RESPONSE OF TOMATO (*Solanumlycopersicon*Mill) VARIETIES TO IRRIGATION INTERVAL AND STAND DENSITY IN NORTHERN GUINEA AND SUDAN SAVANAH OF NIGERIA

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DEPARTMENT OF AGRONOMY,
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MARCH, 2021

DECLARATION

I declare that the work in this dissertation titled "**Response of Tomato (*Solanumlycopersicon*Mill) Varieties to Irrigation Interval and Stand Densities in Northern Guinea and Sudan Savanahof Nigeria''**has been carried out by me in the Department of Agronomy under the supervision of Prof. A. A Muhammadand Dr I. L Hamma. The information derived from the literature has been duly acknowledged in the text and a list of references provided.

USMAN MunkailaBara'u …… …….. ……
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The above declaration is confirmed

Professor A.A Muhammad ……. ……..
Chairman, Supervisory Committee Date Sign

CERTIFICATION

This thesis dissertation**"Response of Tomato (*Solanumlycopersicon*Mill) Varieties to Irrigation Intervaland Stand Densities in Northern Guinea and Sudan Savanah of Nigeria"**by USMAN MunkailaBara'umeets the regulations governing the award of the degree Master of Science in Agronomy of the Ahmadu Bello University, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my mother HajiyaAishat Al -Qasim for her tireless effort and prayers to success of this work. May Allah (S.W.A) continue to give her soundhealth

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ABSTRACT

Field trials were carried out at Institute for Agricultural Research (IAR) Ahmadu Bello University farms in Samaru, Zaria and Irrigation Research Station Kadawa,Kano state during 2017/2018 dry seasons to study the response of tomato varieties to irrigation intervals and stand densities. Treatments consisted of two tomato varieties (UC82-B and ROMA-VF), three irrigation intervals (5, 10 and 15 days) and two stand densities (1 and 2 plants stand^{-1}) which were arranged factorialyin a Split Plot Design with irrigation interval in the main plot while variety and stand density in the sub plot replicated four times. The results revealed that variety ROMA-VF recorded significantly taller plants with higher value for dry matter, numbers of leaves, and branches than UC82-B at Samaru. The same variety took longer days to attain 50% flowers whereas UC82-B recorded significantly superior yield parameters (fruit diameter, fruit weight per plant, total fruit yield in tons ha^{-1}, marketable yield and total fruit number) in both locations. Application of water had significant effect especially on most growth parameters assessed at Samaru. Increasing irrigation interval from 5, 10 and 15 days linearly decreased plant height, number branch and leaf area index (LAI) at all sampling period in Samaru. Linear decrease in fruit weight per plant,fruit diameter and fruit yield was observed with increasing irrigation interval from 5 to 15 days at Samaru. Some parameters were not significantly influence by varying irrigation interval at Kadawa. The effect of stand density was significant on parameters such as number of branch 7WAT, leaf area index, leaf area, dry matter, CGR, RGR, days to 50% flowering, average fruit weight, total fruit weight, and total number of fruits. Higher values of most yield parameters were obtained with 2 plant stand^{-1} in both locations. At Samaru, there was a significant positive correlation between tomato fruit yield and all the yield and growth parameters assessed except dry matter, fruit diameter and unmarketable fruit yield. Similarly, the relationship between marketable

fruit yield was also significant and positive with all the parameters assessed except with dry matter which had no significant correlation. However, the unmarketable fruit yield had positive and significant correlation with only plant height but no correlation with other parameters assessed. At Kadawa, the relationship between tomato fruit yield was positive and highly significant only with marketable (0.997), and unmarketable fruit yield (0.573). Similarly, relationship between marketable fruit yield was only found significant and positively correlated with dry matter and unmarketable fruit among all the yield and growth parameters assessed in this study. Regression analysis of tomato fruits yield against irrigation interval at Samaru and Kadawa. The result indicated that yield responded linearly negative to irrigation interval at Samaru. However, a polynomial trend of relationship was obtained at Kadawa where 15 days recorded higher fruit yield in tons^{-1}.Based on the result obtained in this study, it could be concluded that, the use of 2 plant stand^{-1} in combination with 5 days in Samaru and 15 days at Kadawa irrigation interval gave the best marketable fruit yield of tomato in tons ha^{-1}. Similarly, variety UC82-B was better than ROMA-VF in terms oftotal fruit yield and marketable yields.

CHAPTER ONE

1.0 INTRODUCTION

Tomato (*Solanumlycopersicon Mill*) belongs to the family *Solanaceae.* It is believed to have originated in Peru-Ecuador. It spread many parts of America and was domesticated in Mexico (Anons; 2011). It is the most widely grown and most important vegetable in the country (Ramalan*et al.*, 1998). World production of tomato in 2017 was 182,301,395 metric tons with China leading with 59,626,900 metric tons, while Nigeria is 13th in the world and the fourth producer in Africa and leads in West Africa sub region with an estimated output of 4,100,000 metric tons (FAO, 2017).

The crop tolerates acid soils and prefers well drained sandy loam soil. Liming is unnecessary unless the soil pH is below 5. It's cultivated during both rainy and dry seasons (harmattan period) using irrigation. The crop is grown throughout the year, the best period for production in Nigerian Savanna is dry season when the weather is cooler and the incidence of pests and diseases is minimal (Anonymous, 2000). Large scale tomato production in Nigeria is mainly under irrigation in the dry season, when temperatures are mild and humidity is moderate. The period between March to June is normally too hot for successful tomato production. The rain fed crop (June to September) is also important due to continuous demand for fresh tomato (Ibrahim, 1999).

In Nigeria, tomatoes ranks first among other vegetables with domestic demand of about 2.3 million tons of fresh fruit annually. The national production of 1.8 million tons is estimated, with waste of over 750, 000 tons. Nigeria estimated tomato import bill of N16 billion makes up for shortfall in local production(FMARD, 2015). Nigeria ranks fourth in tomatoes

production in Africa, and the 13th in the world (FAO, 2011). Nigeria is not on the official list of exporting countries of tomato or tomato products. The productivity and economic value of this vegetable crop in Nigeria is hindered by an array of factors that make its cultivation difficult and cumbersome.

Large scale processing of tomato is done into various canned and bottled products such as puree, ketchup and juice for human consumption. Some varieties exhibits medicinal qualities as evident in its flavonoid, carotenoids, vitamin A, xanthins, lutein, vitamin c,and potassium content.The seeds of tomato contain about 24% oil, which can be extracted and used as salad oil, and in the manufacture ofmagarine and soup. After oil extraction the residual cake is used as livestock feed and manure (Werner, 2000). Tomato fruit is a good source of many essential nutrients and vitamins. The proximate analysis showed that 100g of tomato fruit contains; 94ml water, 1g ofprotein,4 gof carbohydrate, 0.6gof fiber,5mgof calcium, 0.4mg ofiron, 0.4mg of vitamin A, 0.7mg ofnicotinamide, 25mg of ascorbic acid, 0.06mg of thiamine and 0.04mg ofriboflavin (FAO, 2007).

1.2Justification and Objectives

Production of vegetables is the major occupation of peoplein Kaduna and neighboring states of north western Nigeria, more especially during dry season when raining season cultivation is over. Virtually the tide of rural urban migration and both is an income generation and source of employment to a large population of otherwise redundant labour force.

Study in many part of the world have shown that tomato production can be enhanced through appropriate cultural practices (Helyes*et al.,* 1999, Hernado and Orihvel*et al.,*1979), though responses vary with weather and soil condition.

Tomato production in Nigeria is very low in terms of yield per hectare (5-10 tons ha^{-1}) compared with China (48.1 tons ha^{-1}). This could be due to several factors such as unavailability of inputs like improved varieties and proper irrigation schedule (Balarabe, 2012) among others. The margin between farmers' and potential yields of tomato in Nigeria is as a result of several constraints that limit tomato production which are either environmentalor agronomic.High temperature, humidity and improper irrigation schedules during the dry season are among the major environmental constraints in tomato production. Agronomic or cultural factors limiting yield of tomato include, low stand density and use of unimproved varieties (Rilwanu, 1999). Other factoris inappropriate use of irrigation water (Husaini, 2007). Any measures that alleviate some or all of the constraints will certainly improve growth and yields performance of tomato. Proper irrigation will help prevent economic losses in yield and quality caused by over or under irrigation; reduce loss of nutrients, pesticides and other chemicals to groundwater, prevent waste of water resources and support more efficient energy consumption. Proper irrigation can lead to increased yields, greater farmer profit, significant water savings, reduced environmental impacts, and improved sustainability of irrigated agriculture (Montoro*et al.*, 2011). Farmers commonly irrigate every three to seven days. Rilwanu,(1999) suggested that,stand density above 1 plant $stand^{-1}$ is needed to improve yields depending on variety. It's in view of these premises that the present work was conducted with the following objectives;

1. To assess the effect of irrigation interval on growth and yield of tomato in the Nigeria savannas
2. To determine suitable tomato variety for production under dry season in the Nigeria savanna.

3. To assess the effect of stand density on the growth and yield of tomato under irrigation conditions.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Effect of Variety on Performance of Tomato

Varieties differ in their growth and yield potential depending mainly on the physiological process which is controlled by interplay of both genetic make-up and the environment. Differential performance of tomato variety could be attributed to genetic variability adaptability, morphological features, and physiological factors during the crop growth period.

In a stu6dy conducted in Nigerian Guinea savannah by Olaniyi*et al.* (2010) using seven varieties of tomatoes DT97-162, DT97-215A, Tropical, Roma VF, UC82B, Ibadan Local and Ogbomosho local revealed that despite environmental constraints encountered by these varieties during the growth period UC82B followed by Ibadan and Ogbomosho local still gave the highest growth, marketable and good quality fruit yield performance. This suggests that UC82B tomato variety has the ability to tolerate the environmental hazards and other yield constraints encountered during the growth periods than other varieties investigated. Olaniyi and Fagbayide (1999) reported that variation in yield may also be due to genetic differences among the varieties since they were grown under the same environmental conditions. Lack of high yielding varieties combined with quality attributes is major constraints in tomato production in the tropics. Olaniyi*et al*. (2010) trial on tomato showed that Ibadan local had higher mean plant height while DT97-215A recorded lowest plant height. They further stressed that tomato plants growth pattern shows an initial slow growth in the nursery stage and the accelerated or exponential growth was observed in the field 8 after the normal slow establishment of the plant after transplanting. In a study

conducted in Tunisia, range of tomato cultivars were evaluated and concluded that tomatoes are adaptable to organic production (Riahi*et al*., 2007).

Tigist*et al*. (2012) in a research to comparefive tomato varieties concluded that varietyFetanehad significant effects on yield. Marglobe, improved had the highest physical quality characteristics while Fetane showed the lowest values. The highest weight loss was obtained in Metadel compared with all other varieties throughout the storage period. Melkasholahad moderatephysical quality characteristics thanthe other two processing varieties while weight loss was almost similar with Roma VF during most of the storage periods. Fresh market tomato fruits had superior physical quality characteristics such as higher fruit weight, volume, specific gravity and juice content than processing fruit varieties. Adedeji*etal.*(2006) indicated that important quality parameters of tomato fruits varies with the types of cultivar including fruit size, volume, juice, specific gravity, maturity etc. The author also explained that factor such as specific gravity, juice, fruit size are specific to a variety which can be used to determine maturity stages and schedule harvest. Absence of defects like sunburn, cracks, blossom end rots; decays, etc are also important criteria for marketable quality of tomato fruits (Duguma, 2000).

(Hussaini*et al*.,2013).Reported that large sized fruits in Petomech VF could be attributed to genetic factor as influenced by the available favorable environmental factors that allowed the plants to grow vigorously resulting in early fruits settings. The fruits utilized the available assimilates that facilitated their expansion and accumulation of more water.Isah (2013) concluded that varieties responded linearlyto growth stages of 5 and7weeks after transplanting(WAT) on plant height, relative growth rate, and crop growth rate (CGR). However, UC82B proves superior over Roma VF on growth indices CGR at 5-7 WAT, net

assimilation rate (NAR) at 7-9 WAT. Similarly, UC82B shows superiority over Roma VF on yield and yield parameters with total fruit yield up to 10.6% higher.

2.2 Effect of Irrigation Interval on Growth and Yield of Tomato

Tomato growth cycle can be divided in to three distinct morphological stages, namely vegetative, flowering and fruiting stages. Salter (2012); Marthin (2013) reported that excessive irrigation delayed crop growth. Jin *et al*. (2000) reported that soil osmotic-stress, which closely correlates with drought, has an impact on growth of both the shoot and the roots of tomato. However, growth of the shoot is affected to a greater extent than that of the roots. Water deficit decreases growth, yield and quality (Byari and Al-Sayed, 1999) Therefore, proper water management is vital for sustainable crop production.

Hussaini*et al.*, (2013) reported that 15 days irrigation intervals gave better growth and yield attributes at Kadawa. This is a clear indication that, tomato needs wider irrigation interval at vegetative and fruiting stages as indicated in more number of fruits, large sized fruits and higher fresh yield when irrigated at 10-15 days interval. Similarly, Martin (1966) revealed that longer irrigation interval increased the percentage of sunburned fruits. Likewise the larger fruits obtained at 10 days interval could be due to more moisture requirement of the crop at a particular development period during reproductive phase which is also influenced by the crop microclimate and assimilate requirement for flower and fruits formation. This necessitates the need for more nutrients and regular moisture supply for efficient assimilation resulting in fruit production with an appreciable size. On the other hand, Mani *et al*. (2007) recorded higher fresh yields when tomato was irrigated at 10 days interval as compared to crop that was irrigated at 15 days interval. However, the non-significant response could be attributed to weather conditions and the high water table of the soil that

kept the soil moisture constant at its upper limit (field capacity). Hernado and Orihuel (1979) found that plant growth and development were significantly affected by irrigation regime with reduction in growth as the irrigation interval was increased from 5 to 10, 15 and 20 days. Thus, the aim is neither to provide excessive water through frequent irrigation nor stress the plants by too long irrigation interval. Rodríguez*et al*., (2010) reported that water stress strongly affects horticultural crops by reducing yield and fruit quality. Also the physiological functions of the crop are reducedby stress due to the formation of reactive oxygen species and water relationships.

Samaila, *et al*. (2011) reported that, 10 day irrigation interval produced the best results in both tomato fruit yield and quality though a 7-day interval is the common practice in the region. (Ramalan, 1994) Experiment showed that in soils with similar characteristics as the one used during the experiment, irrigation can be delayed by a further three days, thus saving water. This indicates that beyond ten-day interval, the available moisture in the root zone has begun to be inadequate for optimum growth. Water is very essential nutrient necessary for the stimulation of rapid vegetative growth, because of its importance in photosynthesis, respiration and other metabolic process. (Rilwanu,1999)Caliandro (1971) where reported an increased in the proportion of unmarketable fruits with increase irrigation frequency. This observation could be associated to too wet condition created by frequent irrigation (5 days interval) which encourages fruit rot. Amans (1992) reported that the proportion of unmarketable fruits increases with irrigation requirement. A number of studies e.g. Obreza*et al.*(1996) indicated that water has an influence on fruit quality,% Brix, physiological disorders (fruit cracking and blossom-end rot), plant growth and yield. The soil water supply and demand by a crop have beenreported to be some of the factors that influence quality and quantity of tomato yield May & Gonzales (1994); Obreza*et al.*, (1996); Sen&Sevgican(1999).

Several researchers have reported that frequency of irrigation and quantity of nutrient solution provided to the crop affect yield and fruit quality (Singandhupe, *et al.*, 2002). Amico*et al.*, (1985) reported that tomato growth and the girth diameter of the plant stem were adversely affected by water stress. They noted a decrease in growth and thickness of the plant stem with water deficit at critical stage of development. But Snyder and Bauele (1985) reported that watering frequencies of 1, 4 and 8 times per day had no significant effect on leaf area and total number of flowers per plant. However, in a trial conducted by Nwadueke (1986) at Kadawa, in the Sudan savannah of Nigeria, tomato cultivars "Ife 1", was used as a test crop using one, two and three week interval. The result showed that one week irrigation interval provided an optimum condition for root growth under deep water- table conditions. But for shallow water two weeks irrigation interval was found to be optimum. Moses (1985) found that irrigation frequency significantly affected all the growth components like plant height, number of branches per plant and number of leaves per plant.

In an experiment carried out on clay soils, an irrigation interval of 7 or 8 days interval was recommended for best yield of tomato (Deidda and Marrus, 2000). The proportion of discarded fruits with blossom-end rot was reduced. According to Abubakar (2014) in a research conducted in Bauchito test the response of tomato to soil moisture depletion least yield was obtained from the plot treated with 30% replacement of moisture depletion and 7days irrigation interval. The highest value of the tomato yield was obtained from the plot treated with 60 % replacement of moisture depleted and 5 days irrigation interval. The yield obtained from this study ranges from 10.90 t/ha to 28.22 t/ha. These values were a bit higher than what was obtained atBauchi. A range of 5 t/ha to 13 t/ha was reported by (BSADP, 2012).

Regulated deficit irrigation saves as a substantial amount of irrigation water and increases water use efficiency (Birhanu and Tilahun, 2010) quoted (kirda*et al.*, 2004). Besides, deficit irrigation reduces production costs, conserves water and minimizes leaching of nutrients and pesticides in to ground water (Nuruddin*et al.*, 2003) and mostly practiced in areas where water scarcity exists. According to Nahar and Gretzmacher (2002), glucose, fructose, sucrose, malic acid, ascorbic acid and citric acid content increased significantly with water stress also sweetness of tomatoes and quality were enhanced. Ethiopia Birhanu and Tilahun (2010) reported decrease in total tomato plant biomass, number and size of tomato fruits as well as increase in fruit dry matter and harvest index (fruit dry matter weight/plant dry matter weight) with irrigation water stress level.

2.3 Effect of Stand Density on Growth and Yield of Tomato

Stand density is the number of individual plants present per unit of ground area. It is easily interpreted in the case of mono specific stand.Annaduraiet *al.* (2010) However, density depends on the germination percentage and the survival rate in the field.Hence, optimum density will lead to effective utilization of soil moisture, nutrients, sunlight etc. When soil moisture and nutrients are not limited, higher density is necessary to utilize other growth factors.Reineke (1933) defined stand density index(SDI)as the relationship between the number plant per unit area and the quadratic mean diameter of stands. Plant height increases with increase in density due to competition for light. Dense plant stands leads to reduction in leaf thickness and alters leaf orientation, dry matter production per unit area increase with increase in stand density up to a limit as in biological yield.Chandrasekaran*et al.*(2010).

Kristof*et al.* (2020) reported that tomato and bell pepper growers in Belgium often increase stem density by increasing the stand density which serves as way to maximize light

interception. However, a denser crop could counteract the positive effects of diffuse glass on the vertical light distribution.

According to Silva *et al*. (2013) increasing density could increase yield through having more plants per unit area, but at the same time, level of inter plant competition increases and often with significant adverse effects on the crop performance. The increase in stand density of tomato plants resulted to a decrease in the number of leaves, flowers, fruits, leaf area, fruit fresh mass and dry mass of the stems. (Salau and Makinde, 2014) in an experiment to test the effect of stand density on growth and yield of Okra established at densities 1, 2 and 3 plants per site (33,333; 66,666; and 99,999 plant ha^{-1}) reported that leaf area was decreased and leaf area index increased. Similarly, there was increase in pod yield ha^{-1} as density increased while number of leaves per plant, number of pod weight per plant decrease as density increased.

Histomi (1972) reported that leaf area and stem thickness were larger than at higher densities. Nguyen Tuan and Thimao (2015) evaluated two planting densities on growth and yield of tomato and observed that higher plant height, number of leaves per plant, number of fruit per plant, fruit weight and fruit yield were recorded with higher density.

According to Larcher (2000) the total assimilates of a plant is directly proportional to photosynthesis, which is a function of the flux density of solar radiation, the atmospheric CO_2 concentration and leaf area. In this sense, increasing density causes a reduction in leaf area per plant and increased shading, and it is expected that the fresh fruit mass decreases with increasing density.In a study conducted at Kadawa, Amans (1988) observed that yield per hectare of tomato responded positivelyto increasing densityfrom 22,200 to 44,400 plant/ha. Withincreasingdensity the negative effect of inter-plant competition and individual plant productivity gradually declined at densities above 44,400 plants/ha, the finding is logically similar asassigning 1 and 2 plants per stand which in turn has direct bearing with yield in tons

per hectare.Argerich (2013) indicated that marketable and total yields were not affected by plant density. Optimal number of plants can be increase in drip irrigation from by doubling plant stand in chilli pepper provided adequate moisture is available. Fruit size is only reduced 10% by increasing number of individual plant standing from 15000 to 30000 plants ha $^{-1}$.

Number of fruits and trusses per plant were dramatically reduced by increasing plant density. Compacted variety was easier to concentrate maturation than vigorous vine type and might be more susceptible to blossom end rot fruits than vigorous vine type under high plant densities.

2.4 Irrigation interval, stand density and variety interaction on Growth andYield of Tomato

Crop response to any environmental factor is often influenced to varying degrees by one or more other factors. Studying the degree or significance of how one factor influences the effect of another factor is a valuable component of factorial experiments.

The interaction between tomato variety and irrigation interval or plant density was reported as being significant in two- years experiment in Sudan (Abdel-Al, 1973). In that experiment, differential responses to irrigation interval (weekly versus fortnightly) were observed among the five varieties tested. Experiments in the Nigerian Savanna indicate that tomato crop response to plant density could vary significantly with the type of cultivar. After years of variety evaluation, Quinn (1980) concluded that some determinate tomato cultivars may require a closer interplant spacing than others. In another experiment with three cultivars planted at varying densities varying between 22,200 and 88,890 plants/ha, Amans (1988) observed some significant factor interactions, although the results were not consistent over the years. In an experiment conducted by the same researcher at Kadawa (Nigeria) under conditions of a high soil water –table, it was found that a plant density helped to ameliorated

the negative effect of excessive soil moisture Amans, (1992). In a trial conducted by Shanmukhi*et al*. (2017) Significant differences were observed in the number of branches, fruits per plant and fruit yield due to variety and planting density combinations and their interactions, the varietyAbhinav recorded the highest number of fruits per plant than variety T124 and stand density at (S2) recorded significantly the highest number of fruits per plant followed by (S3). Crop differences due to variety, stand density and their interactions among the varieties.Abhinavrecorded the highest fruit yield per plot (970.24 kg). Argerich (2013) indicated that marketable and total yields were not affected by plant density. Optimal number of plants can be increase in drip irrigation from 17000-19000 plants ha $^{-1}$. Fruit size is only reduced 10% by increasing from 15000 to 30000 plants ha $^{-1}$, number of fruits and trusses per plant were dramatically reduced by increasing plant density. Compacted variety (XP 2510198) was easier to concentrate maturation than vigorous vine type (PS 2420487) and might be more susceptible to blossom end rot fruits than vigorous vine type under high plant densities. There was significant interaction between irrigation interval and plant density in respect to stem dry weight and fruit yield ha^{-1}. In all of these growth and yield characters, the increase in density from 1 to 2 plants per stand had no significant effects if the irrigation interval in maintained between 5 and10 days. Significant adverse changes in growth or yield attributes were observed as a result of increase in density from 1 to 2 plants per stand only when the irrigation interval was increased above 10days to 15days. These observations showed that when moisture supply was limited by the long irrigation interval (over 10 days), then increasing density above1 plants per standresulted to significant reduction in growth and yield. On the other hand, such adverse effect due to high plant density was not obvious when adequate water supply was provided through shorter irrigation interval. The combination of irrigation intervals of 5 and 10 days with 55,500

plants/ha gave good yields as when combined with the highest density of 83,250 plants/ha. But a longer irrigation interval was detrimental to yield irrespective of the plant density. Irrigation interval at 10 and 15 days resulted in more number of fruits, large diameter and higher fresh yields relative to 20 days intervals.Petomech VF had large sized and more number of fruits compared to UC 82B. There was no significant difference in fresh fruits yield between two varieties. Wudiri and Henderson (1985) reported that tomato CV.'Saladette', performed better then 'VF 145B-7879' under water stress because of itsability to roll its leaves under high evaporative demand, thereby maintaining with high leaf water status as a sort of drought avoidance.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site Description

Field trials were conducted during the 2017/2018 dry season at the Research Farm of the Institute for Agricultural Research Ahmadu Bello UniversitySamaru, Zaria (11^0 11'N, 07^0 38'E, 686 meters above sea level) with temperature of 34.7^0 C and 30.46% relative humidity in the northern guinea savannah and Irrigation Research Station Kadawa,Kano state (11^0 39,N 08^0 02E 500 meters above sea level) temperature of 31^0C and 46.5% relative humidity of the Suddan savanna ecological zone of Nigeria.

3.2 Soil Sampling and Metrological Data Collection

Soils of the experimental fields were collected using W-methods at a depth of 0-30cm prior to land preparation from 15 points at each of the experimental sites using hand auger. The soil samples in each location was bulked, dried, ground, sieved and composite samples was collected and subjected to physical and chemical analysis using standard procedure. Details of soil physical and chemical properties results are presented in table 1.Meteorological data including daily temperature, sunshine hours, and relative humidity during the period of the experiment was obtained from meteorological stations of the Institute for Agricultural Research atSamaru and Kadawa in the seasonsare presented in Appendix 1 and 2.

3.3 Treatments and Experimental Design

The experiment consisted of factorial combinations of three irrigation intervals (5, 10 and 15 days), two stand densities (1 and 2 plants $stand^{-1}$) and two tomato varieties (ROMA-VF and

UC82-B) laid in a split plot design with four replications. Irrigation interval was allocated the main plot while variety and stand density were assigned to sub plot. The gross plot size was 6.0 m × 2.5.0m (15 m^2) while the net plot size was 3.6m × 2.5 m (9.0 m^2).

3.4 Description of the Tomato Varieties

For this research, ROMA-VF and UC82-B varieties were used.

ROMA-VF: This is an open pollinated variety with a height of 121cm and produces numerous branches. It matures in 65-75 days after transplanting (DAT) and has potential yield of 25-30 ton ha^{-1}. It is resistant to common diseases with low resistant to heat set due to it thinner fruit epicarps. The fruits are egg or pea shaped red to yellow in colour with few seeds. The variety is good for canning (Anon 2011).

UC 82-B: This is semi determinate, short or medium in height, with few numbers of branches. It matures in 60-70 days with potential yield of 35 ton ha^{-1}. The fruits are medium – small in size, round and red. It's a processing type with excellent storability when harvested at color break stage, moderate heat tolerant and resistant to cracking (Ibrahim 1999).

3.5.1 Cultural Practices

3.5.2 Seed treatment

Seeds of the tomato varieties were dressed with Apron Star (Metalaxyl and Thiamethoxam) before sowing at the rate of 20 g to 100 g of seeds against soil borne diseases and pest.

3.5.3 Nursery Preparation and Management

Nursery beds of 1m×10m width and length were prepared on the 15th November, 2017 and 29th November, 2018 atSamaru and Kadawa respectively for raising of tomato seedlings. Seeds of each variety were sown on different beds and lightly covered with fine soil tilt. The

beds were mulched with rice straw and watered using a watering can immediately after sowing. As soon as the seedlings emerged after germination the mulching materials were removed. The beds were kept moist and weed free until the seedlings were ready for transplanting at the age of 4 weeks after sowing.

3.5.4 Land Preparation

The experimental fields were harrowed before marking out, check basins of 6.0 m × 2.50 m size dimensions. They were constructed in December, 2017 and January, 2018 in Samaru and Kadawa respectively. The basins were bounded by low bunds in order to retain moisture.

3.5.5 Weed, pest and disease control

Integrated weed management was employed to control weeds. Chemicals, hoe weeding and hand pulling were carried out to controlled weeds for proper plant establishment. Glyphosate was applied at the rate 4 liter ha^{-1} before land preparation using Knapsack sprayer. Two manual hoe weeding were carried out at 3 and 6 weeks after transplanting (WAT). During the cropping season, a regimental spraying of Cypermethrin and Demethoate was carried out fortnightly to control leaf miners (*Helicoverpa*spp) and white flies (*Trialeurodesvaporariorum)*

3.5.6 Transplanting

The seedlings were transplanted according to treatments on the 29th December, 2017 at Samaru and 18th January, 2018 at Kadawa in the late evening hours of the days. The seedlings were transplanted at the age of 4 weeks after sowing. Stand density treatment was

imposed using 60 cm × 60cm inter and intra rows spacing with 1 and 2 plants stand^{-1} for 27,750 plantsha^{-1} and 55,500 plants ha^{-1} respectively

3.6.7 Irrigation

Initially Irrigation was uniformly carried out in the check basin method at 5 days intervals for three weeks after transplanting after which. The irrigation treatments were imposed at both locations.

3.6.8 Fertilizer application

The crop received an application of N P K (15:15:15) fertilizer at the rate of 45kg ha^{-1} of N, 20kg ha^{-1} of P_2O_5 and 37kgha^{-1} of K_2O at one week after transplanting. Additional 65kg of N ha^{-1} was applied as side- dressing in two equal split doses. The first half was applied at 3 weeks after transplanting and the remaining half was applied at 6 weeks after transplanting.

3.6.9 Harvesting

Mature ripe tomato fruits were harvested manually by hand picking seven times at colour brake stage as indicated by colour changes from green to pink or reddish. The harvested, fruits were sorted based on marketable and unmarketable, counted and weighed per net plot using weighing balance.

3.7 Observation and data collection

Three plants per each plot were randomly tagged within the net plots for non-destructive samplings and destructive samples were collected outside the net plot.Observationswere carried out at 5, 7 and 9 weeks after transplanting while yield data were collected at harvest.

3.7.1 Plant height (cm)

Height of the plant was measured from the three tagged plants from the base level to the terminal bud of the plant using a ruler. The average height was calculated per plant and recorded on per plotin centimeter.

3.7.2 Number of leaves per plant

The number of leaves was counted from tagged plants and average was calculated per plant.

3.7.3 Number of branches per plant

The number of primary branches (those arising from the main stem) of each of the three tagged plants/plot was counted and their mean recorded per each plot.

3.7.4 Leaf area index (LAI) and leaf area

Plant leaf area indexes (LAI) were measured at 5, 7, and 9 WAT using ceptometer. The sensor was placed diagonally across the two inner rows, such that the end of the sensor coincided with the line of the plants in each row for each of the crop. The displayed LAI for the plot was recorded as per crop and treatment. While leaf area LAI readings was used to measure the leaf area (LA) by multiplying with appropriate ground area in m^2

3.7.5 Crop dry matter (g)

The above ground dry matter produced per plant was determined separately for each crop by oven drying the whole three samples to a constant weight at 70^o C. Metler balance (Metler Toledo, model SB16001) was used for weight determination and the mean were computed and recorded as per treatment.

3.7.6 Crop growth rate (CGR)

Crop growth rate is the dry matter accumulation of crop community per unit of land area per unit time. This was measured by harvesting a sample at 2 weeks interval and calculating the increase in dry weight in relation to the initial weight.

$$\mathbf{CGR} = \frac{W_2 - W_1}{t_2 - t_1} \times (g/m^2/wk)$$

Where w_1 = is the dry matter accumulation per unit of land area at time t_1

W_2= is the dry matter accumulation per unit of land area at time t_2.

3.7.7 Relative growth rateRGR (g g wk^{-1})

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

$$RGR = \frac{lnW2 - lnW1}{t2 - t1} (ggwk^{-1})$$

Where ln = Natural log, W_1= Dry weight of plant (g) at time t_1

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

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

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

$$\mathbf{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{InLA_2 - InLA_1}{t_2 - t_1} (g\ cm^2wk^{-1})$$

Where ln = Natural logLA_1& W_1 = leaf Area (cm^2) and dry weight of plant (g) respectively at time t_1LA_2& W_2 = leaf Area (cm^2) and dry weight of plant (g) respectively at time t_2

3.7.9 Number of flowers per plant

The flowers on the tagged plants were counted and average valueswere determined in each plot. This was done at full bloom stage and the values obtained for each plot were recorded.

3.7.10 Number of days to first flowering

The number of days it takes the crop in each plot for first flower to appear after transplanting was observed and recorded

3.7.11 Number of days to 50% flowering

The number of days it takes plants in each plot to attain 50% flowering after transplanting was observed and recorded.

3.7.12 Fruit diameter (cm)

Three fruits were randomly selected from the tagged plants at each harvest, diameter was determined using Vanier caliper and average readings recorded in centimeter.

3.7.13 Average fruit weight per plant(g)

The cumulative weight of harvested fruits per plant of each tagged plants in a plot was taken, averaged recorded in grams.

3.7.14 Total fruit yield ton per hectare (t ha^{-1})

Total tomato fruit yields per net plot was compounded for 7 and 5 harvests in Samaru and Kadawa respectively, and expressed in tons per hectare.

3.7.15 Total fruit number

Fruit at every harvest was collected from the tagged plants and were counted for each plot, summation from every harvest was compounded to the number of harvest.

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

From the total fruits harvested, all healthy fresh fruits free from cracks, insect damage and small sized fruits were separated to form the marketable yield and expressed in tons per hectare

3.7.17 Unmarketable fruit yield (t ha^{-1})

The rotten, insect damaged, small sized and cracked fruits were weighed and expressed in tons per hectare basis.

3.7.18 Proportion of unmarketable fruits

At each harvest, mature fruits which are considered as unmarketable (rot affected) were culled and counted per plot at every harvest.

Proportion of unmarketable fruits = $\frac{total\ \ number\ \ of\ unmarketable\ \ \ fruits\ \ per\ plot}{total\ \ number\ \ of\ \ fruits\ \ per\ plot}$

3.8.0 Statistical Analysis of Data

The data collected were subjected to statistical analysis of variance (F-test) as described by Snedecor and Cochran (1967) to test significance of treatment effects. Where 'F'test shows significant difference among the treatment. The treatment means were compared using the Duncan's Multiple Range (DMR) test (Duncan, 1955). The magnitude and type of relationship between characters was assessed through simple correlation analysis (Little

and Hill, 1978). The polynomial response of tomato total fruit yields to irrigation intervals was determined by regression analysis (Barr and Goodnight, 1972).

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Analysis

The results of physical and chemical properties of soil samples collected atSamaru and Kadawa are shown in Table 1. The results showed that soil textures were loamy and sandy loamy in Samaru and Kadawarespectively. The pH was strongly acidic (5.40) at Samaru and slightly acidic (6.57)at Kadawa. Organic carbon contents were 10.98gkg^{-1} and 14.12 g kg^{-1} which are moderate at both locations. However, available phosphorus was low in both location (2.63 mg kg^{-1}) and (8.39 mg kg^{-1}) respectively. Total nitrogen was found to be high 0.31 g kg^{-1} and 0.51 g kg^{-1} at Samaru and Kadawa respectively. For exchangeable bases, calcium and magnesium were moderate while potassium and sodium were low in both locations. Similarly, low cation exchange capacity of 3.72 Cmolkg^{-1} and 4.36 Cmolkg^{-1}was obtained at both locations.

Table: 1 shows results of soil physical and chemical properties ofInstitute for Agricultural research Ahmadu Bello UniversitySamaru, Zaria andIrrigation Research Station,Kadawa farms during 2017/2018 dry season

SamaruKadawa		
Soil characteristics	**Depth (0-30cm)**	**Depth (0-30cm)**
Physical characteristics		
Sand g kg^{-1}	438	640
Silt g kg^{-1}	398	216
Clay g kg^{-1}	164	144
Textural class	Loamy	Sandy loam
Chemical properties		
pH in water (1:2:5)	6.18	6.57
pH in Cacl (1:2:5)	5.40	6.54
Organic carbon (g kg^{-1})	10.98	14.12
Total nitrogen (g kg^{-1})	0.31	0.51
Available phosphorus(mg kg^{1})	2.63	8.39
Exchangeable bases (Cmol $kg^{-1)}$		
Calcium	3.10	3.50
Magnesium	0.41	0.59
Potassium	0.09	0.11
Sodium	0.12	0.16
Cation exchange capacity	3.72	4.36

4.2 Plant Height (cm)

Table 2 Shows plant height (cm) of tomato varieties as influenced by irrigation interval and stand density at Samaru and Kadawa during 2017/2018 dry season. The two tomato varieties did not differ significantly in height at both locations throughout the study period except at 9WAT at Samaru where Roma-VF recorded significantly taller plants than UC-82B. The effect of irrigation on plants height was significant at Samaru only. The height decreased linearly with increasing irrigation interval from 5 to 15 days throughout the sampling periods. The effect of stand density on tomato plant height was not significant across the locations. There was a significant second other interaction on plant height at 5 weeks after transplanting at Kadawa.Keeping irrigation interval constant at 15 days, the use of 2 plants per stand recorded taller plant height when variety Roma VF was used as shown in Table 3.

4.3 Number of Leaves per Plant

The effects of treatments on the number of leaves per plant during 2017/2018 dry season at Samaru and Kadawa are presented in Table 4. Roma-VF significantly recorded higher number of leaves per plant at all sampling periods at Samaru and Kadawa7 weeks after transplanting. Similarly, irrigation interval treatment had significant effect on number of leaves per plant 7 and 9 WAT where 5 days irrigation interval recorded higher number of plant leaves than 10 and 15 days intervalsSamaru. While at Kadawa, the use of 5, 10 and 15 days intervals was statistically similar at 9 WAT only. Stand density had no significant effect on number leaves in both locations. Variety and stand density interaction was found significant on number of leaves at Samaru(9WAT).Interaction of tomato varieties and stand density on number of leaves 9 weeks after transplanting at Samaru shown in Table 5.When stand density was fixed at 1 plant stand^{-1}, Roma VF recorded higher

number of leavesper tomato plant than UC82-B at Samaru 9 WAT. The two tomato varieties were statistically similar when 2 plants stand^{-1} was adopted.

Table 2: Plant height (cm) of tomato varieties as influenced by irrigation interval and stands density during 2017/2018 dry season at Samaru and Kadawa

Treatment	**Samaru**			**Kadawa**		
	Weeks after transplanting			**Weeks after transplanting**		
	5	**7**	**9**	**5**	**7**	**9**
Variety (V)						
UC82B	28.9	33.4	39.5b	24.0	35.8	40.0
Roma VF	29.6	35.0	42.3a	24.9	39.8	50.8
SE ±	0.634	0.567	0.480	0.531	10.745	0.817
Irrigation Interval (day)						
5	32.5a	38.5a	45.2a	24.0	35.1	39.9
10	29.5b	33.1b	41.0b	24.5	41.2	59.2
15	25.7c	31.0c	36.6c	25.0	35.5	38.7
SE ±	0.776	0.694	0.588	0.650	13.160	1.001
Stand density (plants stand^{-1})						
1	28.9	34.8	41.3	24.5	35.7	40.0
2	29.6	33.6	40.5	24.4	39.9	50.8
SE ±	0.634	0.567	0.480	0.531	10.745	0.817
Interaction						
V*I	NS	NS	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	*	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). NS= Not significant *= Significant at

Table 3: Interaction of tomato varieties with irrigation intervals and stand density on plant height (cm) 5 weeks after transplanting during 2017/2018 dry season at Kadawa

Mean plant height of tomato at 5 weeks after transplanting (WAT)						
Treatment	**Variety (V)**					
	UC82B Roma VF					
Irrigation Interval (I) day	**Irrigation Interval (I) day**					
	5	10	15	5	10	15
Density (plants stand $^{-1}$)						
1	23.6abc	24.7abc	25.9abc	25.3abc	23.2abc	24.5abc
2	24.8abc	23.3abc	22.0c	22.5bc	26.8ab	27.2a
SE	1.300					

Means followed by same letter(s) in the same column and row are not different statistically at *P=0.05* usingDuncan's Multiple Range Test (DMRT).NS= Not significant *= Significant at (P<0.05)

Table 4: Number of leaves per plant of tomato varieties as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa

Treatment	**Samaru**			**Kadawa**		
	Weeks after transplanting			**Weeks after transplanting**		
	5	**7**	**9**	**5**	**7**	**9**
Variety (V)						
UC82B	98.0b	145.3b	243.1b	94.8	185.3b	275.9
Roma VF	115.2a	168.6a	266.0a	89.3	211.7a	306.7
SE ±	5.079	5.072	4.666	4.790	7.177	10.861
Irrigation Interval (I) day						
5	119.9a	179.1a	313.1a	86.4	187.3	256.2b
10	112.9a	159.8b	259.3b	98.3	205.1	321.8a
15	87.1b	132.0c	191.2c	91.4	203.0	295.9a
SE ±	6.220	6.212	5.714	5.865	8.790	13.302
Stand density (plants stand^{-1})						
1	113.5	164.0	259.4	93.5	206.5	296.3
2	99.7	149.9	249.7	90.6	190.4	286.3
SE ±	5.079	5.072	4.666	4.790	7.177	10.861
Interaction						
V*I	NS	NS	NS	NS	NS	NS
V*D	NS	NS	*	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). NS= Not significant *= Significant at ($P \leq 0.05$)

Table 5: Interaction of tomato varieties and stand density on number of leaves 9 weeks after transplanting during 2017/2018 dry season at Samaru

Mean Number of leaf 9 weeks after transplanting		
Treatment	**Variety (V)**	
	UC82B	Roma VF
Stand density (plants stand $^{-1}$)		
1	239.4b	279.3a
2	246.8b	252.6b
SE ±	6.598	

Means followed by same letter(s) in the same column and row are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). NS= Not significant *= Significant at

4.4 Number of Branches

The effects of treatments on number of branches per plant at Samaru and Kadawa 2017/2018 dry season are shown in Table 6. The results obtained revealed that Roma –VF variety recordedsignificantly higher number of branches than UC-82B at 7 WAT and 9 WAT atSamaru and 7 WAT at Kadawabut at par at the other periods in both location. Linear decrease in number of branches per plant was observed with increasing irrigation interval at Samaru throughout the sampling periods. However, the parameter was not significantly affected by the irrigation treatment all the study periods at Kadawa. Stand density effect was significant at 7 WAT at both locations. Increasing density from 1 to2 plants per stand resulted in decreased number of branches per plant. Interactionwas significant at 7 WAT at Samaru only as presented in Table 7.When irrigation interval was fixed at 5 days, Roma VF recorded higher number of branches than UC82-B. The two tomato varieties were not par when either 10 or 15 days intervals were adopted. Adopting UC82-B, revealed that 15 days irrigation recorded lowest number of branches than 5 and 10 days which were at par. However, with Roma VF linear decrease in number of branches was observed with increasing irrigation intervals up to 15 days.

4.5 Leaf Area Index

The influence of tomato variety, irrigation interval and stand density on leaf area index of tomato plants are presented in Table 8. The results showed no significant differencesin leaf area index between the varieties at both locations. At Samaru, application of water every 5 and 10 days recorded higher leaf area index than 15 days interval at 7 and 9 WATs only. Similarly, stand density was not significant on leaf area index except at Samaru 9 WAS

where, 2 plants stand $^{-1}$ recorded significantly higher leaf area index than 1 plant per stands. Treatment interactions on leaf area index were not significant.

Table 6: Number of branches of tomato varieties as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa

Treatment	**Samaru**			**Kadawa**		
	Weeks after transplanting			**Weeks after transplanting**		
	5	**7**	**9**	**5**	**7**	**9**
Variety (V)						
UC82B	12.7	19.8b	25.9b	14.1	18.2b	23.7
Roma VF	12.9	20.8a	28.4a	15.1	20.3a	25.1
SE ±	0.346	0.277	0.646	0.811	0.581	0.740
Irrigation Interval (I) day						
5	15.2a	22.8a	32.9a	14.1	19.6	22.8
10	12.6b	20.6b	25.4b	15.9	18.8	25.4
15	10.5c	17.4c	23.3b	13.8	19.3	24.9
SE ±	0.423	0.339	0.792	0.993	0.581	0.906
Stand density (plant stand $^{-1}$)						
1	13.2	20.8a	27.1	14.8	20.2a	25.4
2	12.4	19.8b	27.3	14.4	18.3b	23.4
SE ±	0.346	0.277	0.646	0.811	0.581	0.740
Interaction						
V*I	NS	*	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). NS= Not significant *= Significant

Table 7: Interaction of tomato varieties and irrigation interval on number of branches 7 weeks after transplanting during 2017/2018 dry season at Samaru.

Mean Number of branches 7 weeks after transplanting (WAT)		
Treatment	**Variety (V)**	
	UC82B	Roma VF
Irrigation Interval (I) day		
5	21.5b	24.1a
10	20.5b	20.8b
15	17.3c	17.6c
SE ± 0.480		

Means followed by same letter(s) in the same column and row are not different statistically at *P=0.05* usingDuncan's Multiple Range Test (DMRT).

Table 8: Leaf Area Index of tomato varieties as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa.

Treatment	**Samaru**			**Kadawa**		
	Weeks after transplanting			**Weeks after transplanting**		
	5	**7**	**9**	**5**	**7**	**9**
Variety (V)						
UC82B	0.78	1.29	1.74	0.52	1.10	1.51
Roma VF	0.89	1.43	1.75	0.47	1.12	1.36
SE ±	0.057	0.063	0.080	0.047	0.100	0.069
Irrigation Interval (day)						
5	0.92	1.56a	1.88a	0.53	1.19	1.38
10	0.83	1.37ab	1.87a	0.40	1.07	1.47
15	0.76	1.17b	1.48b	0.55	1.07	1.46
SE ±	0.070	0.080	0.098	0.058	0.122	0.084
Stand density (plants stand^{-1})						
1	0.78	1.34	1.63b	0.52	1.03	1.39
2	0.90	1.38	1.83a	0.48	1.18	1.48
SE	0.057	0.063	0.080	0.047	0.100	0.069
Interaction						
V*I	NS	NS	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). DMRT. NS= Not significant * =Significant

4.6 Leaf Area

Leaf area of tomato as influenced by variety, irrigation interval and stand density at Samaru and Kadawa during the 2017/2018 dry season is presented in Table 9. Varietal effect proved no significant on leaf area at both locations throughout the sampling periods. At 7 weeks after transplanting, 5 days irrigation differed from 15 days irrigation interval and at par with 10 days interval, though 5 days interval recorded numerically the higher leaf area value. Furthermore, at 9 WAT increasing interval from 5 and 10 days had no significant effect, however, further increase to 15 days resulted to significant decrease in leaf area value at Samaru. Stand density treatment was found to have no significant effect on leaf area except at Samaru 9 WAT where increasing density from 1 to 2 plants stand per resulted to significant increase in leaf area. Interactions between treatments had no significant at both locations.

4.7 Dry matter weight(g) per plot

Effect of treatments on dry matter of tomato during the 2017/2018 dry season at Samaru and Kadawa are presented in Table 10. Roma VF produced significantly more dry matter than UC82B variety at Samaru 7 WAT. However, irrigation interval had no significant effect on the parameter at both locations at all sampling periods. Successive stand density had no significant effect except at Samaru 9WAT where 1 plant stand density had significantlyhighest dry matter weight and increasing stand density from 1 to 2 plant stand $^{-1}$ resulted to a significant decreasing weight. However, factorial interaction between variety, irrigation interval and stand density had no significant difference on dry matter weight at all locations.

Table 9: Leaf Area of tomato varieties as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa research farms

Treatment	**Samaru**			**Kadawa**		
	Weeks after transplanting			**Weeks after transplanting**		
	5	**7**	**9**	**5**	**7**	**9**
Variety (V)						
UC82B	2815.5	4660.5	6268.5	1866.0	3961.5	5445.0
Roma VF	3216.0	5148.0	6294.0	1707.0	4023.0	4899.0
SE ±	204.694	226.053	91.496	170.668	359.717	246.778
Irrigation Interval (day)						
5	3309.8	5600.3a	6777.0a	1921.5	4284.0	5296.5
10	3001.5	4916.3ab	6747.8a	1449.0	3856.5	5256.0
15	2736.0	4196.3b	5319.0b	1989.0	3836.3	4963.5
SE ±	250.699	276.857	112.059	209.025	440.562	302.240
Stand density (plant stand $^{-1}$)						
1	2793.0	4837.5	5850.0b	1860.0	3721.5	5014.5
2	3238.5	4971.0	6712.5a	1713.0	4263.0	5329.5
SE ±	204.694	226.053	91.496	170.668	359.717	246.778
Interaction						
V*I	NS	NS	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). NS= Not significant * Significant

Table 10: Dry Matterweight (g) of tomato varieties as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa teaching and research farms

Treatment	**Samaru**			**Kadawa**		
	Weeks after transplanting			**Weeks after transplanting**		
	5	**7**	**9**	**5**	**7**	**9**
Variety (V)						
UC82B	4.1	8.0b	47.1	2.7	11.1	31.8
Roma VF	6.0	11.1a	50.3	2.3	10.0	32.2
SE ±	0.799	0.881	4.649	0.262	1.142	2.768
Irrigation Interval (day)						
5	5.4	9.6	50.0	2.4	9.0	28.3
10	4.3	9.1	46.5	2.3	11.4	33.5
15	5.5	10.0	49.1	2.9	11.2	34.1
SE ±	0.979	1.079	5.694	0.321	1.399	3.390
Stand density (plant stand $^{-1}$)						
1	5.1	10.6	58.0a	2.6	10.6	29.8
2	5.0	8.5	39.4b	2.4	10.5	34.2
SE ±	0.799	0.881	4.649	0.262	1.142	2.768
Interaction						
V*I	NS	NS	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT).NS= Not significant * Significant

4.8 Crop Growth and Relative Growth Rates

Effect of variety, irrigation intervals and stand density treatments onCrop Growth and Relative Growth Rates(CGR and RGR) during 2017/2018 dry season at Samaru and Kadawa are shown in Table 11. The two varieties recorded no significant differences on these parameters at both locations. Similarly, irrigation interval treatment where increasing interval from 5, 10 and 15 days showed no significant difference across the sampling period at both locations. However, a significant difference was observed with stand density treatment where 1 plant per stand recorded significantly higher value of CGR and RGR at 7 WAT sampling period in Samaru, than 2 plants per stand. Factorial interactions of the factors were no significant.

4.9 Net Assimilation Rate

The effects of treatments on net assimilation rate of tomato plant at Samaru and Kadawa during 2017/2018 dry season is presented in Table 12. The results revealed that the variety had no significant effect on net assimilation rates, the varieties were statistically the same at both locations. Irrigation interval had significant effect on net assimilation rate at Samaru7 WAT similarly 5 WAT in Kadawa. At Samaru 10 days irrigation interval was statistically the same with 5 days interval and differed significantly from 15 days irrigation interval which statistically the same with 5 days interval. At Kadawa, 10 days irrigation interval had significantly higher assimilation rate than the two other irrigation interval that were statistically the same at par. Stand density treatment and treatments interactions were no significant at both locations.

Table 11: Crop Growth Rate and Relative Growth rate of tomato varieties as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa

Treatment	**Samaru**				**Kadawa**			
	Weeks after transplanting				**Weeks after transplanting**			
	CGR5	CGR7	RGR5	RGR7	CGR5	CGR7	RGR5	RGR7
Variety (V)								
UC82B	2.3	19.5	1.4	2.7	4.2	11.1	0.7	2.2
Roma VF	2.7	19.8	1.5	2.7	3.9	10.4	0.7	2.3
SE ±	0.439	2.245	0.094	0.098	0.542	1.127	0.049	0.081
Irrigation Interval (day)								
5	2.4	20.4	1.5	2.7	3.3	9.7	0.6	2.2
10	2.6	18.8	1.6	2.6	4.6	11.0	0.8	2.2
15	2.4	19.8	1.4	2.7	4.2	11.5	0.7	2.3
SE ±	0.537	2.750	0.115	0.120	0.664	1.380	0.060	0.099
Stand density (plant stand^{-1})								
1	3.0	23.8a	1.6	2.9a	3.8	9.6	0.7	2.1
2	2,0	15.5b	1.4	2.5b	4.0	11.8	0.7	2.3
SE ±	0.439	2.245	0.094	0.098	0.542	1.127	0.049	0.081
Interaction								
V*I	NS	NS	NS	NS	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using DMRT. NS= Not significant

Table 12: Net Assimilation Rate of tomato varieties as influenced by irrigation interval and stand densityduring 2017/2018 dry season at Samaru and Kadawa

Treatment	**Samaru**		**Kadawa**	
	Weeks after transplanting		**Weeks after transplanting**	
	5	**7**	**5**	**7**
Variety (V)				
UC82B	0.5	2.5	1.4	19.0
Roma VF	0.6	2.1	1.6	18.9
SE ±	0.119	0.422	270.710	2.356
Irrigation Interval (day)				
5	0.6	1.9ab	1.2b	15.8
10	0.7	3.3a	2.2a	20.0
15	0.5	1.7b	1.1b	21.0
SE ±	0.145	0.517	0.332	2.885
Stand density (plant stand $^{-1}$)				
1	0.7	2.3	1.3	16.9
2	0.4	2.3	1.6	21.0
SE ±	0.119	0.422	270.710	2.356
Interaction				
V*I	NS	NS	NS	NS
V*D	NS	NS	NS	NS
I*D	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). NS= Not significant * Signicant

4.10 Days to first, fifty percent and Number of Flowers per plant

Table 13 shows days to first flowering, fifty percent flowering and number of flowers per plant as influence by varieties irrigation intervals and stand density at Samaru and Kadawaduring 2017/2018 dry season. Varietal differences on number of days to first flower was significant at Kadawa only, Roma VF took significantly more number of days to attain first flower than UC82-B. However, UC82-B recorded fewer days to attain 50% than Roma VF at both locations. Again, UC82-B significantly had more number of flowers per plant than Roma -VF at Samaru only. Effect of irrigation was significant on days to 50% flowering and number of flowers per plant across the locations. Increasing irrigation interval from 10 to 15 days resulted to significant number of days to attain 50% flowering at both locations. By and large, wider irrigation interval (15 days) had lower number of flowers compared to either 5 or 10 days irrigation interval at Samaru. The reverse was obtained atKadawa where increasing irrigation intervals from 5 to 10 days onlyresulted to increase of the parameter. Stand density was significant on days to 50% flower only at Samaru, where 2 plants per stand took significantly more number of days to attain 50% flower than 1 plant stands h^{-1}. Treatment interactions were not significant on any of these treatments.

4.11 Fruit Diameter and Average Fruit Weight per plant

Table 14 Shows fruit diameter and average fruit weight of tomato as influenced by variety, irrigation interval and stand density at Samaru and Kadawa in 2017/2018 dry season. The variety UC-82B recorded significantly higher values of both parameters at both locations than Roma VF. Similarly, irrigation interval had significant effect on fruit diameter and average fruit weight per plant where, 5 days irrigation interval recorded significant higher

values of these parameters than the rest of the irrigation intervals at Samaruonly. However, increase in days from 10 to 15 resulted a decrease in the parameters. Irrigation interval had no significant effect on both parameters at Kadawa. Stand density had no significant effect on fruit diameter at both locations. 1 plant stands $^{-1}$ recorded heavier fruits than 2 plants stand $^{-1}$. Treatments interactions were not significant on both fruit diameter and average fruit weight per plant.

Table 13: Days to first, 50% flowering and number of flower of tomato varieties as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa

Treatment	Samaru			Kadawa		
	Days to first flowering	Days to 50% flowering	Number of flower per plant	Days to first flowering	Days to 50% flowering	Number of flower per plant
Variety						
UC82B	28.0	46.1b	35.2a	28.4b	44.7b	38.4
Roma VF	28.2	48.3a	33.7b	30.3a	46.6a	37.8
SE ±	0.487	0.554	0.444	0.443	0.135	0.578
Irrigation Interval (I) day						
5	28.2	45.7b	37.8a	29.2	45.2b	36.0b
10	27.8	46.5b	36.4a	29.4	44.8b	39.7a
15	28.2	49.4a	29.0b	29.4	47.1a	38.7a
SE ±	0.596	0.678	0.543	0.542	0.634	0.708
Stand density (plant stand^{-1})						
1	27.8	46.3b	34.3	29.5	45.5	38.5
2	28.3	48.1a	34.6	29.2	45.8	37.8
SE ±	0.487	0.554	0.444	0.443	0.135	0.578
Interaction						
V*I	NS	NS	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05*using Duncan's Multiple Range Test (DMRT). NS= Not significant

Table 14: Fruit diameter and Average fruit weight of tomato varieties as influenced by irrigation intervaland stand density during 2017/2018 dry season at Samaru and Kadawa

Treatment	**Samaru**		**Kadawa**	
	Fruit diameter (cm)	Average fruit weight (g)	Fruit diameter (cm)	Average fruit weight (g)
Variety (V)				
UC82B	4.1a	72.5a	4.6a	145.6a
Roma VF	3.7b	62.9b	4.3b	117.3b
SE ±	0.125	3.241	0.079	6.925
Irrigation Interval (I) day				
5	4.4a	85.3a	4.5	128.5
10	3.6b	70.0b	4.5	128.1
15	3.6b	47.7c	4.4	137.6
SE ±	0.153	3.969	0.097	8.482
Stand density (plants stand $^{-1}$)				
1	3.8	83.6a	4.5	171.3a
2	3.9	51.8b	4.5	91.6b
SE ±	0.125	3.241	0.079	6.925
Interaction				
V*I	NS	NS	NS	NS
V*D	NS	NS	NS	NS
I*D	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). NS= Not significant

4.12 Total Fruit Yield, Marketable Yield and Unmarketable Yield (tons ha^{-1})

Table 15 show results of treatments variation on total fruit yield, marketable yield and unmarketable yields at Samaru and Kadawa in 2017/2018 dry season. The two varieties differed significantly in total fruit yield and marketable yield in tons ha^{-1} at both locations, where UC-82B had significantly out yielded Roma-VF. Similarly, the effect of irrigation interval was significant on total fruit yield marketable and unmarketable yield at Samaru. While at Kadawa only total fruit yield was significantly affected by irrigation interval. A linear decrease was observed with increasing irrigation interval up to 15 days for total fruit yield, and marketable yield parameters at Samaru. 10 and 15 days irrigation recorded similar fruit at Kadawa statistically. The effect of stand density was significant on fruit yield and marketable yield at Samaru only. 2 plants per stand recorded significantly high total fruits yield and marketable yield than 1 plant per stand. Treatment interactions were not significant at both locations.

4.13 Total Fruit Number, Marketable and Unmarketable Fruits

Effects of variety, irrigation interval and stand density on total fruit number, marketable and unmarketable fruits during 2017/2018 dry season atSamaru and Kadawais presented in Table 16. A significant difference was observed where UC-82B recorded significantly the highest values of these parameters than Roma-VFatSamaru only. Effect of irrigation interval was significant on total fruit number, marketable unmarketable fruitsat Samaru.5 days irrigation interval recorded higher values, while unmarketable fruits were found to be significantly higher with 15 days irrigation interval. AtKadawa no significant difference was observed with changes in irrigation intervals in days for total fruit number, but both marketable and unmarketable were significantly affected by irrigation interval. Marketable fruit was found significant with 5 days interval though, statistically similar with 10 days irrigation interval.

Furthermore, unmarketable fruits were found significant where 15 days interval recorded higher value. Stand density had significant effect on total fruit number and marketable fruits at Samaruonly, where increasing stand density from 1 to 2 plants per stand significantly had the highest value of the parameters. Interaction between the factors found not significant at both locations.

Table 15: Total Fruit yield, Marketable yield and Unmarketable yield of tomato varieties in ton ha^{-1} as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa

Treatment	**Samaru**			**Kadawa**		
	Total fruit yield ton ha^{-1}	Marketable yield ton ha^{-1}	Unmarketable yield ton ha^{-1}	Total fruit yield ton ha^{-1}	Marketable yield ton ha^{-1}	Unmarketable yield ton ha^{-1}
Variety						
UC82B	19.9a	18.1a	1.6	20.7a	18.8a	2.0
Roma VF	17.0b	15.3b	1.5	17.7b	15.9b	1.9
SE ±	0.433	0.471	0.096	0.758	0.711	0.073
Irrigation Interval (I) day						
5	21.9a	20.5a	1.3b	17.6b	17.9	1.9
10	19.6b	18.0b	1.3b	19.9a	15.7	1.8
15	13.8c	11.6c	2.1a	20.3a	18.3	1.9
SE ±	0.530	0.577	0.117	0.929	0.871	0.089
Stand density (plant $stand^{-1}$)						
1	17.0b	15.2b	1.5	18.5	16.6	1.9
2	19.8a	18.2a	1.6	20.0	18.0	1.9
SE ±	0.433	0.471	0.096	0.758	0.711	0.073
Interaction						
V*I	NS	NS	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using Duncan's Multiple Range Test (DMRT). NS= Not significant

Table 16: Total fruit Number, Marketable fruit and Unmarketable fruit of tomato varieties as influenced by irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa

Treatment	Samaru			Kadawa		
	Total fruitNumber	Marketable fruits	Unmarketable fruits	Total fruits Number	Marketable fruits	Unmarketable fruits
Variety						
UC82B	495.9a	449.1a	48.8a	453.6	404.6	45.3
Roma VF	419.3b	379.6b	39.3b	408.9	363.5	45.5
SE ±	16.372	16.289	2.517	19.119	18.050	2.087
Irrigation Interval (day)						
5	539.4a	500.9a	38.6b	456.6	418.6a	38.0b
10	450.6b	413.1b	40.3b	447.8	386.5ab	39.3b
15	382.8c	329.0c	53.2a	389.6	347.2b	58.9a
SE ±	20.051	19.950	3.083	23.415	22.107	2.556
Stand density (plant stand^{-1})						
1	423.2b	380.3b	42.2	416.4	372.6	43.5
2	492.0a	448.4a	45.8	446.3	395.5	47.3
SE ±	16.372	16.289	2.517	19.119	18.050	2.087
Interaction						
V*I	NS	NS	NS	NS	NS	NS
V*D	NS	NS	NS	NS	NS	NS
I*D	NS	NS	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* usingDuncan's Multiple Range Test (DMRT). NS= Not significant

4.14 Proportion and Percentage of Unmarketable Fruits

The proportion and percentage of unmarketable fruits of tomato as influenced by variety, irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawaare shown in Table 17. Variety had no significant effecton proportion of unmarketable and percentage unmarketable at both locations. However, irrigation interval was found to have significant effect on the parameters, where extending irrigation interval from 5, 10 and 15 days resulted to linear increase in proportion of unmarketable and percentage unmarketable across the trial locations. Stand density effect and treatments interaction was found not significant.

4.15Correlation Analysis

The metrics of correlation coefficient among growth and yield parameters of tomato at Samaru and Kadawa during 2017/2018 dry season are presented in Table 17 and 18. At Samaru, there was a significant positive correlation (p=0.01) between tomatofruit yield and all yield and growth parameters assessed except dry matter (-0.214), fruit diameter (0.042) and unmarketable fruit yield (-0.064). Similarly, the relationship between tomato marketable fruit yield was also significant and positive with all the parameters assessed except with dry matter (-0.197) which was negative and not significant. However, the unmarketable fruit yield had positive and significant correlation with only plant height while it correlation with other parameters were negative and not significant. At Kadawa, the relationship between tomato fruit yield was positive and highly significant with marketable (0.997) and unmarketable fruit yield (0.573) only. Similarly, relationship between marketable yields was found to be significant and positively correlated with drymatter and unmarketable fruit among all the yield and growthparameters assessed in this study.

Table 17: Proportion and percentage of unmarketable fruit of tomato varieties as influenced by Irrigation interval and stand density during 2017/2018 dry season at Samaru and Kadawa

Treatment	**Samaru**		**Kadawa**	
	Proportion unmarketable fruits	Percentage unmarketable	Proportion unmarketable fruits	Percentage unmarketable
Variety(V)				
UC82B	0.104	10.4	0.101	10.1
Roma VF	0.097	9.7	0.111	11.1
SE ±	0.005	0.477	0.004	0.360
Irrigation Interval (I) day				
5	0.073c	7.3c	0.085c	8.5c
10	0.091b	9.1b	0.101b	10.1b
15	0.137a	13.7a	0.132a	13.2a
SE ±	0.006	0.584	0.004	0.441
Stand density (plant stand $^{-1}$)				
1	0.103	10.3	0.105	10.5
2	0.098	9.8	0.107	10.7
SE ±	0.005	0.477	0.004	0.360
Interaction				
V*I	NS	NS	NS	NS
V*D	NS	NS	NS	NS
I*D	NS	NS	NS	NS
V*I*D	NS	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* Using. Duncan's Multiple Range Test (DMRT). NS= Not significant

Table 18: Correlation matrix between growth and yield parameters of two tomato varieties at Samaru during 2017/2018 dry season

	1	2	3	4	5	6	7	8	9
1	1.00								
2	0.373**	1.00							
3	0.380**	0.786**	1.00						
4	0.396**	0.307*	0.316*	1.00					
5	-0.214	0.082	0.009	-0.126	1.00				
6	0.667**	0.473**	0.485**	0.384**	0.048	1.00			
7	0.042	0.323*	0.383**	-0.013	0.075	0.239	1.00		
8	0.989**	0.512**	0.399**	0.395**	-0.197	0.662**	0.300*	1.00	
9	-0.064	0.441**	-0.273	-0.057	-0.213	-0.255	-0.194	-0.125	1.00

** = Significant at 1 %, * = Significant at 5 %, ns = not significant

1. Fruit yield 2.Plant height 3.Number of branch 4.Leaf area index 5. Dry matter weight 6.Number of flower 7.Fruit diameter 8.Marketable yield 9.Unmarketable fruit.

Table 19: Correlation matrix between growth and yield parameters of two tomato varieties at Kadawa during 2017/2018 dry season

	1	2	3	4	5	6	7	8	9
1	1.00								
2	0.107	1.00							
3	0.142	0.358*	1.00						
4	0.204	-0.121	0.146	1.00					
5	0.277	0.108	0.101	0.071	1.00				
6	-0.151	-0.060	0.139	0.206	-0.038	1.00			
7	0.080	0.309*	-0.130	0.018	0.038	-0.064	1.00		
8	0.997**	0.103	0.136	0.198	0.277	-0.161	0.085	1.00	
9	0.573**	-0.093	0.165	0.139	0.366*	-0.001	-0.005	0.567**	1.00

** = Significant at 1 %, * = Significant at 5 %, ns = not significant

1.Total fruit yield 2.Plant height 3.Number of branch 4.Leaf area index 5.Dry matter weight 6.Number of flower 7.Fruit diameter 8.Marketable yield 9.Unmarketable fruit.

4.16 Regression Response of Total Tomato Fruit Yield against Irrigation Intervals (Days) In Samaruand Kadawa, 2017/2018 Dry Season

Regression response of tomato total fruit yield to irrigation interval at Samaru and Kadawa are presented in Figure 1 and 2 respectively. When total tomato fruit yield was regressed against irrigation intervals at Samaru, it was observed that negative linear response equation was $Y = 26.53 - 0.81x$ with coefficient of determination (R^2) value of 0.9414 better fit for the data. This implies that the total tomato fruit yield decreased with increasing irrigation interval from 5 to 15 days interval. It suggests that the optimum interval is not achievable within the 5 – 15 days irrigation intervals evaluated. However, a quadratic response was observed in Kadawa, where increasing irrigation intervals from 5, 10 and 15 days resulted to a polynomial response in total tomato fruit yields (tons ha^{-1}). Higher values of total fruit yield was observed with 15 days interval of irrigation. A quadratic equation $y= 13.4 +1.03x -0.038x^2$and 1 as coefficient R^2 value was obtained.

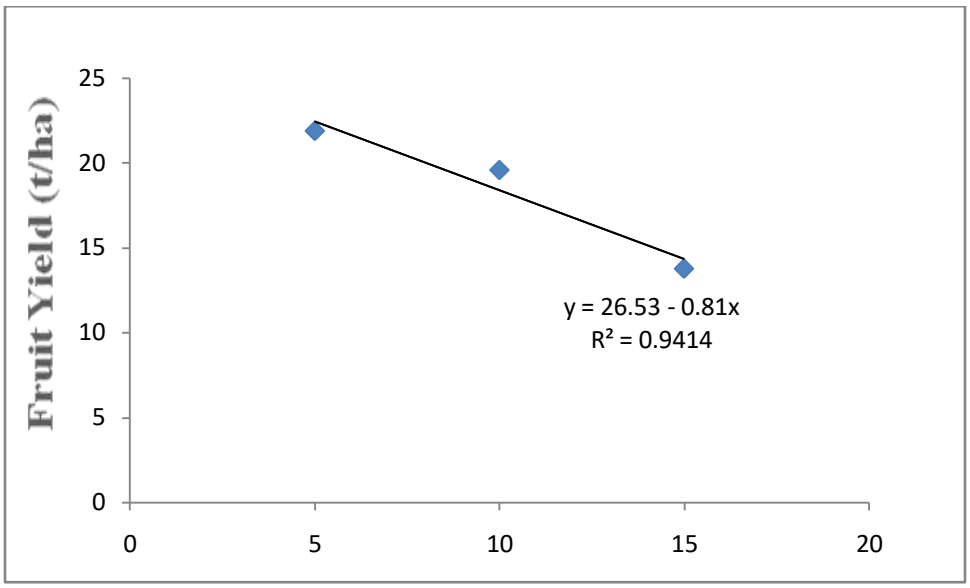


Figure 1: Regression of tomato total fruit yield in tons ha^{-1} and irrigation interval in days at Samaru

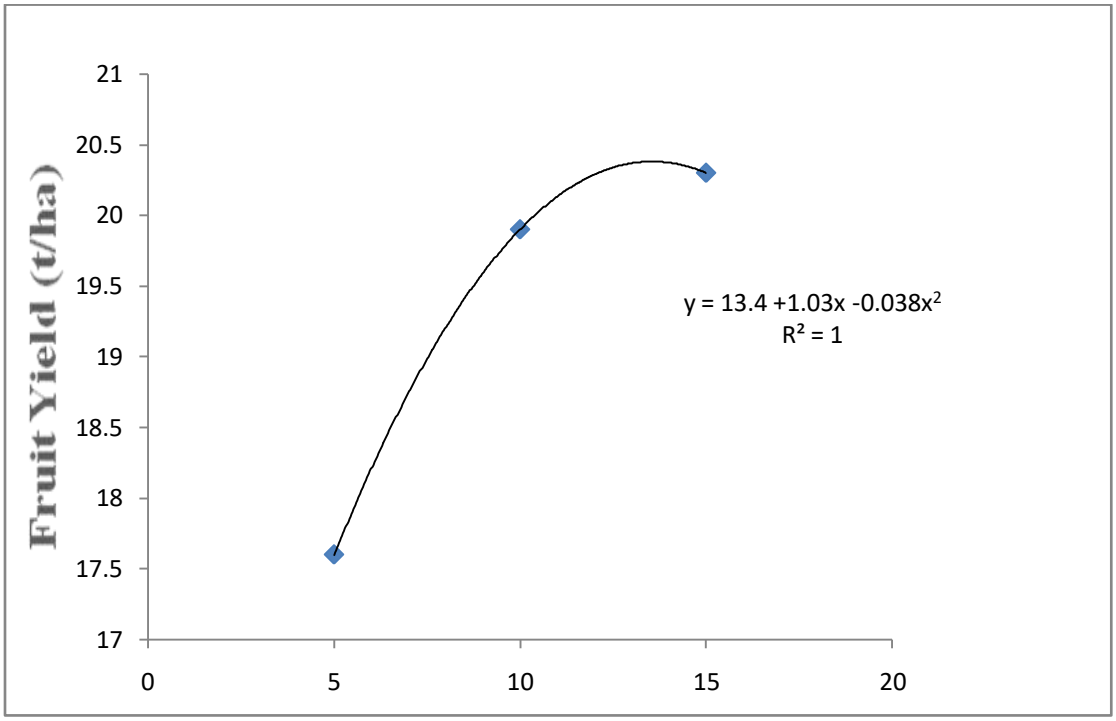


Figure 2: Regression of tomato total fruit yield in tons ha^{-1} and irrigation interval in days at Kadawa

CHAPTER FIVE

5.0 DISCUSSION

5.1 General Performance of the Crop

Performance of tomato plant largely depends on environmental factors importantly soil and climate. Results from this experiment showed that tomato yield varied slightly between the two experimental sites despite same treatment and season in 2017/2018. The crop performed satisfactorily with total fruit of 21.9 tons ha^{-1} and 20.3 tons ha^{-1} observed in Samaru and Kadawa respectively. This is higher than farmers average (5-10 ton ha^{-1}) yield though potential yield was not attained which could be attributed to environment and experimental factors.

High temperature andrelative humidity recorded during the experiment period obviously affectthe growth and yield of the crop. Mean temperature of the environmentranges from 34.7 - 17.1^0 C at Samaru while 31.9 - 24.2^0 C at Kadawa. (Appendix 1 and 2).Similarly, average relative humidity of 30.46 and 46.5% were recorded at Samaru and Kadawarespectively, whichcould be the reason for crop low performance and increased vulnerability to pest and diseases, flower abortion and fruits rotten particularly with Roma-VFvariety. FAO, (2019) reported that optimum mean daily temperature for growth and yield of tomato 18 to 25^0 C with night temperature between 10 and 20 ^{0}C temperature difference however, adversely affect yield. Temperature above 25 ^{0}C accompanied with high humidity and wind may likely resulted in flower abortion and reduced yield depending on variety. Furthermore, (Hanson, 2001: Shankara*etal., 2005*)stated that optimum temperature for tomato growth and development lie between 21 and 27 ^{0} C, above this it may cause fruit cracking and sunscald.

Varieties differed in their growth and yield attributes in this study. Roma – VF variety was superior over UC-82B in terms of most growth parameters. However, UC-82B recorded heavier tomato fruit yield than Roma – VF. This may be attributed to the fact that, variety Roma – VF is a bushy type with thinner epicarps and has low resistance to heat set. This observation confirmed the earlier description of the variety and also agreed with the result of Saidu*et al.*(2012) which reported that varieties with lighter carp has low resistance to heat set.Tomato tolerates a wide range of soil conditions, the crop performed favorably despite differences in soil type and pH. Hanson (2001) reported that tomato thrives better within pH range of 6-7.

5.2 Influence of Variety on Growth and Yield of Tomato

Significant differences were observed on growth parameters between Roma VF and UC82B tomato varieties, where Roma VF proves superiority in terms of plant height, number of branches though it has higher number of days to attained first and 50% flowering than UC82B. This could be attributed to genetics and climatic factors which allows for the variety to grow vigorously. These observations seem to confirm the earlier description of the variety Roma VF and also agreed with the result of Saidu*et al.*(2012). However, UC82B produces higher number of flowers and subsequently the yield and yield component thus: fruit diameter, average fruit weight, fruit yield, and marketable fruits than Roma VF tomato variety. These finding confirm the report of (Isah 2013) which reported that UC82B tomato variety as higher yielder particularly in terms of yield components than Roma VF tomato variety. Higherunmarketable characters were attributed with variety Roma – VF which hasthinner epicarps and has low resistant to heat.This observation confirmed the earlier description of the variety and also agreed with the

result of Saidu*et al*,(2012)which reported that varieties with lighter carp has low resistance to heat set.

5.2 Irrigation Effects on Growth and Yield of Tomato

Increasing irrigation interval from 5 to 10 days has resulted to a decreased in growth parameters at most of the growth stage. Similarly, yield and yield components of tomato plant. Further increase to 15 days interval significantly depressed both growth and yield parameters at Samaru location. These results indicated that after 10 days soil moisture content in the root zone became in adequate for the plant growth and development, which could be attributed to soils and climatic factors during the growing season at Samaru. Similar observation was made by Rilwanu (1999), Rodriguez *et al.,* (2010) and Abubakar (2014) who reported that irrigation that replaces 60% of moisture deflected every 5 days gives better results in terms of yield and water use efficiency.

However, at Kadawachanges in irrigation intervals from had no significant effect on most growth parameters until further increase to 15 dayswhich could be attributed to high water table, temperature fluctuation and extremes during the season in the location. The result agreed with the finding of (Hussaini*et al*., 2013) which reported 15 days interval gave the best yield attributes as indicated in more number of fruit and fruit yields. The proportion and percentage of unmarketable fruits was found significant at 15days irrigation interval. This observation could be associated to extreme high temperature during the harvesting periods at both location and confirming that the plant requires water at all physiological stage. This agreed with earlier research by Amans and Nwaduekwe (1986) that recorded large sized fruit and higher fresh fruits yield, when irrigation was done at 10 days interval than 5 and 20 days. The higher fresh yield obtained at 10 -15 days irrigation interval in 2007/2008 and combined mean could be

attributed to the favorable increases in yield parameters when the crop was irrigated at 10 to 15 days intervals as influenced by weather condition during the season.

5.3 Influence of Stand Density onthe Growth and Yield of Tomato

Not all the growth parameters responded to stand density treatment in the trials at both locations. However, 1 plant per stand was superior over 2 plants perin number of leaves, crop growth rate, relative growth rate at 7WAT and total dry matter 9WAT atSamaru and similarly number of leaves at 7WAT atKadawa. 2 plants stand density treatment recorded significance on leaf area index and leaf area at 9WAT and number of days to 50% flowering atSamaru. The non-response of some growth parameters to change in stand density could attributed to wider inter and intra row spacing (60x60cm) used in the trials which may reduce the intense competition of the plant to growth factors such as space, photosynthetic radiation and plant nutrients. A similar result was observed by (Shanmukhi*et al*., 2017) and (Mohammed & Singh 2007). However, most of the yield parameters responded positively to change in stand density per plant. Increasing stand density from 1 to 2 plant stand $^{-1}$ resulted to a significant difference on total fruits,total fruit yield and marketable yield in tons ha^{-1} at Samaru. This result agreed with the finding of Rilwanu (1999) and (Shanmukhi*et al*., 2017) where doubling the stand density implies doubling plant population and proportionately to higher yield in tons per hectare.

However, the effect of stand density on average fruit weight recorded significant difference, where 1 plant stand $^{-1}$ gives higher fruit weight in grams than 2 plants stand $^{-1}$. This result is in accordance with the findings of Law-ogbomo and Eghaverba (2009) andNguyen *et al.* (2015). According to Wold*et al.*(2004) increasing density per unit area, plants compete for essential growth factors such as nutrients, light and water, with direct influence on yield and

fruit quality. Moreover, unmarketable and proportion of unmarketable fruits were found not significant with change in stand density across the location. This result could be related to availability of growth factors such as nutrient spacing and available moisture despite increase in number of plant per stand.

5.4 Interaction of Treatments on Growth and Yield of Tomato

Interaction was only found significant with some growth parameters. Interaction between varieties, irrigation interval and stand density was found significant at Kadawa, where increasing irrigation interval to 15 days at 2 plants stand $^{-1}$ density with Roma VF tomato variety showed superiority on plant height of tomato plant at 5WAT. Similar observation was observed by Amans (1992) at same location. The finding was attributed to higher stand density which helped the plant in ameliorate the negative effects of excessive soil moisture due to high soil water-table in the location. Similarly, there were interaction between variety and stand density (first order interaction) was found significant on the number of leaves per plant at 9WAT in Samaru, where Roma VF recorded a higher number of leaves per plant than UC82B tomato variety at 1 plant stand $^{-1}$ density. The result obtained could be associated to low competition among plant in space, and other growth factors as a result of lower density at a wider inter and intra row spacing (60x60cm) that enable the plant to produced more number of leaves. The interaction between variety and irrigation interval (first order interaction) was significant on the number of branches per plant, where variety Roma VF recorded a higher number of branches at 5WAT with 5days irrigation interval treatment in Samaru location. The result can be related low water table, high temperature and relative humidity similarly poor water holding capacity. Therefore, frequent soil moisture replacement at shorter interval is

required in soils of such quality. It's also a clear indication that, vegetative growth and development of tomato plant is affected by soil moisture deficit.

5 .5 Simple Correlation Study on Tomato Crop Performance

The study revealed positive and significant correlation between tomato fruit yield and some growth and yield parameters such as plant height, number of branches, leaf area index, number of flowers and marketable fruit yield at Samaru. This implies that the characters are the major determinant of total fruit yield directly or otherwise. Similarly, positive values of growth parameters are require establishing a better total tomato fruit yield. This confirmed the findings ofPrakash&Bahadur (2014) who stated that growth parameters has direct effect on yield per plant indicated that direct selection for these traits might be effective and there is a possibility of improving yield per plant through selection based on these characters. Highly significant positive association was also observed between the parameters like plant height, number of flowers, number of branches and fruit diameter, leaf area index and marketable yield etc. These indicated that an increase in each leads to the direct increase of the other and significant the interrelationship in contributing to the general crop growth development and yield. Significant correlation of characters suggested that there is much scope for direct and indirect selection for further improvement. Genotypic correlation coefficient provides measures of genetic association between traits and thus helps to identify the more important as well as less important traits to be considered in breeding programs reported by Tiwari and Upadhyay (2011).However, dry matter weight was non-significantly negative and positively correlated to total tomato fruit yield. While fruit diameter was not significant but positive, these showed that tomato dry matter in some cases is not the basis for higher and significant

yield and yield parameters like fruit diameter. Dry matter accumulation in some tomato varieties might be related to genetic composition of the crop.

In Kadawa, most of the parameters assessed were positively associated with total fruit yield though non-significant except plant height, marketable and unmarketable yield which were highly and positively correlated. These differed from the result obtained in Samaru. Likewise among most growth parameters assessed were positive but non-significant except number of branches and leaf area index, unmarketable and number of flower, fruit diameter and marketable fruit yield. Negative and non-significant correlation were observed between plant height and number of flowers, plant height and marketable yield, number of branches and un marketable yield were not significantly correlated with other parameters. The overall general no- significant correlation among all the parameters assessed at Kadawa is logical or expected as correlation is not always consistent and location specific. Therefore variety selection based on yield is not always the best for consideration because yield trait in crop may alter by environmental condition. However, selection based on multiple traits could solve the problems of both phonetic and genetic distortion in plants. Selection for yield based on multiple traits is always better than selection based on yield alone Muhammad *et al*. (2003); Bello *et al.*(2010).Using these components, breeders would understand strength of correlated traits that would assists in decision making process to select for simultaneous improvement of more than one character Sivaprasad (2008); Monamodi*et al.*,(2013).

However, correlation alone does not provide information on the contribution of related characters, which need the study of cause and effect relationship of different characters among themselves (McGiffen*et al.*,1994). It has been observed that path coefficient analysis reveals the exact relationship of characters thereby providing more information than simple correlation analysis.

5.6 Regression Response of Tomato Total Fruit yield to Irrigation Interval

When tomato total fruit yield (tons ha^{-1})was regressed against irrigation interval in days. It was observed that the negative linear was the best fitting curve for the data at Samaru. This implies that each increase in irrigation interval from 5 to 10 and 15 days resulted in the significant decreased in the total fruit yield. It suggests that the optimum irrigation interval that will give highest economic yield is not achievable within the irrigation interval evaluated. This could be attributed to low water table, soil and climatic nature of the location which resulted to higher evapotranspiration which enhanced frequent loss of soil moisture. Water is very essential nutrient necessary for the stimulation of rapid vegetative growth, because of its importance in photosynthesis, respiration and other metabolic process. It implies that soil moisture needs to be replacing at a level when the soil is still moist rather than at a root zone water deficit level. This agreed with finding of Abubakar.(2014) in a research to test the response tomato to soil moisture depletion, least yield was obtained from the plot treated with 30% replacement of moisture depletion and 10 days irrigation interval. The highest value of the tomato yield was obtained from the plot treated with 60 % replacement of moisture depleted and 5 days irrigation interval. The yield obtained from this study ranges from 10.90 t/ha to 28.22 t/ha. Rodríguez *et al*. (2010) reported that water stress strongly affects horticultural cultivars by reducing yield and fruit quality. Also the physiological functions of the plant are altered by this stress reducing due to the formation of reactive oxygen species and water relationships.

However, atKadawa, it was observed that quadratic response fitted the curve better the optimum irrigation interval was determined to be 14 days which could be attributed to high water table of the location. This implies irrigating tomato plant every 13 days resulted higher economic yield though, depending on water table and climate.The result is in line with

findings of Hussaini (*et al*., 2013) reported that 15 days irrigation intervals gave better yield attributes at Kadawa.

6.0 CHAPTER SIX

6.1 Summary

Field trials were carried out at Institute of Agricultural Research (IAR) Ahmadu Bello University farms in Samaru and Kadawa during the 2017/2018 dry seasons to study response of tomato varieties to irrigation intervals and stand densities. The objectives of the research entailed; studying the effect of irrigation interval, determining suitable tomato variety for production and studying the effect of stand density on the growth and yield of tomato under dry season in the Nigerian savanna. Treatments consisted of two tomato varieties (UC82-B and ROMA-VF), three irrigation intervals (5, 10 and 15 days) and two stand densities (1 and 2 plants stand^{-1}) which were arranged factorialy using Split Plot Design with irrigation interval in the main plot while variety and density in the sub plot replicated four times.

The results revealed that variety ROMA-VF recorded significantly taller plant height 9 WAT, dry matter, numbers of leaves, dry matter, and branches than UC82-B at Samaru. The same variety took longer days to attain 50% flowers, whereas UC82-B recorded significantly superior yield parameters like fruit diameter, fruit weight per plant, total fruit yield in tons ha^{-1}, marketable yield and total fruit at both trial locations.

Application of water was significant on growth parameters. Increasing irrigation interval from 5, 10 and 15 days linearly decreased plant height, branch number, number of leaves and leaf area index at Samaru. 15 days irrigation recorded longer days to 50% flower, higher number of leaves and least number of flowers per plant at Kadawa. Linear decrease in fruit weight per plant, diameter and total fruit yield were observed with increasing irrigation interval from 5 to 15 days at Samaru. These parameters were not significantly influenced by varying irrigation interval at Kadawa.

Effect of stand density was significant on number of branch 7WAT, leaf area index, leaf area, dry matter, crop growth rate, relative growth rate, days to 50% flowering, average fruit average, total fruit number, and fruit weight in Samaru while only number of branch, average and fruit average were found significant at Kadawa among the parameters assessed. Treatments interaction was found significant between variety Roma VF and stand density 1 plant stand^{-1}on number of leaves at Samaru. Similarly, 5 days irrigation interval and Roma VF on number of branches.

When tomato total fruit yield (tons ha^{-1})was regressed against irrigation interval in days. It was observed that the negative linear was the best fitting curve for the data at Samaru. This implies that each increase in irrigation interval from 5 to 10 and 15 days resulted in the significant decreased in the total fruit yield. It suggests that the optimum irrigation interval that will give highest economic yield is not achievable within the irrigation interval evaluated.However, in Kadawa, it was observed that quadratic response fitted the curve better the optimum irrigation interval was determined to be 14 days which could be attributed to high water table of the location. This implies irrigating tomato plant every 14 days resulted higher economic yield though, depending on water table and climate.

6.2 Conclusion

Based on the result obtained in this study, it could be suggested that, the use of 2 plant stand $^{-1}$, 5 days in Samaru and 14 days in Kadawa irrigation interval gave the best marketable yield in tons ha^{-1}. Similarly, variety UC82-B was better than ROMA-VF in terms marketable yield.

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Appendix I: Samaru Meteorological Observation for 2017-2018 dry seasons.

Month		Temperature			
	RH (%)	T^0max	T^0 min	Sunshine(hrs)	Rainfall (mm)
OCTOBER	64.45	34.06	18.1	NA	NA
NOVEMBER	18.03	34.2	11.97	NA	NA
DECEMBER	16.90	31.36	12.48	NA	NA
JANUARY	17.71	30.16	13	NA	NA
FEBRUARY	20.39	36.39	18	NA	NA
MARCH	13.0	38.61	20	NA	NA
APRIL	28.72	38.13	22	NA	NA
MAY	64.48	35.32	22	NA	NA

Source: IAR Meteorological Unit, IAR/ABU, Zaria.
NA: Not Available

Appendix 2: Kadawa Meteorological Observation for 2017-2018 dry seasons.

Month		Temperature			
	RH (%)	T^0max	T^0 min	Sunshine(hrs)	Rainfall
OCTOBER	65	33.9	26.6	NA	NA
NOVEMBER	35	31.2	15.9	NA	NA
DECEMBER	45	24.4	13.4	NA	NA
JANUARY	42	24.32	21.7	NA	NA
FEBRUARY	37	33.04	36.3	NA	NA
MARCH	36	34.02	24.32	NA	NA
APRIL	50	37.6	27.62	NA	NA
MAY	62	36.8	28.24	NA	NA

Source: KadawaMeteorological Unit, Kano.
NA: Not Available

BIOGRAPHY

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Degree In View: Master of Science, Agronomy