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Effect of water stress on morphological, physiological and biochemical parameters of three varieties of tomato (*Lycopersicon esculentum* Mill.). cultivated in Côte d'Ivoire

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ABSTRACT

. Tomato (Lycopersicon esculentum Mill.),a plant of nutritional and economic interests, is often confronted with adverse environmental conditions including water stress. This phenomenon forced plants to significantly reduce their production. Thus, to address this issue, three varieties of tomato (Petomech, UC82B and Tropimech) were used to assess the impact of water stress on morphological physiological and biochemical parameters. For this, tomato varieties were subjected to five water treatment (150, 100, 75, 50 and 25% of field capacity). Results showed that water stress reduced height, stem diameter, leaf area, number and length of root, number of sheets and the specific weight of the plants. Also, water content of the plant, relative water content of leaves, teneure chlorophyll (a, b, total) and carotenoid were reduced with water stress. However, it was observed a strong accumulation of proline content and an increase in catalase activity. It was noted a strong accumulation of proline and increased enzyme activity in the strongest water restriction levels (50% and 25%).

Keywords: Water stress, tomato, tolerance, Proline, catalase,

INTRODUCTION

In Ivory Coast, vegetable crops occupy a significant proportion (3.3%) of all farm households (Soro et al., 2007). Among these, the tomato is the second largest fruit vegetable.

Production in Ivory Coast is 32364 tons of tomato per year (Fondio et al., 2013). This production is low to meet the needs of the Ivorian people. The country still relies on imports from neighboring countries and other countries worldwide. Today, to meet this shortfall in production, the tomato is produced in all agricultural production areas of Ivory Coast (Soro et al., 2007). She took more and more momentum with diversification, the development of new varieties and processing of agricultural techniques. However, despite efforts to increase production, the cultivation of tomato is often confronted with many difficulties. Among these constraints, water is the main factor limiting plant productivity (Mouna et al., 2010). Scarce water conditions limit the expression of the production potential of varieties and make uncertain the hopes of farmers and consumers (Nana et al., 2009). This rainfall variability remains a constraint to agricultural development. Indeed, the culture of the tomato is often disrupted by drought as most tropical plants. Improving yields in arid tropical countries therefore requires the selection of varieties resistant to water stress (Mawuli et al., 2014). Water stress can no longer be considered an urgent problem, but as a phenomenon to be taken into account in food security and national development strategies (FAO, 2004). It is important to choose the varieties to offer to people considering their resilience to drought stress. Water stress affects the morphology and physicochemical parameters whatever the variety of tomato. It is in this light that three tomato varieties. Cultivated in Ivory Coast precisely, were selected to evaluate their resistance to water stress. This work aimed at studying the behavior of three varieties of tomato grown in Ivory Coast under water stress through the evaluation of a few morphological, physiological and biochemical parameters.

MATERIELS AND METHODS

Study site

The study was conducted in University Jean Lorougnon Guede located in the town of Daloa in the west central Ivory Coast. Geographical position is given by the following coordinates 6 ° 53 'North 6 ° 27'° Ouest. It is located in a forest area with temperatures from 21-31 ° C. It is located 141 km from the political capital Yamoussoukro and 383 km from Abidjan the economic capital. Climate of the region is a four season climate. A great rainy season complicated by shoulder seasons and marked by storms (April to mid-July), the short dry season (mid-July to mid-September), a small rainy season (mid-September to November) and large dry season (December to March).

Experimental design

Three hybrid varieties of tomato (*Lycopersicon esculentum* Mill.) Were used in this experiment. Seed Petomech, UC82B and Tropimech were purchased on the market Daloa with a branch semivoire. These varieties are adapted to the soil and climatic conditions of the Daloa region. They have a strong production, are better quality, are more preferable. They taste good and are from the most cultivated varieties. Stress levels (150%, 100%, 75%, 50% and 25%) relative to the capacity of the field soil were determined with an amount of 4.350 kg of cropland. This amount of soil in the pots is the dry weight of the soil. The pots are then watered to saturation, while covering with aluminum foil to prevent evaporation of water. After 24 hours of rest, the pots are weighed again to get the weight of saturation. The difference between the saturation weight and dry weight of soil is the amount of water retained by the soil. This water is the ability to field soil content in the pots. Field capacity is calculated according to the method of Mouellef (2010). Three logs length 2 m, height 15 Cm, width 1m were used for the realization of the nursery for obtaining tomato plans. These ridges were treated to nématoïdes and fungicides to eliminate all nematodes and fungi. plants for planting was done in pots of 4 liters and 150 g mass containing the treated soil. The pots were perforated at the base (8 holes) and then a thin layer of gravel was deposited before filling with soil. Pots, under glass, are deposited on a support. After twenty one days of seed germination, the more vigorous plants were planted in pots and watered with a nutrient solution NPK 80 mg/L for 6 days. This experiment was conducted in a greenhouse height. The different levels of stress (150%, 100%, 75%, 50% and 25%) relative to the capacity of the field soil were used to irrigate the selected tomato plans. The witness is watered to 100%. Stress levels were applied two weeks after planting tomato plants to the capture morphological data

Data collection

During this experiment, some morphological, physiological and biochemical parameters were evaluated after two months of treatment tomato plants with different stress levels (150%, 100%, 75%, 50% and 25%). Vegetative parameters such as diameter of rod, plant height, number of roots and leaves per plant, root length, specific leaf weight (PSF) and finally leaf area (SF) was evaluated. Regarding the physiological parameters, variables such as plant water content (TP), relative content of water sheets (TRE) and dosage of chlorophyll pigments (Youssef T et al., 2006) and carotenoids were determined. Extraction and assay of proline, catalase (cat) (Yang T et al., 2002) and ascorbate peroxidase (Baghizadeh et al., 2014) were performed as biochemical parameters (Table 1).

Statistical analysis

The one-way analysis of variance (ANOVA 1) was used to evaluate the effect of the concentration, variety and interaction through the comparison of the mean for each parameter. When a significant difference was observed (P <0.05) between the different factors studied for a given parameter, multiple comparisons were performed using the test Least Significant Difference (LSD). This test identified the factor that significantly induces this difference.

RESULTS

Results of statistical tests assessing the influence of water stress and variety of the parameters studied three varieties of tomato.

. Table 2 shows that all the variables analyzed were significantly influenced by the effect of water stress. For cons, the varietal effect and water-stress variety interaction had no influence on the morphological, physiological and biochemical parameters analyzed, giving all identical values. Therefore, only the results of the effect of water stress will be presented

Effect of different capacities in the field of agro-morphological parameters

Statistical analysis showed a significant effect on all parameters studied. The agro-morphological parameters of tomato increased with increasing field capacity. Thus, the height of tomato plants, the stem diameter, leaf area, number of roots and leaves, the length of Raines and leaf specific weight increases with increasing field capacity (Table 3).

Effect of different capacities in the field of physiological parameters

The evaluation of the effect of capacity to the field on the three varieties studied tomatoes covered six agro-physiological parameters which are: the water content of the plant, the relative water content of leaves, chlorophyll a b and total and the carotenoid content (Table 4). Statistical analysis of the results showed a highly significant effect of field capacity on agro-physiological parameters tested. Parameters such as water content of plant, relative water content of leaves, chlorophyll a, and total carotenoid content and increments with increasing field capacity. By cons, chlorophyll b decreases with increasing field capacity.

Effect of different capacities in the field of biochemical parameters

Table 5 illustrates the results of the variation of the content of proline, catalase activity and ascorbate peroxidase activity in leaves of tomato varieties studied. The results for the statistical analysis identified a very significant effect of field capacity on these parameters. Indeed, under drought stress, proline accumulates, catalase and ascorbate peroxidase activities increase in tomato leaves depending on the severity of stress. Thus, the highest accumulations of proline and enzymes activities are observed in plants that have undergone water stress at 25% and 50% of field capacity for the three varieties studied. By cons, in good condition water supply (100% and 150%), proline content, catalase and ascorbate peroxidase activities remains low in tomato leaves.

DISCUSSION

Effect of water stress on agro-morphological parameters of the tomato

The water regime is a very important factor for the growth, development and yield of crops. Indeed, our results showed that under the effect of water stress, measured agro-morphological and physiological variables known throughout a significant reduction compared to the increase of the field capacity. Such results were obtained by Nana et al. (2010) on okra and Lalsaga et al. (2016) on cowpea. In view of these results on the parameters of the three tomato varieties studied, we sayed that the slowdown in the growth rate has been accompanied by a reduction or stoppage of the height and diameter of stressed tomato plants. Indeed, a lack of water slows the key growth mechanisms that is auxin. Regarding our results, the reduction was much more pronounced when water stress came at a quarter (1/4) of field capacity (25%).

Effect of water stress on the physiological parameters of tomato

The water content of the tomato plant was significantly reduced to a quarter (1/4) of the CC. Regarding the three varieties, they adopted these common behavior of tolerance to water stress on the water content. These results confirm those of Hanane (2008) on tomato. It was observed a slight increase in the water content in the medium at 150% DC. The decrease of the water content is considered a loss of turgor expanding cells (Durand, 2007).

The relative water content of the leaves of the tomato fell sharply to 25% of the CC. Our results showed that water intake by 50% over 150% of field capacity has no effect on the relative water content of leaves of tomato. The fall of the leaf relative water content is due to the loss of power accumulation of metabolites and osmotic adjustment for the maintenance of cell turgor and physiological activities (Bayoumi et al., 2008). Pigment chlorophyll content of leaves of tomato varieties is significantly affected by the lack of water in the soil. This pigment chlorophyll content decreases correspondingly over the degree of water deficit. The reduction in total chlorophyll is more pronounced in treatment 25% of the CC. As chlorophylls, the carotenoid content of tomato leaves decreases when the amount of water is reduced relative to the field capacity. The reduction is most prominent at 25% of the CC.

Water stress effect on the biochemical parameters of the tomato

The enhanced water restriction on the three varieties of tomato showed strong accumulation of proline in leaves as the environment became increasingly arid. This content was increased in the processing 25% of the CC. Varieties indicated contents proline which are very close. The accumulation of proline content is consistent with results obtained by Lum et al. (2014) on rice. Treatment 150% of the CC gave a very low accumulation of proline in all varieties. Tomato plants receiving water regime very small compared to field capacity have accumulated remarkably strong activities of catalase and ascorbate peroxidase in the leaves. This high activity is observed in the severe stress environments 25% of the CC. However enzyme activity may decrease in some plants as shown by Saeed et al. (2010) on the beets. Treatments receiving a high water supply is 150% showed very low activities of catalase and ascorbate peroxidase.

Conclusion

The results of this study showed a decrease in agro-morphological and physiological parameters when water deficit is severe (50% and 25). By cons, it was noted a strong accumulation of proline and increased enzyme activity in the strongest water restriction levels (50% and 25%). The high amount of water to 150% of control had low proline content and decreased enzyme activity

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Table 1. Method of measurement of yield components of tomato varieties

Yield and yield components	**Measurement approach and sample size per plot**
Morphological parameters performed on three plants per treatment (concentration)	
Stem diameter (Cm)	Measuring the circumference of the rods, made on three plants per treatment (concentration)
Plant height (Cm)	Measuring the distance separating the outermost sheet from the surface, carried out on three plants per treatment (concentration)
Scale plants (Cm)	Measuring the distance separating the two most extreme sheets, carried out on three plants per treatment (concentration)
Number of sheets	Effective of all the leaves on three plants per treatment (concentration)
Foliar area (Cm^2)	Measuring the surface of the sheet, carried out on three plants per treatment (concentration)
Number of roots	Effective of all roots on three plants per treatment (concentration)
Root depth (Cm)	Measuring the length of the roots, carried on three plants per treatment (concentration)
Physiological parameters performed on three plants per treatment (concentration)	
Relative water content of leaves (%)	Difference between the fresh weight and dry weight of the leaves multiplied by 100
Water content of the plant TEP (ml)	Difference between the fresh weight and dry weight of the whole plant
Chlorophyll a (µg/mL)	Extraction and determination of chlorophyll pigments (a)
Chlorophyll b (µg/mL)	Extraction and determination of chlorophyll pigments (b)
Chlorophyll Total (µg/mL)	Extraction and determination of total chlorophyll pigments (t)
Carotenoide (µg/mL)	Extraction and determination of carotenoids
Biochemical parameters performed on three plants per treatment (concentration)	
Proline content (µg/g MF)	Extraction and determination of proline
Catalase (mol/mn/g MF)	Extraction and determination of catalase
Ascorbate Peroxydase (mol/mn/g MF)	Extraction and determination of catalase and ascorbate peroxidase

Table 2: Results of statistical tests assessing the influence of water stress, variety and variety of water-stress interaction on the variables of the three varieties of tomato.

Variables	Concentrations		Varieties		Concentrations-varieties	
	F	***P***	***F***	***P***	***F***	***P***
Morphological parameters performed on three plants per treatment (concentration)						
Stem diameter (Cm)	55.179	< 0.001	2.488	0.10	2.12	0.063
Plant height (Cm)	44.67	< 0.001	1.441	0.252	0.779	0.623
Scale plants (Cm)	17.671	< 0.001	5.346	< 0.100	2.210	0.055
Number of sheets	15.702	< 0.001	32.502	< 0.100	1.899	0.097
Foliar area (Cm^2)	74.846	< 0.001	3.152	0.057	3.003	0.113
Number of roots	5.468	< 0.002	11.496	< 0.100	0.194	0.989
Root depth (Cm)	29.488	< 0.001	3.899	0.131	0.904	0.526
Physiological parameters performed on three plants per treatment (concentration)						
Relative water content of leaves (%)	18.911	< 0.001	1.454	0.249	0.035	0.999
Water content of the plant TEP (ml)	19.801	< 0.001	0.367	0.695	0.196	0.989
Chlorophyll a (µg/mL)	81.434	< 0.001	0.965	0.392	0.358	0.934
Chlorophyll b (µg/mL)	3.641	< 0.015	3.776	< 0.34	6.426	0.061
Chlorophyll Total (µg/mL)	27.203	< 0.001	2.760	0.079	1.639	0.155

Carotenoide (µg/mL)	34.202	< 0.001	16.063	< 0.100	4.187	0.052
Biochemical parameters performed on three plants per treatment (concentration						
Proline content (µg/g MF)	66.260	< 0.001	3.712	0.056	0.382	0.921
Catalase (mol/mn/g MF)	89.544	< 0.001	0.158	0.855	0.354	0.936
Ascorbate Peroxydase (mol/mn/g MF)	35.639	< 0.001	0.115	0.892	0.268	0.971

Tableau 3: The impact of different levels of field capacity on agro-morphological parameters of the three tomato varieties studied.

	plant height (Cm)	**stem diameter(Cm)**	**Foliar area (Cm^2)**	**Number of roots**	**Number of sheets**	**Scale plants (Cm)**	**Root depth (Cm)**
CC 25%	21.4 ± 3.8^{d}	0.23 ± 0.02^{d}	28.5 ± 12.9^{c}	98.03 ± 29.0^{b}	5.1 ± 0.50^{d}	0.020 ± 0.001^{b}	6.6 ± 1.1^{c}
CC 50%	27.4 ± 4.5^{c}	0.29 ± 0.02^{c}	36.5 ± 12.3^{bc}	130.3 ± 3.0^{ab}	6.7 ± 0.9^{c}	0.023 ± 0.02^{ab}	6.8 ± 1.2^{c}
CC75%	$35\pm 4,46^{b}$	0.35 ± 0.02^{b}	45.66 ± 7.4^{b}	168.5 ± 26.5^{a}	8.92 ± 0.8^{b}	0.023 ± 0.002^{a}	8.9 ± 1.1^{b}
CC100%	$37.2\pm 4,1^{b}$	$0,36 \pm 0.2^{ab}$	$48.48 \pm 9,^{ab}$	149.5 ± 49.7^{a}	8.59 ± 1.1^{b}	0.023 ± 0.003^{a}	9.4 ± 1.1^{b}
CC150%	$44.4\pm 3,8^{a}$	0.39 ± 0.03^{a}	60.63 ± 9.2^{a}	168.2 ± 44.5^{a}	10.8 ± 1.2^{a}	0.024 ± 0.002^{a}	11.4 ± 1.6^{a}
F	55.179	44.67	17.671	15.702	74.846	5.468	29.488
P	< 0,001	< 0.001	< 0.001	< 0.001	< 0.001	0.002	< 0.001

Mean values within column by parameter followed by the same superscripted letter were not significantly different at $p = 0.05$ level, on the basis of the least significant difference test. CC: Percentage water (25%, 50%, 75%, 100% and 150%).

Table 4. The impact of capacity levels in the field of agro-physiological parameters of three tomato varieties studied.

	TRE	**TEP**	**(Chl a)**	**(Chl b)**	**(ChlT)**	**Caro**
CC 25%	6.59± 0.44[d]	33.67± 8.95[b]	0.68± 0.16[e]	0.50± 0.18[b]	1.19± 0.32[d]	0.17± 0.05[c]
CC 50%	7.57± 1.12[cd]	42.83± 5.74[b]	1.09± 0.11[d]	0.59± 0.14[b]	1.69± 0.20[c]	0.23± 0.07[bc]
CC 75%	8.93± 1.20[bc]	54.42± 11.49[a]	1.40± 0.10[c]	0.50± 0.15[b]	1.97± 0.36[bc]	0.30± 0.03[ab]
CC 100%	10.10± 1.5[ab]	57.09± 6.21[a]	1.66± 0.18[b]	0.50± 0.11[b]	2.16± 0.27[ab]	0.34± 0.06[a]
CC 150%	11.69± 1.6[a]	63.98± 6.89[a]	2.10± 0.22[a]	0.39± 0.23[a]	2.48± 0.35[a]	0.36± 0.06[a]
F	18.911	19.801	81.434	3.641	27.203	34.202
P	< 0.001	< 0,001	< 0.001	0.015	< 0.001	< 0.001

Mean values within column by parameter followed by the same superscripted letter were not significantly different at $p = 0.05$ level, on the basis of the least significant difference test TRE : teneur relative en eau des feuilles; TEP : Teneur en eau de la plante; Chl a: Chlorophylle a; Chl b: Chlorophylle b; Chl t: Chlorophylle Totale ; Caro : Caroténoïde,. CC: Percentage water (25%, 50%, 75%, 100% and 150%).

Table 5: The impact of capacity levels in the field of biochemical parameters of three tomato varieties studied

	Proline content	Catalase activity	Ascorbate Peroxidase activity
CC 25%	0.054± 0.005[d]	381.70± 55.25[d]	4.63± 0.73[d]
CC 50%	0.036± 0.007[c]	264.81± 42.59[c]	3.62± 1.07[c]
CC 75%	0.027± 0.006[b]	180.00± 35.35[b]	2.58± 0.51[b]
CC 100%	0.021± 0.005[ab]	120.82± 21.22[a]	1.65± 0.69[ab]
CC 150%	0.013± 0.002[a]	97.47± 19.71[a]	1.27± 0.22[a]
F	66.260	89.544	35.639
P	< 0.001	< 0.001	< 0.001

Mean values within column by parameter followed by the same superscripted letter were not significantly different at $p = 0.05$ level, on the basis of the least significant difference test. CC: Percentage water (25%, 50%, 75%, 100% and 150%).