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RESEARCH ARTICLE

EFFECT OF SALT AND WATER STRESS ON MORPHOLOGICAL AND PHYSIOLOGICAL PARAMETERS OF THREE VARIETIES OF TOMATO (LYCOPERSICON ESCULENTUM MILL.) CULTIVATED IN CÔTE D'IVOIRE.

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Abstract

Tomato (*Lycopersicon esculentum* Mill.), Plant nutrition and economic interests, is often confronted with adverse environmental conditions including saline and water stress. These phenomena are forcing 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 salt and water stress on morphological and physiological parameters. For this, tomato varieties were subjected to four concentrations of NaCl (0, 2, 4 and 6 g / L) and five water treatment (150, 100, 75, 50 and 25% of field capacity). The results show that NaCl decreases significantly the morphological parameters. However, this reduction is accentuated to 6 g / L. At the physiological level, NaCl has significantly reduced water content of the plant, chlorophyll a, b and total (t) and carotenoid content. Water stress reduced the morphological and physiological parameters.

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Introduction:-

In Côte d'Ivoire, 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). The water and salt stress must 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 taking into account their capacity to resist these stresses. These two stresses influence the morphology and the physiological parameters

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of the tomato. It is in this light that three tomato varieties cultivated in Ivory Coast Daloa precisely, were selected to evaluate their resistance to water and salt stress. This work aims to study the behavior of three tomato varieties grown in the Ivory Coast under water and salt stress, through the evaluation of some morphological and physiological parameters

Material and method:-

Study site:-

The study was conducted in the University Jean Lorougnon Guede located in the town of Daloa in the west central Cote d'Ivoire. The 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. The climate of the region has four seasons: the long rains (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 local varieties of tomatoes (*Lycopersicon esculentum*) were used for this experiment. This is Petomech, UC82 and B Tropimech. The seeds were purchased in the market Daloa. These varieties are fixed with a specific growth and high production. Three ridges of 2m length, height 20 Cm, width 1m were used for the realization of the nursery for obtaining tomato plans. These logs were treated with two nematicide and fungicide. The transplanting was done in 4-liter pots containing the treated soil. The pots were perforated at the base and a thin layer of gravel was deposited before filling with soil. Pots, under glass, are deposited on a support. Some days (21) after seed germination, the more vigorous plants were planted in pots. This experiment was conducted in a greenhouse 3m height. Salt solutions (2, 4 and 6 g.l-1) NaCl were used to water tomato selected plans. The witness watered by tap water. NaCl solutions and water were applied a week after planting tomato plants to the capture morphological data. As regards the water stress, the stress levels (150%, 100%, 75%, 50% and 25%) relative to the capacity of the ground field were determined with an amount of 4.350 kg of ground culture. 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):

Data collection:-

During this experience, some morphological and physiological parameters were evaluated after two months of treatment plants with different solutions of NaCl and water. The vegetative parameters such as the diameter of the rod, the height and size of the plant, number of roots and finally sheet by plant leaf area were evaluated. Regarding the physiological parameters, variables such as the water content of plants, relative water content of the sheet (ERR) and the determination of chlorophyll pigments and carotenoids were determined (Table 1).

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 ($\mu\text{g/mL}$)	Extraction and determination of chlorophyll pigments (a)
Chlorophyll b ($\mu\text{g/mL}$)	Extraction and determination of chlorophyll pigments (b)
Chlorophyll Total ($\mu\text{g/mL}$)	Extraction and determination of total chlorophyll pigments (t)
Carotenoide ($\mu\text{g/mL}$)	Extraction and determination of carotenoids

Statistical analysis of the data:-

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 Smallest Significant Difference (LSD). This test identified the factor that significantly induce this difference.

Results and Discussion:-

Effect of different concentrations of NaCl and field capacity on agro-morphological parameters of the three tomato varieties:-

Salinity has a significant influence on the development of leaves, number of roots and scale of the studied tomato plants. These parameters decrease with increasing NaCl concentration in the medium (Table 2). Thus, lower values for these parameters are obtained at concentrations of 4 and 6 g / L NaCl. For cons, the highest values are observed in the control and the lowest concentration (2g / L). The results showed a complete difference in the depths of the roots for the four concentrations studied. Thus, when the NaCl concentration increases, the depth of the roots increases. The greatest value of the depth of the roots is obtained at the highest concentration (6 g / L). In the parameters such as the diameter of the rod, the plant height and leaf area, a partial difference has been observed. This difference shows that these parameters decrease with increasing concentration of the medium. And the larger values are obtained with low concentrations of NaCl. 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).

Table 2:- Effect of the various NaCl concentrations on the morphological parameters.

	plant height (Cm)	stem diameter(Cm)	Foliar area (Cm^2)	Number of roots	Number of sheets	Scale plants (Cm)	Root depth (Cm)
Témoïn	0,4 \pm 0,05 ^a	32,8 \pm 4,09 ^a	34,7 \pm 3,3 ^a	8,51 \pm 0,80 ^a	48,1 \pm 5,04 ^a	175,6 \pm 22,59 ^a	10,78 \pm 1,6 ^d
2 g/L	0,3 \pm 0,04 ^b	31,29 \pm 2,06 ^{ab}	32,3 \pm 3,11 ^{ab}	7,64 \pm 0,91 ^{ab}	44,14 \pm 2,7 ^{ab}	150,4 \pm 25,71 ^{ab}	12,54 \pm 3,11 ^c
4 g/L	0,3 \pm 0,01 ^{bc}	29,36 \pm 2,53 ^{ab}	30,0 \pm 3,2 ^b	7,37 \pm 0,63 ^b	41,4 \pm 5,67 ^b	143,7 \pm 23,18 ^b	13,25 \pm 1,33 ^b
6 g/L	0,3 \pm 0,02 ^c	28,6 \pm 2,70 ^b	28,7 \pm 2,4 ^b	7,19 \pm 1,11 ^b	35,4 \pm 3,46 ^c	139,81 \pm 18,18 ^b	14,3 \pm 1,37 ^a
P	< 0,001	0,016	< 0,001	0,015	< 0,001	0,001	0,010
F	14,717	4,140	15,565	4,244	11,228	6,726	4,642

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, salt solutions (2, 4 and 6 g.l-1)

Table 3:- Results of statistical tests assessing 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%	21,04 \pm 3,8 ^d	0,23 \pm 0,028 ^d	28,51 \pm 12,95 ^c	98,03 \pm 29,00 ^b	5,00 \pm 0,50 ^d	0,020 \pm 0,001 ^b	6,06 \pm 1,11 ^c
CC 50%	27,4 \pm 4,53 ^c	0,29 \pm 0,022 ^c	36,5 \pm 12,34 ^{bc}	130,3 \pm 30,61 ^{ab}	6,77 \pm 0,94 ^c	0,023 \pm 0,002 ^{ab}	6,84 \pm 1,27 ^c
CC 75%	35,0 \pm 4,46 ^b	0,35 \pm 0,029 ^b	45,66 \pm 7,42 ^b	168,56 \pm 26,51 ^a	8,92 \pm 0,82 ^b	0,023 \pm 0,002 ^a	8,91 \pm 1,13 ^b
CC100	37,2 \pm ,12 ^b	0,36 \pm 0,026 ^{ab}	48,48 \pm 9,05 ^{ab}	149,59 \pm 49,73 ^a	8,59 \pm 1,10 ^b	0,023 \pm 0,003 ^a	9,49 \pm 1,09 ^b

%							
CC150 %	44,4±3,86 ^a	0,39 ± 0,035 ^a	60,63 ± 9,23 ^a	168,22±44,52 ^a	10,8±1,22 ^a	0,024± 0,002 ^a	11,4±1,63 ^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 Percentage water (25%, 50%, 75%, 100% and 150%)

Effect of different concentrations of NaCl and field capacity in fields on the physiological parameters of varieties of Tomato:-

The statistical analysis of these parameters showed a significant effect for the different concentrations of NaCl used. The results show that in the total chlorophyll and carotenoid, the highest values were obtained at the low concentration (2 g / L). Beyond 2g / L, it was observed that the concentrations (4g / L and 6 g / L) have the same values at these two parameters. At the water content and chlorophyll (a), a decrease of the values was observed with the increase in salt concentration (table 4).

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. Statistical analysis of the results showed a highly significant effect of field capacity on agro-physiological parameters tested. Parameters such as the water content of the plant, the 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 (table 5).

Table 4:- Results of statistical tests assessing the influence of salt concentration on the relative water content of the leaves and the water content of the tomato plants

	TRE	TEP	(Chl a)	(Chl b)	(ChlT)	Caro
Témoïn	66,58 ± 7 ^a	10,14 ± 0,8 ^a	11,2 ± 2,2 ^a	6,29 ± 2,3 ^a	17,77 ± 4,3 ^a	9,923 ± 2,6 ^a
2 g/L	60,13 ± 3,3 ^a	9,234 ± 1,4 ^a	9,49 ± 2,1 ^a	5,15 ± 2,2 ^a	13,63 ± 2,4 ^b	7,00 ± 1,7 ^b
4 g/L	47,2 ± 5,8 ^b	8,375 ± 0,5 ^{ab}	5,86 ± 2,1 ^b	2,71 ± 1,0 ^b	7,204 ± 2,1 ^c	3,797 ± 1,4 ^c
6 g/L	40,57 ± 7,0 ^b	7,756 ± 1,1 ^b	2,96 ± 0,9 ^c	1,88 ± 1,3 ^b	4,48 ± 1,2 ^c	2,233 ± 0,7 ^c
P	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001
F	36,162	8,830	15,565	9,894	40,517	30,885

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, salt solutions (2, 4 and 6 g.l-1)

Tableau 5:- Results of statistical tests assessing 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 ^c	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± 1,50 ^{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± 1,69 ^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, Percentage water (25%, 50%, 75%, 100% and 150%)

Discussion:-

Effect of salt and water stress on agro-morphological parameters of the three tomato varieties:-

The results of this study show a reduction morpho physiological parameters of the three varieties according to the increase of NaCl concentration. Similar results were obtained by Hassani (2008) on some chili varieties. Indeed this author in a study on pepper varieties, showed that high salt concentrations have a negative influence on the growth of the pepper varieties. The decrease in the growth of the vegetative observed in tomato plants can be explained by the fact that the NaCl acts by increasing the osmotic pressure of the medium. Which prevents the absorption of water by the root system. This lack of water absorption leads to the reduction in growth is a result of a decrease in the number of cell divisions (Benamar et al., 2009). The reduction of the growth may result from the increase in abscisic acid concentration in the aerial part or cytokinin concentration reduction. The reduction in growth is an adaptation strategy allowing the plant to reduce resource spending. These strategies, implemented to maintain homeostasis under conditions of stress, are consuming energy and resources they divert the expense of growth. According to our results, the salt stress causes a delay in plant growth. This results in a reduction in plant height. A decrease in leaf area that is accompanied by symptoms of stress such as foliar chlorosis and necrosis, leading to death of the leaves. This same symptom was observed by Chartzoulakis and Klapaki,(2000).

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 will say 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 mechanism for growth, which are the auxè. Regarding our results, the reduction was much more pronounced when water stress intervened (25%) of the field capacity. At the three varieties of tomato, they all use the same strategy of tolerance to water stress for these two parameters (height and diameter). Our results are similar to those of Kara and Bellkhiri (2011) on wheat. The results also showed that 50% more than field capacity, tomato plants growing in height and thickness significantly. The leaf surface of tomato plants receiving a severe water deficit was much smaller. The reduction was more pronounced at the peak stress level to 25%. These results are consistent with those of Hanane (2008) on tomato. It confirms a reduction of leaf area of tomato plants under water stress. Indeed, this reduction in surface area is due to the reduction of cell division. The intensity of the imposed water stress caused a reduction in the number and length of roots. The irrigation level 150% has a large root but has no effect on the number of root. Water stress reduced the number sheet. These results confirm the observations of Amoumen et al. (2013) on durum wheat. A water intake above field capacity (CC) 150% promotes the formation of the leaves (10 leaves). The specific leaf weight of the tomato in the results obtained shows a slight decrease in the medium at the most severe water deficit of 25% of the CC.

Effect of salt and water stress on the physiological parameters of three tomato varieties:-

The physiological approach made in this study shows that chlorophyll a, b, and total carotenoid are negatively influenced by salt diet. Indeed, in our study, a decrease in the content of these pigments was observed with the increase in salt concentration. This is explained by the fact that a plant under stress reduced all metabolic activities that may induce excessive energy expenditure. Thus, reduction of the leaf surface involves a reduction in CO₂ uptake and consequently a reduction of the photosynthetic activity. The similar results were observed by Baghizadeh explains that under saline regime, chlorophyll a, b, and total carotenoids were significantly reduced in two wheat varieties (Baghizadeh et al., 2014). Other studies have also revealed similar results to ours. Indeed, Abbas et al., (2013) found that excessive amounts of toxic ions in leaf tissue of tomato cultivars can act as agent degrading chlorophyll pigments. The study also revealed a decrease in the relative water content of the leaves and the water content in the tomato varieties. Indeed, increasing the NaCl concentration results in a decrease of tissue hydration increasing the concentration inside and therefore prevents the water outlet of the plant to the outside. The intensification of salt treatment is accompanied by a decrease in the level of hydration which still remains tolerable. Maintaining a relative high content of water, under salt stress, is a remarkable form of resistance.

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). The 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.

Conclusion:-

Salt stress exerts in three varieties of tomatoes a depressive effect on all morphological parameters, physiological and biochemical. 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 content and increased enzyme activity in the strongest water restriction levels (50% and 25%).

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