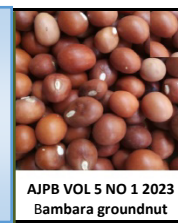


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## Effect of Water Stress on the Morphology of Tomato (*Solanum lycopersicum* M.) at Different Growth Stages

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### ABSTRACT

Large sections of tomato farming rely heavily on surface irrigation because rainfall is insufficient to supply crop water needs. This technique may result in water waste. Throughout and directly afterwards transplanting, at flowering, and during the development of fruit, tomatoes are extremely susceptible to water deficiencies. Therefore, preserving agricultural water supplies and boosting water productivity, coupled with increased tomato production, necessitate satisfying the water needs of tomatoes. This is why we set out to investigate how water stress affects tomato's (Tandilo and Rukuta varieties) agro-morphological traits in this study. The research was conducted at the Botanical Garden, Gombe State University. The experiment was laid out in a Complete Randomized Block Design with six (6) replications and three (3) treatments. Three different water levels were termed as severe deficit at 14-day intervals, mild deficit at 7 d and control treatments were applied to each group. The impact of water stress on various tomato cultivars was calculated by measuring their height, stem diameter, leaf area, stem diameter, and number of branches. Water stress was found to significantly ( $P < 0.05$ ) reduce stem diameter, plant height, leaf area, and the number of branches. In conclusion, the agro morphological efficiency of tomato cultivars improved after modest water stress mitigation. Tandilo and Rukuta varieties can be adopted in semi-arid regions to optimize yield and ensure food security.

### INTRODUCTION

The tomato (*Solanum lycopersicum* L.), a fruit vegetable, is a member of the Solanaceae family, which includes various plants with significant agricultural value, such as tobacco, potato, eggplant, and other pepper and tomato species [1]. This family has about 100 genera and 2500 species. The crop is a native of South America and is the second most significant vegetable crop grown worldwide [2,3]. According to [4], tomato fruits are occasionally processed into tomato paste, tomato sauce, tomato juice, and ketchup in addition to being cooked as vegetables or used in salads. One of the most widely grown and highly consumed horticulture crops is the tomato. According to [5], is one of the most significant vegetable fruits grown for consumption in every family in Nigeria. It is eaten both fresh and in paste form and is an inexpensive source of vitamins A, C, and

E as well as minerals that help to keep the body healthy. Due to their low-calorie content, lack of cholesterol, and high-fibre content, tomatoes and tomato-based products are regarded as healthful foods.

Tobacco is an economically significant horticulture product that can raise the standard of living for underprivileged farmers in rural areas, claim [6]. The significant antioxidant content of tomato fruit, which is known to lower cancer occurrences, has increased the value of tomato consumption [7]. Lycopene, beta-carotene, ascorbic acid, and phenolic compounds, which have nutritional advantages for consumers, are present in tomato fruit, according to [8]. Frequent droughts and water resource restrictions in agriculture are projected to have a negative effect on plant development and agricultural yield [9]. In wide areas where tomatoes are grown, rainfall is insufficient to meet crop

water needs, thus farmers typically use surface irrigation instead, which can waste water [10]. Because of climate change and the aggressive exploitation of natural resources (soil, water, and biodiversity), there is a global shortage of water for irrigation [11]. Water stress is a serious issue that is primarily restricting plant growth in dry and semi-arid places as a result of climate change [12, 13, 14].

Tomato plant development and yield are restricted by water stress. Water deficiencies during and immediately after transplanting, at flowering, and throughout fruit development can be particularly harmful to tomatoes. Compared to the latter stage (30-day stage), water stress is more inhibitive at the early stage (20-day stage) of growth [15]. Water is typically the most restrictive element for plant growth in nature. The drought stress that results if plants do not get enough rain or irrigation can inhibit growth more than all other environmental pressures combined. In order to conserve water, a plant responds to a water shortage by slowing down other plant functions such as photosynthesis and development [16].

According to the severity, timing, and duration of the water deficit as well as genotype, plants' development, growth, and productivity can be impacted as seen in the tomato. [17,18]. According to [19], deficit irrigation a strategy for reducing water consumption in which crops are purposefully allowed to retain a particular amount of water deficit is the best way to meet the objective of improving water usage efficiency. A new strategy for irrigation scheduling must be created, one that makes the best use of the water that is available rather than one that is based on the crop's total water requirement. For enhanced management procedures and breeding efforts in agriculture under climate change, a greater understanding of how drought affects plants is essential [20]. Therefore, ensuring that tomato production is of high quality while also preserving agricultural water resources and improving water use efficiency is essential. Because of this, the current study intended to comprehend how tomato agro morphology is affected by water deficiency.

## MATERIALS AND METHODS

### Study site

The experiments were carried out at the Botanical Garden, Department of Botany, Gombe State University-Nigeria. It is geographically located at an altitude 490 meters above sea level between longitude 10°18.283'E, and latitude 11°10.601'N.

### Study materials

Four (4) tomato varieties were used for the research and were obtained from the Department of Botany, Gombe State University. Three (3) were local varieties (Rukuta, Syria and Tandilo) and one improved variety (Rio Grande).

### Seed germination and transplanting

Seeds of tomato varieties were broadcasted on beds, and they were transplanted two weeks after reaching 15cm height (three foliage) into individual pots of 30 × 25 cm filled with sandy loam (1:1) soil in an outfield. Tomato plants were fertilized by fifteen grams of nitrogen, phosphorus and potassium (N: P: K) 15:15:15 to every pot twice in the life of tomato plants.

### Experimental Design and Treatments

The experiment was laid out in a Complete Randomized Block Design with six (6) replications and three (3) treatments. Two weeks after transplanting, tomato plants were divided into three groups for each variety. The first group were stressed at the vegetative, the second at the reproductive stage and the third at

all stage of life. Three different water levels were termed as severe deficit at 14-day intervals, and mild deficit at 7 d and control treatments were applied to each group according to a modified procedure described by [21].

### Data Collection and Analysis

Information on morphological parameters at vegetative, reproductive and all life stages was taken. Collected data was subjected to Analysis of Variance and means were separated using the Duncan Multiple Range Test (DMRT) at a 5% significance level.

## RESULTS

### Effect of Water Deficit on Tomato at Vegetative Stage

The result for water deficit in tomatoes at the vegetative stage is presented in Table 1. The statistical analysis showed that there are significant differences ( $P < 0.05$ ) between variety and treatment, but there is no significant difference ( $P > 0.05$ ) between variety by treatment interaction on plant height at 14 d. The result of the water deficit at 14 d showed that Syria (21.22) had the highest plant height and Rukuta (16.33) had the lowest height. In 28 d the statistical analysis showed that there is no significant difference ( $P > 0.05$ ) between variety, treatment and variety by treatment interaction.

Rio Grande (28.83) had the highest plant height, while Rukuta (21.44) recorded the lowest height. Also at 42 d, there is a significant difference ( $P < 0.05$ ) between variety and variety by treatment interaction, but no significant difference ( $P > 0.05$ ) between treatments. Rio Grande (47.31) had the highest plant height, also Rukuta (33.13) recorded the lowest height. The result of the analysis showed that there is no significant difference ( $P > 0.05$ ) between variety, treatment and variety by treatment interaction on several branches at 14 d. The result of the water deficit shows that Syria (9.11) had the highest branch number, with Tandilo (6.88) having the lowest branch number. Statistical analysis at 28 d shows there is a significant difference ( $P < 0.05$ ) between variety, but no significant difference between treatment and variety by treatment interaction. The highest number of branches was recorded by Syria (14.94) and Tandilo (8.77) recorded the least branch number.

At 42 d, there is a significant difference ( $P < 0.05$ ) between variety, but there is no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction. At 42 d Syria (37.88) had the highest branch number, while Rukuta (11.66) recorded the lowest branch number.

Statistical analysis showed that there is no significant difference ( $P > 0.05$ ) between variety, treatment and variety by treatment interaction at 14 d on several leaf areas. It shows that Rukuta (8.82) recorded the highest leaf area, while Tandilo (7.16) had the least leaf area. At 28 d, the result shows a significant difference ( $P < 0.05$ ) between variety and variety by treatment interaction, but no significant difference ( $P > 0.05$ ) between treatments. Rukuta (12.22) had the highest leaf area and Syria (8.34) had the lowest leaf area. The result shows no significant difference ( $P > 0.05$ ) between variety, treatment and treatment by variety interaction at 42 d on leaf area. Rio Grande (13.68) had the highest leaf area and Tandilo (10.13) with least leaf area.

On stem girth, the statistical analysis showed a highly significant difference ( $P < 0.05$ ) between variety, and no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction at 14 d. Syria (1.91) had the highest stem girth, with Tandilo (1.16) having the least stem girth. At 28 d, there is a highly significant difference ( $P < 0.05$ ) between variety,

but no significant difference between treatment and variety by treatment interaction. Rio Grande (2.43) had the highest stem girth and Tandilo (1.46) had the lowest stem girth. The result showed a highly significant difference ( $P < 0.05$ ) between variety and variety by treatment interaction at 42 d on stem girth. The highest stem girth was recorded by Rio Grande (2.93), while Tandilo (1.72) recorded the lowest stem girth.

#### Effect of Water Deficit on Tomato at Reproductive Stage

Table 2 shows the result of the water deficit in tomatoes at the reproductive stage. The statistical analysis showed a highly significant difference ( $P < 0.05$ ) between variety, but no significant difference between treatment and variety by treatment interaction at 14 d on plant height. Tandilo (55.00) recorded the highest plant height, while Rio Grande (21.11) recorded the lowest height at 28 d after deficit inducement, the statistical result showed a highly significant difference ( $P < 0.05$ ) between variety and variety by treatment interaction, but no significant difference ( $P > 0.05$ ) between treatment. Tandilo (68.00) had the highest plant height, while Syria (25.22) had the least height. Highly significant differences ( $P < 0.05$ ) were observed between variety, treatment and variety by treatment interaction. Tandilo (73.22) had the highest plant height, while Syria (43.85) had the least plant height on 42 d.

Analysis of the result showed a highly significant difference ( $P < 0.05$ ) between variety, but no significant difference between treatment and variety by treatment interaction on branch number at 14 d. Tandilo (20.66) recorded a high number of branches while Rio Grande (8.00) recorded the lowest number of branches at 14 d. There is a highly significant difference ( $P < 0.05$ ) between variety, while no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction at 28 d on branch number. Tandilo (24.66) had the highest number of branches, while Rio Grande (13.16) had the lowest branch number. At 42 d after the treatment, there is a significant difference ( $P < 0.05$ ) between variety, and no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction. Syria (42.27) had the highest number of branches, while Rukuta (24.66) had the lowest branch number.

A highly significant difference ( $P < 0.05$ ) was observed between variety on leaf area at 14 d, but no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction. Rukuta (15.97) had the highest leaf area, while Syria (5.81) had the lowest leaf area. At 28 d, there is a significant difference ( $P < 0.05$ ) between variety, but no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction. Rukuta (16.55) recorded a high leaf area, while Syria (11.08) had the least leaf area. There is no significant difference ( $P > 0.05$ ) between variety, treatment and variety by treatment interaction on leaf area at 42 d after treatment at the vegetative stage. Tandilo (17.17) recorded a high leaf area, while Syria (12.76) recorded the lowest leaf area.

Statistical analysis showed a significant difference ( $P < 0.05$ ) between variety, treatment and variety by treatment interaction at 14 d on stem girth after water deficit inducement at the reproductive stage. Rio Grande (2.38) had a high stem girth, while Rukuta (1.95) and Tandilo (1.95) had the lowest stem girth. At 28 d, there is a significant difference ( $P < 0.05$ ) between variety, but no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction. The result showed a highly significant difference ( $P < 0.05$ ) between variety, while there is no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction on stem girth at 42 d.

#### Effect of Water Deficit on Tomato at All Life Stage

Table 3 show the result of water deficit in all life stage of tomato. The result of the statistical analysis showed a highly significant difference ( $P < 0.05$ ) between variety, but no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction on plant height at 14 d. Syria (29.81) recorded the highest plant height, while Tandilo (15.22) recorded the lowest height in the plant. At 28 d after water deficit inducement, the statistical analysis showed a highly significant difference ( $P < 0.05$ ) between variety and variety by treatment interaction, while there is no significant difference ( $P > 0.05$ ) between treatment at the life stage.

Statistical analysis showed high significant difference ( $P < 0.05$ ) between variety, treatment and variety by treatment interaction at 42 d on plant height at stage of life water deficit. Syria (42.32) recorded the highest plant height, while Tandilo (30.20) had the lowest plant height. At 56 d, there is no significant difference ( $P > 0.05$ ) between variety, while there is a high significant difference ( $P < 0.05$ ) between treatment and variety by treatment interaction. Rio Grande (46.43) recorded high plant height and Tandilo (44.66) recorded low plant height.

Statistical analysis showed a significant difference ( $P < 0.05$ ) between variety, while no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction on several branches at 14 d. Syria (8.51) recorded a high branch number, while Tandilo (6.33) had a low branch number. There is a highly significant difference ( $P < 0.05$ ) between variety and variety by treatment interaction, while there is no significant difference ( $P > 0.05$ ) between treatment at 28 d on branch number. Syria (16.28) recorded a high branch number, while Tandilo (8.00) had a low number of branches. The result showed a high significant difference ( $P < 0.05$ ) between variety, while there is no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction at 42 d. Rio Grande (30.00) had the highest branch number, and Tandilo (10.00) recorded the lowest branch number. At 56 d, there is a highly significant difference ( $P < 0.05$ ) between variety, treatment and variety by treatment interaction on branch number. Syria (43.85) had the highest branch number, while Tandilo (17.11) had the lowest branch number.

A highly significant difference ( $P < 0.05$ ) between variety was observed, but no significant difference ( $P > 0.05$ ) between treatment and variety by treatment interaction at 14 d on leaf area at all life stages of water deficit. Rio Grande (13.07) had the highest leaf area, and Tandilo (6.40) had the lowest leaf area. At 28 d, there is a highly significant difference ( $P < 0.05$ ) between variety, but no significant difference ( $P < 0.05$ ) between treatment and variety by treatment interaction. Rio Grande (15.52) recorded high leaf area, while Tandilo (8.47) recorded low leaf area. Results showed no significant difference ( $P > 0.05$ ) between variety, treatment and variety by treatment interaction at 42 d on leaf area. Rio Grande (15.52) had the highest area of leaf, and Rukuta (10.93) had the least area of leaf.

Analysis showed a significant difference ( $P < 0.05$ ) between variety, treatment and variety by treatment interaction on leaf area at 56 d. Tandilo (18.98) recorded the highest leaf area, while Syria (12.69) recorded low leaf area. Stem girth analysis showed a highly significant difference ( $P < 0.05$ ) between variety, but no significant difference ( $P > 0.05$ ) between treatment and variety by interaction at 14 d. Rio Grande (2.00) had a high stem girth, while Tandilo (1.25) had a low stem girth.

**Table 1.** Effect of water deficit on tomato at vegetative stage.

Variety	Plant Height			Branches			Leaf Area			Stem Girth		
	14 d	28 d	42 d	14 d	28 d	42 d	14 d	28 d	42 d	14 d	28 d	42 d
RioGrande	18.73 <sup>ab</sup>	28.83 <sup>a</sup>	47.31 <sup>a</sup>	8.50 <sup>a</sup>	14.61 <sup>a</sup>	35.00 <sup>a</sup>	8.77 <sup>a</sup>	10.07 <sup>ab</sup>	13.68 <sup>a</sup>	1.87 <sup>ab</sup>	2.43 <sup>a</sup>	2.93 <sup>a</sup>
Rukuta	16.33 <sup>b</sup>	21.44 <sup>b</sup>	33.13 <sup>c</sup>	7.77 <sup>a</sup>	9.00 <sup>b</sup>	11.66 <sup>b</sup>	8.82 <sup>a</sup>	12.22 <sup>a</sup>	10.99 <sup>a</sup>	1.64 <sup>b</sup>	1.95 <sup>b</sup>	2.12 <sup>b</sup>
Syria	21.22 <sup>a</sup>	25.62 <sup>ab</sup>	41.08 <sup>ab</sup>	9.11 <sup>a</sup>	14.94 <sup>a</sup>	37.88 <sup>a</sup>	7.56 <sup>a</sup>	8.34 <sup>b</sup>	12.66 <sup>a</sup>	1.91 <sup>a</sup>	2.53 <sup>a</sup>	2.01 <sup>b</sup>
Tandilo	17.02 <sup>b</sup>	24.03 <sup>b</sup>	34.11 <sup>bc</sup>	6.88 <sup>a</sup>	8.77 <sup>b</sup>	11.88 <sup>b</sup>	7.16 <sup>a</sup>	8.65 <sup>b</sup>	10.13 <sup>a</sup>	1.16 <sup>c</sup>	1.46 <sup>c</sup>	1.72 <sup>c</sup>
Control	20.74 <sup>a</sup>	25.36 <sup>a</sup>	37.95 <sup>a</sup>	7.29 <sup>a</sup>	11.62 <sup>a</sup>	21.95 <sup>a</sup>	8.28 <sup>a</sup>	9.63 <sup>a</sup>	13.18 <sup>a</sup>	1.79 <sup>a</sup>	2.22 <sup>a</sup>	2.12 <sup>a</sup>
Mild	17.28 <sup>b</sup>	24.52 <sup>a</sup>	37.55 <sup>a</sup>	8.25 <sup>a</sup>	11.37 <sup>a</sup>	25.79 <sup>a</sup>	8.20 <sup>a</sup>	10.26 <sup>a</sup>	10.80 <sup>a</sup>	1.58 <sup>ab</sup>	2.10 <sup>ab</sup>	2.19 <sup>a</sup>
Severe	16.95 <sup>b</sup>	25.05 <sup>a</sup>	41.22 <sup>a</sup>	8.66 <sup>a</sup>	12.50 <sup>a</sup>	24.58 <sup>a</sup>	7.76 <sup>a</sup>	9.57 <sup>a</sup>	11.61 <sup>a</sup>	1.56 <sup>b</sup>	1.95 <sup>b</sup>	2.27 <sup>a</sup>
Variety	*	NS	**	NS	**	**	NS	**	NS	***	***	***
Treat.	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Var*Treat	NS	NS	*	NS	NS	NS	NS	**	NS	NS	NS	**

Means within a column following different alphabets are significantly different at  $P \leq 0.05$  using Duncan's Multiple Range Test.

**Table 2.** Effect of water deficit on tomato at reproductive stage.

Variety	Plant Height			Branches			Leaf Area			Stem Girth		
	14 d	28 d	42 d	14 d	28 d	42 d	14 d	28 d	42 d	14 d	28 d	42 d
RioGrande	21.15 <sup>b</sup>	25.50 <sup>b</sup>	57.87 <sup>b</sup>	8.00 <sup>c</sup>	13.16 <sup>b</sup>	39.27 <sup>a</sup>	8.00 <sup>b</sup>	12.43 <sup>b</sup>	15.59 <sup>ab</sup>	2.38 <sup>a</sup>	2.71 <sup>a</sup>	2.77 <sup>a</sup>
Rukuta	46.66 <sup>a</sup>	59.55 <sup>a</sup>	67.11 <sup>ab</sup>	13.44 <sup>b</sup>	22.44 <sup>a</sup>	24.66 <sup>b</sup>	15.97 <sup>a</sup>	16.55 <sup>a</sup>	16.63 <sup>a</sup>	1.95 <sup>b</sup>	2.27 <sup>b</sup>	2.30 <sup>b</sup>
Syria	20.58 <sup>b</sup>	25.22 <sup>b</sup>	43.85 <sup>c</sup>	9.16 <sup>c</sup>	14.66 <sup>b</sup>	42.27 <sup>a</sup>	5.81 <sup>b</sup>	11.80 <sup>b</sup>	12.76 <sup>b</sup>	2.16 <sup>ab</sup>	2.51 <sup>ab</sup>	2.85 <sup>a</sup>
Tandilo	55.00 <sup>a</sup>	68.00 <sup>a</sup>	73.22 <sup>a</sup>	20.66 <sup>a</sup>	24.66 <sup>a</sup>	26.88 <sup>b</sup>	14.39 <sup>a</sup>	16.51 <sup>a</sup>	17.17 <sup>a</sup>	1.95 <sup>b</sup>	2.23 <sup>b</sup>	2.24 <sup>b</sup>
Control	35.38 <sup>a</sup>	48.17 <sup>a</sup>	66.12 <sup>a</sup>	11.29 <sup>a</sup>	18.79 <sup>a</sup>	28.45 <sup>a</sup>	11.97 <sup>a</sup>	14.42 <sup>a</sup>	15.48 <sup>a</sup>	1.88 <sup>b</sup>	2.28 <sup>a</sup>	2.49 <sup>a</sup>
Mild	34.71 <sup>a</sup>	40.53 <sup>a</sup>	59.82 <sup>ab</sup>	13.91 <sup>a</sup>	18.41 <sup>a</sup>	38.70 <sup>a</sup>	9.70 <sup>a</sup>	14.63 <sup>a</sup>	16.10 <sup>a</sup>	2.34 <sup>a</sup>	2.57 <sup>a</sup>	2.67 <sup>a</sup>
Severe	37.45 <sup>a</sup>	45.00 <sup>a</sup>	55.59 <sup>b</sup>	13.25 <sup>a</sup>	19.00 <sup>a</sup>	32.66 <sup>a</sup>	11.45 <sup>a</sup>	13.92 <sup>a</sup>	15.04 <sup>a</sup>	2.11 <sup>ab</sup>	2.44 <sup>a</sup>	2.45 <sup>a</sup>
Variety	***	***	***	***	***	*	***	*	NS	*	*	***
Treat.	NS	NS	*	NS	NS	NS	NS	NS	NS	*	NS	NS
Var*Treat	NS	*	*	NS	NS	NS	NS	NS	NS	*	NS	NS

Means within a column following different alphabets are significantly different at  $P \leq 0.05$  using Duncan's Multiple Range Test.

**Table 3.** Effect of water deficit on tomato at all life stages.

Variety	Plant Height				Branches				Leaf Area				Stem Girth			
	14 d	28 d	42 d	56 d	14 d	28 d	42 d	56 d	14 d	28 d	42 d	56 d	14 d	28 d	42 d	56 d
Rio Grande	21.12 <sup>b</sup>	26.38 <sup>b</sup>	32.95 <sup>b</sup>	46.43 <sup>a</sup>	7.62 <sup>ab</sup>	14.25 <sup>a</sup>	30.00 <sup>a</sup>	38.28 <sup>a</sup>	13.07 <sup>a</sup>	15.21 <sup>a</sup>	15.52 <sup>a</sup>	14.51 <sup>b</sup>	2.00 <sup>a</sup>	2.38 <sup>a</sup>	2.73 <sup>a</sup>	2.73 <sup>a</sup>
Rukuta	20.98 <sup>b</sup>	29.50 <sup>b</sup>	35.11 <sup>b</sup>	43.00 <sup>a</sup>	8.11 <sup>a</sup>	10.00 <sup>b</sup>	11.33 <sup>b</sup>	15.66 <sup>b</sup>	11.19 <sup>a</sup>	14.55 <sup>a</sup>	10.93 <sup>a</sup>	12.92 <sup>b</sup>	1.47 <sup>b</sup>	1.85 <sup>b</sup>	2.13 <sup>b</sup>	2.27 <sup>b</sup>
Syria	29.81 <sup>a</sup>	35.83 <sup>a</sup>	42.32 <sup>a</sup>	43.03 <sup>a</sup>	8.57 <sup>a</sup>	16.28 <sup>a</sup>	26.14 <sup>a</sup>	43.85 <sup>a</sup>	11.70 <sup>a</sup>	12.69 <sup>a</sup>	12.23 <sup>a</sup>	12.69 <sup>b</sup>	1.92 <sup>a</sup>	2.34 <sup>a</sup>	2.34 <sup>b</sup>	2.51 <sup>a</sup>
Tandilo	15.22 <sup>c</sup>	20.10 <sup>c</sup>	30.20 <sup>b</sup>	42.66 <sup>a</sup>	6.33 <sup>b</sup>	8.00 <sup>b</sup>	10.00 <sup>b</sup>	17.11 <sup>b</sup>	6.40 <sup>b</sup>	8.47 <sup>b</sup>	11.07 <sup>a</sup>	18.98 <sup>a</sup>	1.25 <sup>c</sup>	1.32 <sup>c</sup>	1.54 <sup>c</sup>	1.63 <sup>c</sup>
Control	20.27 <sup>a</sup>	27.12 <sup>a</sup>	31.50 <sup>b</sup>	40.47 <sup>b</sup>	7.81 <sup>a</sup>	12.09 <sup>a</sup>	13.81 <sup>b</sup>	20.00 <sup>a</sup>	9.41 <sup>a</sup>	11.23 <sup>a</sup>	12.05 <sup>a</sup>	12.93 <sup>b</sup>	1.77 <sup>a</sup>	2.18 <sup>a</sup>	2.09 <sup>a</sup>	2.21 <sup>a</sup>
Mild	23.07 <sup>a</sup>	27.12 <sup>a</sup>	35.86 <sup>b</sup>	48.50 <sup>a</sup>	7.20 <sup>a</sup>	10.90 <sup>a</sup>	17.70 <sup>ab</sup>	30.44 <sup>a</sup>	11.22 <sup>a</sup>	11.75 <sup>a</sup>	13.06 <sup>a</sup>	17.67 <sup>a</sup>	1.60 <sup>a</sup>	1.82 <sup>b</sup>	2.27 <sup>a</sup>	2.27 <sup>a</sup>
Severe	22.02 <sup>a</sup>	28.91 <sup>a</sup>	38.07 <sup>a</sup>	42.00 <sup>b</sup>	7.75 <sup>a</sup>	12.33 <sup>a</sup>	23.83 <sup>a</sup>	31.33 <sup>a</sup>	11.14 <sup>a</sup>	13.21 <sup>a</sup>	1.70 <sup>a</sup>	13.65 <sup>b</sup>	1.61 <sup>a</sup>	1.91 <sup>b</sup>	2.20 <sup>a</sup>	2.34 <sup>a</sup>
Variety	***	***	**	NS	*	***	**	***	***	***	NS	*	***	***	***	***
Treat.	NS	NS	*	*	NS	NS	NS	**	NS	NS	NS	*	NS	**	NS	NS
Var*Treat	NS	**	*	***	NS	*	NS	***	NS	NS	NS	*	NS	**	NS	**

Means within a column following different alphabets are significantly different at  $P \leq 0.05$  using Duncan's Multiple Range Test.

A highly significant difference ( $P < 0.05$ ) between variety, treatment and variety by treatment interaction was observed on stem girth at 28 d. Rio Grande (2.38) recorded high stem girth, while Tandilo had the lowest stem girth. Highly significant difference ( $P < 0.05$ ) between variety and variety by treatment interaction, but no significant difference between treatment at 42 d on stem girth. Rio Grande (2.73) had the highest stem girth, while Tandilo (1.54) had the lowest stem girth. Statistical analysis showed a highly significant difference ( $P < 0.05$ ) between variety and variety by treatment interaction, while no significant difference ( $P > 0.05$ ) between treatment on stem girth at 56 d. Rio Grande (2.73) recorded high stem girth, while Tandilo (1.63) recorded low stem girth.

## DISCUSSION

### Effect of water deficit on tomato at vegetative stage

At the vegetative stage, water stress had a significant impact on plant height at 14 d, but there was no difference in how they interacted. The most restricting element for early plant growth in nature is water. Water pressure in the leaves decreases as a plant experiences water stress, and the plant wilts as a result. Nearly all crops and plants will grow less if they are dried to the point of wilting [16]. Rukuta had poor plant height at 28 and 42 d, but Rio Grande had a decent mean height. This shows that whereas Rio Grande maintains a higher plant height, Rukuta's plant height has dropped as a result of water stress on all d. The primary effect of water stress is a reduction in growth and development due to a reduction in photosynthesis. [22] studied four tomato genotypes and found that irrigation treatment significantly reduced most growth parameters. According to [23], water stress is to blame for tomato cultivars' poor development and, in extreme situations, stem dieback.

Results of water stress treatment on the Syria and Rio Grande types reveal no influence on the number of branch characteristics. This might be a result of their enhancement for cultivation in drought-prone locations and their ability to adapt to those conditions. Additionally, mild water stress treatment was effective in supplying tomato varieties with the nutrients and water they needed. The tomato plants develop well when the irrigation is increased to 80%, according to [24] and [25], which has a positive impact on the branches, blooming, and fruit yield. Due to their varying sensitivity to water deficits, local tomato varieties are not significantly impacted by water stress.

Tomato landraces, which frequently exhibit high levels of stress tolerance and local adaptability, have been discovered to exhibit this variation [26]. Tomato plants that were under water stress had less leaf area overall, but not significantly. Comparatively speaking to the control, the drop in leaf area was minimal. Because of its early adaptation to the environment under water stress, Rukuta possessed a healthy leaf area. Tomato leaves are impacted by how a plant reacts to its surroundings, particularly when there is a water shortage, which is the most severe growth-restraining stress.

The type and length of the stress affect it differently [27,9]. Similar outcomes were also demonstrated in *Phaseolus vulgaris*, *Pennisetum glaucum*, and *Sesbania aculeate* [28], among other plants [29]. The tomato types employed in the study responded favourably to water stress treatment on stem girth, with a significant impact seen from the early to late stages of growth. Water stress has a significant impact on tomato plant physiological traits, yield, and growth and development (27). Due to osmotic stress, the first drop was probably brought on by hormonal cues [30]. [31] discovered that stem diameter is

decreased by water stress. Despite complete turgor maintenance in the growing regions, stem growth may be inhibited at low water potentials due to osmotic adjustment.

### Effect of water deficit on tomato at the reproductive stage

Drought that results from insufficient irrigation for plants can inhibit growth more than all other environmental stresses combined. The local variety (Tandilo) fared better in the current study in terms of plant height throughout the treatment period, which is a positive sign of stress tolerance. But for the Syria and Rio Grande varieties, water stress has a negative effect on plant height. Under the pressure of the drought, [32] noticed a considerable decline in plant height, indicating the impact of the drought on tomato plant height. According to [33], one of the main causes of agricultural growth problems and increased susceptibility to disease is water stress. Water stress is also linked to crop failure. Tomato under stress conditions inhibits its vegetative growth, according to [10] and [33], a comparable outcome was seen.

Reduction in the lateral branches of tomato types has been linked to water deficiencies. The quantity of tomato branches per plant is greatly influenced by the soil moisture level [32]. Similar to the findings of the current investigation, significant effects were observed on the Rio Grande during the stress treatment period. [34] research also supports a higher decline in tomato vegetative parts along with a decline in branch output. According to the time and varieties observed, water stress has an impact on tomato crop growth and development.

A reduction in leaf area was seen as a result of the water stress therapy. According to [35], this decrease may be the result of a decline in the mitotic activity of epidermal cells, which lowers the overall number of leaf cells. Treatments for water stress cause the leaf area of every tomato to vary when compared to untreated tomatoes, but the difference was not appreciably larger. High levels of water stress also dramatically reduced leaf area and leaf area indices [36]. Sesame [37] also demonstrated comparable outcomes, showing that water stress decreased leaf area.

When tomato cultivars are under water stress, the diameter of the stems is significantly reduced. Tomatoes that are under stress have smaller growth components than plants that receive adequate water. The findings of this study are consistent with those made by [38], who discovered that the stem diameter and plant height of plants under water stress were lower than those of the same components in plants receiving adequate water. At lower water potentials, stem growth may be affected, and changes in stem diameter correspond to variations in the hydration of stem tissue [31].

### Effect of water deficit on tomato at all life stage

According to the findings, Syria and the Rio Grande exhibited better height quality under water stress at the life stage than any other kind. This might be due to the type of strong root systems, which serve as an adaptation for survival in drought situations and to draw more water from the soil. In soil with water contents slightly below field capacity, tomato plants develop more root mass [39]. [40] research also demonstrated that tomato quality, growth, and development were enhanced under conditions of increasing water stress at all stages of development. Under conditions of water scarcity, plants typically exhibit increased shoot growth. As more water can be absorbed from the soil due to the increased root surface area, this is thought to be an adaptation for survival in drought areas [41]. Reduced vegetative growth is a result of water stress. At every stage of the tomato



plant's life, the Tandilo variety showed this. Different water stress levels resulted in limited vegetative development in the cultivar. Reduced photosynthesis as a result of moisture stress leads to impaired growth and development [31]. The same was seen in the current investigation. [42] assert that water stress at initial growth stages is more inhibiting than at later growth stages. Additionally, tomatoes under stress at every stage of growth and development were smaller than tomatoes under stress during the vegetative and reproductive stages. [43] reported a different outcome, stating that there was no difference in the height of tomato plants exposed to various water levels.

After water deprivation treatments, a significant variation in branching number was seen in later days. Throughout the treatment period, Syria and the Rio Grande among the varieties exhibit more branching than Rukuta and Tandilo. In both herbaceous and woody plants, soil water shortages have also been linked to decreased lateral branching, leaf production, shoot height, and pace of leaf and shoot expansion [44;41]. In their work, [45] discovered that the production of tomato branches is severely depressed under drought stress. This is in line with the most recent findings, which show a greater reduction in the number of branches in Rukuta and Tandilo. This was confirmed by the fact that when the tomato plant's growth stage, time interval, and stress duration rise, the number of branches decreases. Similar findings were published by [11], who found that plant development will be reduced depending on the stage of growth, the length of the stress, and other factors.

The water stress of tomato plants was visible in the leaf area. All the used varieties showed this to be the case. When tomato plants and other vegetables are treated with deficit irrigation, there is a greater reduction in leaf area, according to [46]. The majority of plants experience decreased transpiration, dry matter production, leaf area, and water status as a result of drought [47]. Water shortage reduced the number of leaves, leaf area, and water content of the leaf blades [48]. The results showed that as the water pressure increased in tomato plants, the distinctive water pressure caused a steady diminution in leaf area. With increased water pressure, the leaf area of the wheat plant shrank [49]. By reducing the part of cell extension that reduces cell size, the leaf region of the plant shrunk. By limiting the development of transpiring leaves in tomato plants that are under water stress, the reduction in leaf area serves an adaptive purpose [45].

Tomato plants with a water deficit showed that, except the control, all plants suffered from low soil moisture. The crop's entire morphology, including stem diameter, suffered from water stress, the result showed. In every tomato variety utilized in the experiment, this was seen. These findings support those of [50] and [51], which showed that plants under water stress had lower plant heights, internode lengths, and stem diameters than plants not under stress. The findings from a report of changes in cell size and tissue hydration indicating, that when soil water becomes less than field capacity close to the permanent wilting point, plant development is often reduced, were also validated by [52]. Water stress can also decrease tomato plants' ability to fight pathogen [53]. Osmotic adjustment may cause stem growth to be hindered at lower water potentials even while perfect turgor maintenance is maintained in the growing areas [54].

## CONCLUSION

Plant morphological characteristics were significantly influenced by water stress treatment levels and duration. It can be concluded that tomato plants under mild stress treatment performed well in terms of plant height, leaf area, stem diameter and number of

branches. Also, among the tomato varieties, Tandilo and Rukuta performed better in water stress tolerance. This characteristic response of tomato varieties to these water stress levels can be used as a tomato production protocol in semi-arid regions where water sources are scarce and in high demand to optimize yield and ensure food and water security.

## CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest between them.

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