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Alleviation of Drought Stress in Tomato *(Solanum lycopersicon)* Using Organic Mulch

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Abstract

Despite the importance of tomato in human nutrition, occurrence of drought stress constitutes a major bane to its bountiful production. Therefore, this experiment was conducted to determine the effectiveness of organic mulch in improving growth, yield and quality of water stressed tomato. The experiment was laid out in randomized complete block design (RCBD) with three replications. The six treatments used in the experiment were normal irrigation with zero mulch, drought stress with zero mulch and drought stress with mulch at the rates of 10tons/ha, 15tons/ha, 20tons/ha and 25tons/ha. The organic mulch material used was maize husk and the tomato variety tested was Platinum 107 F1. Water deficit treatment was imposed at flowering stage (five weeks after transplanting (5WAT)) by applying 50% field capacity as irrigation water. Data were collected on plant height, number of leaves per plant, number of branches per plant, number of flowers per plant and mass of fruit yield per plant. Furthermore, leaf proximate compositions (crude fat, crude protein, crude fibre, ash content and dry matter) and leaf chlorophyll content were determined. All the data collected were subjected to analysis of variance (ANOVA) and significant means were separated using least significant difference (LSD) at 5% probability level. Results from this research work showed that stressed plants without mulch application had a drastic reduction in all the measured parameters. The plants subjected to drought and treated with 20tons/ha mulch showed higher plant height, number of branches and yield as well as chlorophyll, fiber and ash content compared to the plants treated with 10tons/ha, 15tons/ha and 25t/ha mulch. It is, therefore, concluded that 20tons/ha mulch be used for alleviating drought stress condition in Platinum 107 F1 tomato variety in the study area when all the conditions in this research are maintained.

1. Introduction

Tomato is sensitive to water scarcity and requires abundance of water for vegetative and reproductive growth, especially flowering and fruit enlargement stage [1]. Stress is an adverse condition in which plant is influenced by external factors such as low and abundant water, high and low temperature, light which exert a disadvantageous effect. In water stress condition tomato crop is affected in various ways such as reduced growth and leaf surface area, flower shedding, mineral deficiency due to lack of absorption, reduction in fruit size, fruit splitting, puffiness and many physiological disorders related to calcium deficiency such as blossom end rot (BER), poor seed viability and so on[2].There are many factors which affect the impact of drought on plants such as environmental and genotypic interaction, timing, severity and duration of water stress condition. Water availability is the key factor for dry matter production in plant. Low water availability decreases water and nutrient uptake, photosynthetic rate and translocation of photo assimilates. An experiment conducted by Nahar et al. [3] with four tomato genotype showed reduction in dry matter production under water deficit condition.

Effect of mulching on conserving moisture and increasing productivity of crops had been reported in maize [4], wheat [5], vegetables [6] and other crops [7] as well as bare fields [8]. Mulch has the potential to control weed growth [9] and retain soil moisture [10]. Research results have strongly established that the conserved moisture through mulching have been very effective to plants during stress.

Mulch has a great role in soil moisture conservation through modification of microclimatic soil conditions. It helps to prevent weed growth, reduce evaporation, and increase infiltration of rain water during growing season [11]. Different research result showed mulch increase soil moisture through increasing infiltration, reducing evaporation, and modifying water retention capacity of the soil [12] Water holding capacity of the soil improved through mulch decomposition and humus formation [12]. In aqua crop water productivity model by Raes et al. [13], soil evaporation reduction by 50% was modeled with 100 percent cover of the soil by organic mulch. This is in line with Hatfield et al. [14] who also reported a 34–50 percent reduction in soil water evaporation as a result of crop residue mulching.

Mulch plays an important role to regulate soil temperature, conserve moisture, restrict evaporation losses, and suppress weed growth, reducing the number of dirty and diseased berries [15], enhancing nutrient uptake, and improving water use efficiency and yield [16]. Mulching technique increases the vegetative growth, flowering of plants, yield, and quality of strawberry [17] and creates loose soil surface that increases the total intake of water and reduces surface runoff [18]. Kirnak et al. [19] found that mulching can mitigate negative effects of water stress on the plant growth and fruit yield of strawberry under the field grown condition especially in semiarid regions. Root zone temperatures play an important role in plant growth and development through the uptake of water and nutrients by roots. Pandey et al. [20] found beneficial effects of mulching on root zone temperature which were reflected in an increased number of fruits and fruit size. He recommended mulch for effective root zone temperature, weed control, and moisture regulation to grow strawberry. Mulches were found to act as a barrier to the action of rainfall that compacts soil thereby reduce soil erosion by water and inhibits weed growth. Black plastic significantly enhanced root growth and facilitated higher nutrient uptake thereby promoted growth and development of plants [16]. The application of organic mulches as a soil cover is effective in improving the quality of soil and increasing crop yield, especially in organic farming. Mulching is an effective method in manipulating crop growing environment to increase yield and improve product quality by controlling weeds, ameliorating soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content [21].

The objective of this work was to determine the effectiveness organic mulch in improving growth, yield and quality traits of water-stressed tomato

2. Methodology

2.1. Site description

The experiment was conducted at the pavilion of the Department of Agronomy, Faculty of Agriculture, University of Ilorin, Kwara State in the Southern Guinea savanna agro ecological zone of Nigeria. The site was located at latitude 8’29’N, Longitude 4’35’E using the global positioning station. The annual rainfall in Ilorin is between 1000-1240mm with mean temperature range of 19°C – 33°C. The study was carried out between November 2018 and April 2019.

Raising of Seedlings and Transplanting

Seeds of tomato of variety Platinum 701 F1 were obtained from an agro-chemical shop in Ilorin, Kwara State. The seedlings of the seeds were raised for a month in a nursery using a wide plastic container filled with soil in the same pavilion. The seedlings were transplanted four weeks after sowing to 7liter pots filled with 10kg of air dried soil. That was free of gravel and non-biodegradable materials. There were three plants per pot. The pots were perforated for removal of gravitational water. The transplanted tomatoes were watered till 80% flowering stage before commencing water-deficit treatment.

2.2. Experimental Design, Treatments and Cultural Practices

The experiment was laid out in randomized complete block design (RCBD) with three replications. There were six treatments in the experiment to have a total of eighteen experimental pots. The treatments were normal irrigation with no mulch, drought stress without mulch, drought stress with mulch application at the rates of $10tha^{-1}$, $15tha^{-1}$, $20tha^{-1}$ and $25tha^{-1}$. The organic mulch material used was maize husk and the tomato variety planted was Platinum 107 F1. Water deficit treatment was imposed at flowering stage (five weeks after transplanting (5WAT)) by applying 50% field capacity as irrigation water.

Plants were irrigated on daily basis till the time of imposition of water-deficit stress. The experimental pots were kept weed-free from the beginning to the end of the experiment using hand pulling.

2.3. Data collection

At maturity after stress imposition and alleviation, data were collected on plant height (measured from the base of the plant to the apex of the topmost leaf), number of leaves per plant, number of branches per plant, number of flowers per plant (by counting) and mass of fruit yield per plant. Furthermore, leaf proximate compositions (crude fat, crude protein, crude fibre, ash content and dry matter) and leaf chlorophyll content were equally determined.

Determination of Leaf Total Chlorophyll

Leaf chlorophyll content was determined by homogenizing 1g of fresh leaf samples in 15ml of ethanol. The mixture was then filtered and the filtrate was covered with aluminum foil to prevent it from being broken down by sunlight. The concentration of chlorophyll was then measured as a function of intensity of absorbed light in a spectrophotometer. Absorbance at 647 and 664 nm wavelengths was measured with UV spectrophotometer.

Total and actual chlorophyll were calculated using the following formulae:

$$\text{Chlorophyll a} = (13.19 \times A_{664})-(2.57 \times A_{647}) \quad (1)$$

$$\text{Chlorophyll b} = (22.1 \times A_{647})-(5.26 \times A_{664}) \quad (2)$$

$$\text{Total chlorophyll} = \text{Chlorophyll a} + \text{chlorophyll b} \quad (3)$$

A_{664} and A_{647} are absorbance at wavelengths 647 and 664 nm respectively

Proximate Composition Determination

Preparation of Sample for Proximate Analysis

Dried samples of leaves were ground into fine powder. From the ground samples, crude fat, crude protein, crude fibre and ash contents were determined using the methods described by Kirk and Sawyer [22], AOAC [23] and James [24].

2.4. Crude Protein Determination

This was done using Kjeldahl method described by Chang [25]. In this method, total nitrogen was determined and multiplied by 6.25 to obtain crude protein content of plant samples. 0.5g of each plant sample was mixed with 10ml of H_2SO_4 in a digestion flask. A tablet of selenium was then added to the mixture and the resulting mixture was heated under a fume cupboard until the mixture turned to a clear solution (sample digest). The digest was made up to 100ml using distilled water and kept in a volumetric flask. 10ml of the digest was mixed with equal volume (10ml) of 45% sodium hydroxide solution of Kjeldahl distillation apparatus. The mixture was distilled into 10ml of 40% boric acid containing three drops of mixed indicators (bromocresol green and methyl red). A total of 50ml distillate was collected and titrated against 0.02N EDTA until the colour turned from green to deep red (the end point). Reagent without plant sample (blank) was also distilled and titrated. The nitrogen and crude protein contents were then calculated using the following formulae:

$$\%\text{Nitrogen} = \frac{100\text{x}N\text{x}14\text{x}Vt}{W\text{x}1000\text{ X }Va} xTxB \quad (4)$$

$$\%\text{Crude Protein} = \%N\text{ x}6.25 \quad (5)$$

W= Mass of sample (0.5g)
N= Normality of titrant (0.02N H_2SO_4)
Vt= Total digest volume (100ml)
Va= Volume of analyzed digest (10ml)
T= Sample titre value
B=Blank titre value
Note:1ml of 1N H_2SO_4 =14mg

2.5. Determination of Crude Fat

The determination was through gravimetric method described by Krick and Sawyer [22]. Five grams of plant sample was wrapped in a porous paper (whatman filter paper) and put in a thimble. The thimble was put in a soxlet reflux flask and mounted on weighed extraction flask (W_1) containing 200ml of petroleum ether. The upper part of the reflux flask was connected to a water condenser. The solvent (petroleum ether) was heated to boil, vapourize and condense into soxlet reflux flask. Through this process the sample in the thimble was shortly covered with the solvent after it was put there until soxlet reflux flask was filled and then siphoned. The oil extract was carried down to the boiling flask. This process was allowed to go on repeatedly for four hours before the defatted sample was removed. The solvent was recovered and the oil extract was left in the flask. The flask containing the oil extract was dried in an oven at 60^{o}C for 30minutes to remove any remove any residual solvent. The flask was then cooled in a desiccator and weighed (W_2). The mass of oil (fat) extract was determined as follows:

$$\%\text{Fat} = \frac{W2-W1}{\text{Mass of plant sample}} x100 \quad (6)$$

Where:
W_1=Mass of empty extraction flask
W_2=Mass of flask + Oil (fat) extract

2.6. Determination of Total Ash Content

This was determined through furnace incineration gravimetric method as described by James [24] and AOAC (1984). Five grams of prepared plant sample was weighed into a porcelain crucible of mass W_1. The sample was burnt to ashes at 550^{o}C in a muffle furnace. After it has completely burnt into ashes, it was cooled in a desiccator and the mass of the crucible and ash was determined and recorded as W_2. Percentage of ash in the sample was determined as follows:

$$\%Ash = \frac{W2-W1}{\text{Mass of plant sample}} x100 \quad (7)$$

Where:
W_1=Mass of empty extraction flask
W_2=Mass of crucible + Ash

2.7. Determination of Crude Fibre

This was determined by the procedure described by James [24]. Five grams of the prepared plant sample was weighed and boiled in 150ml of 1.25% H_2SO_4 solution for 30minutes under reflux. The boiled sample was washed in several portions of hot water using a two-fold cloth to trap plant particles. The sample was returned to the flask and boiled again in 150ml of 1.25% sodium hydroxide for 30 minutes under the same condition. After the sample was washed in several portions of hot water, the sample was allowed to drain and dry before being transferred into a weighed crucible where it was dried to a constant mass at 105°C using an oven. The mass of crucible + the dry sample was recorded as W_2. The dried sample was then transferred into a muffle furnace and burned into ashes. Percentage of crude fibre was determined as follows:

$$\%Crude\ Fibre = \frac{W2-W3}{\text{Mass of plant sample}} x100 \quad (8)$$

Where:
W_2=Mass of crucible + sample after washing, boiling and drying
W_3=Mass of crucible + Sample of ash

2.8. Statistical Analysis

All the data collected were subjected to analysis of variance (ANOVA) and significant means were separated using least significant difference (LSD) at 5% probability level.

3.0. Results and Discussion

3.1. Effects of mulch on plant height of water stressed tomato

Drought stress was alleviated through increasing application of mulch from zero to 20t/ha after which there was a decline. The tallest plants were from stressed plants treated with 20t/ha of mulch followed by plants treated with 25t/ha mulch while the shortest plants were plants without mulch. The height increased from plants with zero mulch to plants with 20t/ha mulch after which there was a decline (Table 1). This implies that beyond 20t/ha, effectiveness of mulching on mitigation of drought stress in tomato would stop. This is also true for number of leaves, number of branches and chlorophyll content of leaves (Tables 1 and 2).

Increase in height of tomato under drought stress with increase in the rate of mulch application might be linked to better conservation of water for the use of plants during the stressful period. This led to higher height and increase in number of leaves and branches produced because of alleviation of drought stress. Furthermore, increase in height as a result of increase in mulch application could be attributed to usage of the conserved water by mulch for crop growth and yield rather than allowing the water to evaporate [26]. In the same vein, the result could be attributed to ease of nutrient release in the soil and its absorption by plants in solution. This consequently led to luxuriant growth of the plants in form of increase in height, number of branches and leaves. Similarly, increase in application rate of mulch could have resulted in lowering soil temperature to suit growth and development of the plants as revealed by result of plant height (Table 1).

Decrease in height as water deficit increased showed clearly that the plants were adversely affected by water deficit condition. The study of Hussein et al. [27] also found reduction of plant height with increase in water deficit or drought levels. Reduction in height could be linked to alteration of water potential, increase in ion toxicity, obstruction of cell division and expansion as well as ion imbalance [28]. Moreover, height reduction could be the result of inhibition of apical growth and endogenous hormonal imbalance caused by water deficit stress [29]. It might equally be the result of inability of getting sufficient water and nutrient needed for cell elongation and enlargement as a result of physical dryness experienced by the plants. This might have had consequential effect on photosynthate production because water and some nutrients like potassium and chlorine are needed for successful photosynthetic activities. With less photosynthate production, translocation to the growing areas becomes a great difficulty and, therefore, growth also found reduction of plant height with increase in water deficit or drought levels. Reduction in height could be linked to alteration of water potential, increase in ion toxicity, obstruction of cell division and expansion as well as ion imbalance [28]. Moreover, height reduction could be the result of inhibition of apical growth and endogenous hormonal imbalance caused by water deficit stress [29]. It might equally be the result of inability of getting sufficient water and nutrient needed for cell elongation and enlargement as a result of physical dryness experienced by the plants. This might have had consequential effect on photosynthate production because water and some nutrients like potassium and chlorine are needed for successful photosynthetic activities. With less photosynthate production, translocation to the growing areas becomes a great difficulty and, therefore, growth The desirability of having tall plants is hinged on avoidance of intra- or inter-species shading which might make a plant prone to etiolation and reduction in photosynthetic efficiency when light harvesting apparatus receive solar energy below the threshold for efficient production of photo-assimilates. Furthermore, plant height and the angle of inclination of the leaves are major factors affecting light interception by plants. Nevertheless, excessive height could make a plant prone to lodging and reduction in number of branches believed to have been caused by height gain. The consequences of excessive height constitute limitations to plant productivity because higher number of branches is a pre-requisite to having higher number of flowers and consequently fruits. This in turn is a very important yield determinant and, therefore, it becomes a target trait for all agronomic, physiological and genetic manipulations.

3.2. Effects of mulch on number of leaves and branches of water stressed tomato

Effect of drought on leaf production in tomato was mitigated by increase in the rate of mulch application. However, there was a drop in the number of leaves per plant beyond application of 20t/ha mulch. The highest number of leaves produced was from application of 20t/ha mulch followed by application of 25t/ha while the lowest number of leaves was from the control (zero mulch application). This result implies that the optimum application rate should be 20t/ha. Beyond this, the law of diminishing return would set in (Table 1).

In the same vein, mulch application alleviated drought stress in tomato plants. This was showcased through steady increase in number of branches with increase in the rate of mulch application till application of 20t/ha mulch. After that, there was a drop in the number of branches produced. The highest number of branches was produced by plants from pots that received 20t/ha mulch followed by those that received 25t/ha mulch while the lowest number was from the ones with zero mulch (Table 1).

Improvement in the number of leaves and branches produced by drought stressed tomato through increase in application rate of organic mulch might be attributed to enhancement of node production as a result of availability of suitable hormones for production of more nodes which consequently led to more leaf and branch production. These hormones could only be translocated in the presence of water and that was made easy with conservation of water through application of mulch. Similarly, considerable enhancement in tomato growth parameters (plant heights, numbers of branches, numbers of leaves) was as a result of availability of water for growth and yield of the crop in consideration through reduction in evaporation, regulation of soil temperature and making of nutrient available for absorption by plant as a result of availability of water for dissolution of the needed solutes. In the same vein, the result could be attributed to having greater soil profile moisture under mulch which has important implication in the utilization of water by crop and in soil reactions

that control the availability of nutrient and biological nutrient fixation that leads to improved plant growth [30].
High number of branches show vegetative growth success in non-grass plants and are equivalent of tillers in grasses. They can predict plant biomass yield. To some extent, economic yield can also be predicted by them. This is because the number of branches determines the number of leaves to be produced and the number of leaves produced determines the amount of photosynthate that will be produced. Therefore, if photosynthate produced is judiciously partitioned, economic yield will increase. There was reduction in the number of branches produced under water deficit condition in this work. This was equally observed by Saeed et al. [31] when they subjected okra varieties (Parbhani Karanti and DLPG) to drought stress. Along with reduction in number of branches, they equally found reduction in fresh fruit yield per okra plant as the severity of drought stress increases. Furthermore, Zhang et al. [32] recorded reduction in number of branches when they subjected soybean plants to moderate water stress. These results might be because of the fact that plants were not able to produce enough assimilates as a result of inhibited photosynthesis under water stress. It could also be attributed to inhibition of cell division and enlargement of meristematic tissue as well as having less amount of water uptake to prepare sufficient food needed for growth [33].
There was an inverse relationship between water deficit and number of leaves produced. This implies that increase in water deficit led to decrease in number of leaves produced. In the same vein, Manivannan et al. [34] found that water stress mostly decreased leaf growth and leaf areas in okra crop and sunflower respectively. This might be because plants faced with the problem of water deficit experienced a change in cell wall properties and photosynthetic rates which then led to reduction in number of leaves produced. Furthermore, reduction in number of leaves could have resulted from reduced turgor or reduction in extensibility of cell walls [35]. The problem might equally be due to water stress in the short run and ion toxicity in the long run [36]. This reduction in number of leaves can be seen as an avoidance mechanism which occurs so as to reduce water loss by transpiration. This reduction in water loss by transpiration is also capable of limiting accumulation of the salt ions in the shoot by favouring the retention of toxic ions in the roots [37].

Table 1: Effects of mulch on plant height, number of leaves and number of branches of water stressed tomatoes

Application Rate (t/ha)	Plant Height(cm)	Number of Leaves	Number of Branches
Control	55.50^a	85.50^a	16.50^a
0	26.25^b	33.25^b	4.75^b
10	35.75^c	44.50^c	9.00^c
15	43.25^d	52.75^d	11.50^d
20	65.75^e	78.25^e	15.25^a
25	53.75^a	61.00^f	13.50^d

3.3. Effects of mulch on number of flowers of water stressed tomato

Effect of drought stress was alleviated in tomato by increasing the number of flowers produced above the control. Number of flowers increased linearly with increase in the rate of mulch application though 20t/ha and 25t/ha produced the same number of flowers. So, the highest number flowers was produced by plants from pots that received 20 and 25t/ha mulch followed by those that were from plot with 15t/ha while the lowest number of flowers was produced by pots without mulch (Table 2).
Availability of water to crops through the use of mulch enhanced production of more flowers. This could be attributed to the fact that hormone for flowering requires water to flow to destination (target organ) for its action. In the same vein, availability of water enhanced other biochemical activities in the plant that are responsible flower production. The enhancement from water availability was

because it has been established that increase in water stress affect flower development and crop production [38]. Furthermore, increase in number of flowers as well as earliness in flowering has been reported for water -stressed crops treated with mulch compared with plants without mulch [39]. So, the optimum rate of mulch needed for tomato production could be pegged at 20t/ha since application of 25t/ha did not result in appreciable betterment in the number of flowers produced.

3.4. Effects of mulch on fruit yield of water stressed tomato

Fruit production followed the pattern of dry matter production and biological yield. The highest fruit yield was found in plants from pots that received 20t/ha mulch followed by those from pots that received 25t/ha mulch while the lowest fruit yield was found in plants from pots that received 15t/ha mulch. The trend was that there was increase in fruit yield of plants from pots that received 10t/ha mulch followed by a decline in plants from pots that received 15t/ha much after which there was a rise with a final fall in plants from pots with 20t/ha and 25t/ha respectively (Table 2).

Increase in fruit yield could be linked to better conservation and usage of water for cell multiplication and cell enlargement at the reproductive stage. Similarly, it could have been that better water conservation eased release of nutrients which were used for growth and development of the plant as well as better photosynthesis coupled with judicious partitioning of the photosynthates to the fruit. It should also be noted that flower production had a linear relationship with rate of mulch application. However, abortion of flowers occurred at the time of fruit formation and it occurred across all the application rates without following a particular trend. This has made the prediction of the trend of fruit production difficult. Despite that, the optimum rate (20t/ha) as found in other parameters still had the highest fruit yield.

In this study, it was found that number of fruits decreased with increase in severity of water stress. Abdulrahman and Nadir [40] also found reduction in okra yield with increase in severity of drought stress. In the same vein Specht et al. [41] found decrease in yield of soybean when it was raised under drought stress condition. Furthermore, Nahar and Ullah [42] discovered yield reduction in two tomato cultivars when they subjected them to water stress condition. This reduction in yield under water deficit stress may be attributed to low cell expansion, less photosynthetic rate and leaf senescence [43]. Furthermore, the growth of drought-stressed plants is mostly limited by the osmotic effect of water deficit stress which results in reduced growth rate and low stomatal conductance. As water deficit stress increases, yields move towards zero because most plants (mesophytes) will not grow in high water deficit condition and are severely inhibited or even killed at very high stress level because they were not genetically bred to tolerate that stress level. Furthermore, reduction in yield could be attributed to reduction in number of leaves, plant height and number of branches found in this work. Yield reduction might equally be linked to action of water deficit to induce Fe2+, K+, and Ca2+ deficiencies [44] which resulted in yield losses [45].

Table 2: Effects of mulch on number of flowers and fruit yield of water stressed tomato

Application Rate (t/ha)	Numbers of Flowers	Fruit yield (g)
Control	14.50^{a}	11.04^{a}
0	9.25^{a}	5.51^{a}
10	12.50^{a}	8.65^{a}
15	14.75^{a}	4.95^{a}
20	15.25^{a}	13.47^{a}
25	15.25^{a}	12.31^{a}

3.5. Effects of mulch on leaf chlorophyll content of water stressed tomato

Application of mulch alleviated moisture stress effect by improving the chlorophyll contents of the leaves above that of control. There was linear relationship between application rate and chlorophyll contents till 20t/ha mulch application after which there was a decline in the chlorophyll contents. So, the highest level of chlorophyll content was from plants that received 20t/ha mulch followed by those that received 25t/ha mulch while the lowest chlorophyll content was from plants that received no mulch at all (Table 2).

Increase in the severity of drought stress led to chlorophyll degradation as a result of production of chlorophyllase. In the same vein, it equally prevents its synthesis [46]. With increase in the mulch application rate, more water was retained in the plant system and the rate of chlorophyllase production decreased and that led to increase in chlorophyll contentment of the plant leaves. With increase in chlorophyll content, absorption of solar radiation will increase and dry matter production will be increased in turn provided all other variables of photosynthesis are constant. It might equally be said that leaf chlorophyll content decreases with drought stress while application of mulch leads to the maintenance of chlorophyll level of plants under drought condition. Finally, better water conservation and utilization through mulch application increased chlorophyll production in a drought condition [46].

Chlorophyll is very important because it indicates the status of leaf nitrogen and nitrogen content is an indicator of the plant source strength [47]. Chlorophyll content is an indication of nitrogen status of the plant and it is significantly decreased by exposure to moisture stress especially chlorophyll-a and chlorophyll-b [48]. If the chlorophyll content is high, it implies high source strength. High source strength will in turn lead to high yield and consequent high harvest index [49]. if the assimilates are judiciously partitioned to the developing fruits. It has been made known that chlorophyll content has positive and significant correlation with both rice yield and harvest index [50]. There was decline in chlorophyll content as water stress increased in this work. This was equally reported that Manivannan et al. [51] found that decrease in chlorophyll content was caused by water deficit stress in different sunflower varieties. Furthermore, Jaleel et al.[52] reported that both chlorophyll a and b are reduced drought stress. It should be noted that decrease in chlorophyll content or unchanged level of chlorophyll is dependent on the duration and severity of drought [53]. The result of this study might be ascribed to damage done to the chloroplast by reactive oxygen species which are normally produced as a result of moisture or other environmental stresses [54]. Furthermore, water deficit induced reduction in chlorophyll content could be linked to loss of chloroplast membranes, excessive swelling, distortion of the lamellae vesiculation, and the appearance of lipid droplets [55]. In the same vein, decrease in chlorophyll content could be as a result of water- deficit- induced weakening of protein-pigment- lipid complex and increased chlorophyllase activities [56]. This reduction in chlorophyll content together with reduced potassium uptake which results in K/Na antagonism resulted in impaired photosynthesis which consequently led to low yield. It should be noted that photosynthesis is adversely affected during moisture stress through lowering of chlorophyll level, disturbance of chlorophyll components and destruction of photosynthetic apparatus [57]. From the on-going, it is evident that the assertion that chlorophyll content has strong relationship with yield in rice [50] is equally true for okra. However, there are still other contributing factors that influence yield. Therefore, chlorophyll cannot singly determine the yield magnitude except if other yield contributors are also in line.

3.6. Effects of mulch on dry matter production of water stressed tomato

The highest dry matter content was found in plants from pots that received 20t/ha mulch followed by those from pots that received 25t/ha mulch while the lowest dry matter content was found in plants from pots that received 15t/ha mulch. The trend was that there was increase in dry matter content of plants from pots that received 10t/ha mulch followed by a decline in plants from pots that received 15t/ha much after which there was a rise with a final fall in plants from pots with 20t/ha and 25t/ha respectively (Table 2).

Increase in dry matter production and biological yield as a result of increase in mulch application under water stress was because of water availability resulting from water retention of the soil through application of mulch. This was so because water availability is a key factor for dry matter production. It has been established that mulch application led to increase in photosynthetic rate, water uptake and photo-assimilate translocation [3]. Furthermore, increased mulch application might have led to prevention of soil moisture which resulted in better utilization of moisture by tomato plants as well availability and absorption of soil nutrients which then led to improved growth [30] of tomato.

All these are improvements through mulch application led to increase in dry matter production. It has been observed that increase in chlorophyll contents as found in this work (Table 3) could lead to higher photosynthetic rate which consequently result in overall yield of the plant. In the same vein, increase in dry matter yield could be attributed to increased number of leaves which resulted in better production of photo-assimilates and consequent increase in dry matter yield.

Table 3: Effects of mulch on chlorophyll content and dry matter production of water stressed tomato

Application Rate (t/ha)	Chlorophyll(μmolcm^{-2})	Dry matter(g)
Control	1.45a	2.62a
0	0.13b	0.72b
10	0.23c	2.95c
15	0.32d	1.30b
20	1.55e	1.92a
25	0.66f	1.81a

3.7. Effects of mulch on leaf crude fibre content of water stressed tomato

The highest crude fibre content of leaves was from plants that received 10t/ha while the lowest was from pots that received 20t/ha mulch. There was a surge after the control (i.e.10t/ha) after which there was a decline in the crude fibre content. So, higher application rates (15, 20 and 25t/ha mulch) resulted in lower crude fibre production in water-stressed tomato leaves (Table 4).

High content of crude fibre implies low digestibility of the food or feed material as well as low energy and total digestible nutrient (TDN). There was increase in crude fibre with water deficit in this work. Other researchers like Essafi et al.[58] and Sumithra et al.[59] have equally reported increased fibre production with increase in water stress in plants. These results might be due to plants' increased production of crude fibre in response to water stress condition. Hale and Orcutt [60] have observed that plants synthesize special high molecular proteins during water stress to assist them in resisting the effects of water stress. The implication of this result is that the fruits produced would be less useful as either food or feed. Although fruit bulking is through increase in fibre and water contents which are both disadvantages because they result in low shelf life, low dry matter content and low digestibility. However, high fibre content in okra is useful in stabilizing blood sugar by slowing down or regulating the rate at which sugar is absorbed from the intestinal tract and, therefore, useful for managing diabetes [61].

3.8. Effects of mulch on leaf crude protein content of water stressed tomato

Leaf crude protein contents followed the trend in plant height, number of leaves, number of flowers, chlorophyll content and number of branches. Crude protein contents increased with application of mulch as a result of alleviating moisture stress from zero application to application of 20t/ha after which there was a drop in the highest application rate (25t/ha). So, the highest crude protein content was from pot with application rate of 20t/ha mulch followed by 25t/ha mulch while the lowest crude protein content was from pots with zero application (Table 4). The implication is that beyond 20t/ha, it is not profitable to use mulch in alleviating moisture stress in tomato. It might also be that application of mulch beyond 20t/ha hampered the smooth growth of the plants or that it led to addition of toxic materials (allelopathic chemicals) which were harmful to the plants in the soil.

There was decrease in crude protein with increasing water deficit in this work. Similar to this result was that of Khalil et al.[62] who observed that increasing water stress lowered crude protein percent in cowpea (*Vigna unguiculata*) plants. However, some researchers have reported contrary to this result of ours. For example, Rostamza et al.[63] observed increase in crude protein content of pearl millet with increase in water stress. Similarly, Bibi et al.[64] found that increase in moisture stress resulted in increase in percentage of crude protein in sorghum (sudan grass hybrids). Finally, Fariaszewska et al.[65] discovered increase in crude protein contents of forage grasses when they were subjected to mild water stress. It is generally concluded that positive or negative effect of water stress on forage crops depends on plant species. The result of this work might be linked to decreased synthesis of protein as well as increased activities of protein hydrolysing enzymes which led to accumulation of amino acids at the expense of protein [66]. Furthermore, protein reduction could be attributed to higher ratio of Na^+ to K^+ at high water deficit level which inactivates enzymes and inhibits synthesis of protein. Moreover, low crude protein content can be linked to low nitrogen level in the plant because the amount of nitrogen in the plants is used in calculating the crude protein content (Equation 5). Finally, reduction in protein content might also be attributed to low nitrate reduction activity (NR) which could have accounted for decline in plant growth. The implication of our result is that crude protein of crops could be purposely increased or decreased using water stress by choosing the appropriate plant species.

Table 4: Effects of mulch on crude fibre, crude protein content of water stressed tomato

Application Rate (t/ha)	Crude Fiber (%)	Crude Protein (%)
Control	1.60^a	4.43^a
0	1.86^a	1.40^b
10	2.61^b	2.48^c
15	1.70^a	4.65^a
20	0.84^c	6.55^d
25	0.95^c	5.65^e

3.9. Effects of mulch on leaf ash content of water stressed tomato

The highest ash content was found in plants from pots with zero application of mulch. This was followed by plants from pots with 10t/ha mulch while the lowest ash content was from plants with 25t/ha mulch application (Table 5). So, there was negative relationship between mulch application rate and ash content of leaves.

This implies that higher mulch application does not improve ash production in water-stressed tomato despite the fact that it had positive impacts on other growth and nutritional parameters of the same plant.

There was decrease in ash contents with increase in severity of water stress in this research. In similar studies, Haji Hassani Asl et al.[67] reported decrease in ash content with increase in severity of water stress in three forage crops which were corn, sorghum and millet. Also, Bibi et al.[64] found reduction in ash content of sorghum-sudangrass hybrids with increase in severity of water stress. Moreover, Shoaei and Rafiei [68] discovered significant decrease in ash content of two hybrids of maize. In cowpea, Khalil et al. [62] found significant reduction in ash content of cowpea plants when raised under water stress conduction. This result could be attributed to the effect of reduced soil nutrient availability and uptake as a result of decrease in soil water or it could be the consequence of limited energy source (carbohydrates) supplied by leaves being affected by water stress [62]. Furthermore, ash content signifies the level of minerals in the plant. However, increase in water deficit stress leads to progressive inhibition of mineral uptake by the plants. This is because plant roots have less access to soil nutrients [69]. This then results in having low ash content which is an indicator of the amount of minerals absorbed by the plants. Furthermore, insufficient moisture might have led to tenacious adsorption of the minerals to the clay and the plant roots could not absorb the minerals. Moreover, already absorbed minerals needed sufficient water for their translocation to the fruits but that was not available as a result of deficit water supply. Therefore, the fruits could not get enough minerals as the water deficit level increased and that resulted in low ash content.

3.10. Effects of mulch on leaf crude fat content of water stressed tomato

The highest level of crude fat (ether extract) was from the plants with 15t/ha mulch application. This was followed by plants with zero application of mulch while the lowest crude fat content was found in plants with 20t/ha mulch. There was an up and down trend in the effect of mulch application. Application of 10t/ha led to decline in crude fat content followed by a surge with application of 15t/ha mulch. This was followed by a decline in crude fat content with application of 20t/ha while application of 25t/ha mulch led to a surge again in the content of crude fat in the leaves of tomato under water stress alleviated with application of mulch (Table 5).

Ether extract (crude fat) is an indicator of energy production (twice that of carbohydrate), a means of absorption of fat soluble vitamins, a protector of delicate organs in the body as well as an insulator against cold. Crude fat content in this work decreased with increase in severity of drought stress. Similar to this result, Onwugbuta-Enyi [70] and Martins –Junior et al.[71] reported that crude fat content of cowpea seedlings was reduced by water stress. Bibi et al.[65] also showed that crude fat of sorghum (sudan grass hybrids) decreased with imposition of water stress. Furthermore, Osuagwu and Edeoga [72] found that water stress caused a significant reduction in the crude fat content of leaves of African basil (*Ocimum gratissimum* L.) and Bush buck (*Gongronema latifolium* Benth.). This might be because increase in water deficit triggered production of lipase which was responsible for breaking down of fat. Therefore, increase in water deficit resulted in decrease in crude fat content. The implication of this reduction as a result of breakdown of crude fat is that it leads to formation of osmotic materials which aids plants in tolerating water stress.

Table 5: Effects of mulch on ash and crude fat contents of water stressed tomato

Application Rate (t/ha)	Ash (%)	Crude Fat (%)
Control	6.13^{a}	2.51^{a}
0	3.65^{a}	2.12^{a}
10	3.38^{a}	1.79^{a}
15	3.22^{a}	2.95^{a}
20	2.80^{a}	1.25^{a}
25	3.32^{a}	1.60^{a}

4.0. Conclusion

From this research work, it was found that stressed plants without mulch had a drastic reduction in all the tested parameters. The plants subjected to drought and treated with 20tons/ha mulch showed higher plant height, number of branches, yield, chlorophyll, fiber and ash content compared to the plants treated with 10tons/ha, 15tons/ha,25t/ha mulch. It is, therefore, concluded that 20tons/ha mulch be used for alleviating drought stress condition in Platinum 107 F1 tomato variety in the study area when all the conditions in this research are maintained.

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