment 60 kg N/ha CPOF III (T3) gave the highest stem girth while 60 kg N/ha CPOF II (T2) had the lowest. Variety and fertiliser interactions were significant at 8 WAT (Table 4.15). The combinations of tomato varieties, fertilisers and interactions with the amount of branches/plants have shown that varietal effect was more significant at 4, 6 and 8 WAT. At each sampling period, Ibadan local and Roma VF consistently produced branches than UC82B variety. Again, fertilisers also had a sizable influence on the plant branches at each sampling period. The Ibadan local had higher branches/plant than UC82B and Roma VF varieties. Treatment 120 kg N/ha CPOF I (T1) showed the maximum branches (12.80) compared to control (8.69). Similar values were obtained with 60 kg N/ha CPOF III (T3) and 60 kg N/ha Urea+35kg P_2O_5/ha SSP+30kg N/ha K_2O/ha MOP (T7) for treatment with 120 kg N/ha CPOF I (T4). The interactive effect of tomato variety and fertilisers was substantial only at 6 WAT (Table 4.16). Fertiliser applications on leaves/plant showed that the foliage production increased gradually from 4 to 8 WAT. At each sampling period, Ibadan local significantly displayed higher values than the other two varieties. At 8 WAT, the Ibadan local gave 78.61 leaves/plant which was statistically similar to 73.61 leaves/plant obtained from Roma VF, but significantly higher than 60.76 leaves/plant recorded in UC82B. Fertilisers showed significant effects on leaves per plant during the sampling period, except at 8 WAT. The values recorded for amended plants had higher values than control T9. At 6 WAT, 120 kg N/ha CPOF I (T4) treatment had the highest number of leaves (51.09) while the least (35.79) was recorded at 60 kg N /ha CPOF II (T3) treatment.

Table 4.13: Effect of fertilisers on plant height of the plant (cm) of three tomato varieties grown on the field

	Weeks After Transplanting		
Treatments	**4**	**6**	**8**
TV			
Ibadan local	36.25a	64.57a	78.10a
UC82B	27.56b	49.07c	69.58b
Roma VF	36.19a	58.47b	75.95a
Fertiliser (F)			
T1	35.04ab	57.85a	75.80a
T2	29.70c	55.98ab	73.17ab
T3	37.83a	61.84a	79.43a
T4	35.12ab	57.50a	76.72a
T5	32.56bc	57.07a	75.11ab
T6	32.13bc	58.24a	74.43ab
T7	35.12ab	57.50a	76.72a
T8	36.00ab	58.22a	74.05ab
T9	29.24c	50.50b	66.58b
Interaction:			
TV x F	ns	**	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.14: Effect of fertilisers and three tomato varieties on plant height (cm) of the field grown plants

Fertilisers	Tomato Variety		
	Ibadan local	**UC82B**	**Roma VF**
T1	85.65a	71.50c	65.0d
T2	77.15c	70.0d	72.35b
T3	67.30d	88.0a	77.0a
T4	79.0c	77.0b	69.33b
T5	80.67ab	75.33b	67.30c
T6	81.63ab	75.97b	71.27b
T7	85.65a	77.35b	67.15c
T8	85.65a	71.50c	65.0d
T9	61.45e	76.30b	62.0e

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.15: Influence of fertilisers on stem girth (cm) of the three tomato varieties grown on the field

	Weeks After Transplanting		
Treatments	**4**	**6**	**8**
TV			
Ibadan local	2.63b	3.76b	4.25b
UC82B	2.17c	3.25c	3.91c
Roma VF	3.43a	4.37a	5.07a
Fertilisers (F)			
T1	2.58bc	4.04a	4.57a
T2	2.55c	3.20c	3.70c
T3	3.05ab	3.92a	4.73a
T4	2.97ab	4.02a	4.61a
T5	2.74ab	3.69ab	4.52ab
T6	2.66abc	3.8ab	4.48ab
T7	2.75ab	3.93a	4.64a
T8	2.68abc	3.79ab	4.37ab
T9	2.75ab	3.00b	4.05bc
Interaction:			
TV x F	ns	ns	*

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

There was no significant influence on the interaction between variety and fertiliser on a number of leaf/plant during the sampling period (Table 4. 17). Tomato varieties and fertilisers affected the leaf area/plant. Variability in leaf production of tomato varieties was observed at all sampling periods. At 8 WAT, Ibadan local performed better than the other two varieties with regards to leaf area production. From 6 to 8 WAT, 120 kg N/ha CPOF I (T4) consistently gave the plants with wider leaf area over the other treatments. At 8 WAT, the use of 120 kg N/ha CPOF I (T4) gave the highest leaf area/plant (536.3 cm^2) while untreated plant (T9) had the least (358.6 cm^2). In most cases, fertilized plants had better leaf area/plant than unfertilized plants. The interactive effect of the variety and fertilisers on the leaf area/plant at all sampling period was not significant (Table 4.18).

4.2.2 Dry matter accumulation and partitioning of three tomato varieties

Shoot, root and total dry matter yield of the tomatoes were influenced by varietal differences. On the average, Ibadan local had significantly higher dry matter than UC82B and Roma VF varieties. The shoot dry matter yield of Ibadan local was 73.2 % and 58.4 % higher than the values recorded for UC82B and Roma VF respectively. The fertilisers, though had different effects on dry matter yield, they generally improved dry matter partitioning in tomato plants. For shoot dry matter, treatment 120 kg N/ha CPOF I (T4) gave the highest value (104.20 g /plant) while no fertiliser T9 and 60 kg N /ha Urea (T1) had the lowest values (91.11 and 90.11 g /plant) respectively. The root dry matter treated 120 kg N/ha CPOF I (T4) had the highest (10.71 g) while 60 kg N /ha Urea (T8) had the lowest. In the case of total dry weight, 120 kg N/ha CPOF I (T4) gave the best value which was significantly similar to treatments 60 kg N /ha CPOF I (T1) to 120 kg N/ha CPOF III (T6). The interactive effect of variety and fertilisers had effect only on root dry matter yield (Table 4.19).

4.2.3 Growth analysis of three tomato varieties under different fertilisers

4.2.3.1. Leaf Area Index (LAI) at 4, 6 and 8 WAT

Leaf area index (LAI) of tomato plant influenced varietal differences, fertilisers and their interactions (Table 4.20). The LAI increased gradually from 4 WAT to 8 WAT. At 4 WAT, LAI index of Ibadan local gave the highest, while UC82B had the lowest. For the 6 WAT,

Table 4.16: Effect of fertilisers on number of branches /plant of three tomato varieties at 4, 6 and 8 WAT

	Weeks after transplanting		
Treatments	**4**	**6**	**8**
TV			
Ibadan local	3.15a	7.47a	10.68a
UC82B	1.74b	5.70b	7.50b
Roma VF	3.00a	6.70a	10.12a
Fertiliser (F)			
T1	2.27bc	5.74cd	9.63bc
T2	1.64d	5.08d	9.01bc
T3	3.18ab	8.56a	11.62a
T4	3.00abc	6.79ab	12.80a
T5	2.75abcd	6.50bc	10.17ab
T6	2.84abc	6.84bc	10.21ab
T7	2.91abc	7.48ab	11.19ab
T8	1.96cd	5.79cd	9.10bc
T9	2.40cd	6.40bc	8.69c
Interaction:			
TV x F	ns	**	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.17: Effect of fertilisers on number of leaves /plant of three tomato varieties

	Weeks After Transplanting		
Treatments	**4**	**6**	**8**
TV			
Ibadan local	28.97a	44.44a	78.61a
UC82B	16.78b	36.31c	60.76b
Roma VF	26.75a	43.81a	73.61a
Fertiliser (FT)			
T1	21.62ab	45.61ab	68.11a
T2	16.19b	35.79b	59.61a
T3	23.16ab	45.96ab	71.77a
T4	26.22a	51.09a	70.66a
T5	22.32ab	44.00ab	67.89a
T6	24.54ab	46.78ab	69.22a
T7	23.94ab	48.20ab	71.22a
T8	21.62ab	44.84ab	70.22a
T9	18.89ab	41.63ab	65.88a
Interactive:			
TV x F	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

the LAI ranged from (1.78 cm) in UC82B to (2.38 cm) in Ibadan local. At this sampling period, the LAI of Ibadan local and Roma VF were similar. At 8 WAT, the LAI of Ibadan local were 69.91 and 52.31 % higher than Roma VF and UC82B, respectively. Fertilisers also had significant effects on the LAI of tomato varieties at all sampling periods. Irrespective of the sampling period, the LAI of treated plants performed better than untreated plants.

At 4 WAT, 120 kg N/ha CPOF I (T4) indicated the highest LAI (0.22 cm), while control was the least (0.04 cm). At 6 WAT, highest LAI was obtained with treatments 120 kg N/ha CPOF I (T4), 120 kg N/ha CPOF (T5) and 120 kg N/ha CPOF III (T6) fertiliser, while untreated plants had the lowest (T9). The highest LAI was observed in 120 kg N/ha CPOF I (T4) (3.72 cm) at 8 WAT but lowest in control plants (2.32 cm^2). Only at 4 WAT were significant interactive effects of the variety and the fertiliser noticed. At 4 WAT, 120 kg N/ha CPOF I (T4) and 120 kg N/ha CPOF II (T5) treatments to Ibadan local had the best values which were significantly similar to the same variety when fertilized with 120 kg N/ha CPOF III (T6) (Table 4.21).

4.2.3.2. Crop Growth Rate (CGR) of three tomato varieties as influenced by fertilisers

The Crop Growth Rate (CGR) of tomato in response to variety and fertilisers is shown in Table 4.22. The tomato CGR increased with age and reached maximum at 8 WAT. At each sampling period, the Ibadan local consistently had the highest CGR reaching this value (15.50 g $m^{-2}day^{-1}$) 8 WAT but similar to Roma VF while UC82B had the least (5.71 g $m^{-2}day^{-1}$). Fertilisers equally had significant effects on tomato CGR at each sampling period. At 8 WAT, 120 kg N/ha CPOF I (T4) treatment gave the best CGR value (14.94 g $m^{-2}day^{-1}$) but significantly higher than the values obtained in other treated plants except in 60 kg N/ha Urea+35 kgP_2O_5/ha SSP+30 kgK_2O/ha MOP (T7) treatment while the least CGR (8.33 g $m^{-2}day^{-1}$) was observed in untreated plants (T9). The interactive effects of variety and fertiliser on CGR of tomato are as presented in Table 4.22 and interactions were influenced all sampling periods.

Table 4.18: Effect of fertilisers on leaf area /plant (cm^2) of three tomato varieties

	Weeks after transplanting		
Treatments	**4**	**6**	**8**
TV			
Ibadan local	359.9a	472.5a	440.0a
UC82B	313.1b	358.2b	384.2c
Roma VF	364.8a	454.8a	418.4b
Fertiliser (F)			
T1	404.2ab	437.6bc	461.9ab
T2	415.5b	341.8c	429.2b
T3	549.2a	430.3b	529.1a
T4	526.6a	571.2a	536.3a
T5	507.2a	453.2b	416.4b
T6	488.4ab	468.2ab	439.0ab
T7	428.3b	482.5ab	442.1ab
T8	513.5b	448.3bc	483.2ab
T9	301.8c	316.4c	358.6c
Interaction:			
TV x F	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.19: Effect of fertilisers on shoot, root and total dry weight of three tomato varieties at onset of flowering

Treatments	Dry weight (g)		
	Shoot	**Root**	**Total**
TV			
Ibadan local	130.20a	10.71a	140.91a
UC82B	75.41c	7.70c	83.11c
Roma VF	82.20b	8.40b	90.60b
Fertiliser (F)			
T1	96.41bc	7.71de	104.12a
T2	97.80b	7.51de	105.31a
T3	90.22d	8.51cd	98.73b
T4	104.20a	10.71a	114.91a
T5	99.81ab	10.41ab	110.22a
T6	99.00ab	10.62ab	109.62a
T7	95.61bcd	10.21ab	105.82a
T8	90.11d	6.91e	97.42b
T9	91.11cd	7.31e	98.42b
Interaction:			
TV x F	ns	**	**

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

4.2.3.3. Relative Growth rate (RGR) of three tomato varieties as influenced by fertilisers

The RGR were significantly influenced by fertilisers on the three tomato varieties (Table.4.22). RGR increased gradually from 4 to 8 WAT, reaching maximum at 8 WAT. At each sampling period, the Ibadan local significantly had the highest RGR which was consistently higher than the other two varieties. At 8 WAT, the Ibadan local gave better RGR which was 28.3 % and 126 % higher than that of Roma VF and UC82B, respectively. The RGR of UC82B decreased with age.

Fertilisers had a significant effect on RGR. Again, at 6 WAT, 120 kg N/ha CPOF I (T4) gave the highest RGR but significantly higher than observations in the control plants (T9), 60 kg N/ha Urea (T8), 60 kg N/ha CPOF I (T1) and 60 kg N/ha CPOF II (T2) fertiliser treatments. The values of RGR at 6 and 8 WAT were significantly similar. At 4 WAT, treatment 120 kg N/ha CPOF I (T4) had the best values while control (T9) was the least. Again, at 6 and 8 WAT, the RGR of tomato treated with 120 kg N/ha CPOF I (T4) had higher values than all other treated plants including control. The interactive effects of variety and fertiliser on tomato RGR were highly significant ($P \leq 0.01$) at each sampling period.

4.2.3.4. Net Assimilation Rate (NAR) of three tomato varieties as influenced by fertilisers

Generally, the NAR decreased as plant aged and this was observed for the three varieties. At 4 WAT, the NAR had the highest (3.15 kg/ha) in Ibadan local and this was 45.2 and 21.5 % better than UC82B and Roma VF varieties respectively. At 6 WAT, where the NAR gave highest, Ibadan local still gave the highest, follow by Roma VF but UC82B variety had the lowest. Despite the reduction in NAR at 8 WAT as compared to the values recorded for 6 WAT age, the Ibadan local still had the best NAR. The order of increase in NAR was Ibadan local > Roma VF > UC82B variety. The NAR at 4 WAT was highest with 120 kg N/ha CPOF I T4 fertilized plants. This was similar to 120 kg N/ha CPOF II (T5) plant and significantly higher than NAR obtained from all other fertilisers while control had (T9) had the least. At 6 and 8 WAT, 120 kg N/ha CPOF I (T4) had significantly higher NAR compared to other treated plants and the control (Table 4.23).

Table 4.20: Effect of fertilisers on Leaf Area Index (LAI) of three tomato varieties at different sampling period

	Weeks after transplanting		
Treatments	**4**	**6**	**8**
TV			
Ibadan local	0.30a	2.38a	3.67a
UC82B	0.04c	1.78b	2.16c
Roma VF	0.08b	2.22a	3.29b
Fertilisers (F)			
T1	0.08f	1.78c	2.78cd
T2	0.12e	1.98bc	2.87cd
T3	0.15d	2.23ab	3.07bc
T4	0.22a	2.47a	3.72a
T5	0.18bc	2.33a	3.29b
T6	0.19b	2.41a	3.29b
T7	0.20ab	2.19ab	3.27b
T8	0.06fg	1.86c	2.62de
T9	0.04g	1.74c	2.32e
Interactive:			
TV x F	**	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.21: Effect of fertilisers on Leaf Area Index (LAI) of three tomato varieties at 4 WAT

Fertilisers	Tomato variety		
	Ibadan local	UC82B	Roma VF
		4WAT	
T1	0.14e	0.03d	0.07d
T2	0.25d	0.04c	0.07d
T3	0.33d	0.04c	0.07d
T4	0.47a	0.06a	0.13a
T5	0.40c	0.05b	0.08c
T6	0.44b	0.05b	0.07d
T7	0.47a	0.04c	0.10b
T8	0.14e	0.03d	0.07d
T9	0.44b	0.05b	0.07d
Interaction:			
V x F	ns	**	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5=120 kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.22: Influence of fertilisers on Crop Growth Rate (g $m^{-2}day^{-1}$) and Relative Growth Rate (g $g^{-1}week^{-1}$) of three tomato varieties (WAT)

	Crop Growth Rate			Relative Growth Rate		
Treatment	**4**	**6**	**8**	**4**	**6**	**8**
TV						
Ibadan local	0.91a	2.08a	15.50a	0.28a	0.62a	0.68a
UC82B	0.31c	0.97c	5.71b	0.03c	0.07c	0.50c
Roma VF	0.70b	1.57b	15.27a	0.17b	0.32b	0.53b
Fertiliser (F)						
T1	0.26d	1.13d	10.67d	0.12cd	0.28e	0.35c
T2	0.52c	1.30cd	11.11d	0.15b	0.31de	0.39c
T3	0.76bc	1.64b	12.67c	0.17a	0.35cd	0.46b
T4	0.87ab	2.21a	14.94a	0.19a	0.44a	0.52a
T5	0.89ab	2.48a	12.78c	0.18a	0.38bc	0.47b
T6	1.07a	2.22a	13.22bc	0.18a	0.40ab	0.45b
T7	1.04a	2.27a	14.64ab	0.18a	0.38bc	0.46b
T8	0.16d	0.40e	10.11d	0.13bc	0.27e	0.31d
T9	0.15d	0.35e	8.33e	0.10d	0.19e	0.26d
Interaction:						
TV x F	*	*	*	*	*	*

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5=120 kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kg/haK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

4.2.4. Effect of fertilisers on tomato leaf nutrients uptake of three tomato varieties at flowering stage

Tomato plants were greatly affected by the absorption concentration of nutrients (Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Zinc and Copper). The highest nitrogen, phosphorus and potassium contents were found in Roma VF leaf, but least in UC82B leaf. The leaf concentrations of Ca and Mg showed that, Roma VF contained the highest concentrations; follow by UC82B while Ibadan local had the least. The highest Zn and Cu concentrations were obtained in Roma VF, but Ibadan local and UC82B were similar while UC82B had the lowest Cu concentration.

Fertilisers had significant effects on leaf macro and micro-nutrients uptake in tomato plants (Table 4.24) except for N. The P uptake ranged from 56.3 g kg^{-1} obtained in 120 kg N/ha CPOF I (T4) to 42.0 g kg^{-1} in untreated T9 plants. The leaf concentration of K, Ca and Mg were significantly similar. For these macro-nutrients, their uptakes significantly had highest leaf nutrient uptake in the plants treated with 120 kg N/ha CPOF I (T4) and lowest in plants that received no fertiliser (T9) treatment. Treatment 120 kg N/ha CPOF I (T4) also had the highest Zn leaf concentration (0.36 mg kg^{-1}), but similar to 60 kg N/ha Urea+35 kgP_2O_5/ha SSP+30 kgK_2O/ha MOP (T7), 120 kg N/ha CPOF II (T5) and 120 kg N/ha CPOF III (T6) treatments while the lowest (0.25 mg kg^{-1}) were obtained in plants without treatment (T9). Fe content in the leaf of untreated plants had the lowest (T9) while 120 kg N/ha CPOF I (T4) had the highest (0.54 mg kg^{-1}) but significantly not different from 60 kg N/ha CPOF III (T3) treated plants. Effect of tomato varieties and fertilisers influenced leaf nutrient uptake with the exception of N and K (Table 4.24).

4.2.5 Influence of fertilisers on components of yield and fruit yield of three tomato varieties grown in the field

Effects of fertilisers on components of yield of the three tomato varieties were significant in all the components of yield measured (Table 4.25). Days to 50% of flowering was considerably affected by varietal variations, Ibadan local produced flowers earlier (56.40 days) than the other two varieties whereby Roma VF flowered at (61.80 days) after transplanting, whereas UC82B produced its first flower at (65.20 days) after transplanting. Ibadan local had the highest number of flowers, fruits per plant and fruit set.

Table 4.23: Effect of fertilisers on Net Assimilation Rate (g m^{-2} $week^{-1}$) of three tomato varieties

	Weeks after transplanting		
Treatments	**4**	**6**	**8**
TV			
Ibadan local	3.15a	7.17a	5.17a
UC82B	0.14c	0.28c	0.06c
Roma VF	2.17b	4.67b	1.70b
Fertiliser (F)			
T1	1.36de	3.06e	2.04ef
T2	1.43d	3.39e	2.16ed
T3	1.82c	3.99d	2.32cde
T4	2.56a	5.68a	2.83a
T5	2.39ab	4.81bc	2.56abc
T6	2.16b	4.71bc	2.71ab
T7	2.08bc	5.03b	2.67ab
T8	1.27de	2.93e	1.76fg
T9	1.05e	2.34f	1.62g
Interaction:			
TV x F	*	**	*

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60 kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.24: Influence of fertilisers on leaf nutrient uptake of three tomato varieties at flowering stage

Treatment	N	P	K	Ca	Mg	Zn	Fe	Cu
	g kg^{-1}				mg kg^{-1}			
TV								
Ibadan local	0.15b	47.54b	65.36b	108.17c	0.29c	0.29b	0.46a	0.16b
UC82B	0.15b	48.07b	64.93b	116.24b	0.33b	0.29b	0.47a	0.14c
Roma VF	0.17a	53.91a	71.26a	122.67a	0.40a	0.35a	0.46a	0.20a
Fertiliser (F)								
T1	0.15a	45.3e	67.67cde	111.3d	0.31d	0.28de	0.46def	0.14b
T2	0.15a	49.0d	67.78bcd	117.7bcd	0.34c	0.32bc	0.49bcde	0.17a
T3	0.16a	53.0bc	68.78abc	120.3bc	0.36bc	0.31cd	0.51abc	0.17a
T4	0.17a	56.3a	73.00a	130.7a	0.39a	0.36a	0.54a	0.18a
T5	0.15a	51.3bcd	65.89cd	114.6bcd	0.34bc	0.33abc	0.48cde	0.18a
T6	0.16a	49.9cd	68.67abc	114.3cd	0.35bc	0.34abc	0.47def	0.18a
T7	0.17a	53.2b	67.07cd	118.6bc	0.37ab	0.34abc	0.49bcd	0.18a
T8	0.15a	44.0ef	63.67de	105.4ef	0.30d	0.27e	0.45def	0.14b
T9	0.15a	42.0f	61.00e	101.9f	0.29d	0.25e	0.44f	0.13b
Interaction:								
TV x F	ns	*	ns	**	*	**	**	*

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

The values recorded for UC82B and Roma VF significantly similar. For percent fruit set, Ibadan local significantly higher (64.9 %) than UC82B (57.0 %) and Roma VF (57.1 %), (Table 4.25).

Days to 50% flowering ranged from 56.4 days in non-fertilised (T9) plants to 65.6 days in 120 kg N/ha CPOF III (T6) treatment. Application of 120 kg N/ha CPOF II (T5) produced more flowers, but similar to all amended plants including control plants (T9). Treatment 60 kg N/ha CPOF III (T3) produced the highest number of fruit/plant (17.11/ plant) but lowest (14.0/plant) in control (T9). The least per cent fruit set was obtained in 60 kg N/ha CPOF I (T1) (61.7 %) while 60 kg N/ha CPOF II (T2) (72.7 %) had the highest (Table.4.25). The interactive influence of variety and fertilisers was not significant on all the components of yield.

Varietal differences were significant on the marketable fruits/plant, fruit weight/plant, fruit dry matter and yield of tomato. From the observation, Roma VF had the highest marketable fruits/plant (11.80 t ha^{-1}) but higher than UC82B (10.60 t ha^{-1}) and Ibadan local (10.80 t ha^{-1}). Treatment 120 kg N/ha CPOF II (T5) at ($P \leq 0.01$) had significantly higher fruit yield (18.91 t/ha) than the control plants T9 (13.20 t ha^{-1}). It should be noted that application of fertilisers produced plants with a higher fruit yield than unamended plants (T9). Interactive effect of tomato varieties and fertilisers on tomato fruit yields were also significant (Table 4.27). Treatment 120 kg N/ha CPOF II (T5) to UC82B had the best interaction. This is similar to UC82B and 60 kg N/ha CPOF II (T2) and UC82B with 60 kg N/ha CPOF III (T3) interactions. The least fruit yield was obtained in Ibadan local that received no fertiliser (T9).

4.2.6. Effect of fertilisers on fruit phytochemicals composition of three tomato varieties

All the phytochemicals composition were affected by varietal differences except ether extract. The highest crude protein (0.85 g kg^{-1}) was obtained in Roma VF fruit while the least (0.69 g kg^{-1}) was in UC82B fruit. The maximum crude fibre was recorded in UC82B (1.42 g kg^{-1}), followed by Ibadan local (1.38 g kg^{-1}) while the minimum was obtained in Roma VF (1.29 g kg^{-1}). Fruit ether extract contents in UC82B had significantly highest (2.98

g kg^{-1}) which was statistically similar with Roma VF (2.19 g kg^{-1}) while Ibadan local had the lowest (1.17 g kg^{-1}) ether extract. Fertilisers significantly influenced phytochemicals composition in tomato varieties. On tomato crude protein, application 60 kg N/ha CPOF II (T2) to 120 kg N/ha CPOF III (T6) were similar and significantly higher than control (T9). Again, application of 60 kg N/ha CPOF III (T3) had higher fruit crude fibre content (1.48 g kg^{-1}) compared to (1.03 g kg^{-1}) the control (T9). Highest tomato fruit ether extract (2.67 gram per kilogram) recorded with 60 kg N/ha CPOF III (T3) while least was obtained in untreated plants (1.07 g kg^{-1}). The interactive effect of variety and fertilisers was not significant on all the proximate compositions except crude protein (Table 4.28).

The potassium content in Roma VF fruit gave the highest which was similar to UC82B, but significantly higher than Ibadan local. The fruit Vitamin A and Vitamin C contents were highest in UC82B (21.04 mg kg^{-1}) whereby the values recorded in Roma VF and Ibadan local (19.62 and 19.10 mg kg^{-1}) were similar and had the lowest values. The fruit lycopene content in UC82B (0.43 mg kg^{-1}) showed significantly higher value than Roma VF and Ibadan local (0.26 and 0.21 mg kg^{-1}).

Fertiliser applications produced significant effects on tomato fruit phytochemicals composition. The fruit K contents were better in fertilized plants than in non-fertilised plants. Fruit Vitamin C and A treated with120 kg N/ha CPOF I (T4) had the highest value (21.26 and 406.67 mg kg^{-1}). Also, treatment 120 kg N/ha CPOF I (T4) gave the highest deep red colour while untreated plant (T9) had the least red colour. The interactive effect of tomato varieties and fertilisers were significantly affected by tomato fruit K, vitamins A and C and lycopene contents (Table 4.29).

Table 4.25: Effect of fertilisers on components of yield in three tomato varieties

Treatment	Days to 50% flowering	Number of flowers/ Plant	Number of fruits/ Plant	Fruit set (%)
TV				
Ibadan local	56.40c	25.70a	16.70a	64.90a
UC82B	65.20a	22.10b	12.60b	57.00b
Roma VF	61.80a	22.40b	12.80b	57.10b
Fertiliser (F)				
T1	64.3a	25.6a	15.8ab	61.7b
T2	61.5ab	21.6b	15.7ab	72.7a
T3	60.9ab	24.9ab	17.11a	68.5a
T4	61.80a	24.6ab	15.2ab	61.8b
T5	63.10a	25.7a	17.1a	66.5a
T6	63.20a	25.5a	16.9a	66.3a
T7	65.60a	25.3a	16.5a	65.2a
T8	61.2ab	24.2b	14.6b	62.5b
T9	56.4b	22.4b	14.3b	63.4b
Interaction:				
TV x F	ns	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

4.3 RESIDUAL EXPERIMENT

4.3.1 Residual effects of fertilisers on the components of yield, fruit yield, phytochemicals, elemental compositions and lycopene contents in three tomato varieties

The residual effect of fertilisers on yield components of three tomato varieties was significant across the parameters taken. The Ibadan local reached flowering earlier at 56.35 days than UC82B and Roma VF. Roma VF first flowered at 58.70 days while UC82B produced its first flower at 66.51 days after transplanting. However, Ibadan local and Roma VF varieties had the highest number of flowers (21.70/plant) and (21.30/plant) while UC82B produced the lowest number of flowers (20.54/plant). Higher fruit number was recorded in Ibadan local (13.76/plant), followed by the UC82B (12.42/plant) while Roma VF produced the lowest (11.51/plant) fruit number. The percentage fruit set of Ibadan local (63.41 %) significantly produced higher % fruit set than the other two varieties. Meanwhile, UC82B was higher than (61.05 %) Roma VF (54.04 %) (Table 4.30).

Influence of residual effects on the yield components significantly not different on days to 50% flowering. 60 kg N/ha CPOF III (T3) produced the highest number of flowers/ plant (22.46/plant and 22.38/plant) but untreated plants (T9) had the lowest number of flowers (17.52/plant). However, the residual effect of 60 kg N/ha CPOF III (T3) yielded the highest number of fruit (13.72/plant) whereas, lowest was obtained in untreated plot (9.83/plant) T9. The performance of percentage fruit set was higher (61.09 %) in 60 kg N/ha CPOF III (T3) compared to other treatments as well as control (T9) had similar values (Table 4.30).

The varietal response to residual effects on marketable fruit /plant was significant while fruit weight had no significant difference. Highest marketable fruit was produced in UC82B (7.98 fruit/plant) while Ibadan local (7.35 fruit/plant) was the lowest. There was no significant difference in the residual effect on the number of marketable fruit because they had similar values. The residual effect of fertilisers significantly affected tomato fruit weight. Also, residual effect 60 kg N/ha CPOF I (T1) to 120 kg N/ha CPOF III (T6) performed better than control plants T9 and 60 kg N/ha urea (T8), (Table 4.31).

Table 4.26: Influence of fertilisers and their interactions on fruit parameters of three tomato varieties grown in field

Treatments	Number of marketable fruit /plant	Fruit weight/plant (g)	Fruit dry matter (g kg^{-1})	Fruit yield (t ha^{-1})
TV				
Ibadan local	10.80a	642.14a	88.33b	14.80b
UC82B	10.60b	516.52c	89.41ab	17.70a
Roma VF	11.80a	568.52b	90.80a	15.90b
Fertiliser (F)				
T1	10.80bc	527.25c	89.67a	14.60cd
T2	11.10ab	553.99b	88.77a	15.50c
T3	11.80ab	656.92a	87.80a	17.64ab
T4	12.20a	589.36b	89.28a	16.42b
T5	12.30a	619.89ab	89.40a	18.90a
T6	11.80ab	633.67ab	89.80a	17.56ab
T7	11.50ab	604.04ab	90.32a	17.72ab
T8	10.20bc	528.57c	89.62a	14.70cd
T9	8.9c	475.59d	88.66a	13.20d
Interaction:				
TV x F	ns	**	ns	**

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.27: Effect of fertilisers and three tomato varieties on the fruit yield

Fertiliser	Tomato Variety		
	Ibadan local	**UC82B**	**Roma VF**
T1	11.97d	16.93c	14.80c
T2	12.00d	20.03a	14.80c
T3	17.93a	19.52b	15.47bc
T4	16.10b	21.43a	16.93b
T5	16.23b	16.23c	17.30a
T6	16.37b	19.27b	17.10b
T7	16.63b	19.27b	17.27b
T8	13.27c	15.80c	14.93c
T9	11.88d	13.83d	13.87d

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

The response of tomato varieties to the residual effect of fertilisers on the fruit dry matter and fruit yield showed that UC82B had higher dry matter compared to Roma VF and Ibadan local varieties. Also, UC82B and Ibadan local significantly yielded more fruit, but not different from each other while Roma VF showed the least fruit yield. The residual effect of applied treatments was not significant in the fruit dry matter. For the fruit yield, a residual effect of 120 kg N/ha CPOF I (T4) gave the highest (11.67 t ha^{-1}) while untreated (T9) plant had the lowest (9.22 t ha^{-1}), (Table 4.31).

The varietal effects on fruit phytochemicals composition showed significant differences in fruit crude protein, crude fibre, ether extract and carbohydrate concentrations in tomato fruit. The crude protein content of Ibadan local and UC82B varieties was more than Roma VF variety. The Ibadan local also gave the maximum crude fibre, but similar to UC82B and significantly higher than Roma VF. UC82B gave the highest ether extract and carbohydrate compared to Ibadan local and Roma VF varieties (Table 4.32).

Residual effect influenced proximate compositions except in crude fibre and fruit carbohydrate. For the crude protein, 60 kg N/ha CPOF II (T2) gave the best result, while untreated had the least (T9). Residual effect of 120 kg N/ha CPOF I (T4) gave the highest ether extract over all other treated plants, including control (T9) while 60 kg N/ha urea (T8) had the lowest. The interactive effect of varieties and fertilisers on fruit phytochemicals composition were not significant (that is residual did not affect phytochemicals composition of the fruits) (Table 4.32).

The residual effect of fertilisers and varieties on some fruit phytonutrient compositions are presented in Table 4.30. Varietal differences were ($p<0.05$) observed on all the phytonutrient compositions tested. Fruit K was highest in UC82B and Roma VF fruits with similar results (0.26 mg kg^{-1}) while Ibadan local had the lowest fruit K (0.21 mg kg^{-1}), Vitamin C had a similar trend with Fruit K (Table 4.33).

Table 4.28: Effect of fertilisers on fruit phytochemicals composition (g kg^{-1}) of three tomato varieties

Treatment	Crude protein	Crude fibre	Ether extract	Carbohydrate
TV				
Ibadan local	0.69c	1.38ab	1.71b	3.85b
UC82B	0.79b	1.42a	2.98a	3.99a
Roma VF	0.85a	1.29b	2.19a	3.70c
Fertiliser (F)				
T1	0.74c	1.32b	2.14b	3.80abc
T2	0.76bc	1.42a	2.23a	3.85abc
T3	0.80ab	1.48a	2.67a	3.87ab
T4	0.84a	1.45a	2.48a	3.99ab
T5	0.83a	1.21b	2.34a	3.76bc
T6	0.82a	1.33b	2.46a	4.02a
T7	0.82a	1.23b	2.32a	3.82abc
T8	0.69d	1.33b	1.82b	3.79abc
T9	0.66e	1.03c	1.07c	3.62c
Interaction:				
TV x F	**	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60 kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.29: Effect of fertilisers on some fruit phytochemicals composition (mg kg^{-1}) of three tomato varieties

Treatments	K	Vitamin C	Vitamin A	Lycopene
TV				
Ibadan local	0.18b	19.10b	380.66b	0.21b
UC82B	0.27a	21.04a	400.95a	0.43a
Roma VF	0.29a	19.62b	370.66b	0.26b
Fertiliser (F)				
T1	0.23bc	19.02abc	380.78cde	0.26ef
T2	0.27a	19.18abc	386.33cd	0.29de
T3	0.27a	20.14abc	391.44bc	0.33bc
T4	0.28a	21.26a	406.67a	0.38a
T5	0.26a	20.78ab	383.10cd	0.31cd
T6	0.28a	20.74ab	390.23c	0.31cd
T7	0.28a	20.87a	385.13cd	0.33bc
T8	0.20bc	18.47bc	374.00de	0.23f
T9	0.16c	18.33bc	370.10e	0.19g
Interaction:				
TV x F	**	**	*	**

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.30: Residual effect of fertilisers on yield components of three tomato varieties

Treatment	Days to 50% flowering	Number of flowers/ Plant	Number of fruits/ Plant	Fruit set (%)
TV				
Ibadan local	56.35c	21.70a	13.76a	63.41a
UC82B	66.51a	20.54b	12.42b	61.05b
Roma VF	58.70b	21.30a	11.51c	54.04c
Fertiliser (F)				
T1	56.48a	21.54b	12.57b	58.36b
T2	54.38a	20.56c	11.91b	57.93b
T3	57.46a	22.38a	13.72a	61.09a
T4	57.35a	21.45b	12.27b	57.20b
T5	57.45a	21.25b	12.43b	58.49b
T6	57.34a	21.23b	12.21b	57.51b
T7	56.23a	20.24c	11.42b	56.42b
T8	55.45a	20.32c	11.52c	56.67b
T9	55.56a	17.52d	9.83d	56.10b
Interaction:				
TV x F	*	ns	ns	*

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

The residual effect of the applied treatments influenced phytonutrient compositions. The plant treated with 120 kg N/ha CPOF III (T6) had the highest fruit K but was close to 60 kg N/ha CPOF III (T3), 60 kg N/ha Urea+35 kgP_2O_5/ha SSP+30 kgK_2O/ha MOP (T7), 120 kg N/ha CPOF I (T4) and 120 kg N/ha CPOF II (T5) while control (T9) was the least. The residual effect of treatment 120 kg N/ha CPOF II (T5) had the highest vitamin C while all other treated plants were similar but T9 had the lowest. Likewise, vitamin A content of the plants treated with 120 kg N/ha CPOF I (T1) fertiliser were greater compared to untreated plant that had the least vitamin A. Application of 60 kg N/ha CPOF III (T3), 120 kg N/ha CPOF I (T4) and 120 kg N/ha CPOF II (T5) was equivalent but significantly higher than the lowest control (T9) and 60 kg N/ha urea (T8). The interactive effect of variety and fertilisers on fruit lycopene content during residual trial was significant (Table 4.33).

Table 4.31: Residual effect of fertilisers on fruit parameters of three tomato varieties

Treatments	Number of marketable fruit /plant	Fruit weight/plant (g)	Fruit dry matter (g kg^{-1})	Fruit yield (t ha^{-1})
T V				
Ibadan local	7.35b	426.51a	77.25a	10.67a
UC82B	7.98a	425.34a	77.89a	10.52a
Roma VF	7.44ab	432.61a	76.90a	9.82b
Fertiliser(F)				
T1	8.52a	452.10a	76.95a	10.20b
T2	8.43a	442.51a	76.78a	11.22a
T3	8.50a	454.71a	75.80a	11.10a
T4	8.45a	445.91a	77.82a	11.67a
T5	8.46a	458.35a	76.72a	11.50a
T6	8.44a	446.56a	77.64a	11.60a
T7	8.42a	454.54a	77.51a	10.70b
T8	8.30a	355.41b	75.33a	10.41b
T9	8.20a	364.02b	75.22a	9.22c
Interaction:				
TV x F	ns	ns	ns	*

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5=120 kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.32: Residual effect of fertilisers on fruit phytochemicals composition (g kg^{-1}) of three tomato varieties

Treatment	Crude protein	Crude fibre	Ether extract	Carbohydrate
TV				
Ibadan local	0.72a	1.41a	1.78c	3.24b
UC82B	0.72a	1.38a	2.65a	3.85a
Roma VF	0.68b	1.27b	2.12b	3.32b
Fertiliser(F)				
T1	0.74b	1.32a	2.14bc	3.87a
T2	0.81a	1.34a	2.21bc	3.72a
T3	0.76b	1.37a	2.47b	3.79a
T4	0.75ab	1.38a	2.68a	3.75a
T5	0.79ab	1.42a	2.16b	3.92a
T6	0.72b	1.33a	2.48b	3.79a
T7	0.78ab	1.41a	2.44b	3.94a
T8	0.68c	1.25a	1.17c	3.83a
T9	0.17b	1.23a	2.10bc	3.60a
Interaction:				
TV x F	ns	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

Table 4.33: Residual effect of tomato varieties and fertilisers on some phytochemicals composition in the fruit

Treatments	K	Vitamin C	Vitamin A	Lycopene
	←	mg $100g^{-1}$	→	
TV				
Ibadan local	0.21b	16.50b	370.45b	0.31b
UC82B	0.26a	21.45a	430.35a	0.36a
Roma VF	0.26a	23.32a	385.56b	0.33ab
Fertiliser(F)				
T1	0.25ab	20.11ab	379.56abc	0.27c
T2	0.25ab	20.21ab	398.43abc	0.30bc
T3	0.29a	21.18a	397.80abc	0.34a
T4	0.30a	21.67a	405.65a	0.35a
T5	0.27a	21.89a	393.13ab	0.35a
T6	0.31a	20.69ab	380.43bc	0.32ab
T7	0.29a	21.49a	386.36bc	0.33ab
T8	0.19c	17.56bc	377.10dc	0.21d
T9	0.18c	16.34c	368.10d	0.20d
Interaction:				
TV x F	ns	ns	ns	ns

Means along a column with the same letter(s) do not differ significantly from each other using the Duncan Multiple Range Test ($\alpha_{0.05}$). T1= 60kg N/ha CPOF I; T2= 60kg N/ha CPOF II; T3= 60kg N/ha CPOF III; T4=120kg N/ha CPOF I; T5= 120kg N/ha CPOF II; T6=120kg N/ha CPOF III; T7= 60kg N/ha Urea+35kgP_2O_5/ha SSP+30kgK_2O/ha MOP; T8=60kg N/ha Urea; T9= non fertilized (control);TV = Tomato Variety and F = Fertiliser.

4.4 Experiment 2: Effect of planting seasons and fertiliser form of applications on the growth, fruit yield, and phytochemicals compositions of UC82B variety at six different ripening stages

4.4.1 Influence of planting seasons and forms of fertiliser applications on the growth and development of UC82B variety during early and late planting seasons

Early planting season tomato were significantly higher (83.9 cm) than late planting season (76.00 cm). Similarly, leaf production in the early grown plants was better than late planting. The number of leaves /plant in the early planting season (79.4 /plant) was higher than what was obtained from late planting (73.7 /plant) season. The leaf area /plant at early planting season 480.10 cm^2 significantly higher compared to late planting season 461.80 cm^2 (Table 4.34).

Fertiliser forms influenced tomato stem height, leaf area /plant and dry matter yield (Table 4.34). Plant height ranged from 72.3 cm in the plants that received residue form to 88.8 cm in the plants that received pelletized form. The plants that received shredded and liquid form of fertilisers had similar value and significantly taller than the other two fertiliser forms. Application of residue form had the maximum leaf area /plant, whereas shredded and pelletized forms were similar and statistically better than liquid form. In the case of plant dry matter yield, the values ranged from 85.6 g/plant in the liquid form treatment to 88.8 g/plant in plants that received pelletized form. It was noted that plants that received organic fertiliser in the form of pelletized, shredded and residue form performed similarly and better than the liquid form of organic fertiliser. The interactive effect of fertiliser forms and season influenced tomato plant height at 8 WAT.

4.4.2. Influence of planting season and fertiliser forms on fruit dry matter and fruit yields of UC82B variety

The effects of planting seasons and fertiliser forms on tomato fruit dry matter and total fruit yield is shown in Table 4.35. The mean fruit dry matter and total fruit yield in early grown tomato plants were higher than that of late season plants. The dry matter/fruit of the early planting season was 6.03 g/fruit while the late planting season recorded 5.53 g/plants. The total fruit yield at early planting season gave 15.98 t/ha but higher than late season (14.85 t/ha) planting.

Table 4.34: Influence of planting seasons and fertiliser forms on growth and development of UC82B variety at 8 WAT in early and late planting seasons of 2013

Treatment	Plant height (cm)	Stem girth (cm)	Number of branches	Number of leaves	Leaf area (cm^2)	Plant dry matter yield (g)
Season (S)						
Early	83.90a	3.10a	9.70a	79.40a	480.10a	87.40a
Late	76.00b	3.30a	10.70a	73.70b	461.80b	87.30a
Fertiliser form (FF)						
Residue	72.30c	3.10a	10.80a	77.70a	443.20a	87.30a
Shredded	80.30b	3.40a	9.20a	75.20a	423.70b	87.60a
Pelletized	88.80a	3.30a	11.10a	77.70a	429.20b	88.80a
Liquid	78.30b	3.00a	9.80a	75.70a	415.70c	85.60b
Interaction:						
S x FF	**	ns	ns	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at ($\alpha_{0.05}$) probability level, ns = not significant (($p \leq 0.05$); * and ** significant at 5% and 1% probability level respectively. S = Season and FF = Fertiliser form

The fertiliser forms significantly influenced only total fruit yield. The order of increment in total fruit yield are pelletized > residue > liquid > shredded organic fertiliser forms. Again, application of pelletized compost gave the highest total fruit yield (15.38 t ha^{-1}) while application of shredded form produced the minimum (14.56 t ha^{-1}) fruit yield. Interactions of planting seasons and fertiliser forms on fruit dry matter and total fruit yield was not significant (Table 4.35).

4.4.3 Effects of planting seasons, fertiliser forms and ripening stages on tomato fruit phytochemicals composition

Tomato fruit proximate compositions in response to planting season, fertiliser forms and ripening stages were shown in Table 4.36. Seasonal variations appeared on all the proximate parameters assessed except pH, crude protein and ether extract. The fruit crude fibre, total soluble solids and sugar contents were higher in late season plants than in the early season planting. However, for fruit acidic content, the reverse was the case. For this parameter, the values obtained for early planting (0.66 g $100g^{-1}$) was significantly higher than what was recorded for the (0.55 g $100g^{-1}$) late planting season. The fruit hydrogen ion concentration (pH), crude protein and ether extract were also seasonal dependent.

Fertiliser forms significantly affected tomato fruit crude protein, ether extract, total soluble solid, sugar and acid contents while pH and crude protein were not significantly different among the seasons. Tomato crude protein was highest (0.72 g kg^{-1}) in plant treated with residue form and lowest in pelletized form of treatment. The crude protein values obtained from residue (0.72 g kg^{-1}), liquid (0.71 g kg^{-1}) and shredded (0.70 g kg^{-1}) were similar and higher than 0.68 g kg^{-1} pelletized treatment. Ether extracts ranged from 4.92 g kg^{-1} in plants that were treated with residue form to 5.61 g kg^{-1} in plants that received pelletized form. For the total soluble solid, liquid form enhanced its production better than other forms of organic fertiliser. The highest total soluble solid (4.98 g kg^{-1}) was recorded in liquid form while the least (4.65 g kg^{-1}) was obtained in a pelletized form of organic fertiliser. The highest total soluble solid (4.98 g kg^{-1}) was recorded in liquid form while the lowest (4.65 g kg^{-1}) was observed in pelletized form of organic fertiliser. Tomato fruit sugar and acidic contents were significantly affected by fertiliser forms.

Table 4.35: Influence of planting season and fertiliser forms on fruit dry matter and total fruit yield of UC82B at early and late planting season of year 2013

Treatments	Fruit dry matter (g/fruit)	Fruit yield (t ha^{-1})
Season (S)		
Early	6.03a	15.98a
Late	5.53b	14.85b
Fertiliser form (FF)		
Residue	5.89a	15.00a
Shredded	5.69a	14.56b
Pelletized	5.78a	15.38a
Liquid	5.74a	14.73b
Interaction:		
S x FF	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at ($p \leq 0.05$) probability level, ns =not significant (($p \leq 0.05$); * and ** significant at 5% and 1% probability level respectively. S = Season and FF = Fertiliser form

The highest fruit sugar content was obtained in liquid treatment, while the lowest was recorded from the residue form. For fruit acidic content, the order of increase was pelletized > residue >liquid > shredded (Table 4.36).

Tomato fruit ripening stages had effects ($P \leq 0.05$) on the tomato fruit phytochemicals composition. The fruit pH increased with ripening of tomato fruit. Matured green fruits recorded the lowest pH (3.95) content while deep red fruit had the highest pH (4.65) content. The highest crude protein was obtained with deep red fruits while the lowest was observed in mature green fruits. Mature green produced the best crude fibre (1.18 g kg^{-1}) while deep red fruits had the least (1.08 g kg^{-1}). The ether extract was highest (7.57 g kg^{-1}) in deep red fruit and lowest in mature green fruit. In the case of fruit total soluble solid, fruit ripening had a significant effect with mature green fruit having the highest value while the deep red fruits had the lowest. The fruit sugar content had no defined pattern of variation with fruit ripening stages. It was noted that deep red fruits had the highest amount of sugar (52.2 g kg^{-1}), followed by light red fruit (49.57 g kg^{-1}) and least (38.21 g kg^{-1}) was obtained with mature green fruits. The fruit acid content in mature green fruit gave the highest (0.63 g kg^{-1}) while the lowest (0.39 g kg^{-1}) was obtained from deep red fruits Table 4.36.

The interactive effects of planting season and fertiliser forms was significant on crude fibre, ether extract and fruit acidic contents while that of fertiliser form and ripening stages were significant only on ether extract. Effects of fertiliser forms and fruit ripening stages on tomato fruit acid content was significant (Table 4.36). It should be noted that irrespective of fertiliser form, deep red tomato fruits consistently have the least acid content. Interactive effects of planting seasons, fertiliser forms and fruit ripening stages were significant on tomato fruit acid content, late season x pelletized form treatment combination had the highest while late season x shredded form was the lowest. Highest fruit acid content (0.67 g kg^{-1}) was obtained from matured green fruits treated with shredded form in the late planting season while the lowest (0.38 g kg^{-1}) was from deep red fruit in early planting season (Table 4.37).

Table 4.36: Tomato fruit phytochemicals composition (g kg^{-1}) in response to fertiliser forms and ripening stages of UC82B variety in the early and late planting seasons of year 2013

Treatment	pH	Crude protein	Crude fibre	Ether extract	Total soluble solid	Sugar content	Acid content
Season (S)							
Early	4.30a	0.72a	1.28b	5.43a	4.69b	43.43b	0.66a
Late	3.40a	0.69a	1.44a	5.25a	4.89a	49.35a	0.55b
Fertiliser form (FF)							
Residue	4.28a	0.72a	1.41a	4.92b	4.69ab	42.83b	0.54b
Shredded	4.34a	0.70ab	1.36a	5.23b	4.84a	48.18a	0.50b
Pelletized	4.23a	0.68b	1.30a	5.61a	4.65b	46.22a	0.85a
Liquid	4.35a	0.71ab	1.36a	5.59a	4.98a	48.33a	0.53b
Ripening Stages (RS)							
Matured green	3.95c	0.57f	1.81a	3.60f	5.74a	38.21d	0.63a
Breaker	4.28b	0.62e	1.51b	4.14e	5.23b	43.69c	0.58b
Turning	4.35ab	0.69d	1.32bc	4.72d	5.03b	47.0c	0.56bc
Pink	4.38ab	0.75c	1.26cd	5.47c	4.69e	48.0b	0.52cd
Light red	4.50ab	0.78b	1.21cd	6.53b	4.28d	49.57ab	0.46d
Deep red	4.65a	0.83a	1.08d	7.57a	3.78e	52.21a	0.39e
Interactive effect:							
S x FF	ns	ns	**	**	ns	ns	**
S x RS	ns	ns	ns	ns	ns	ns	**
FF x RS	*	ns	ns	*	ns	ns	**
S x FF x RS	ns	ns	ns	ns	ns	ns	**

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at ($\alpha_{0.05}$) probability level, ns = not significant (($p \leq 0.05$); * and ** significant at 5% and 1% probability level respectively. S = Season and FF = Fertiliser form

4.4.4 Influence of planting seasons, fertiliser forms and ripening stages of UC82B variety on tomato fruit phytochemicals compositions

The response of tomato fruit phytochemicals to fertiliser forms and ripening stages in early and late planting season is shown in Table 4.38. Amended plants had influence on fruit lycopene, vitamins A, C and E, phenols, carotene and total flavonoid. Planting seasons had significant effects on all the phytochemicals assessed except vitamin A content. The lycopene content of late planting season tomato fruit (10.11 mg kg^{-1}) was higher than early season planting (7.77 mg kg^{-1}). Seasons had no effect on fruit Vitamin A content, except Vitamins C and E, phenols, carotene and total flavonoid. The late planting tomato contained higher contents of vitamins C (28.83 mg kg^{-1}) and E (2.65 mg kg^{-1}) when compared to the values obtained during the early season (22.52 mg kg^{-1}) and (2.22 mg kg^{-1}) respectively. The response of fruit total phenol was opposite to Vitamins C and E. In this trial, early grown fruit contained higher phenols. For carotene and total flavonoid, late planting season contained higher values than early planting seasons.

Fertiliser forms affected tomato fruit lycopene, vitamins C and E and phenols contents. Application of pelletized form produced highest amount of lycopene followed by the shredded form while the liquid form gave the least. The pelletized form also had the highest fruit vitamin A (17.74 mg kg^{-1}) while the least (14.31 mg kg^{-1}) was obtained with residue form of fertiliser. In case of vitamin C and E, application of liquid form gave the highest value while, for both parameters, the use of residue form had the lowest. Fruit total phenols were significantly affected by fertiliser forms. Values obtained with residue, shredded and liquid forms of organic fertiliser significantly greater than pelletized form (Table 4.38).

Fruit ripening stages had influence on all phytochemicals assessed. The highest lycopene was obtained in deep red tomato fruits while least was in matured green fruit. For vitamin A, breaker fruits had the highest value (21.18 mg kg^{-1}), followed by matured green (1.18 mg kg^{-1}) while the lowest (12.55 mg kg^{-1}) was recorded in deep red fruits. Fruit total phenols ranged from 107.33 mg kg^{-1} in matured green fruits to 69.78 mg kg^{-1} in deep red fruits. Likewise, vitamin A, and fruit phenol decreases with ripening of tomato fruit reaching the peak with deep red fruit.

Table 4.37: Interactive effects of season, fertiliser form and ripening stages on acidic content of tomato fruit in year 2013

Ripening stage		Fertiliser form			
		Residue	**Shredded**	**Pelletized**	**Liquid**
Matured green		0.62a	0.52a	0.64a	0.65a
Breaker		0.57b	0.47b	0.57ab	0.59ab
Turning		0.60ab	0.41bc	0.58ab	0.50b
Pink	Early season	0.50b	0.45b	0.50b	0.52b
Light red		0.42c	0.52a	0.45c	0.46c
Deep red		0.39d	0.38c	0.42c	0.41d
Matured green		0.66a	0.67a	0.65a	0.65a
Breaker		0.62b	0.62a	0.63ab	0.60ab
Turning	Late season	0.66a	0.53b	0.60ab	0.57b
Pink		0.62b	0.52b	0.52b	0.49bc
Light red		0.47c	0.51b	0.43c	0.42c
Deep red		0.40c	0.44c	0.40c	0.42c
Interaction:					
S x FF x RS		ns	**	*	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at ($\alpha_{0.05}$) probability level, ns = not significant (($p \leq 0.05$); * and ** significant at 5% and 1% probability level respectively. S = Season and FF = Fertiliser form

The fruit carotene and total flavonoid were significantly influenced by tomato fruit ripening stages. Fruit carotene improved from 0.46 mg kg^{-1} in mature green fruit to 0.73 mg kg^{-1} in deep red fruits. It should be noted that turning and pink stage fruits contained similar fruit carotene content. Again, the order of increase in tomato fruit total flavonoid was deep red > light red > pink > turning > breaker > matured green. The fruit total flavonoid increased with fruit age of ripening reaching the peak at deep red fruit (Table 4.38). Fruit vitamin E, total flavonoid and acid contents were influenced by the interactive effect of planting season and fertiliser forms. The interactions produced highest fruit vitamin E in late planting using the shredded form (best total flavonoid with shredded form and late planting season) while residue in the late planting season gave the highest acid content (Table 4.38).

The interactive effect of planting seasons and fruit ripening stages was significant on fruit lycopene, vitamin C and acid content. The fruit lycopene was highest (12.85 mg kg^{-1}) with the combination of late season plant with deep red fruits and lowest (6.23 mg kg^{-1}) in mature green fruits. Irrespective of the season, fruit lycopene increased across tomato fruit ripening stage. Similarly, fruit vitamin C content was significantly affected by season x ripening stages. Late season fruits harvested at matured green stage contained the highest vitamin C content (34.93 mg kg^{-1}) while the least was obtained in deep red fruits harvested during the early season. Matured green fruits of late season tomato contained the highest acid contents while the lowest was obtained in deep red fruit of late season plants (Table 4.39).

Table 4.38: Tomato phytochemicals content in response to fertiliser form and ripening stages in the early and late season of 2013

Treatment	Lycopene	Vitamin			Phenols	Carotene	Total flavonoid
		A	C	E			
	g $100g^{-1}$	←		mg kg^{-1}			→
Season (S)							
Early	7.77b	15.40a	22.52b	2.22b	94.15a	0.56b	7.82b
Late	10.11a	15.64a	28.83a	2.65a	84.59b	0.68a	8.34a
Fertiliser form(FF)							
Residue	8.76ab	14.31b	24.21c	2.05c	91.77a	0.62a	7.85a
Shredded	8.88a	14.38ab	25.43bc	2.44b	92.21a	0.61a	8.32a
Pelletized	9.36a	17.74a	25.74b	2.51ab	84.96b	0.62a	8.03a
Liquid	8.74b	15.71a	27.33a	2.74a	88.54ab	0.63a	8.12a
Ripening Stages							
Matured green	6.85d	17.9ab	17.27e	1.22e	107.33a	0.46e	6.57e
Breaker	7.00d	21.18a	22.74d	1.81d	99.35ab	0.57e	6.95de
Turning	7.42d	15.06bc	25.58c	2.39c	93.95b	0.62cd	7.64cd
Pink	8.71c	13.48bc	27.75b	2.72b	84.81c	0.66bc	7.78c
Light red	11.11b	12.93c	28.95b	2.91b	80.99c	0.69ab	9.19b
Deep red	15.51a	12.55c	31.76a	3.55a	69.78d	0.73a	10.34a
Interactive effect:							
S x FF	**	ns	*	**	ns	ns	**
S x RS	**	ns	*	ns	ns	ns	ns
FF x RS	**	ns	ns	ns	ns	ns	ns
S x FF x RS	ns	ns	ns	ns	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at ($p \leq 0.05$) probability level, ns = not significant (($p \leq 0.05$); * and ** significant at 5% and 1% probability level respectively. S = Season and FF = Fertiliser form

Table 4.39: Effects of season and ripening stages on some tomato fruit phytochemicals in year 2013

Ripening stage	Lycopene		Vitamin C		Acidic content	
	Early	Late	Early	Late	Early	Late
Matured green	6.23d	8.88c	28.59a	34.93a	0.66a	0.61a
Breaker	6.18e	7.84d	19.37c	26.12b	0.55b	0.62a
Turning	6.54d	8.30c	21.48c	29.68b	0.52b	0.59ab
Pink	7.08c	10.34b	24.44ab	31.06ab	0.49c	0.54b
Light red	9.38b	12.43ab	25.26ab	32.65ab	0.46c	0.45c
Deep red	11.15a	12.85a	15.99d	18.53d	0.42d	0.35d
Interaction:						
S x RS	*		*		**	

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at ($p \leq 0.05$) probability level, ns = not significant ($(p \leq 0.05)$; * and ** significant at 5% and 1% probability level respectively. S = Season and FF = Fertiliser form

4.5. Experiment 3: Response of three tomato varieties to different light intensities at different phenological stages, growth, dry matter partitioning, fruit yield and phytochemicals composition.

4.5.1 Influence of different light intensities at different phenological stages on the growth parameters of three tomato varieties grown in pots

The results showed considerable differences at ($p<0.05$) on growth parameters measured at different levels of light intensities. The plants that received L2 (673.70 Lux) had the tallest plant height (66.26 cm), which was insignificantly different to those plants grown at L3 (450.44 Lux) light intensity while unregulated plants had the shortest height (58.99 cm). Different light intensities showed insignificant differences in plant girth of three tomato varieties. Tomato plants that received L1 (673.70 Lux) gave the highest number of leaves (52.83/plant), while L1 (897.89 Lux) (44.94 plant) had the lowest. The effect on the region of the leaves at different light intensities was significantly higher in L3 (450.44 Lux) (346.69 cm^2), whereas L2 (673.70 Lux) had the lowest leaf area (281.38 cm^2) (Table 4.40).

The phenological stages significantly influenced selected vegetative parameters assessed. However, at fruit physiological maturity, plant height (74.56 cm) gave the highest, while active vegetative (43.16 cm) had the lowest. At this stage, stem girth at fruit physiological maturity and 50% fruiting were similar (1.05 and 0.04 cm) and significantly higher than active vegetative and onset of flowering stage (0.97 and 0.87 cm). The leaves produced were more during the onset of flowering (63.37/plant) while the leaf formation was lower at active vegetative (22.96/plant). However, leaf area at 50% fruiting had the highest, while active vegetative stage was the lowest.

The response of three tomato varieties was statistically ($p\leq0.05$) similar across selected parameters for the exception of stem girth that was insignificant at ($p\leq0.05$). The Ibadan local significantly had the tallest plant height (60.32 cm), whereby UC82B had the shortest plant height (60.17 cm).The Ibadan local produced the highest number of leaves (56.61) than Roma VF (48.64) and UC82B (44.56) varieties. Variety UC82B had abroad leaf area surface than Roma VF and Ibadan local varieties, although, statistically similar (331.50 cm and 317.75 cm) but significantly higher and wider than Ibadan local.

Table 4. 40: Response of tomato varieties to different light intensities at phenological stages on growth of selected vegetative parameters

Treatment	Plant height (cm)	Stem girth (cm)	No of leaves/plant	Leaf area/plant (cm)
Light Intensity(LI)				
L1	58.99b	0.95a	44.94b	299.64b
L2	66.26a	0.98a	52.83a	281.38b
L3	65.37a	0.98a	52.03a	346.69a
Phenological stages				
Active vegetative	43.16c	0.87c	22.96c	235.24b
Onset of flowering	65.59b	0.97b	63.37a	329.40a
50% fruiting	70.88ab	1.04a	54.48b	345.46a
Fruit physiological maturity	74.56a	1.05a	55.93b	326.85a
Tomato variety				
Ibadan local	67.32a	0.94a	56.61a	278.46b
UC82B	60.19b	0.98a	44.56b	331.50a
Roma VF	63.10ab	0.99a	48.64b	317.75a
Interaction:				
LI x G	ns	ns	ns	ns
TV x G	ns	ns	ns	ns
TV x LI	ns	ns	ns	*
TV x LI x GS	ns	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant, L1= 897.89 Lux(uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

The interaction between light intensities and the three tomato varieties showed some level of significance. The interaction between light intensity and phenological stages, varieties and phenological stages, varieties and light intensities and varieties, light intensities and phenological stages insignificantly influenced stem height, stem diameter and the number of leaves except variety and light intensity interaction on leaf area/plant. The highest leaf area was obtained in UC82B that received L3 (450.44 Lux), whereas Ibadan local that was grown under L2 (673.70 Lux) had the lowest leaf area (Fig 4.1).

4.5.2 Effect of different light intensities at different phenological stages on chlorophyll content in the leaves of tomato varieties.

The reaction of the three tomato varieties to different light intensities and phenological stages on chlorophyll content is presented under Fig. 4.2 and Fig. 4.3. It was revealed that phenological stages influenced chlorophyll content. However, active vegetative (42.72 %) showed highest chlorophyll content which was not significantly different from chlorophyll at the onset of flowering (42.49 %) but active physiological maturity stage was the lowest (33.59 %).

There were also differences in the chlorophyll content among the tomato varieties tested. Maximum chlorophyll content was obtained in UC82B (39.64 %) while Ibadan local had the minimum. The order of increase was UC82B > Roma VF > Ibadan local varieties. Comparison of the three factors showed significant differences in chlorophyll contents. The uppermost chlorophyll was obtained in UC82B grown under L1 (897.89 Lux) that received a reduction in light intensity at active vegetative while Ibadan local grown without reduction in light intensity L1 (897.89 Lux) at 50% fruiting had the lowest chlorophyll content Table 4.41.

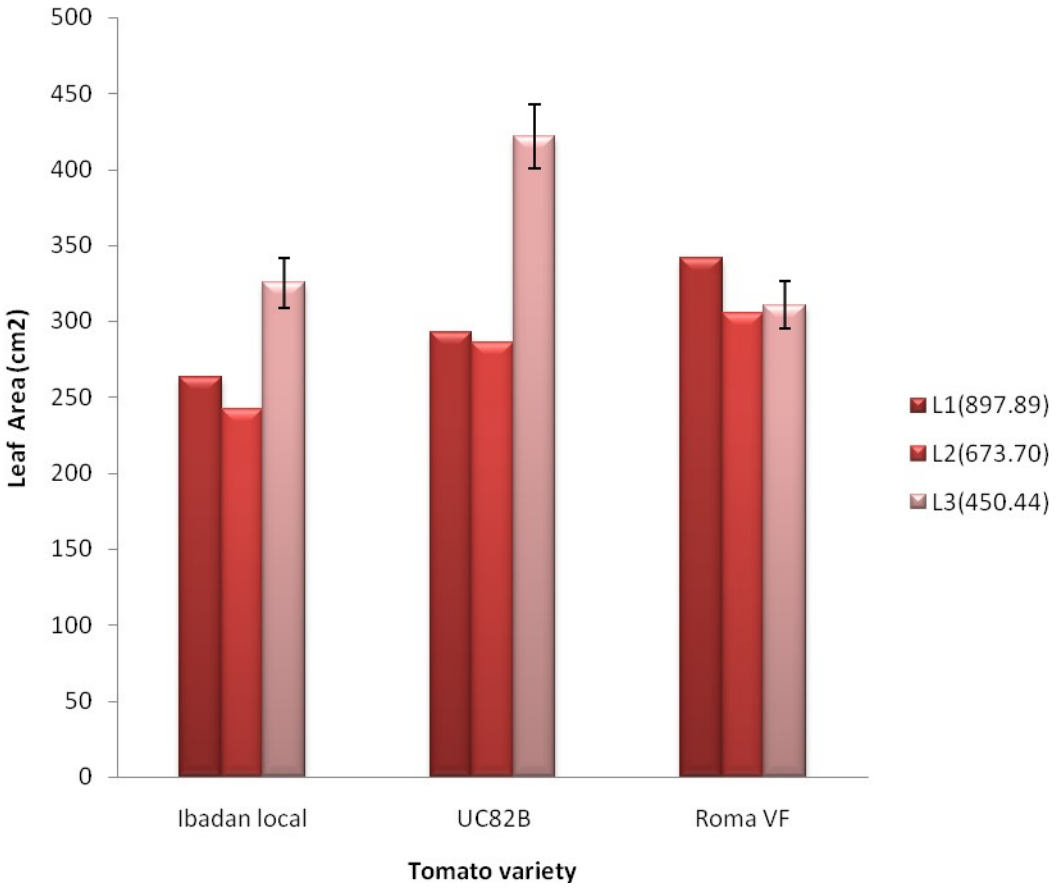


Fig.4.1: Effect of different light intensities on the leaf area of three tomato varieties grown in pot

L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net)

| = SE bar 5%

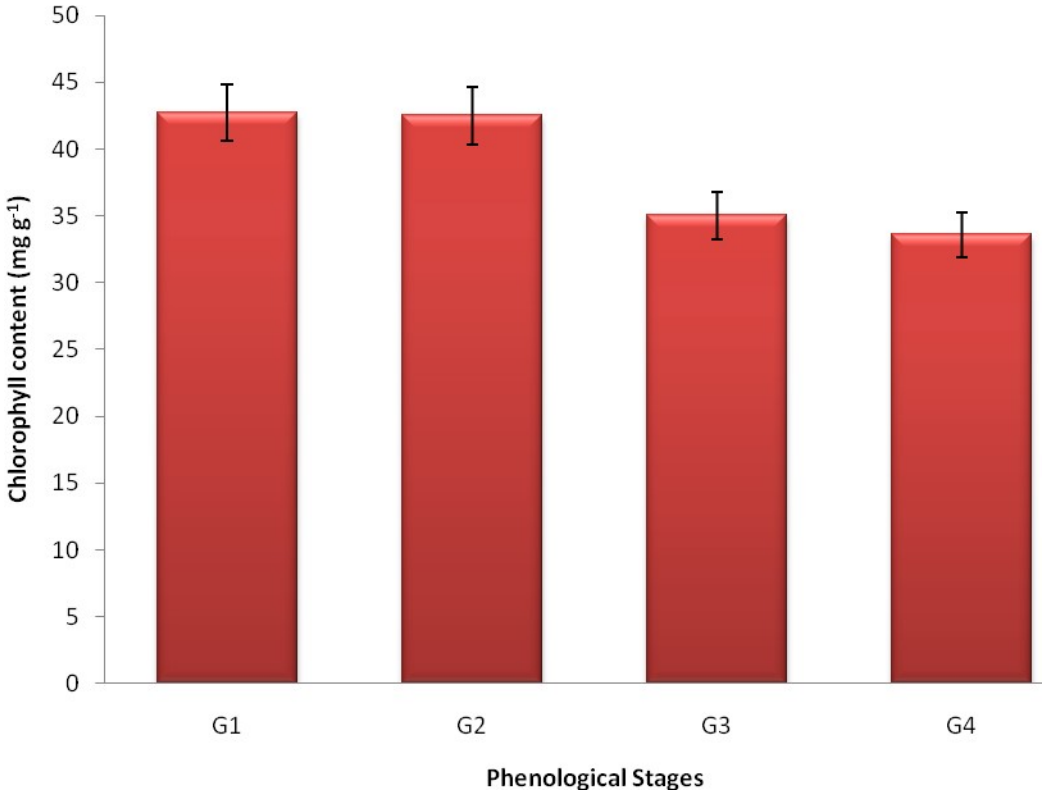


Fig.4.2. Influence of leaf chlorophyll content on different phenological stages of tomato plants grown in the pot

G = Phenological stage of light reduction; G1 = Active vegetative; G2 = Onset of flowering; G3 = 50% fruiting and G4 = Fruit Physiological maturity.

| = SE bar 5%

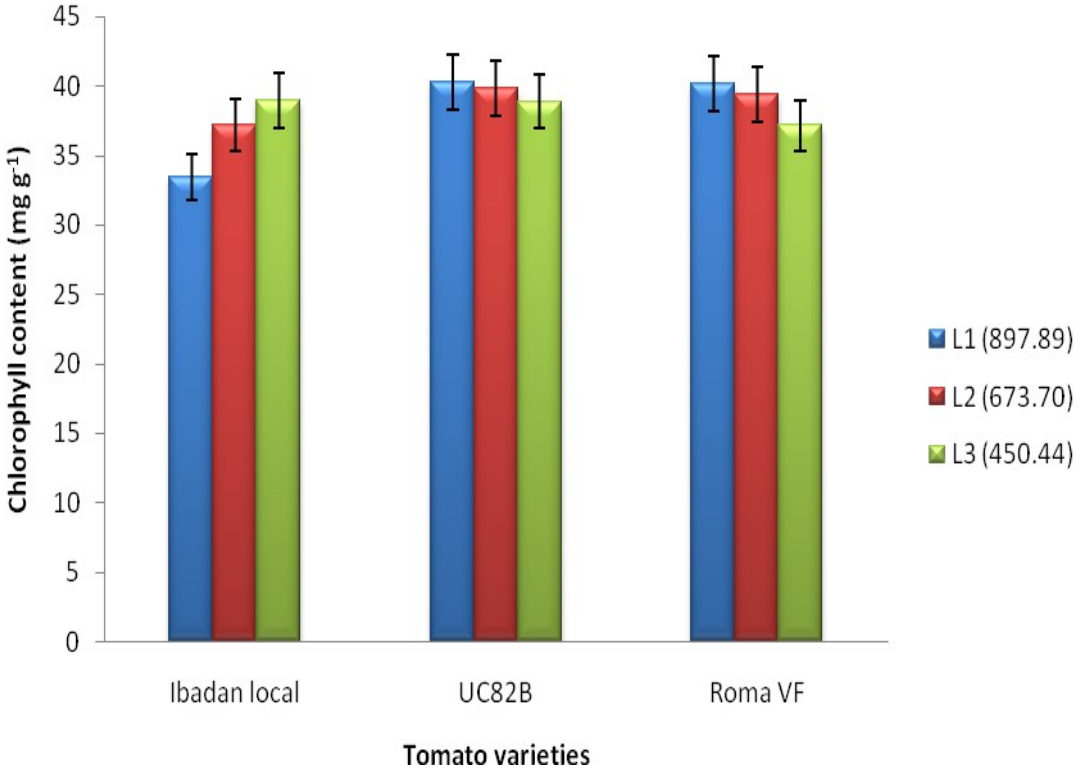


Fig.4.3. Effects of light intensities on chlorophyll contents of three tomato varieties grown in pot

L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net)

| = SE bar 5%

Table 4.41: Comparison of interactions between light intensities, phenological stages and three tomato varieties on chlorophyll content (mg g^{-1}).

T V	Phenological Stages	Light Intensity		
		L1	L2	L3
Ibadan local		37.83c	38.90bc	38.53c
UC82B	Active Vegetative	51.63a	44.77a	41.37b
Roma VF		47.17b	42.33b	41.97b
Ibadan local		42.20b	41.22b	39.25c
UC82B	Onset of flowering	44.77b	39.83bc	47.07a
Roma VF		44.83b	42.97b	40.32b
Ibadan local		26.17d	35.43c	37.93c
UC82B	50% fruiting	35.50c	38.63c	33.33c
Roma VF		35.53c	36.17c	36.70c
Ibadan local		27.57d	33.17c	40.03b
UC82B	Fruit physiological maturity	29.20d	35.93c	33.73c
Roma VF		36.93c	36.10c	29.60d

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net)

4.5.3 Influence of different light intensities at phenological stages on dry matter accumulation and partitioning of three tomato varieties

The response of three tomato varieties to different intensities of light at phenological stages is shown under Table 4.42. The dry weights of the various plant parts, shoot, root and total dry matter were initially lower in uncovered plants L1 (897.89 Lux) than covered plants L2 (673.70 Lux) and L3 (450.44 Lux) light intensities. The highest total dry weight was obtained from the plants that received L3 (450.44 Lux) (21.29 g), while the lowest (10.49 g) was from uncovered plants L1 (897.89 Lux).

The phenological stages had effects on dry matter yield. The shoot and root dry matter yield at the onset of flowering were significantly higher than other phenological stages (19.19 and 2.80 g) while 50% fruiting had the lower dry weight (9.69 and 1.15 g). The total dry weight at the onset of flowering and fruit physiological maturity were similar (21.99 and 20.00 g), but significantly higher than 50% fruiting and active vegetative 9.69 and 1.25 g.

There are varietal differences on the dry matter weight at various plant parts. Among the three tomato varieties, Ibadan local displayed significantly superior performance over the other two varieties, meanwhile Roma VF was less to superior. The highest dry weight was obtained in UC82B, while Ibadan local had the lowest. The total dry weight of Ibadan local, UC82B and Roma VF were 18.81, 15.43 and 14.20 g, respectively.

The interactive effect of various light intensities on dry matter partitioning of three tomato varieties had an influence on the shoot, root and total dry weight. Variety UC82B grown without covering L1 (897.89 Lux) had the lowest (7.82 g) shoot dry weight, whereas Ibadan local that was grown under L1 (673.70 Lux) gave the highest dry weight. The UC82B variety that received L3 (450.44 Lux) had the highest dry weight (3.41 g), while Roma VF grown under L1 (897.89 Lux) light had the lowest (1.24 g). Furthermore, the total dry weight of Ibadan local grown under L3 (450.44 Lux) significantly higher than others (25.16 g), while UC82B that uncovered L1 (897.89 Lux) had the lowest (8.80 g) value Table 4.42.

Table 4.42: Effect of different light intensities at phenological stages on dry matter yield of three tomato varieties grown in the pot

	Dry matter (g)		
Treatment	Shoot	Root	Total
Light intensity (L1)			
L1	9.28c	1.21c	10.49c
L2	14.89b	1.85b	16.68b
L3	18.63a	2.66a	21.29a
Phenological stages			
Active vegetative	10.55c	1.25c	11.78b
Onset of flowering	19.19a	2.80a	21.99a
50% fruiting	9.69cd	1.15c	10.76b
Fruit physiological maturity	17.58b	2.42b	20.00a
Tomato Varieties			
Ibadan local	17.09a	1.72c	18.81a
UC82B	13.33b	2.10a	15.43b
Roma VF	12.31c	1.89b	14.20c
Interaction:			
LI x G	**	**	ns
TV x G	**	**	ns
TV x LI	**	**	*
TV x LI x G	**	**	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

Table 4.43: Effects of different light intensities on dry matter partitioning of three tomato varieties

Tomato variety	Light intensity (LI)	Dry weight (g/plant)		
		Shoot	**Root**	**Total**
Ibadan local	L1	12.14c	1.40c	13.53d
	L2	15.82b	1.93b	17.75c
	L3	23.33a	1.83b	25.16a
UC82B	L1	7.82e	0.98d	8.80e
	L2	15.05b	1.98b	17.03c
	L3	20.13ab	3.41a	23.54b
Roma VF	L1	10.87d	1.24c	12.11d
	L2	13.62cb	1.70b	15.32c
	L3	12.45c	2.74a	15.19c

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

4.5.4 Response of three tomato varieties to different light intensities at phenological stages on components of yield, fruit and fruit yield parameters

The response of the three tomato varieties to different light intensities significantly affected components of yield (Table 4.44). The plants that received L1 (897.89 Lux) and L2 (673.70 Lux) (21.51 and 21.38/plant) significantly had higher number of flowers than the plants that received L1 (450.44 Lux) 11.50 %. The number of fruit/plant at L2 (673.70 Lux) 11.19/plant, significantly higher compared to L1 (897.89 Lux) 8.33/plant. The percentage fruit set of those plants grown under L1 (897.89 Lux) gave the highest (60.17 %) value while L2 (673.70 Lux) 54.16 % had the lowest fruit set.

The phenological stages had significant effects on yield components. The highest number of flowers and fruits/plant (23.0 and 13.48/plant) was obtained at the onset of flowering whereby, reduction at 50% fruiting produced the lowest number of fruits and flowers/plant (18.41 and 10.30/plant). Percentage fruit set across all the phenological stages was significantly not different, that is, had similar values. Although, the highest percentage fruit set (58.23 %) was obtained at the fruit physiological maturity while 50% fruiting (55.22 %) had the lowest.

The Ibadan local significantly and consistently exhibited the highest number of flowers/plant, number of fruits and % fruit set (25.19/plant, 15.92/plant, 64.31 %) respectively, than UC82B and Roma VF, but Roma VF had the lowest values for the number of flowers and fruits (16.25/plant, 9.22/plant) meanwhile UC82B had the lowest percentage fruit set (49.69 %), (Table 4.44). The interactions between tomato varieties and light intensities were lowest in Roma VF grown under L3 (450.44 Lux) (15.00/plant), but the highest in Ibadan local grown under L2 (673.70 Lux) (28.25/plant.). Also, Ibadan local grown under L2 (673.70 Lux) significantly had higher number of flowers (16.50/plant), while UC82B grown under L3 (450.44 Lux) had lower value (7.92/plant). Lastly, the Ibadan local that received under L3 (450.44 Lux) had the highest percentage fruit set (62.08 %), while Ibadan local grown in the open place L1 (897.89 Lux) had the lowest value (42.47 %) Table 4.45.

Table 4.44: Influence of different light intensities at phenological stages on yield components of three tomato varieties

Treatments	Number of Flowers / Plant	Number of fruits / Plant	% Fruit set
Light Intensity (LI)			
LI	21.51a	8.33c	60.17a
L2	21.38a	11.19a	54.14b
L3	17.50b	10.42b	56.17b
Phenological stages			
Active vegetative	20.48b	11.37b	55.81a
Onset of flowering	23.00a	13.48a	58.00a
50%f Fruiting	18.41c	10.30c	55.22a
Fruit physiological Mat.	18.63c	10.96bc	58.23a
Tomato Variety			
Ibadan local	25.19a	15.92a	64.31a
UC82B	18.94b	9.44b	49.69c
Roma VF	16.25c	9.22c	56.47b
Interaction:			
LI x G	ns	ns	ns
TV x G	*	*	*
TV x LI	**	**	*
TV x LI x G	ns	*	**

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

Table 4.45: Effects of different light intensities on components of yield of three tomato varieties

Tomato variety	Light intensity (LI)	No. of flowers /plant	No. of fruits / plant	Fruit set (%)
	L1	25.50b	10.83bc	42.47d
Ibadan local	L2	28.25a	16.50a	59.17ab
	L3	21.83bc	13.42b	62.08a
	L1	22.00bc	11.92bc	54.00b
UC82B	L2	19.17c	8.50cd	44.50c
	L3	15.67d	7.92d	50.58bc
	L1	16.42cd	9.17c	54.83b
Roma VF	L2	17.33cd	10.17bc	58.75ab
	L3	15.00d	8.33cd	55.83b

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

The plants grown under L2 (673.70 Lux) had the maximum fruit yield (20.48 t ha^{-1}) followed by the plants that received L3 (450.44 Lux) (16.92 t ha^{-1}), while those ones grown in the open place L1 (897.89 Lux) had the minimum (13.32 t ha^{-1}) fruit yield, Fig. 4.5.

Different phenological stages significantly varied the production of tomato plants. Initially, compared to other phenological stages, the total fruit yield of tomato plants covered at active vegetative was significantly higher (19.21 t ha^{-1}), but yield at fruit physiological maturity was lower (17.26 t ha^{-1}) (Fig.4.6). The effect was significant on the three tomato varieties tested. UC82B variety significantly produced more fruit yield (19.48 t ha^{-1}), but the least fruit yield was produced by Roma VF (16.91 t ha^{-1}). The order of decrease in the level of fruit yield among the tomato varieties was UC82B > Ibadan local > Roma VF (Fig.4.6).

The influence of intensities of light and phenological stages was significantly different. The plants that received L1 (897.89 Lux) at each phenological stages significantly had higher fruit yield, while plants grown under L1 (897.89 Lux) had the lowest fruit yield. The plants that received L2 (673.70 Lux) at active vegetative stage had the highest fruit yield, while those plants grown under full daylight L1 (897.89 Lux) at fruit physiological maturity had the lowest fruit yield (Fig. 4.7).

The total fruit yield is being influenced by varying light intensities. The variety UC82B that was grown under L2 (673.70 Lux) produced more fruit (23.76 t ha^{-1}) than other varieties, but this was not significantly different from Ibadan local x L2 (673.70 Lux) and Roma VF x L2 (673.70 Lux) (22.50 and 22.02 t ha^{-1} respectively), while Roma VF grown in the open L1 (897.89 Lux) (12.08 t/ha) produced less total fruit yield. (Fig. 4.8)

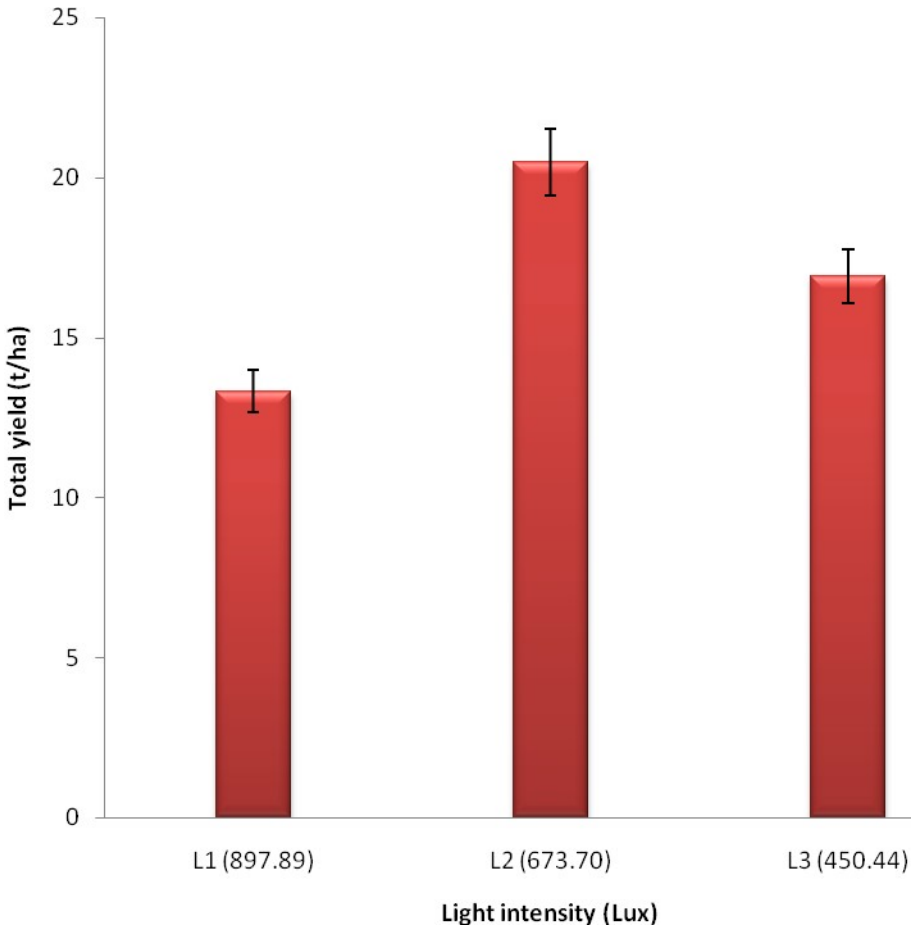


Fig. 4.4: Influence of different light intensities on total fruit yield of three tomato varieties.

| = SE bar 5%

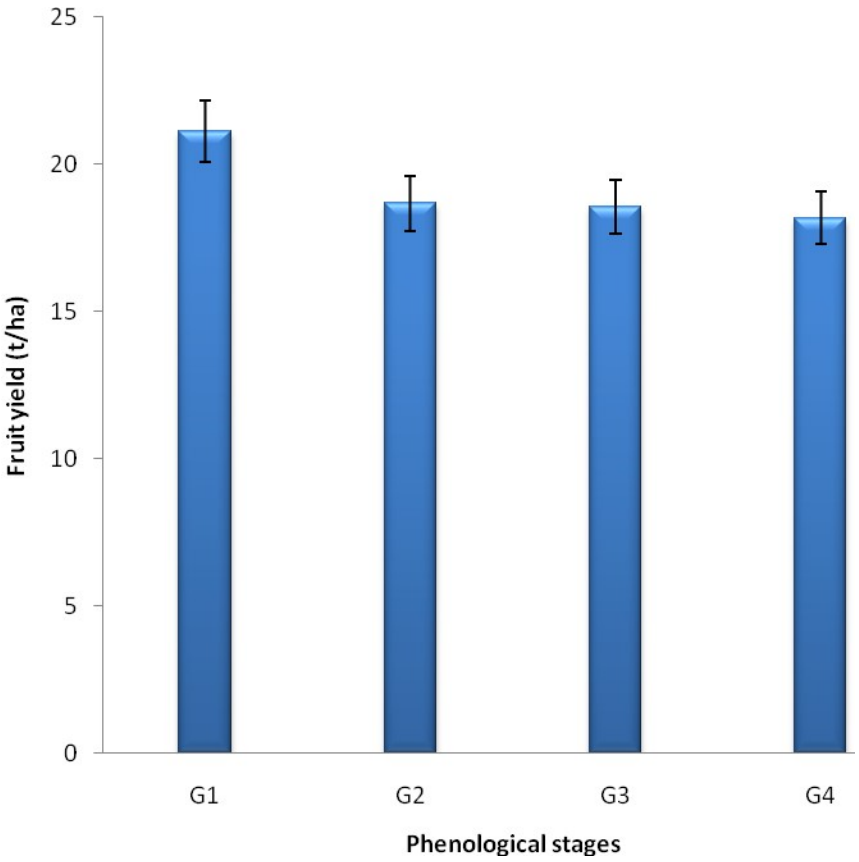


Fig.4.5: Effect of phenological stages on total fruit yield of three tomato varieties.

G = phenological stage of light reduction; G1 = Active vegetative; G2 = Onset of flowering; G3 = Fruiting and G4 = Physiological maturity.

| = SE bar 5%

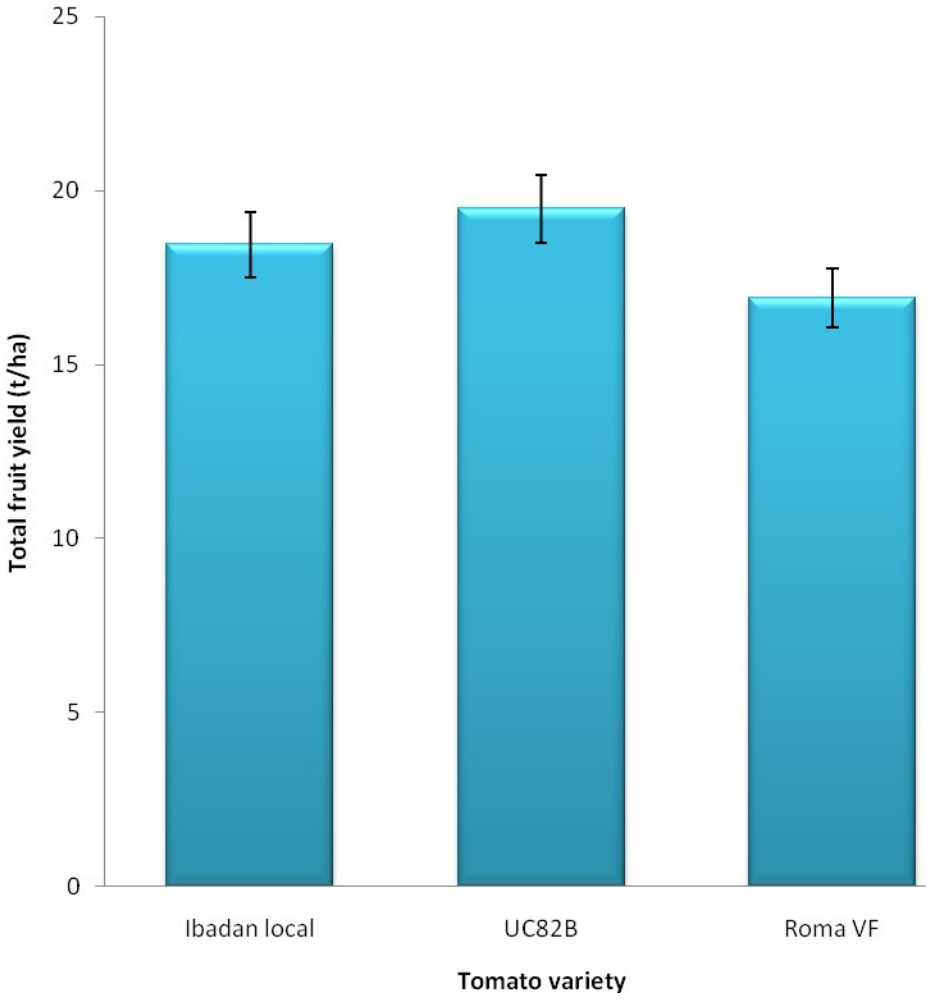


Fig.4.6: Effect of tomato varieties on total fruit yield in the pot experiment

| = SE bar 5%

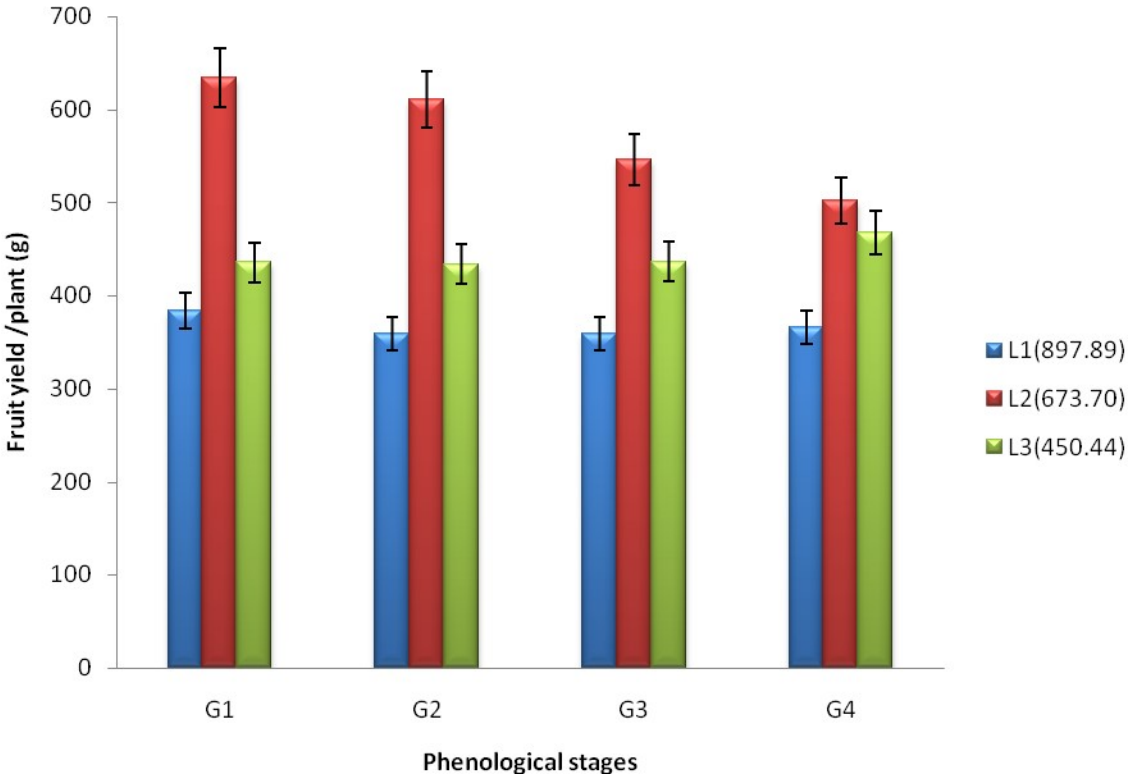


Fig.4.7: Effect of different light intensities at phenological stages on fruit yield of three tomato varieties.

G = phenological stages of light reduction; G1 = Active vegetative; G2 = Onset of flowering; G3 = 50% Fruiting and G4 = Physiological maturity.L1= 897.89 Lux(uncovered plants), L2 =673.70 Lux (single layer net) and L3 =450.44Lux(double layer net).

| = SE bar 5%

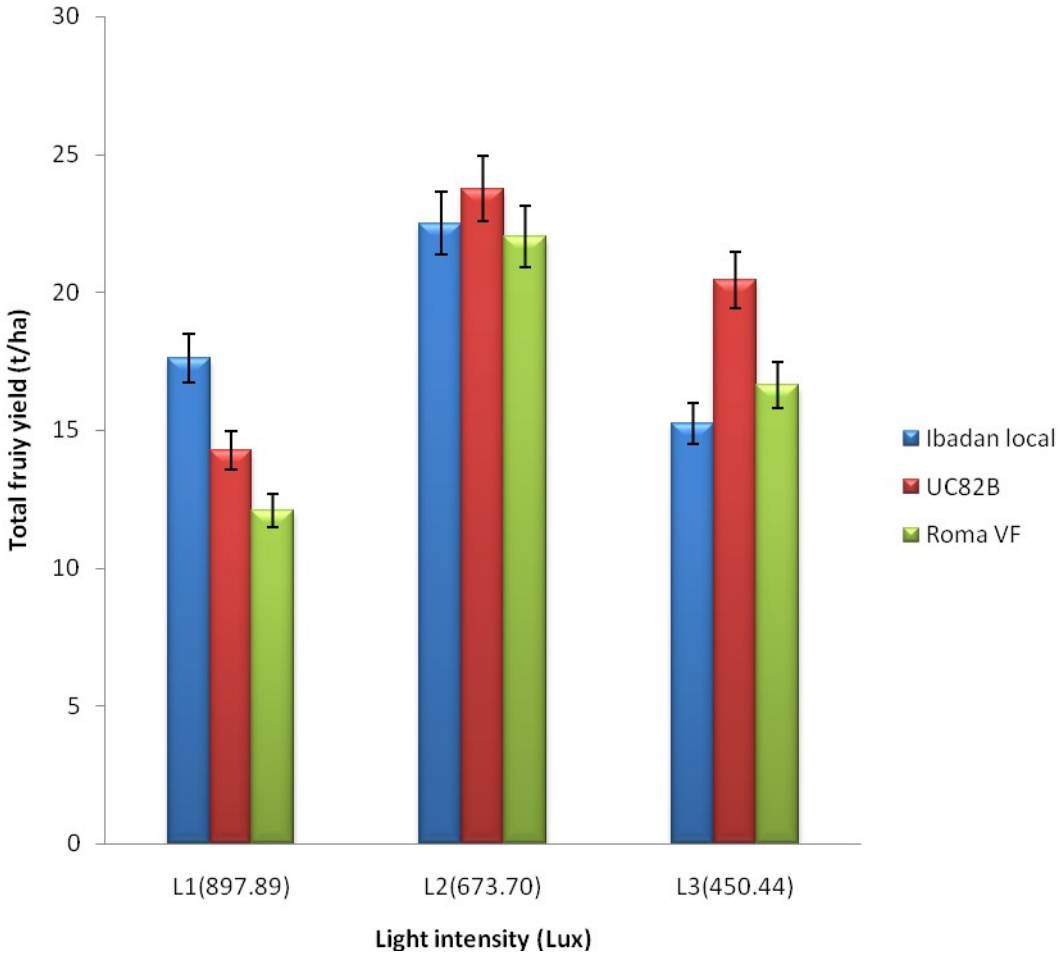


Fig. 4.8: Influence of different light intensities on total fruit yield of three tomato varieties.

| = SE bar 5%

4.5.5 Response of three tomato varieties to different light intensities at various phenological stages on fruit phytochemicals composition

The effect of different light intensities on fruit phytochemicals composition is presented in Table 4.46. Light intensity influenced selected proximate compositions except crude protein and crude fibre, which was insignificant across light intensities. However, the dry matter of plant grown in an open place L1 (897.89 Lux) and double layer net L3 (450.44 Lux) gave the highest but similar (6.10 and 6.15 g/plant), while single layer net L2 (673.70 Lux) had the lowest dry matter (5.69 g/plant). For the ether extract, the fruit that was produced under reduced intensity L2 (673.70 Lux) and L3 (450.44 Lux) performed better than open place L1 (897.89 Lux). The total ash in reduced light intensities L2 (673.70 Lux) and L3 (450.44 Lux) were lower than uncovered plants L1 (897.89 Lux).

Tomato plants treated at the onset of flowering and 50% fruiting significantly had higher dry matter and crude protein compared to active vegetative and fruit physiological maturity stage. The maximum crude fibre was obtained at physiological maturity (13.61 g kg^{-1}), while the other phenological stages were similar (11.83, 11.72 and 11.94 g kg^{-1}). The highest ether extract was obtained at the onset of flowering, while other stages were not different. Total ash varied drastically with variations on phenological stages and light reduction. The best total ash was obtained at active vegetative, while other phenological stages were not different from each other, (Table 4.46).

The influence of three tomato varieties and different light intensities showed significant variations on phytochemicals composition. The Roma VF (0.80 g kg^{-1}) had greater crude protein under double net L3 (450.44 Lux), but UC82B covered with single net L2 (673.70 Lux) had the least. Ether extract in UC82B grown under single net layer L2 (673.70 Lux) gave higher value (0.87 kg ha^{-1}), while Roma VF under double layer net 450.44 Lux (L3) had lower value. The Ibadan local variety grown under single layer net L2 (673.70 Lux) was significantly higher than the other two varieties with different light intensities. Ibadan local variety that was grown under L3 (450.44 Lux) accumulated more moisture (95.97 %), but Ibadan local that received 450.44 Lux (L3) had the least (93.32 %). The highest dry matter was obtained in Ibadan local that was grown in an open place L1 (897.89 Lux) (6.61 g kg^{-1}), while the same variety grown under L3 (450.44 Lux) had the least, (Table 4.47).

Table 4.46: Effect of different light intensities at phenological stages on selected fruit phytochemicals composition (g kg^{-1}) in three tomato varieties

Treatment	Dry matter (g/plant)	Crude protein	Crude fibre	Ether extract	Total ash
Light intensity (L1)					
L1	6.10a	0.71a	12.50a	0.80b	14.71a
L2	5.69b	0.69a	12.17a	0.82a	14.19b
L3	6.15a	0.70a	12.17a	0.83a	14.25b
Phenological stages					
Active vegetative	5.93b	0.68b	11.83b	0.81b	14.59a
Onset of flowering	6.21a	0.75a	11.72b	0.84a	14.33b
50% fruiting	6.17a	0.74a	11.94b	0.81b	14.22b
Fruit physiological maturity	5.62c	0.65c	13.61a	0.80b	14.39ab
Tomato Varieties					
Ibadan local	6.51a	0.69b	11.92b	0.82a	15.33a
UC82B	5.88b	0.65c	12.42a	0.83a	13.61c
Roma VF	5.55c	0.78a	12.50a	0.79b	14.21b
Interaction:					
LI x G	**	**	*	**	**
TV x G	**	**	*	**	*
TV x LI	**	**	ns	**	**
TV x LI x G	**	*	**	**	*

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

Table 4.47: Effect of different light intensities on fruit phytochemicals composition of three tomato varieties

Tomato variety	Light intensity (LI)	Crude protein ($g\ kg^{-1}$)	Ether extract ($g\ kg^{-1}$)	Total ash ($g\ kg^{-1}$)	Moisture (%)	Dry matter (g/plant)
Ibadan local	L1	0.69b	0.79c	15.50ab	93.32c	6.61a
	L2	0.71ab	0.84b	16.00a	94.19b	5.96b
	L3	0.67b	0.84b	14.50b	95.97a	5.03d
UC82B	L1	0.67b	0.81b	13.75c	94.12b	5.86b
	L2	0.62c	0.87a	13.08d	94.26	5.77b
	L3	0.64b	0.81b	14.00b	93.98c	6.00ab
Roma VF	L1	0.77ab	0.80b	14.88ab	94.23b	5.84b
	L2	0.76ab	0.76d	13.50c	94.54b	5.35c
	L3	0.80a	0.83b	14.25b	94.48b	5.48c

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level,L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

4.5.6 Response of different light intensities at phenological stages on fruit lycopene content of three tomato varieties

The response of various intensities of light significantly influenced the rates of synthesis and accumulation of lycopene content in tomato fruit. Tomato varieties grown under L2 (673.70 Lux) contained higher lycopene content (0.26 mg kg^{-1}) compared to L3 (450.44 Lux) and L1 (897.89 Lux) light intensities Fig. 4.9. The lycopene concentration in the fruit grown under L3 (450.44 Lux) and L1 (897.89 Lux) were similar (0.25 and 0.25 mg kg^{-1}).

The phenological stages significantly influenced lycopene content ($p \leq 0.05$). Plants that received covering at onset of flowering gave the highest lycopene content (0.27 mg kg^{-1}), but at active vegetative gave the lowest (0.24 mg kg^{-1}) lycopene. The order of increase in lycopene content is the onset of flowering > 50% fruiting > fruit physiological maturity > active vegetative stage at 0.27 > 0.26 > 0.25 > 0.24 mg kg^{-1} (Fig. 4.10).

The influence of various intensities of light and phenological stages on tomato varieties is shown in Fig. 4.11a. Tomato plants that received L2 (673.70 Lux) at onset of flowering (L2 x G2) produced deep red lycopene content, while uncovered plants L1 (897.89 Lux) at active vegetative stage had least lycopene content (L1 x G1). UC82B variety grown under reduction at onset of flowering and 50% fruiting had more lycopene accumulation than other stages of growth, while Ibadan local variety at active vegetative stage was the least, Fig. 4.11b.

4.5.7 Influence of different light intensities at different phenological stages on fruit elemental compositions of three tomato varieties

Different light intensities had significant influence on fruit macro and micro nutrient element in tomato varieties except Ca, Mg and Cu, were not significant. The plant that was grown under L3 (450.44 Lux) gave the highest P content, while L1 (897.89 Lux) and L2 (673.70 Lux) were similar and the least. The fruit K in tomato grown under L2 (673.70 Lux) had higher K compared to 897.89 Lux (L1) and L3 (450.44 Lux) light intensities. However, the highest Zn was obtained under double layer net L2 (450.44 Lux), but similar to L2 (673.70 Lux) while uncovered L1 (897.89 Lux) was the least.

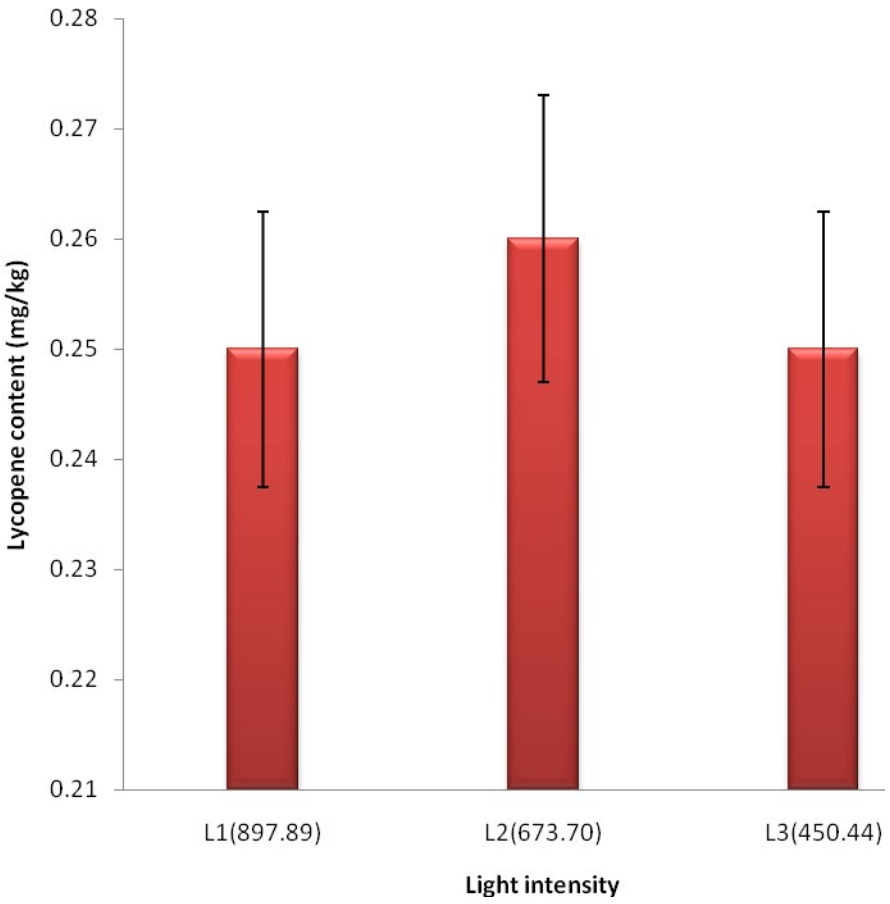


Fig.4.9: Main effect of different light intensity on fruit lycopene content of tomato plants.

L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

| = SE bar 5%

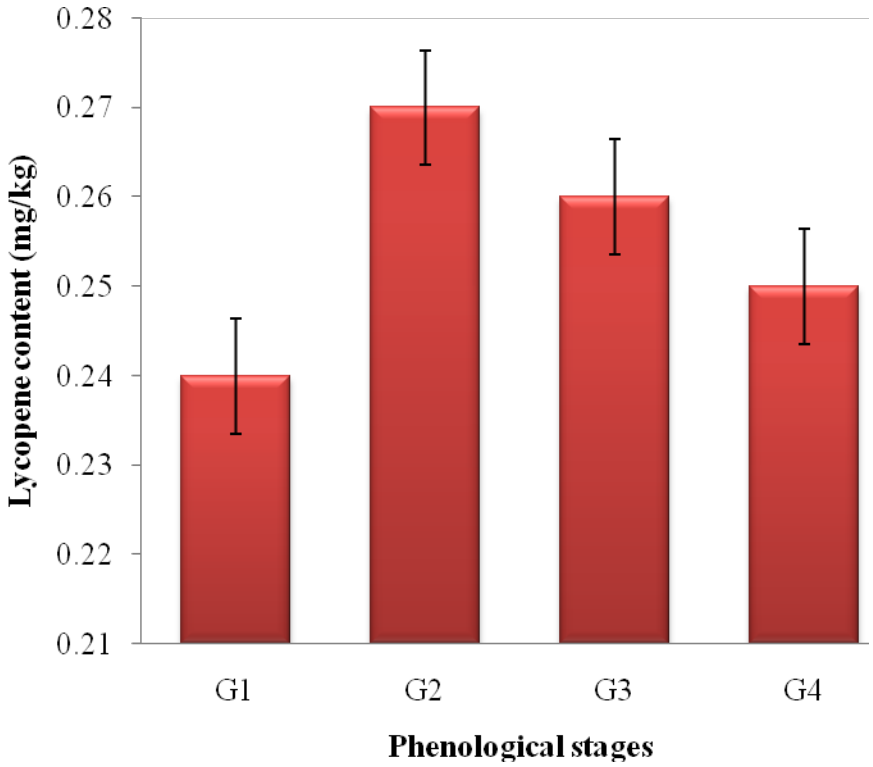
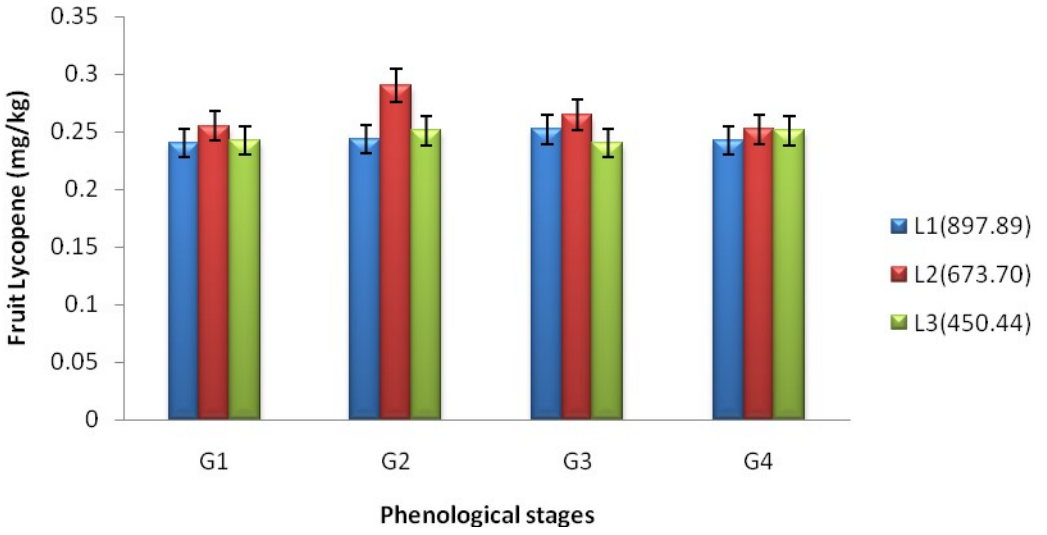


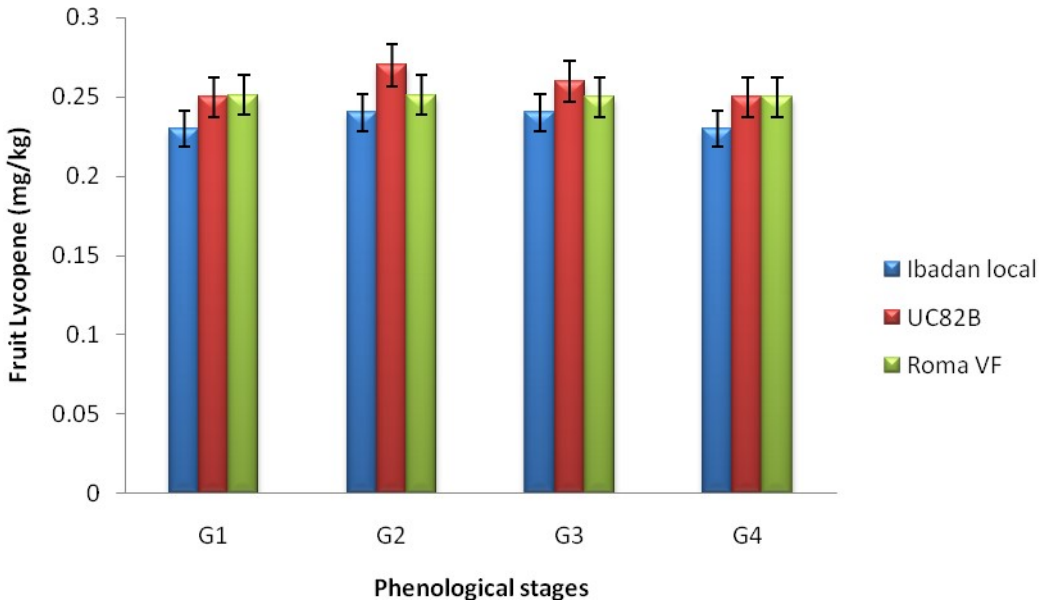
Fig.4. 10: Main effect of phenological stages on lycopene content of tomato fruits

Phenological stages: G1= Active vegetative; G2 = Onset of flowering; G3= 50% Fruiting and G4 = Physiological maturity

| = SE bar 5%



(a)



(b)

Figs.4.11: Effects of (a) different light intensities at various phenological stages (b) effect of phenological stages on fruit lycopene content of three tomato varieties. G1 = Active vegetative; G2= Onset of flowering; G3=50% Fruiting and G4 = Physiological maturity.L1= 897.89 Lux(uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

| = SE bar 5%

The Fe content in tomato fruit under L2 (673.70 Lux) was higher (0.46 g kg^{-1}), but not significantly different from under L2 (450.44 Lux) (0.44 g kg^{-1}), compared to being significantly higher than L1 (897.89 Lux) light intensity (0.43 g kg^{-1}) as in Table 4.48.

The fruit P was highest in plants where light reduction was imposed at fruit physiological stage and least at active vegetative. The fruit P increased with increase in plant age of exposure to light reduction reaching fruit physiological stage. The fruit Ca ranged from plants that were reduced at active vegetative, while the best obtained at fruit physiological maturity. In case of Mg content, highest was (10.18 g kg^{-1}) obtained with plants exposed to reduction at 50% flowering than all others treatments. The fruit K and Cu were not significantly influenced by phenological stages of light reduction. However, for fruit Zn and Fe contents imposition of light reduction at 50% flowering enhanced their values. Among the 2-way and 3-way interactions, only variety and phenological stages that was significant on all of the fruit macro and micro nutrient contents (Table 4.48).

The results revealed that, the response of three tomato varieties to phenological stages were significant except Ca, Mg, Cu and Fe contents. Roma VF had the highest P (17.21 g kg^{-1}), while Ibadan local was the least (15.94 g kg^{-1}) and also, Ibadan local significantly had higher fruit K than other varieties. The highest fruit Zn was observed UC82B variety, whereas Ibadan local was the lowest. But for the Fe content, Roma VF gave more Fe content than UC82B and Ibadan local varieties.

Table 4.48.: Effect of different light intensities at phenological stages on fruit elemental compositions (g kg^{-1}) of three tomato varieties

Treatment	P	K	Ca	Mg	Cu	Zn	Fe
Light Intensity(LI)							
L1	16.63b	215.65b	4.39a	8.89a	0.03a	0.30b	0.43ab
L2	16.92b	217.45a	4.39a	8.99a	0.03a	0.35a	0.46a
L3	17.45a	215.25b	4.37a	8.97a	0.03a	0.36a	0.44a
Phenological stages							
Active vegetative	16.85b	212.52b	4.28a	8.98b	0.04a	0.12b	0.43b
Onset of flowering	18.86a	214.30a	4.35a	10.45a	0.03a	0.13b	0.45b
50% fruiting	17.27b	215.51a	4.25a	9.86b	0.02a	0.10c	0.44b
Fruit physiological maturity	17.64b	214.52a	4.42a	10.81a	0.04a	0.16a	0.48a
Tomato Variety							
Ibadan local	15.94c	214.25a	4.30a	8.25a	0.04a	0.14c	0.44b
UC82B	16.54b	213.42b	4.32a	8.31a	0.04a	0.16a	0.43c
Roma VF	17.21a	212.32c	4.21a	8.25a	0.03a	0.15b	0.45a
Interaction:							
LI x G	**	ns	ns	ns	ns	*	*
TV x G	ns	*	ns	ns	ns	ns	ns
TV x LI	**	*	ns	ns	ns	ns	ns
TV x LI x G	**	ns	ns	ns	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant,L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

4.6. Experiment 3 Field: Response of three tomato varieties to different light intensities at phenological stages on growth, dry matter partitioning, fruit yield and phytochemical compositions

4.6.1 Influence of light intensities at phenological stages on selected vegetative parameters.

The response of three tomato varieties to different light intensities had significant difference among the parameters tested at active vegetative, Table 4.49. The results revealed that, the plants grown under L2 (673.70 Lux) was significantly higher (72.32 cm) than uncovered plants L1 (897.89 Lux) and L3 (450.44 Lux). The thickness of the stem of tomato plants grown under shade (1.18 and 1.17cm) was thicker than open plants (0.93 cm) L1 (897.89 Lux). The highest number of leaves was obtained under L2 (673.70 Lux) 56.83/plant, whereas uncovered plants L1 (897.89 Lux) had the lowest value (51.80/plant). Plants grown under L2 (450.44 Lux) had larger leaf area (332.71cm^2) than L1 (897.89 Lux) and L2 (673.70 Lux) (278.35 and 292.32cm^2) respectively.

Initially, tomato plants treated at 50% fruiting showed wider leaf area compared to fruit physiological maturity, onset of flowering and active vegetative stages. However, the stem girth at onset of flowering, 50% fruiting and fruit physiological maturity were significantly not different (1.23, 1.20 and 1.04 cm), but active vegetative was the least (0.93 cm). Also, at onset of flowering, highest number of leaves was recorded (60.35/plant), while fruit physiological maturity had the lowest (49.21/plant). Leaf area at onset of flowering, 50% fruiting and fruit physiological maturity stages were highest and similar, but active vegetative had the lowest, Table 4.49.The plant height of Ibadan local had the tallest height (69.45 cm), meanwhile UC82B and Roma VF varieties were similar and shorter to Ibadan local in height (65.34 and 65.90 cm). The stem girth of UC82B and Roma VF varieties were not significantly different (1.0 and 1.1 cm), while Ibadan local (0.94 cm) had the lowest stem girth. The Ibadan local had higher number of leaves (54.78 cm), but Roma VF was the lowest (48.42 cm). Variety UC82B significantly had larger leaf area (344.41/plant) followed by Roma VF (334.18/plant), while the least was obtained in Ibadan local (249.21/plant), Table 4.49.

Table 4.49: Influence of different light intensities at phenological stages on selected vegetative parameters of three tomato varieties

Treatment	Plant height (cm)	Stem girth (cm)	No. of leaves/ plant	Leaf area/plant (cm)
Light intensity (L1)				
L1	66.87c	0.93b	51.80c	312.35b
L2	72.32a	1.18a	56.83a	292.32c
L3	68.34b	1.17a	53.12b	332.21a
Phenological stages				
Active vegetative	43.21c	0.91b	55.67b	255.43b
Onset of flowering	60.56b	1.20a	60.35a	345.32a
50% fruiting	77.86a	1.23a	56.43b	359.89a
Fruit physiological mat.	74.43ab	1.04a	49.21c	345.87a
Tomato Variety				
Ibadan local	69.45a	0.94b	54.78a	249.21c
UC82B	65.24b	1.0a	50.26b	344.41a
Roma VF	65 90b	1.1a	48.42c	334.18.b
Interaction:				
LI x G	ns	ns	ns	ns
TV x G	ns	ns	ns	ns
TV x LI	ns	ns	ns	**
TV x LI x G	ns	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; and ns = not significant, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

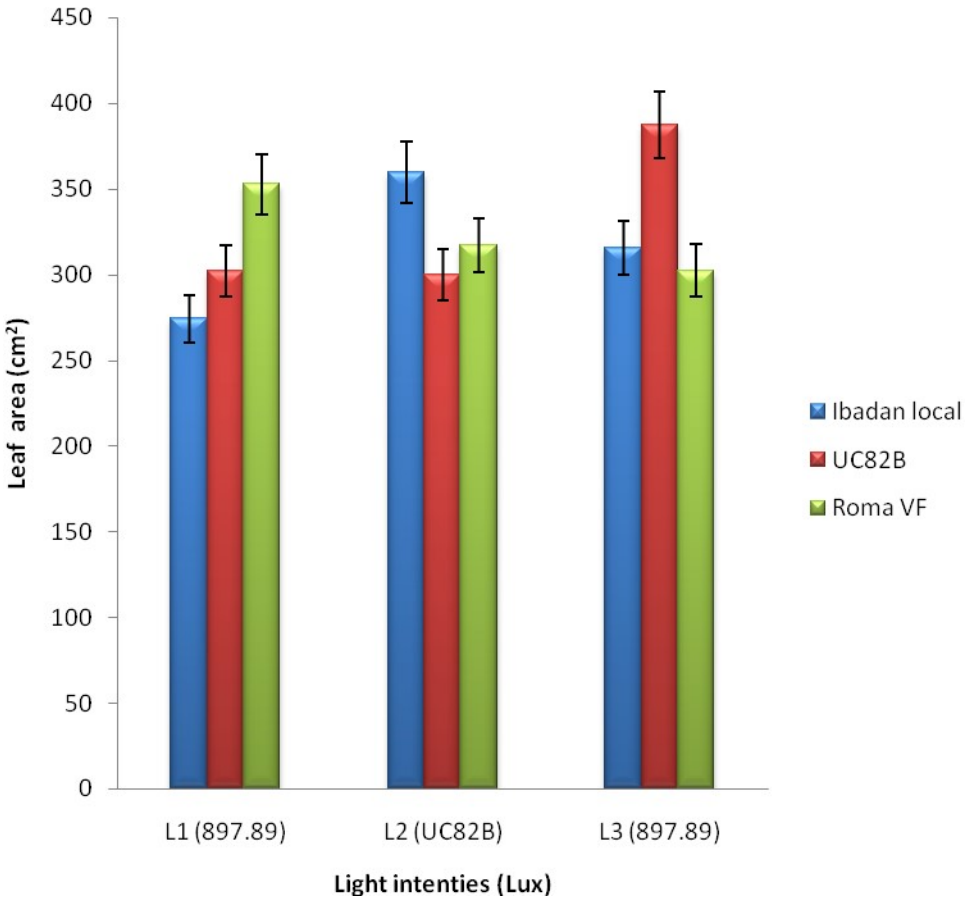


Fig. 4.12: Effect of different light intensities on leaf area of three tomato varieties.

L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

=SE bar 5%

Among the interactive effects on vegetative parameters, interactions among LI and G, TV and G, and TV x LI and G were not significant. It was only TV and LI that showed significant variations. Variety UC82B grown under L2 (450.44 Lux) had significantly wider leaf area, while Ibadan local under L1 (897.89 Lux) was the least Table 4.49.

4.6.2 Response of three tomato varieties to different light intensities at phenological stages on chlorophyll concentration.

The results revealed that, chlorophyll content at different intensities showed significant effect. Nonetheless, chlorophyll content at L1 (897.89 Lux) were significantly higher than L2 (673.70 Lux) and L3 (450.44 Lux), but L2 (673.70 Lux) and L3 (450.44 Lux) were similar. Chlorophyll content was higher in the sequence L1 > L2 > L3 (Fig 4.13).The chlorophyll content in the plants that was reduced at onset of flowering gave the highest, but not significantly different from active vegetative while fruit physiological maturity had the lowest chlorophyll content (Fig 4.13).

The effect of different intensities of light on three tomato varieties was significant. The Ibadan local variety grown under L2 (673.70 Lux) obtained highest chlorophyll content which was similar to Roma VF grown L1 (897.89 Lux), but interactions between other varieties and light intensities were similar.

4.6.3 Effect of different light intensities at phenological stages on dry matter accumulations and partitioning of three tomato varieties.

Different light intensities significantly influenced dry matter accumulation and partitioning of three tomato varieties. However, regulated intensities, either L2 (673.70 Lux) or L3 (450.44 Lux) significantly had higher dry matter accumulation, as weight of dry shoot was (17.69 g) L3 (450.44 Lux), (15.13 g) L2 (673.70 Lux) and lowest (9.13 g) in L1 (897.89 Lux). Also, root dry weight and total dry weight under L1 (897.89 Lux) were initially lower (1.34 g) and (10.65 g) while (450.44 Lux) had higher (2.76 g) and (20.40 g) value Table 4.50.

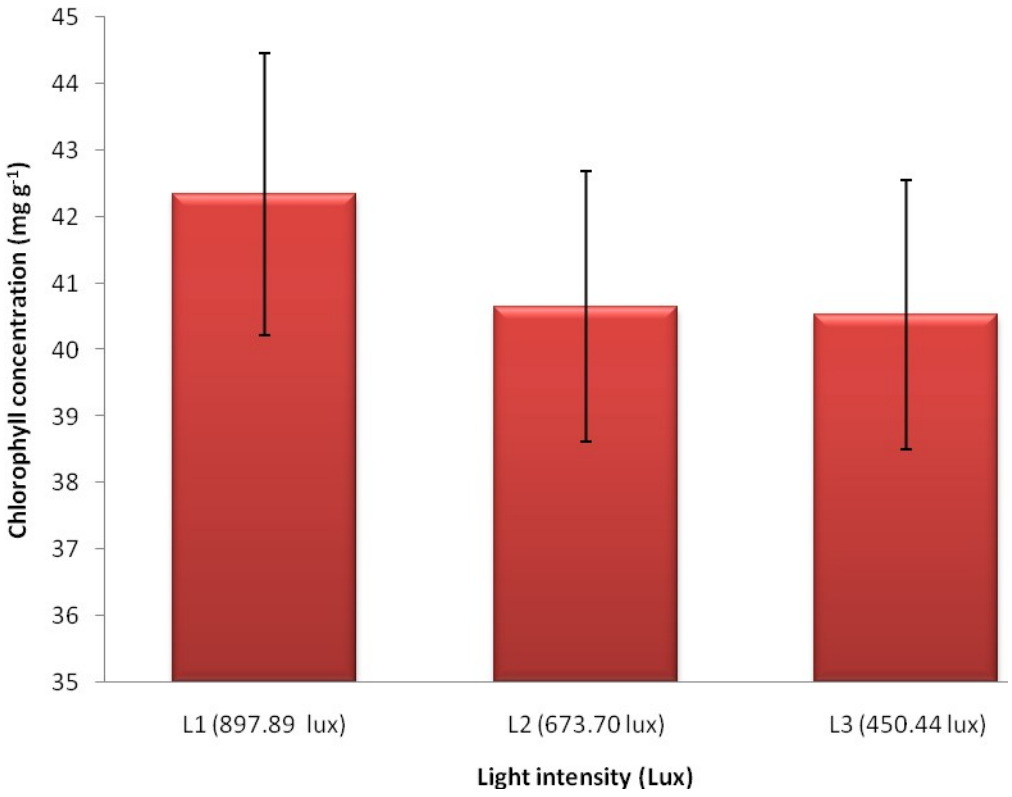


Fig. 4.13: Main effect of different light intensities on the chlorophyll content of tomato leaves.

L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

| = SE bar 5%

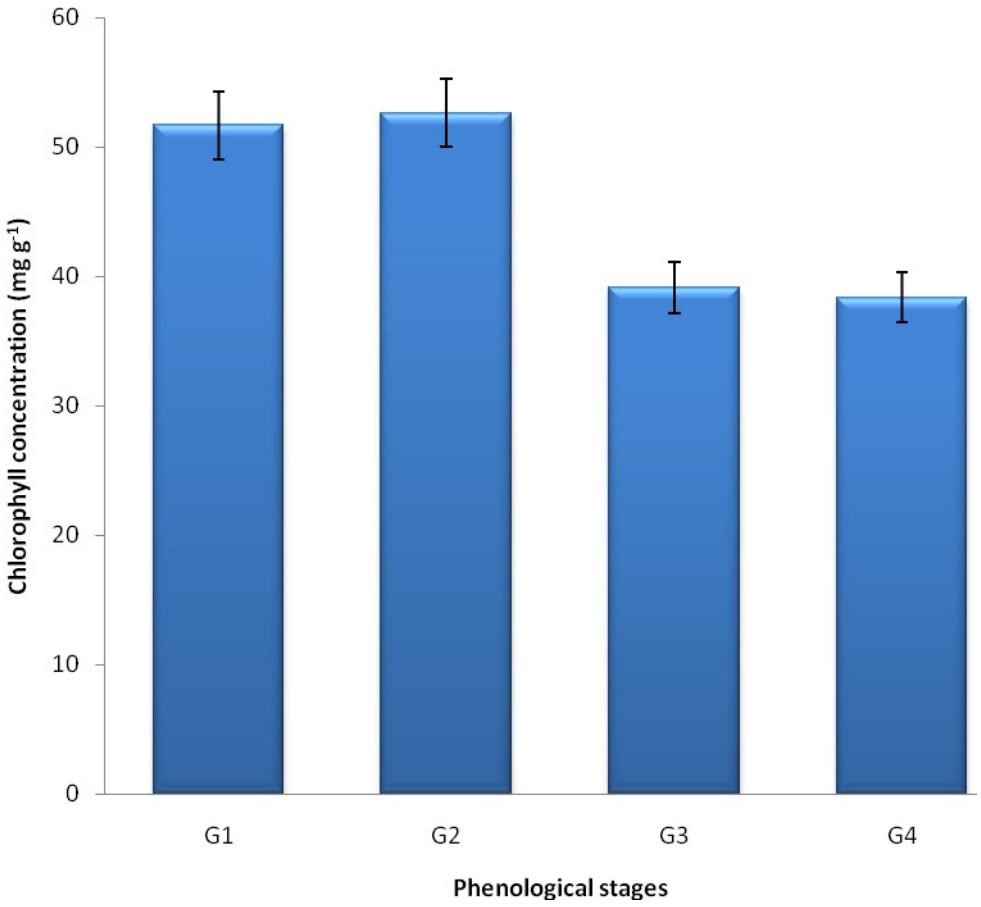


Fig.4.14: Influence of different phenological stages on the chlorophyll content in the tomato leaf.

G = phenological stages of light reduction; G1 = Active vegetative; G2 = Onset of flowering; G3= Fruiting and G4 = Fruit Physiological maturity

| = SE bar 5%

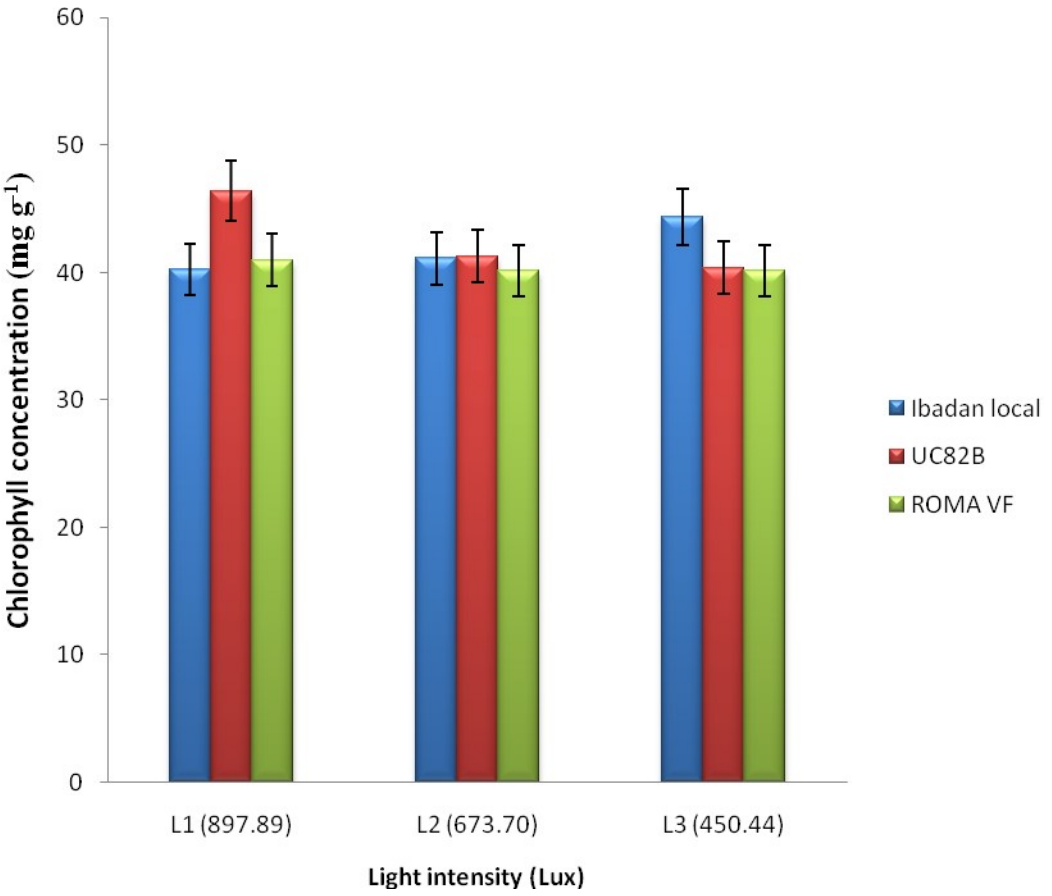


Fig.4.15: Influence of different light intensity on the chlorophyll content of the leaves of three tomato varieties.

L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

| =SE bar 5%

However, the shaded plants at onset of flowering, that is reduction in light intensity across the dry matter partitioning, on the shoot, root and total dry weight was the highest (17.99, 3.01 and 21.00 g) while lowest in 50% fruiting (10.29, 1.21 and 11.50 g). Among the three tomato varieties, Ibadan local displayed significantly higher shoot dry weight (19.40 g) over other two varieties. The shoot dry weight was highest in Roma VF fruit while UC82B was the lowest. The total dry matter of Roma VF gave the highest (21.27 g) and lowest in UC82B (19.39 g) Table 4.50.The interactions between light intensity and the dry matter of various plant parts showed some level of significance. The shoot weight produced with Ibadan local grown under L3 (450.44 Lux) had the highest (26.28 g), while L1 (897.89 Lux) (10.53 g) was the lowest. The root dry weight of Roma VF grown under L3 (450.44 Lux) gave the highest weight (20.94 g), but UC82B grown under L1 (897.89 Lux) was the lowest (14.7 g). Highest total dry matter yield was obtained in Ibadan local grown under L3 (450.44 Lux), while UC82B that was grown under L1 (897.89 Lux) had the lowest Table 4.51.

4.6.4 Response of three tomato varieties to different light intensities at phenological stages on components of yield, fruit yield and yield parameters

Three tomato varieties reacted differently to light intensities on yield and yield components Table 4.52. However, highest number of flowers/plants was obtained under L2 (673.70 Lux) and uncovered plant L1 (897.89 Lux), which was not significantly different from each other (29.21/plant and 28.23/plant), but higher than L3 (450.44 Lux) (26.40/plant). Again, the highest fruit/plant and percentage fruit set was obtained under L2 (673.70 Lux) (16.45/plant and 56.32 %), while uncovered plants L1 (897.89 Lux) had lowest number of fruits (14.23/plant) and L3 (450.44 Lux) had the lowest percentage fruit set (46.67 %).

The influence of phenological stages was significantly different with respect to fruit yield and yield component, Table 4.52. Flowers/plant at onset of flowering gave highest (25.01/plant and 14.62/plant), whereby fruit physiological maturity had the lowest (19.70/plant and 11.24/plant). Active vegetative stage showed the highest percent fruit set (63.20 %), whereby onset of flowering (51.07 %) was the least. The three tomato varieties responded differently among the varieties with respect to yield components. However, the highest number of flowers/plant was observed with UC82B variety (32.63/plant) and least with Roma VF variety (27.57/plant).

Table 4.50: Effect of different light intensities at phenological stages of on dry matter yield of three tomato varieties

Treatment		Dry matter (g)	
Light intensity (L1)	Shoot	Root	Total
L1	9.13c	1.34c	10.65c
L2	15.13b	2.13b	17.23b
L3	17.69a	2.76a	20.40a
Phenological stages (G)			
Active vegetative	10.83c	1.24c	12.07c
Onset of flowering	17.99a	3.01a	21.00a
50% fruiting	10.29c	1.21c	11.50c
Fruit physiological mat.	16.85b	2.51b	18.91b
Tomato Varieties			
Ibadan local	18.14b	1.87b	20.01b
UC82B	17.42c	1.94a	19.39c
Roma VF	19.40a	1.93a	21.27a
Interaction			
LI x G	*	ns	*
TV x G	*	ns	*
TV x LI	**	*	**
TV x LI x G	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant,L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

Table 4.51: Effect of different light intensity on dry matter partitioning of three tomato varieties

Tomato variety	Light intensity (LI)	Dry weight (g/plant)		
		Shoot	Root	Total
Ibadan local	L1	14.45c	1.78b	16.23c
	L2	17.52b	1.91b	19.43bc
	L3	26.28a	1.89b	28.17a
UC82B	L1	10.53d	1.47c	12.00d
	L2	14.21c	2.78a	16.99c
	L3	17.20b	2.11ab	19.31bc
Roma VF	L1	12.93cd	1.78b	14.68cd
	L2	17.90b	2.67ab	20.56b
	L3	17.14b	2.94a	20.08b

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

Also, Ibadan local produced highest number of fruits compared to UC82B and Roma VF varieties. The maximum percent fruit set (61.41 %) was obtained in UC82B while Ibadan local performed least (56.25 %), Table 4.52.

Ibadan local grown under L2 (673.70 Lux) gave the highest number of flowers/plant (31.72/plant) but UC82B x L2 (450.44 Lux) and Roma VF x L1 (897.89 Lux) had the lowest (18.14/plant and 18.14/plant), respectively. Moreover, Ibadan local grown under L2 (673.70 Lux) had highest number of fruit/plant (18.31/plant) while UC82B under L3 (450.44 Lux) 9.41/plants had the lowest. Percent fruit set in Roma VF grown under L2 (673.70 Lux) and L3 (450.44 Lux) with 69.57 and 67.54 % significantly higher compared to L1 (897.89 Lux) in UC82B (41.77 %), Table 4.53.

Effect light intensities on three tomato varieties had effect on total fruit attributes. Plants grown under full light L1 (897.89 Lux) had the lowest total fruit yield (15.45 t ha^{-1}) while highest fruit yield were obtained under L2 (673.70 Lux) (20.71 t ha^{-1}), Fig.4.17. Influence of phenological stages on fruit yield was significantly different. However, the tomato plants treated at active vegetative produced maximum fruit yield (21.12 t ha^{-1}) than other phenological stages. Also, at onset of flowering to fruit physiological maturity, it shows insignificant differences among the phenological stages on the yield, Fig 4.18. The highest total fruit yield (22.57 t ha^{-1}) was obtained in UC82B, followed by Ibadan local (21.54 t ha^{-1}) and lastly, Roma VF which was the lowest had (19.48 t ha^{-1}), Fig 4.19.

Also significant differences in the interactions between light intensities and three tomatoes were shown. The maximum fruit yield was obtained in tomato plants that received regulation in light intensities. However, UC82B grown at L2 (673.70 Lux), L3 (450.44 Lux) and Roma VF grown under L2 (673.70 Lux) recorded higher fruit yield which are similar, but lower in Roma VF grown unregulated L1 (897.89 Lux), Fig. 4.20.

Table 4.52: Response of different light intensity at phenological stages on components of yield of three tomato varieties

Treatment	Number of flowers/ plant	Number of fruits/plant	Fruit set (%)
Light intensity (L1)			
L1	28.23a	14.23c	50.41b
L2	29.21a	16.45a	56.32a
L3	26.40b	14.82b	46.67c
Phenological stages			
Active vegetative	22.31ab	14.10ab	63.20a
Onset of flowering	25.01a	14.62a	57.06b
50% fruiting	19.71b	12.21b	61.95ab
Fruit physiological mat.	19.70b	11.24b	58.46b
Tomato Varieties			
Ibadan local	30.51b	14.52a	56.25c
UC82B	32.63a	13.32b	61.41a
Roma VF	27.57c	13.87b	58.32b
Interaction			
LI x G	ns	ns	ns
TVx G	ns	*	ns
TV x LI	*	*	**
TV x LI x G	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

Table 4.53: Influence of different light intensity on components of yield of three tomato varieties

Tomato variety (V)	Light intensity (LI)	No. of flowers /plant	No. of fruits / plant	Fruit set (%)
	L1	28.00b	16.42ab	58.64b
Ibadan local	L2	31.72a	18.31a	57.72b
	L3	24.74c	15.41b	62.29ab
	L1	24.68c	10.31d	41.77c
UC82B	L2	20.19cd	12.42c	61.52ab
	L3	18.14d	9.41e	51.87b
	L1	18.14d	10.32d	56.89b
Roma VF	L2	21.13cd	14.70b	69.57a
	L3	18.24d	12.32c	67.54a

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level,L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

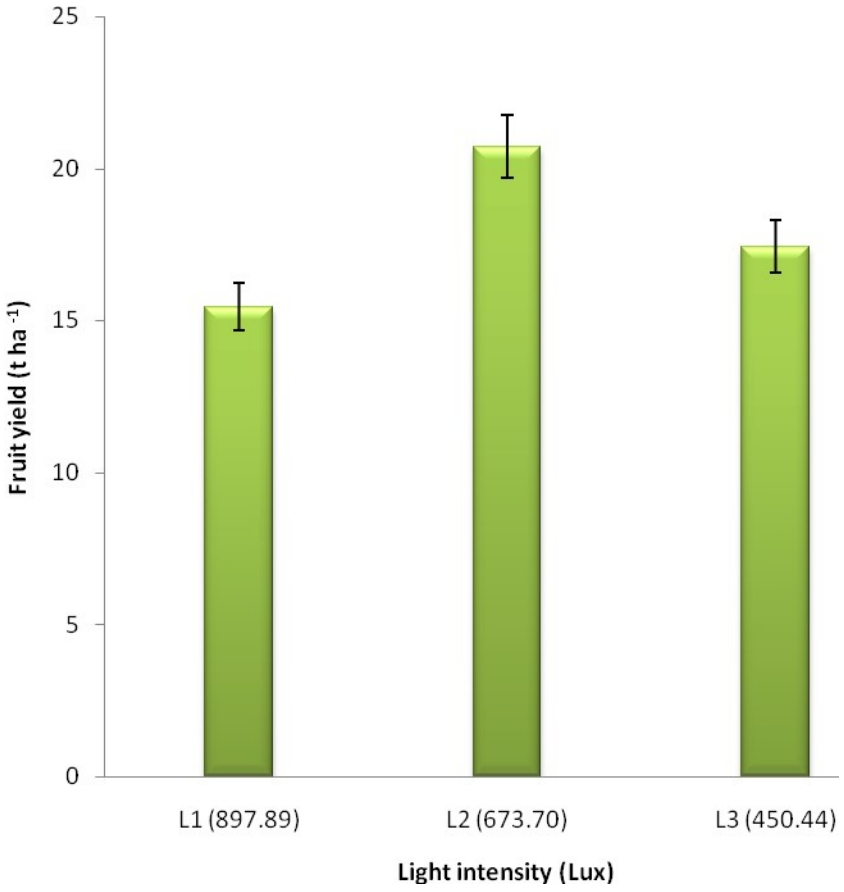


Fig. 4.16. Effect of different light intensities on fruit yield (t ha^{-1}) of three tomato varieties.

|=SE bar 5%

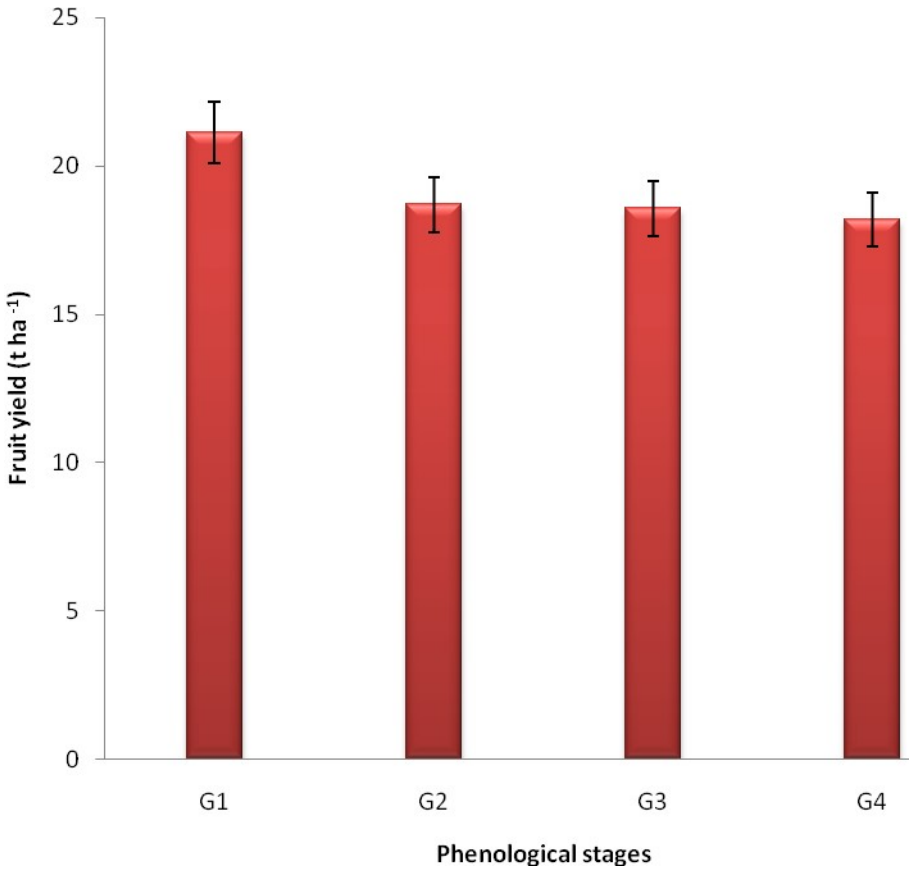


Fig. 4.17 Influence of phenological stages on fruit yield (t ha^{-1}) of three tomato varieties

G = phenological stages of light reduction; G1 = Active vegetative; G2 = Onset flowering; G3 = Fruiting and G4 = Fruit Physiological maturity

| =SE bar 5%

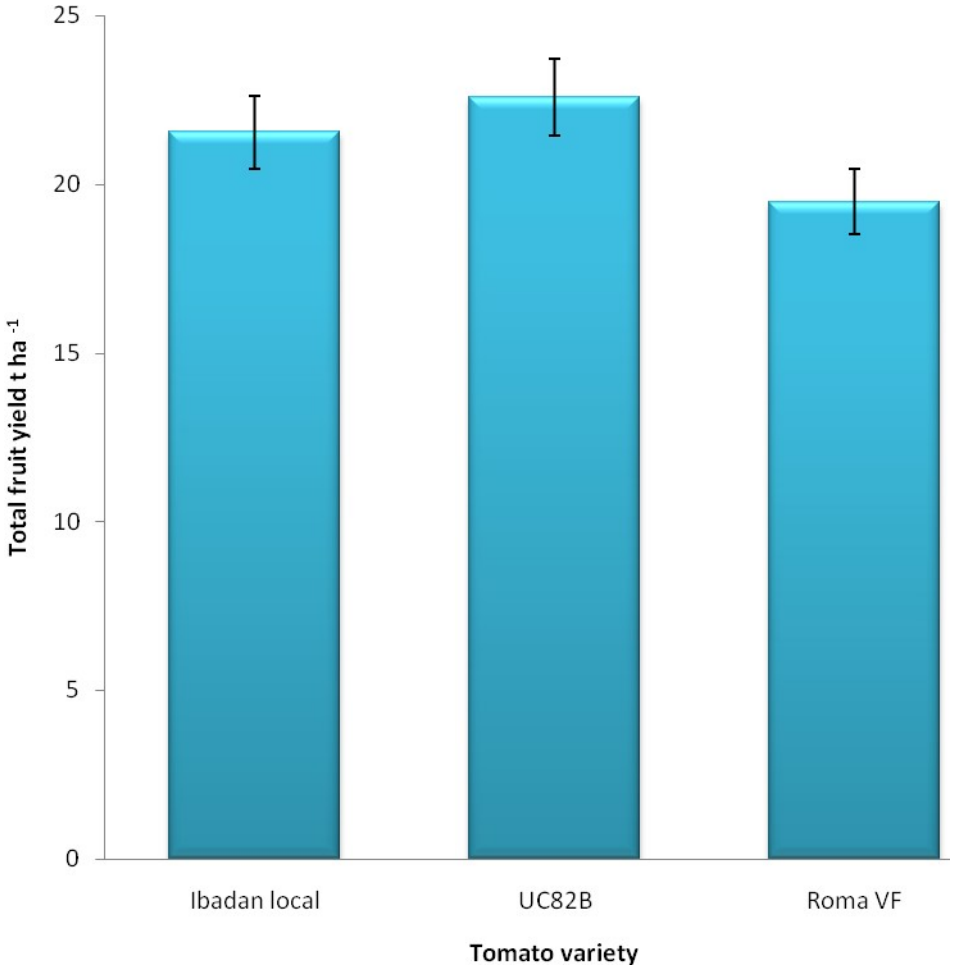


Fig. 4.18 Varietal effect of total fruit yield on three tomato varieties tested on the field

| = SE bar 5%

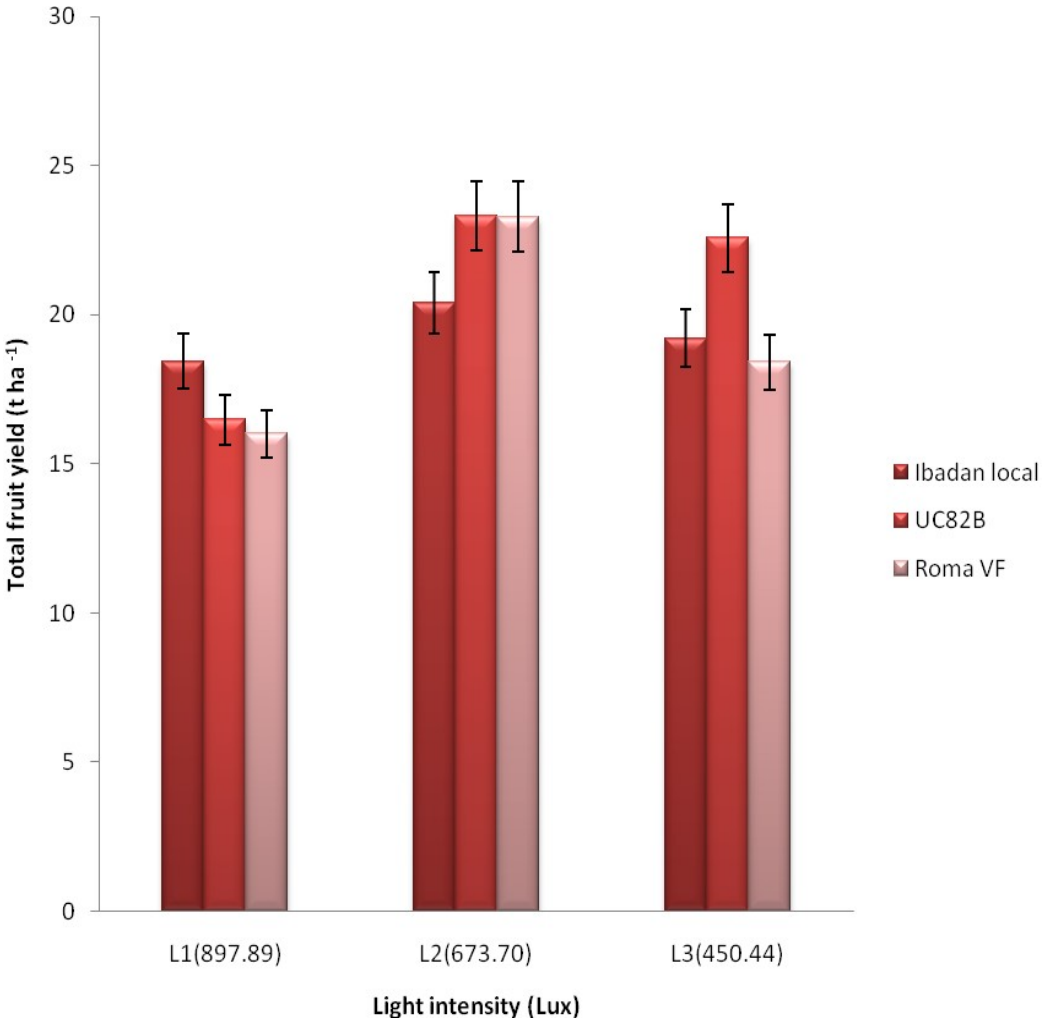


Fig. 4.19 Effect of different light intensities and three tomato varieties on total fruit yield

| = SE bar 5%

4.6.5 Influence of different light intensities at phenological stages on fruit phytochemicals composition of three tomato varieties

Different light intensities influenced the fruit phytochemicals composition, except dry matter, crude protein, crude fibre and moisture content which showed insignificant. However, ether extract in the fruits grown under L2 (673.70 Lux) and L3 (450.44 Lux) was significantly higher than that of uncovered plants L1 (897.89 Lux). The highest total ash was obtained in plants that received L3 (450.44 Lux) while L1 (897.89 Lux) and L2 (673.70 Lux) were the lowest. The soluble solid in the fruit obtained atL1 (897.89 Lux) and L2 (673.70 Lux) were significantly higher compared to L3 (450.44 Lux). The highest total sugar was obtained under L1 (897.89 Lux) and L3 (450.44 Lux), while L2 (673.70 Lux) had the lowest Table 4.52.

The highest dry matter was obtained at the onset of flowering and 50% fruiting while active vegetative had the lowest. Crude protein at onset of flowering was higher and similar. Likewise, crude fibre content at active vegetative gave the highest (0.49 g kg^{-1}), while the onset of flowering had the lowest (0.43 g kg^{-1}). The ether extract at onset of flowering performed best (0.96 g kg^{-1}), while fruit physiological maturity was the least (0.74 g kg^{-1}). Active vegetative had higher soluble solid and total sugar compared to other phenological stages.

Varietal effect was also significant ($p \leq 0.05$) except crude protein and total ash that were similar. Ibadan local and UC82B were significantly higher (0.69 and 0.68 g/plant) in dry matter than Roma VF (0.58 g/plant). Highest crude protein was obtained in Roma VF, but lowest in Ibadan local and UC82B varieties. The ether extract of UC82B was significantly higher than Ibadan local and Roma VF varieties. The moisture content of UC82B and Roma VF varieties was significantly higher than Ibadan local variety. Total soluble solid in UC82B variety gave the highest, but least in Ibadan local. Total sugar in UC82B and Roma VF were similar, but significantly higher than Ibadan local variety. Effect of light intensities and tomato varieties were significantly influenced. UC82B variety grown under L2 (673.70 Lux) had highest crude protein content (0.83 g kg^{-1}), while Ibadan local variety had the smallest (0.65 g kg^{-1}). The performance of UC82B variety grown under L2 (673.70 Lux) light intensity was significantly higher than others.

Table 4.54: Response of different light intensities at phenological stage on selected fruit phytochemicals composition of three tomato varieties

Treatment	Dry matter (g/plant)	Crude protein (g kg^{-1})	Crude fibre (g kg^{-1})	Ether extract (g kg^{1})	Total ash (gkg^{-1})	Moisture content (%)	Soluble solid (g kg^{-1})	Total sugar (g kg^{-1})
Light intensity (LI)								
LI	6.64a	0.84a	12.44a	0.78b	0.25ab	93.66a	25.06a	2.91a
L2	6.58a	0.84a	12.38a	0.84a	0.19b	91.78a	25.16a	2.19b
L3	6.56a	0.84a	11.87a	0.84a	0.30a	93.31a	24.77b	2.90a
Phenological stages								
Active vegetative	4.96c	0.84ab	0.49a	0.80b	0.23a	92.69a	25.44a	2.93a
Onset of flowering	6.37a	0.85a	0.43c	0.96a	0.23a	93.39a	25.24b	2.9a
50% fruiting	6.30a	0.84ab	0.44b	0.80b	0.22a	93.94a	25.02c	2.90b
Fruit physiological mat.	6.21b	0.83b	0.46ab	0.74b	0.22a	90.83a	24.42d	2.88b
Tomato Variety								
Ibadan local	0.69a	0.84a	0.43b	0.84b	0.22a	91.12b	23.90c	2.86b
UC82B	0.68a	0.84a	0.43b	0.90a	0.23a	93.40a	26.67a	2.93a
Roma VF	0.58b	0.84a	0.46a	0.82b	0.23a	93.61a	24.52b	2.93a
Interaction:								
LI x G	**	**	*	*	**	**	**	ns
TV x G	**	**	**	**	**	ns	**	**
TV x LI	ns	**	ns	ns	**	ns	**	ns
TV x LI X G	**	*	*	*	*	ns	**	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant,L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

Table 4.55: Effect of different light intensities on fruit phytochemicals composition of three tomato varieties

Tomato variety (V)	Light intensity (LI)	Crude protein ($g\ kg^{-1}$)	Ether extract ($g\ kg^{-1}$)	Total ash ($g\ kg^{-1}$)	Moisture (%)	Dry matter ($g\ kg^{-1}$)
	L1	0.75c	0.81b	14.45c	93.79a	5.74c
Ibadan local	L2	0.77b	0.85ab	16.50a	94.91a	5.84d
	L3	0.65d	0.82b	15.42b	94.68a	6.70a
	L1	0.69d	0.75d	14.81c	95.56a	6.53b
UC82B	L2	0.83a	0.87a	15.02b	94.95a	6.85a
	L3	0.78b	0.84ab	16.02a	94.45a	6.15b
	L1	0.81ab	0.82b	15.54b	94.84a	6.68a
Roma VF	L2	0.79b	0.85ab	14.60c	94.56a	6.21b
	L3	0.78b	0.80c	15.34b	94.59a	5.84a

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level,L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

The effect of different light intensities and three tomato varieties were significantly similar. The highest moisture content was obtained in Ibadan local grown at L2 (673.70 Lux) (95.91 %), whereby, Ibadan local unregulated L1 (897.89 Lux) had the lowest. UC82B variety that received L2 (673.70 Lux) had higher dry matter than Ibadan local grown under L1 (897.89 Lux), Table 4.55.

4.6.6 Effect of different light intensities at phenological stages on phytochemicals composition in tomato varieties

The response of different light intensities had effect only on vitamin A content. The total phenol, vitamin C and E were not significantly different across the levels of light intensities. The highest vitamin A content was obtained under reduced light intensities L2 (673.70 Lux) (52.54 mg kg^{-1}), while uncovered plants L1 (897.89 Lux) had the lowest (51.70 mg kg^{-1}) vitamin A content (Table 4.56). The phenological stages significantly influenced selected fruit phytochemicals composition ($p \leq 0.05$) except total phenol which was similar across the phenological stages. The plants treated at onset of flowering and fruit physiological maturity stages significantly had higher vitamin A compared to active vegetative and 50% fruiting stages. The highest vitamin C and E contents was obtained at the onset of flowering and significantly more than other stages.

Vitamin A content in Roma VF (53.14 mg kg^{-1}) and UC82B (52.99 mg kg^{-1}) were similar and higher Ibadan local (50.61 mg kg^{-1}). Also, UC82B variety produced the highest vitamin C and E, while Ibadan and Roma VF had the lowest value (Table 4.56).

The effects of different light intensities were significantly different with respect to lycopene content tomato, Fig.4.21. Tomato plants grown under reduced light regimes had significantly higher lycopene content. Plants that received L2 (673.70 Lux) had the most deep red colour, followed byL3 (450.44 Lux), while L1 (897.89 Lux) was minimal. The order of lycopene contents was L2> L3 >L1 (Fig. 4.21).

Phenological stages had effect on lycopene content of tomato Fig. 4.22. Regulation of light intensity at the onset of flowering had highest lycopene content (0.24 mg kg^{-1}) whereas, 50% fruiting and fruit physiological maturity had similar results (0.23 and 0.23 mg kg^{-1}) while active vegetative had the least lycopene content (0.22 mg kg^{-1}) Fig 4. 22.

Table 4.56: Effect of different light intensities at phenological stages on total phenol (mg kg^{-1}) and vitamin contents (mg kg^{-1}) of three tomato varieties

Treatment	Total phenol	Vitamin		
Light intensity (L1)		A	C	E
L1	0.13a	51.70b	17.87a	0.32a
L2	0.13a	52.54a	17.76a	0.33a
L3	0.13a	52.49ab	17.86a	0.32a
Phenological stages				
Active vegetative	0.13a	51.71b	17.83b	0.33ab
Onset of flowering	0.13a	52.99a	18.05a	0.35a
50% fruiting	0.13a	51.01b	17.69b	0.31b
Fruit physiological maturity	0.13a	52.28a	17.75b	0.31b
Tomato Varieties				
Ibadan local	0.14a	50.61b	17.64b	0.30b
UC82B	0.13b	52.99a	18.01a	0.36a
Roma VF	0.13b	53.14a	17.85ab	0.31b
Interaction				
LI x G	ns	ns	ns	ns
TV x G	**	**	**	**
TV x LI	ns	ns	ns	ns
TV x LI x G	ns	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

The lycopene content in UC82B grown under L2 (673.70 Lux) was more than Ibadan local grown under L1 (897.89 Lux), (Fig 4.23).

4.6.7. Effect of different light intensities at different phenological stages on fruit elemental compositions in three tomato varieties

The effect of different light intensities on the elemental compositions was insignificant. The influence of phenological stages on fruit elemental compositions was also significant except fruit K, Cu and Fe that was not significant.

The regulation in light intensity at fruit physiological maturity recorded the highest fruit K content, whereby, at active vegetative, onset of flowering and 50% fruiting were similar. The fruit Ca content at active vegetative had the lowest Ca, whereas, at the onset of flowering, 50% fruiting and fruit physiological maturity were highest and had similar values. However, fruit Mg content at the onset of flowering (10.18 mg kg^{-1}) got significantly higher than other phenological stages. Highest fruit Zn (0.11 mg kg^{-1}) was recorded at the onset of flowering and fruit physiological maturity, while the onset of flowering and 50% fruiting had the lowest (0.10 mg kg^{-1}).

Varietal effects were also different from one another, except fruit K and Cu content. The P content in Roma VF was more than UC82B and Ibadan local varieties. However, Ca and Mg contents in UC82B were the highest (4.37 and 10.21 mg kg^{-1}), while Ibadan local had the lowest (4.10 and 9.74 mg kg^{-1}). Lastly, the Zn and Fe content were significantly higher in UC82B than Ibadan local and Roma VF varieties (Table 4.57).

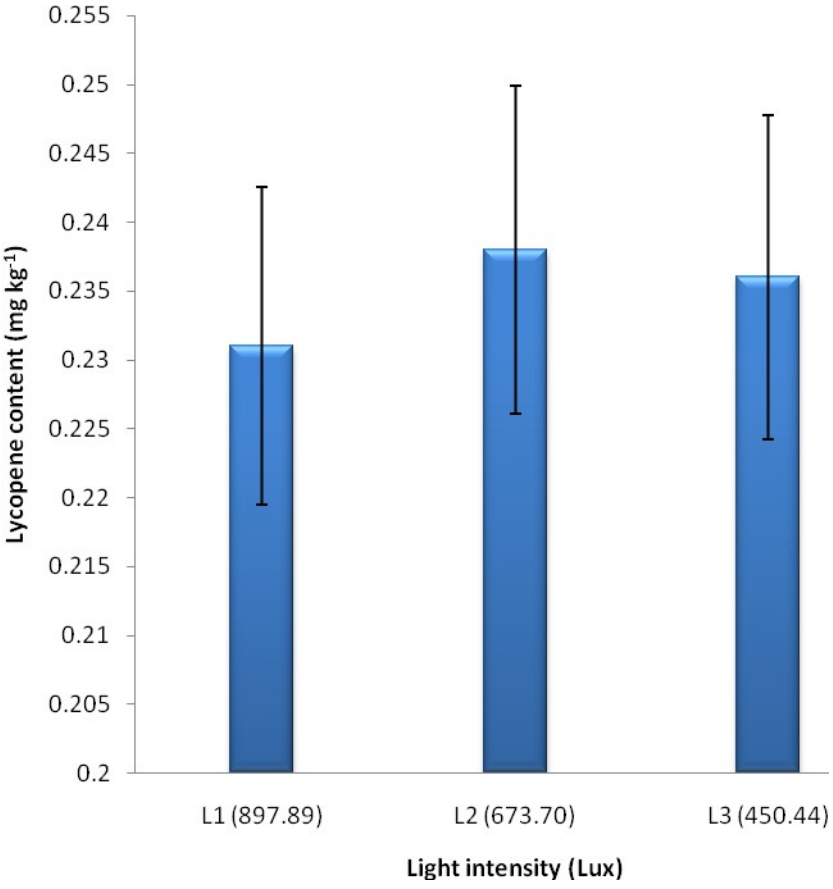


Fig.4.20: Influence of different light intensities on fruit lycopene content of tomato plants.

L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

| = SE bar 5%

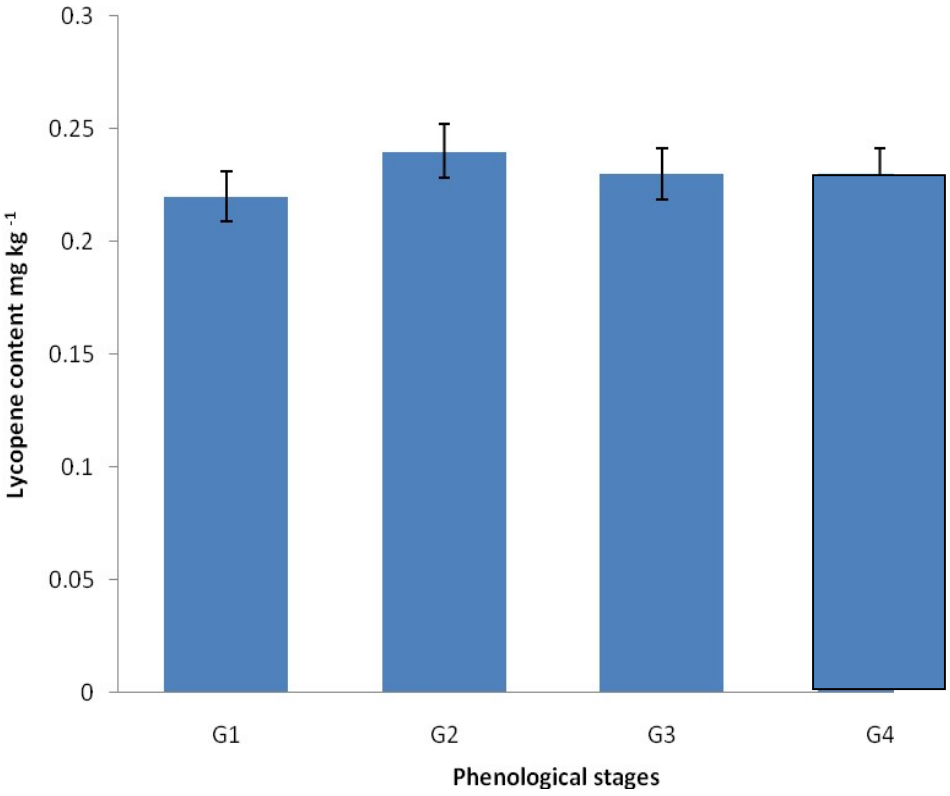


Fig.4.21: Influence of different phenological stages on fruit lycopene content of three tomato varieties grown on the field

G = phenological stages of light reduction; G1 = Active vegetative; G2 = Onset of flowering; G3 = Fruiting and G4 = Fruit Physiological maturity

| = SE bar 5%

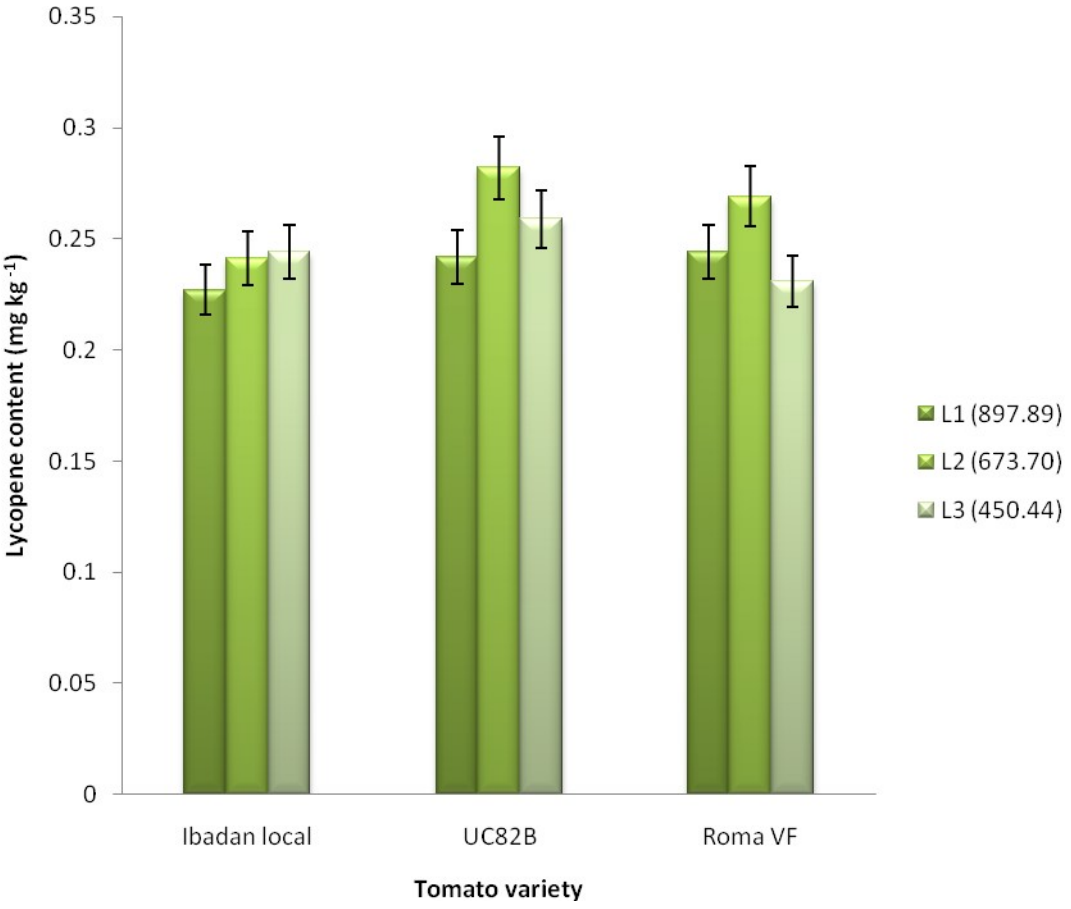


Fig.4.22: Effect of light intensities on fruit lycopene (mg kg^{-1}) content of three varieties of tomato

L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

| = SE bar 5%

Table 4.57: Effect of different light intensities at phenological stages on fruit elemental compositions of three tomato varieties

Treatment	P	K	Ca	Mg	Cu	Zn	Fe
Light intensity (LI)	→	g kg^{-1}	←	→	mg kg^{-1}	←	
L1	18.17a	216.74a	4.29a	9.95a	0.03a	0.10a	0.43a
L2	18.09a	216.44a	4.30a	9.97a	0.03a	0.10a	0.43a
L3	18.28a	217.80a	4.30a	9.95a	0.03a	0.10a	0.43a
Phenological stages							
Active vegetative	17.89b	216.12a	4.24a	9.95b	0.03a	0.10ab	0.43a
Onset of flowering	17.79b	216.30a	4.29ab	10.18a	0.03a	0.11a	0.43a
50% fruiting	18.14b	216.23a	4.33a	9.90b	0.03a	0.10b	0.42a
Fruit physiological mat.	18.75a	216.63a	4.34a	9.81b	0.03a	0.11a	0.42a
Tomato Variety							
Ibadan local	17.60c	216.40a	4.10b	9.74c	0.03a	0.10ab	0.42b
UC82B	18.15b	216.70a	4.37a	10.21a	0.03a	0.11a	0.44a
Roma VF	18,78a	217.80a	4.43a	9.93b	0.03a	0.10b	0.42b
Interaction:							
LI x G	ns	ns	ns	ns	ns	ns	ns
TV x G	**	ns	**	**	**	**	**
TV x LI	ns	ns	ns	ns	ns	ns	ns
TV x LI x G	ns	ns	ns	ns	ns	ns	ns

Means along the column with the same letter(s) are not significantly different from each other using Duncan Multiple Range Test at 5% probability level, ** = significant at 1%; * = significant at 5%; and ns = not significant, L1= 897.89 Lux (uncovered plants), L2 = 673.70 Lux (Single layer net) and L3 = 450.44 Lux (Double layer net).

CHAPTER FIVE

DISCUSSION

Generally speaking, the production of economic yields on certain crop depends on the growing conditions and their interactions with many variables, such as the genetic make-up of the variety of crops, the environment, the mineral nutrition and the cultural practices implemented. The production of photosynthate and translocation within the plant are responsible for various environmental factors, including rainfall, temperature, light and relative humidity, which had a significant effect during the growth of plant and development, fruit yield and nutritional composition. Application of organic fertiliser has been a good source of improving soil organic matter and conventional exercise in retaining soil physical condition and productiveness (Togun *et al*. 2003). Also in this study, different varietal observations with respect to vegetative development in the three varieties of tomatoes cultivated. Ibadan local had higher values for most of the vegetative parameters taken. Togun *et al*. (2003) recorded similar observations on tomato and Akanbi *et al*. (2010) on okra. The varietal differences in this work could be attributed to possible variation in plant genetic potential.

The tomato variety Roma VF performed better in number of marketable fruits / plant, fruits dry matter yield, compared to Ibadan local and UC82B. The greater development and yield components recorded in Roma VF had higher fruit dry matter yield. This variety might also have a better hereditary makeup for the use of the environmental factors like light intensity, temperature, relative humidity and nutrients compared with local types. In terms of fruit yield, UC82B was the best despite the fact that it had lower dry matter yield. It could be because of better partitioning of dry matter into economic part (fruits) in UC82B variety. A similar observation was observed in cucumber by Marcelis (1996) who reported an increase in dry matter partitioning into the fruits due to nutrient uptake and shoot activity source strength.

The findings from this research also revealed differences in the yield of tomato plants as a result of applied fertilisers. Maximum plant height, number of leaves and leaf area at different growth stages were significantly influenced by the applied fertilisers compared to

control. These parameters were high in 120 kg N/ha CPOF I (T4). This could be due to slow and steady release of nutrients. The response was contrary to the report of Sharma (1995) on tomato where better growth performance of plants treated with mineral fertiliser was recorded.

The increase in components of yield could be related to the performance at vegetative stage, which improved height of the plant, stem girth, branches number and leaf area in the tomato plants. Enhanced growth, yield components and fruit yields was due to application of fertilisers as it improved organic matter in the soil (Naidu *et al*., 2002), favouring uptake and use of nutrients. More so, substantial nitrogen content available in organic fertilisers consisted of uric acid that was readily accessible to crop thereby resulting in better crop performance.

Application of fertilisers improved yield, which could be ascribed to the higher nutrient absorption from the fertilisers which positively affected chlorophyll concentration of the leaves, ensuing improved carbohydrates synthesis and build up of new cells. This investigation supported the conclusion of Sharma (2017) that reported an essential improvement of chlorophyll concentration and protein synthesis regulation due to application of fertilisers.

On the other hand, among the mineral fertilisers, the yield of urea mineral fertiliser was also high, but not in comparison to other fertiliser types. This may be attributed to imbalance and low nutrient supply than what was needed by the plant in the course of amendment. The outcome of physiological and yield parameters were low in the plants that received this treatment. Such fruit yield variation in response to nutrient source was also reported in tomato by Oikeh and Asiegbu (1993).

Varietal differences and fertilisers affected various yield parameters of tomato. Among the interactions, UC82B variety grown with 120 kg N/ha CPOF II (T5) recorded an appreciably higher yield. This interactive effect of fertilisers and tomato varieties on growth could be due to macro and micro nutrients likewise growth hormones, which have been reported to enhance organically fertilised crops. This result is in line with the findings of earlier

researchers: Aliyu and Kuchinda (2002) on pepper where they reported significantly greater performance and yield parameters due to good nutrient supply from organic fertiliser.

At fruit maturity and ripening stages, the fruits undergo physiological and biochemical changes which determines the nutritional quality of the fruits. The fruits with high phytochemicals composition and phytonutrient like vitamins, lycopene and carotenoid etc. are generally preferred as good quality fruits. However, the degree of variability could differ with variety and fertiliser types. Therefore, having favourable nutrient source and availability during fruit formation is an essential pre-requisite for having high quality tomato fruits. In this study, apart from crude protein, UC82B was best in fruit quality, recording greatest original value in support of the food quality parameters. The fruit from this variety was superior in terms of fruit ether extract, total carbohydrate, K, vitamins A and C and lycopene contents of tomato fruit. The next best variety was Roma VF which had the best fruit crude protein. The lowest performance in terms of fruit quality parameters was observed in Ibadan local. Similar variation in varietal performances in terms of fruit nutritional composition was reported in three tomato varieties by Olaniyi *et al*. (2010).

The better quality of fruit from organically grown fruits may be due to the applied nutrients and other phytohormones that promote growth during organic manure decomposition. This might have helped in accelerating the uptake of nutrients, most importantly micro nutrients that are involved in various enzymatic and metabolic processes. Similar results of better quality fruits with the use of organic nutrients were reported by Hsiech-Chingfung and Hsukuonan, (1994).

The superiority of UC82B and 120 kg N/ha CPOF I (T4) combination compared to others may be due to the effects of good genetic makeup of the UC82B variety with better supply of nutrients by 120 kg N/ha CPOF I (T4) fertiliser treatment. Similar variations in crop fruit nutritional composition in response to different fertilisers have been reported in pepper (Sharu and Meerabai, 2001).

In most cases, the application of pelletized organic fertiliser enhanced the development of growth parameters. The area of the leaf and dry matter yield were all enhanced through the use of pelletized form compared to other fertiliser forms. This may be as a result of better

nutrient availability in pelletized organic fertiliser. The higher plant growth observed with the use of organic fertiliser in a pelletized form as compared to the other fertiliser forms in both seasons confirms the report of Stewart *et al*. (2000) that nutrient availability and retention in the soil determines the plant vegetative development.

The dry matter yield was also influenced by the use of pelletized organic fertiliser form in both seasons. The early tomato plants however accumulated more dry matter than the late seasoned irrespective of fertiliser form. This is an indication that early season plants had better opportunity for capturing and utilizing solar radiation, which was endorsed by Crozier *et al*. (1997).

Higher fruit yield in tomato treated pelletized form of organic fertiliser in the early season might also be due to higher nutrient uptake with this fertiliser form and presence of adequate water. This facilitated better photosynthetic and food partitioning of dry matter to fruits. A similar report was stated by Olaniyi *et al*. (2010) and the increased photosynthetic activity of plants has been endorsed following storage of dry matter. Akanbi *et al*. (2010) reported similar results; Akanbi (2010) and Babajide (2012) noted that higher dry matter yields observed with the use of pelletized fertiliser might be because of increased area of the leaf development and longer maintenance of functional leaf recorded for this fertiliser form during the growth period.

Light intensities influenced vegetative parameters and tomato fruit yield tested in the study. Light regulation promotes the growth of tomato compared to the plants that were exposed to full light. This shows that in tomato, optimum chlorophyll formation needs full light intensity. This is in line with the report of Manaker (1981). The imposition of light reduction at different phenological stages also influenced the performance of tomato.

In this study regulation in light intensity at the vegetative stage interfered with assimilate production and partitioning. This might be the reason for better growth of the plants at this stage. In the case of leaf chlorophyll content, reduction of light at the vegetative stage produced plants with higher chlorophyll contents. Plants with less strength of light had higher area of the leaf at the onset of flowering stage than untreated plants. In accordance

with Odeleye (1998) findings that plants grown under reduced light intensities had broad and better leaves than unshaded plants.

Dry matter partitioning was significantly influenced by light regulation and stages of the imposition of the light. Ibadan local had the highest dry matter production over the two other varieties. It may be because of the higher leaf numbers and leaf area/plant. These parameters supported the total photosynthetic surface of the plant and hence the quantity of photosynthates produced. A similar result was obtained by Akanbi (2002) on Okra.

In terms of the partitioning of the total dry matter produced, tomato variety UC82B partitioned more materials into the leaf than the two other varieties. Phenological stages of light reduction also influenced the dry matter production. The lower the amount of light received the higher the dry matter production. Those plants grown under L3 (450.44 Lux) light intensity had higher dry matter (Buriol *et al*., 2000).

In the recent research, significant enhancement of dry matter production recorded for plants under reduced light intensity may be as a consequence of reduction in the net respiration as high sunlight could trigger off excessive respiration which might lead to loss of substantial amount of stored dry matter. This is supported by the report of Challa and Bakker (1998). The lower dry matter accumulation recorded in tomato plants treated at vegetative stage may be possibly due to the fact that plants that suffered light reduction at vegetative stage might not be able to recover from the shock, hence lower partitioning and dry matter production. The research related to reports by Odeleye (1998) who obtained lower dry matter production among soyabean plants subjected to different light intensities.

On the varietal effect, higher leaf area/plant, number fruits/plants and percentage fruit set could be attributed to higher number of leaves which was more common in Ibadan local than the two other varieties. The variety had more leaves which could have been used to produce higher dry matter that is required to sustain higher number of flowers and fruits. Related work was done by Buriol *et al*. (2000).

The fruit yield and yield parameter varied based on the treatments with higher fruits weight, and overall fruit yield observed in UC82B. Although Ibadan local recorded the highest

number of fruit/plant, but its fruit yield was lower than that of UC82B. It means that crop may produce many small fruits, the aggregate weight of which may be less than what could be obtained from a variety with lower number but bigger fruits. This is related to results of Olaniyi *et al*. (2010) that experienced disparities in fruit yield production potentials of different varieties of tomato plant.

Fruit yield and yield parameters were better in tomato that experienced L2 (673.70 Lux) light intensity at the vegetative stage. It was suggested that plants that were treated at this phenological stages were able to recover and still produce the best fruit yield compared to the other phenological stages. It could be deduced that light reduction at early growth stage may not have a deleterious effect on fruit production in tomato. Akanbi (2002) reported similar result on okra.

Tomato fruits proximate compositions were significantly influenced by variety, light and phenological stages. Among the varieties tested, UC82B had the highest crude protein, ether extract, total ash, total soluble solids and sugar. It could be inferred that fruits of UC82B are more nutrititious compared to other varieties. This may be due to the fact that the variety is more efficient in the biosynthesis of organic compounds which are of nutritional importance or that it is more efficient in the partitioning of organic compounds into the fruit. This improves the fruit quality over what was observed in the other varieties. These observed variations in the nutritional content of different crop varieties been reported earlier (Olaniyi *et al*., 2011).

However, plant grown under full light L1 (897.89 Lux) had higher crude protein and total ash due to high solar radiation which may be required for biosynthesis and accumulation of these essential tomato fruit nutritional attributes. This supported the report by Katura *et al*. (1996), which reported a greater production of dry matter by high light intensity. This supported the growth of plant parameters and improved production of dry matter and translocation of photosynthate into plant economic parts such as fruit (Akanbi, 2002).

Light reduction at flowering stage tends to enhance higher accumulation of crude protein and ether extract compared to other stages. This might be due to the remobilization of materials accumulated in the plants during the early growth stages into fruits which in turn

leads to improved production of these fruit products. Accumulation of vitamins A, C, and E and lycopene in three varieties of tomato fruits was enhanced by light reduction at flowering stages. These parameters increased with reduction in light and reached maximum value in plants that received L2 (673.70 Lux) light intensity. Accumulation of tomato phyto-nutrients in the fruits had been reported by Govindacharya (2004) to be favoured by light reduction.

SUMMARY, CONCLUSIONS AND RECOMMENDATION

Tomato fruit cultivation is increasing rapidly throughout Nigeria due to increase in awareness of its nutritional importance, despite many production constraints which had considerably limited the crop yield. The elevated price, scarcity and environmental hazard associated with application of chemical fertilisers had placed them beyond the reach of many farmers. Apart from this, the form of application of different available organic fertilisers coupled with variability in amount and intensity of solar radiation received by plants in tomato production area in Nigeria had placed limitation in the yield of the crop. Hence, the need for this study is to investigate the most suitable form, source and optimum rate of organic fertiliser for optimum production of different tomato varieties under different solar radiation. To shed light on the role of these production factors, three experiments were carried out between 2012 and 2014 at the University of Ibadan, Ibadan and Ladoke Akintola University of Technology, Ogbomoso. The experiments aimed at determining the effects of different light intensities and various organic fertilisers on growth, yield of and dietary of tomato fruits. This is the summary of the results obtained:

1. For optimum production of tomato, the soil should be augmented with fertilisers. Different organic fertilisers were found to consist of different concentrations of macro and micro nutrients. The chemical analysis of organic fertilisers indicated high nutrient contents, but no heavy metals like Pb and Se. This confirms the appropriateness as organic fertiliser in tomato production. The organic source of nutrients had better fruit yield and quality than the case where no fertiliser (T9) or mineral fertiliser (T8) was used. The application rate of organic fertilisers must be based on nutrient needs. The higher mean values of morphological and components of yield of tomatoes was obtained with 120 kg N/ha CPOF I (T4). The plant performance with this treatment was better than the situation where only NPK was applied. Application of fertiliser improved tomato crop nutrient uptake. The highest nitrogen, phosphorus, potassium, zinc and copper in tomato plant was achieved through 120 kg N/ha CPOF I (T4). The Fe uptake was found to be more favoured by application of inorganic fertilisers.

2. The Ibadan local variety gave the highest vegetative and dry matter yield than UC82B and Roma VF. However, variety UC82B gave the highest fruit yield. The fruit yield of UC82B

was similar to Roma VF, but both were higher than Ibadan local.

3. Season significantly influenced tomato growth, fruit yield and its quality. Development of vegetative parameters was better in early season plants. However, in terms of fruit yield and quality, late season plants performed better. The fruit lycopene, vitamins A and E, total flavonoid and carotenoid were all better in the fruits of late season plants, but in the case of vitamin C and total phenols, they were higher in early season plants.

4. Forms of organic fertiliser determine their effectiveness in supplying needed nutrients to tomato plants. Application of organic fertiliser in the form of pellet enhances growth and fruit yield. The treatment also brought about higher biosynthesis and accumulation of nutritional attributes of tomato fruit. This enhanced the fruit quality which has health benefits in human being.

5. Tomato fruit ripening stages influenced the nutritional quality. The nutritional attributes of tomato fruit increased gradually from green stage to deep red stages. The fruit crude protein, total ash, dry matter, total sugar, vitamin E, total phenols and lycopene contents were more present in the deep red tomato fruits. The values for these parameters were low in most cases, with mature green fruit. But in the case of fruit vitamin C, crude fibre and acidity contents the reverse was the case. These parameters were more in mature green fruit compared with what were obtained with deep red fruits.

6. Variation in light intensity during different phenological stages significantly affected development and fruit yield of tomato plants. Growing tomato at reduced light intensity reduced the vegetative growth of tomato, particularly if the treatment is applied at the vegetative phase of growth. Reduction of light reduced chlorophyll concentration in the leaves of treated plants. This implies that high solar radiation is required for chlorophyll formation in tomato plants. The reduced light intensity at different growth stages had minimal effects on vegetative growth of Ibadan local variety. However, this failed to be translated into higher fruit yield as this variety recorded the poorest yield under reduced solar radiation and irrespective of the phenological stage at which the treatment was augmented. Dry matter production and accumulation were higher in plants treated with light reduction. Accumulation of dry matter was lowest among plants treated at vegetative growth

stages. Light reduction increased fruit yield in tomato plants. This becomes more pronounced when the light restriction was imposed before flowering. It was also observed that light reduction at fruiting and fruit physiological maturity stages had negative effects on fruit yield. Light regulation favoured biosynthesis and accumulation of phytonutrient compositions of tomato fruits. Plants grown under reduced light intensity had higher fruit crude protein, lycopene, vitamins A and C, and Ca contents.

CONCLUSION

Conclusions from the series of experiments in this study are as follows:

1. Application of organic fertiliser is required to improve soil concentration, essential nutrients and organic matter.
2. Application of 120 kg N/ha CPOF I (T4) enhanced growth and productivity of tomato.
3. The UC82B tomato variety gave more productivity with fertiliser application as well as reduction in light intensity. It gave higher fruit yield over that of Ibadan local and Roma VF.
4. Irrespective of variety, fruits of late season tomato plant had higher nutritional values than early grown ones.
5. Harvesting of tomato fruit at deep red ripening stage gave fruits with the best proximate, elemental and phytonutrient contents.
6. Light reduction in tomato enhanced fruit yield and accumulation of phytochemical compositions in tomato fruits.

RECOMMENDATION

In conclusion, for the best production of tomato, application of 120 kg N/ha commercially produced organic fertiliser could be applied. The effectiveness of this organic fertiliser could be improved when it is formulated and applied in a pelletized form. Also, reduction in the amount of light intensity most especially at active vegetative stage is recommended as it enhanced performance of tomato production.

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Rainfall pattern, maximum and minimum temperature during 2012 and 2013 planting season at Ogbomoso.

Month	Amount of Rainfall (mm)		Temperature (^{0}C)			
			Minimum	Maximum	Minimum	Maximum
	2012	2013	2012	2012	2013	2013
January	0.00	0.00	22.8	35.0	22.8	35.0
February	8.7	6.7	21.0	40.0	21.0	40.0
March	10.8	8.4	24.0	35.0	24.0	35.0
April	146.5	104.2	26.8	35.0	26.8	35.0
May	100.2	78.4	28.8	33.8	28.8	33.8
June	135.5	125.4	27.8	35.0	27.8	35.0
July	127.9	110.1	28.3	33.8	28.3	33.8
August	54.3	20.2	27.2	33.8	27.2	31.6
September	173.3	140.3	28.0	30.0	28.0	30.0
October	158.5	115.4	27.8	31.6	27.8	31.6
November	20.0	6.7	24.1	38.5	24.6	38.8
December	00.0	1.4	23.2	38.7	23.4	38.8
Total	935.7	717.2	309.8	420.2	310.5	418.4
Mean	78.0	59.8	25.8	35.0	25.9	34.9

Source: Department of meteorological, Ministry of Aviation Ilorin.

Temperature, Rainfall and Relative humidity condition of University of Ibadan (April - December, 2014)

	Temp (^{0}C)			Relative humidity (%)	
	Maximum	Minimum	Rainfall (mm)		
	Mean	Mean	Mean	Minimum	Maximum
April	33.6	23.5	1.1	67.8	84.9
May	32.6	24.3	3.6	75.2	84.7
June	31.4	23.2	3.4	78.0	84.3
July	29.3	23.1	1.7	74.9	83.3
August	28.4	22.9	2.2	76.0	83.9
September	29.8	22.6	2.5	78.5	85.5
October	31.1	22.7	4.7	79.7	85.9
November	32.8	23.8	3.1	75.3	86.5
December	35.0	22.8	0.0	52.5	80.2

Source: Department of Geography, University of Ibadan, Ibadan Nigeria.

APPENDIX I

Soil weight = 10 kg $\quad \frac{Plot\ size}{10\ 000} x \frac{Rate}{Nutrient\ cont} x \frac{100}{1}$

T1: Commercially Produced Organic Fertiliser (CPOF I): Rate = 60 kg N/ha, Nut.cont. = 3.0 $= \frac{10kg}{2 x 10^6} x \frac{60}{3.0} x \frac{100}{1}$ = 0.01 kg x 1000 = 10 g/pot

T2: Commercially Produced Organic Fertiliser (CPOF II): Rate = 60 kg N/ha, Nut. cont. = 3.5 $= \frac{10kg}{2 x 10^6} x \frac{60}{3.5} x \frac{100}{1}$ = 0.00857 kg x 1000 = 8.57 g/pot

T3: Commercially Produced Organic Fertiliser (CPOF III): Rate = 60 kg N/ha, Nut. cont. = 2.5 = $\frac{10kg}{2 x 10^6} x \frac{60}{2.5} x \frac{100}{1}$ = 0.012 kg x 1000 = 12 g/pot

T4: 120 kg N/ha CPOF I: Rate = 120, Nut cont = 2.4 = $\frac{10kg}{2 x 10^6} x \frac{120}{3.0} x \frac{100}{1}$ = 0.02 x 1000 = 20 g/pot

T5: 120 kg N/ha CPOF II: Rate = 120, Nut cont. = 2.5 = $\frac{10kg}{2 x 10^6} x \frac{120}{3.5} x \frac{100}{1}$ = 0.00875 x 1000 = 8.75 g/pot

T6: 120 kg N/ha CPOF III: Rate = 120, Nut cont. = 0.6= $\frac{10kg}{2 x 10^6} x \frac{35}{2.5} x \frac{100}{1}$ = 0.00972 kg x 1000 = 9.72 g/pot

T7: Urea + SSP and MOP, calculated values was bulked together for treatment T7

Urea = $\frac{10}{2 x 10^6} x \frac{60}{46} x 100$ = 0.0006521 x 1000 kg = 0.65 g.

P = $\frac{10}{2 x 10^6} x \frac{35}{18} x 100$ = 0.0097 x 1000 kg= 0.97 g.

K= $\frac{10}{2 x 10^6} x \frac{30}{60} x 100$ = 0.00025 x 1000 kg = 0.25 g

T8: Urea: Rate = 60 kg N/ha, Nut content = 46%

$= \frac{10kg}{2 \times 10^6} x \frac{60}{46} x \frac{100}{1}$ = 0.0006521 kg x 1000 = 0.65 g/pot

T9: Control (No treatment)

FIELD EXPERIMENT

Fertiliser Requirement: $\frac{Plot\ size}{10\ 000} x \frac{Rate}{Nutrient\ cont} x \frac{100}{1}$

Plot size = 2 x 3 m^2 = 6 m^2

T1: Commercially Produced Organic Fertiliser (CPOF I). Nut cont = 3.0% N, Rate = 60

kg N/ha = $\frac{6m^2}{10\ 000} x \frac{60}{3.0} x \frac{100}{1}$ = 1.2 kg x 1000 = 1200 g/plot

T2: Commercially Produced Organic Fertiliser (CPOF II). Nut cont = 3.5% N, Rate = 60

kg N/ha = $\frac{6m^2}{10\ 000} x \frac{60}{3.5} x \frac{100}{1}$ = 1.03 kg x 1000 = 1028.6 g/plot

T3: Commercially Produced Organic Fertiliser (CPOF III). Nut cont = 2.5 % N, Rate = 60

kg N/ha = $\frac{6m^2}{10\ 000} x \frac{60}{2.5} x \frac{100}{1}$ = 1.44 kg x 1000 = 1 440 g/plot

T4: 120 kg N/ha (CPOF I). = $\frac{6m^2}{10\ 000} x \frac{35}{1.4} x \frac{100}{1}$ = 1.5 kg x 1000 = 1500 g/plot

T5: 120 kg N/ha (CPOF II). = $\frac{6m^2}{10\ 000} x \frac{35}{2.0} x \frac{100}{1} = 1.05$ kg x 1000 = 1.050 g/plot

T6: 120 kg N/ha (CPOF II) = $\frac{6m^2}{10\ 000} x \frac{35}{1.8} x \frac{100}{1}$ = 1.1666 kg x 100= 1.167 g/plot

T7: Urea + SSP and MOP, calculated values was bulked together for treatment T7

Urea = $\frac{6m^2}{10\ 000} x \frac{60}{46} x\ 100$ = 0.07826 x 1000 kg = 78.3 g

P $\frac{6m^2}{10\ 000} x \frac{35}{18} x\ 100$= 0.11666 kg x 1000= 116.67 g

K $\frac{6m^2}{10\ 000} x \frac{30}{60} x\ 100$= 0.03 kg= 30 g.

T8: Urea Nut cont = 46% N, Rate = 60 kg N/ha= $\frac{6m^2}{10\ 000} x \frac{60}{46} x \frac{100}{1}$ = 0.078 kg x 1000 = 78 g/plot

T9: Control (No fertiliser)

Table 53: Mean values of light measurements (in lux) taken within and outside, the cages used for this experiment inside crop garden and on the field.

Crop garden

	Sunny day			Rainy day			
	8 am Morning	2 pm Afternoon	6 pm Evening	8 am Morning	2 pm Afternoon	6 pm Evening	Grand mean
Outside L1 (100%)	1362.514	1364.423	628.671	871.259	648.327	663.105	923.050 lux
Single layer net L2	829.140	630.321	1144.425	518.122	687.680	249.493	693.030 (75.08 lux)
Double layer net L3	675.00	648.00	179.00	621.370	461.295	195.00	463.278 (50.19 lux)

Field

	Sunny day			Rainy day			
	8 am Morning	2 pm Afternoon	6 pm Evening	8 am Morning	2 pm Afternoon	6 pm Evening	Grand mean
Outside L1 (100%)	1455.213	470.161	330.191	1184.521	1128.175	668.095	872.726 lux
Single layer net L2	661.110	1327.015	245.427	641.210	772.280	279.147	654.365 (74.97 lux)
Double layer net L3	539.026	908.411	225.281	385.313	370.429	197.171	437.605 (50.1 lux)

Values for L1,L2 and L3 for both pot and field were added to get a single value for L1-897.89, L2-673.70 and L3-450.44 Lux
Light intensity within the cage expressed as a percentage of light intensity outside.