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Effect of NaCl Concentration on the Agrophysiological and Biochemical Parameters of Tomato Varieties by a Chemometric Approach

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Abstract: ***Salinity is a constraint in many field perimeters. Thus, the search for plants adapted to high salinity thresholds becomes an imperative for agricultural production. This accumulation of salts in the soil reduces the yield of crops and mainly the food crops of which the tomato belongs. The objective is to use a chemometric approach using different statistical techniques to evaluate the effect of NaCl concentration on the agrophysiological and biochemical parameters of three varieties of tomato. In order to carry out this study, the experimental setup in complete random blocks with three repetitions was used. During the experiment, concentrations of NaCl 0 g / L, 2 g / L; 4g / L and 6g / L prepared were applied one week after transplanting three tomato varieties (Petomech, UC82 B and Tropimech) periodically (every two days) to agrophysiological and biochemical data. The results of the analysis showed that, in addition to the concentration of NaCl 2g / L, the mean values of the biochemical parameters varied significantly, resulting in differences between the three varieties of tomato. Further studies extended to mineral and organic elements will allow to better understand the level of the effect of NaCl on all the agronomic and biochemical parameters.***

Keywords: Salinity, chemometric approach, NaCl

1. Introduction

The economy of Côte d'Ivoire is mainly based on agriculture. The high availability of fertile land and hydrological resources combined with a favorable climate is a major asset to a varied range of agricultural production in West Africa [1].Agricultural output accounts for 33% of gross domestic product and 75% of export earnings. Agriculture employs almost 67% of the active population in Côte d'Ivoire [2]. However, this agriculture is mainly based on industrial crops (wood, coffee, cocoa, cotton, rubber, oil palm, cashew nuts, pineapples) to the detriment of food crops, which nevertheless ensures the daily feeding of the populations.Among these crops, we can mention the tomato which plays a very important socio-economic role. Tomato, is one of the most important vegetables in the diet after the potato. It is consumed fresh or processed[3]. In addition, global tomato production has steadily increased steadily in recent decades. In Côte d'Ivoire, annual production fluctuates between 22 000 and 35 000 tones[1]. In fact, tomato needs estimated at more than 100 000 tones are only covered by local production [4]. The country imports a very large quantity of tomatoes to satisfy demand. Statistics on the 2011-12 crop year yielded an estimated production of more than 120 million tones, placing tomatoes first in terms of fruit production[5].This solanacea is of great organoleptic richness and brings vitamin A to our body. Like any fruit and vegetable, it contains few calories and its micronutrients participate in a balanced diet and prevents obesity[6]. The tomato is rich in essential amino acids, vitamin B, iron and phosphorus.

However, despite the increase in tomato production in the world, its culture is increasingly confronted with multiple problems. These problems are related not only to climate change and the misuse of pesticides, but also to soil degradation and acid rain that cause salinity in irrigation soils and waters. This accumulation of salts in the soil reduces crop yields and mainly the food crops of which the tomato is part[7]. Salinity is a constraint in many field perimeters where water quality plays a major role. Thus, the search for plants adapted to high salinity thresholds becomes an imperative for agricultural production [8]. Therefore, the present study investigating the effect of NaCl concentration on the agrophysiological and biochemical parameters of three varieties of tomato by a chemometric approach finds its full meaning. The use of a chemometric approach using different statistical techniques could be an aid in understanding the effect of the concentration of salt (NaCl) on the agrophysiological and biochemical parameters of the three varieties of tomato.

2. Materials and Methods

2.1. Experimental Systems

In this study, three local varieties of tomatoes (Lycopersicomesculentum) were used for the experiment. These are Petomech, UC82 B and Tropimech. The seeds were bought on the Daloa market. These varieties are fixed with a determined growth and a strong production. The experimental setup is in complete random blocks with three repetitions. Each block is represented by 4 liter pots containing the treated soil (nematicide and fungicide). The pots were perforated at the base then a thin layer of gravel was put before filling it with the soil. Plants were transplanted in 21 days after seed germination. The most vigorous plants were transplanted into the pots (3 plants per pot) previously watered by a basic nutrient solution consisting of 80 mg NPK per liter. This experiment took place under a greenhouse of size: length: 10 m, width: 5 m and height: 3m.

For this experiment, concentrations of NaCl 0 g / L, 2 g / L; 4g / L and 6g / L were prepared to water the tomato plants. The different concentrations of NaCl were applied one week after the transplanting of the tomato plants periodically (every two days) until the agrophysiological and biochemical data were taken.

2.2. Data collection

In this experiment, agrophysiological and biochemical parameters were evaluated after two months of treatment of the tomato plants with different concentrations of NaCl. Vegetative parameters such as stem diameter, plant height and span, number of roots and leaf per plant and leaf area were evaluated. As for the physiological parameters, variables such as water content of plants, relative water leaf content (TRE), chlorophyll pigment and carotenoid dosage were determined. Biochemical parameters such as the proline, catalase (cat) and ascorbate peroxidase assay were determined.

2.3. Chemometricmethods

Statistical tools are used in almost all areas of life. It follows that the statistical methods of data processing are diverse. To this end, the data recordedfromthe agrophysiological and biochemical evaluation of tomato varieties were subjected to statistical analyzes. Thus, the first analyzes concerned the mean, the standard deviation and the coefficient of variation. The average is the most traditional position parameter. The arithmetic mean of a set of numbers is equal to the sum of the values divided by the number of values. Like the variance, the standard deviation is a dispersion characteristic. It gives an account of the dispersion of the measures around the mean value. A statistic that is often used to measure the variability of a data set is the coefficient of variation (CV). This is the standard deviation expressed as a percentage of the mean. The idea is to make comparable the variability of several datasets when the units of measurement are different. It is not possible to give a general rule to know from what level a CV is acceptable. However, in the case of a repeat test, it is recommended that the CV be less than 15% for the biological material and 5% for the others.

Multidimensional analysis of variance (MANOVA) were done. Whereas, the former consists in grouping identicalindividuals into sets, the later deals with comparing differentmeans in order to identify if they are different or equal. In this study, cluster analysis was based on Ward's method as agglomerate one. The square Euclidean distance was the chosen metric as recommended by Johnson and Wichern (2007) [9]. The quality of the typology was evaluated by the proportion (%) of total sum of squares explained. This proportion is calculated using agglomeration schedule according to Tenenhaus (2011) [10]. The MANOVA is a generalization of analysis of variance (ANOVA) method to one or several factors (qualitative variables) in which two or several dependent variables are measured simultaneously. It enables to examine the main effects and factors interaction. Analysis of variance (ANOVA) was also done. The above analyses were performed using Statistica 7.1. Software package.

3. Results

3.1. Characterization of agrophysiological and biochemical parameters

The composition of the average agrophysiological and biochemical parameters of tomato varieties is presented in the table. At the analysis, the tomato varieties have a relative water content of about 53,68 ± 11,89 for the leaf (TRE) and 8,85 ± 1,33 for the plant (TP). The number of leaves (NF) and roots (NR) were 7,68 ± 0,99 and 152,22 ± 25,82, respectively. In addition, tomato varieties have an average height (HT) of 30,52 ± 3,27, a carotenoids (CARO) of 5,78 ± 3,45 and a leaf area (SF) of the order of 42,27 ± 6,29. At the root depth (PRO RA), it gives an average of the order of 12.73 ± 2.32. In addition, the varieties of tomatoes contain average Chl t contents (10,78 ± 5,93 %), including Chla (7,39 ± 3,74%) and Chl b (4,01 ± 2,50). As for the mean value of the diameter of the rod (DT), it is of the order of 0,35 ± 0,05. They also have mean catalase (CATA) and proline (PROL) values of the order of 0,12 ± 0,12 and 0,78 ± 0,47, respectively. The varieties of tomatoes also have an ascorbate peroxidase (ASC P) content (0,0011 ± 0,0010). Analysis of the coefficient of variation (CV) revealed that eleven agrophysiological and biochemical parameters of tomato varieties have a CV greater than 15%, with the exception of four vegetative parameters: leaf number, height of the plant, the diameter of the stem and the leaf area.

Table 1: Average composition of agrophysiological and biochemical parameters of tomato varieties

Parameters	*N*	*Means*	*Minimum*	*Maximum*	*Standard deviation*	*Coefficient of variation*
NF	36	7,68	4,7	9,67	0,99	12,89
NR	36	152,22	105,67	213,33	25,82	16,96
PRO RA	36	12,73	8,47	19,67	2,32	18,22
HT	36	30,52	23,23	36,77	3,27	10,71
DIA T	36	0,35	0,27	0,50	0,05	14,28
SF	36	42,27	30,67	54,67	6,29	14,88
TRE	36	53,68	30,43	74,92	11,89	22,14
TE	36	8,85	5,35	11,96	1,33	15,02
Chl a	36	7,39	1,85	14,98	3,74	50,6
Chl b	36	4,01	0,81	11,14	2,50	62,34

Chl t	36	10,78	2,49	24,93	5,93	55
CARO	36	5,78	1,42	13,52	3,45	59,68
CATA	36	0,122	0,014	0,68	0,125	102,45
ASC P	36	0,0011	0,0001	0,0047	0,0011	100
PROL	36	0,78	0,22	1,90	0,47	57,69

N: Number of samples

PR: proline content, CARO: carotenoid content, TE: plant water content, SF: leaf area, PRO RA: root depth, NR: number of roots, NF: Number of leaves, HT: plant height, Chl a: chlorophyll a content, Chl b: chlorophyll content b, CATA: catalase content, DIA T: rod diameter, AUC P: ascorbate peroxidase content, T: total chlorophyll content

3.2. Correlation between agro-physiological and biochemical parameters of tomato varieties

The correlation matrix of agro-physiological and biochemical parameters characterizing tomato varieties (Table 2) shows that there are many significant relationships between agro-physiological and biochemical parameters. Thus, there is a positive and significant relationship between the relative leaf water content (TRE) and the carotenoid content (Pearson's correlation coefficient of 0,72). This means that tomato varieties characterized by a high relative leaf water content (TRE) are those in which the amount of carotenoid is high. The same applies to the diameter of the stem (Pearson's correlation coefficient of 0,75) and the total chlorophyll content (Pearson's correlation coefficient of 0,77). Positive relationships also exist between the carotenoid content and parameters such as chlorophyll a (Pearson's correlation coefficient of 0,77), chlorophyll b content (Pearson's correlation coefficient of 0,77). Other positive relationships exist between the leaf surface and the diameter of the stem (Pearson's correlation coefficient equal to 0,63). To this must be added the correlations between chlorophyll a content and total chlorophyll content (Pearson correlation coefficient equal to 0,71).

On the other hand, there are many significant and negative relationships between the agro-physiological and biochemical parameters of tomato varieties. This is the case for the proline content which is correlated with the carotenoid content (Pearson correlation coefficient equal to -0,77), with the total chlorophyll content (Pearson's correlation coefficient equal to -0,78). The same applies to root depth and chlorophyll a (Pearson correlation coefficient equal to -0,59). Parameters such as proline content and root depth are correlated (Pearson correlation coefficient equal to -0,76) and Pearson correlation coefficient equal to -0,57, respectively, with the relative water content of the roots leaves.

In sum, the study of the correlation matrix indicated that the most significant correlations at the 5% threshold were +0,84 and -0,79. The correlation of 0,84 is for the total chlorophyll content and the carotenoid content with a coefficient of determination of 0,92; Which means that the increase in total chlorophyll content is explained at 92% by the importance of the carotenoid content. In the case of a negative correlation of -0,79 between the total chlorophyll content and the proline content, the coefficient of determination of 0,89 shows that the increase in total chlorophyll content is explained at 89% by the low proline content of different varieties of tomato. Similarly, the increase in the proline content of tomato varieties is explained at 88% by the low carotenoid content.

Table 2: Matrix of correlation between agrophysiological and biochemical variables of tomato varieties

Effet	TR F	PROL	CARO	TE P	SUR F	PRO RA	NB RA	NB F	HAUT	CHL A	CHL B	CATA	DIA T	ASC P	CHL T
TR F															
PROL	- 0,760663														
CARO	0,721401	-0,775081													
TEP	0,632193	-0,564409	0,554227												
SUR F	0,618751	-0,670001	0,468626	0,558225											
PRO RA	-0,473961	0,439975	-0,503401	-0,556477	-0,356120										
NB RA	0,480712	-0,353281	0,467725	0,328849	0,400552	-0,240315									
NB F	0,308626	-0,411634	0,412721	0,085954	0,390820	-0,097831	0,583876								
HAUT	0,509150	-0,447799	0,589906	0,247703	0,232324	-0,207757	0,377462	0,433810							
CHL A	0,695478	-0,790697	0,775766	0,624342	0,628529	-0,592272	0,399237	0,360116	0,296775						
CHL B	0,479906	-0,652092	0,772809	0,487761	0,464751	-0,296899	0,299694	0,460311	0,458204	0,599832					
CATA	0,581715	-0,530636	0,668629	0,444525	0,345516	-0,270648	0,484066	0,364554	0,463390	0,463850	0,475083				
DIA T	0,753273	-0,615993	0,642764	0,510810	0,631880	-0,259670	0,627073	0,399882	0,344728	0,568945	0,470437	0,606317			
ASC P	0,607672	-0,537105	0,542197	0,470992	0,526381	-0,203380	0,425339	0,363128	0,302321	0,467759	0,519825	0,512429	0,687050		
CHL T	0,770508	-0,788790	0,839043	0,581548	0,655764	-0,478672	0,533103	0,458710	0,526367	0,834902	0,689451	0,675875	0,712234	0,593245	

3.3. Effect of variety and NaCl concentration on agrophysiological and biochemical parameters

3.3.1. Multidimensional variance analysis of agrophysiological and biochemical parameters of tomato varieties

The results obtained are shown in Table 3. The analysis shows that the effects of the NaCl concentration and the tomato varieties on the agrophysiological and biochemical parameters are significant (p <0,05). On the other hand, the effects related to the interaction concentration* varieties are not significant (p> 0,05).

Table 3: Multidimensional analysis of variance on the agrophysiological and biochemical parameters

Effects	Test	Values	F	p
Concentration	Wilk	0,001015	6,219	0,000000
Varieties	Wilk	0,034318	2,932	0,007311
Concentration*Varieties	Wilk	0,004353	1,138	0,295396

*Concentration*Varieties : Interaction concentration-varieties ; the effects are significant p <0,05.*

3.3.2. Analysis of variance withtwocontrolledfactors of agrophysiological and biochemical parameters

This analysis is done to see if the factors (NaCl concentration and varieties) have a significant influence on each of the parameters allowing to differentiate between tolerant tomato varieties. The results obtained are presented in Table 4. The analysis of variance revealed that the effects of the concentration of NaCl was significant (p <0,05) over all the parameters studied. As for the crop variety, only three parameters (root, leaf number and plant height) out of fifteen showed a significant effect (p <0,05). Moreover, the interaction of concentration * varieties showed a non-significant effect (p> 0,05) on all studied parameters with the exception of the proline content. In sum, Nacl concentrations significantly (p <0,05) influence the agro-physiological and biochemical parameters of the different tomato varieties.

Table 4: Analysis of variance to two controlled factors of agrophysiological and biochemical parameters

Parameters	Effects	Sum of squares	Degree of Freedom	Estimated variance	F	P
TRE	C	3791,8	3	1263,9	36,162	0,000000
	V	152,4	2	76,2	2,180	0,134952
	C-V	165,9	6	27,6	0,791	0,585935
PROL	C	6,96836	3	2,32279	169,850	0,000000
	V	0,05885	2	0,02942	2,152	0,138200
	CV	0,42388	6	0,07065	5,166	0,001552
CARO	C	316,480	3	105,493	30,8852	0,000000
	V	7,973	2	3,987	1,1671	0,328307
	C-V	10,788	6	1,798	0,5264	0,782632
TE	C	26,301	3	8,767	8,833	0,000401
	V	5,049	2	2,524	2,543	0,099599
	C-V	6,419	6	1,070	1,078	0,403166
SF	C	769,20	3	256,40	11,228	0,000085
	V	26,74	2	13,37	0,585	0,564620
	C-V	39,47	6	6,58	0,288	0,936860
PRO RA	C	59,960	3	19,987	4,642	0,010700
	V	1,462	2	0,731	0,170	0,844900
	C-V	23,204	6	3,867	0,898	0,512214
NR	C	7018,5	3	2339,5	6,726	0,001878
	V	7385,0	2	3692,5	10,616	0,000498
	C-V	582,7	6	97,1	0,279	0,941179
NF	C	9,276	3	3,092	4,244	0,015336
	V	6,224	2	3,112	4,272	0,025882
	C-V	1,131	6	0,189	0,259	0,950687
HT	C	96,98	3	32,33	4,140	0,016878
	V	58,33	2	29,16	3,735	0,038701
	C-V	31,30	6	5,22	0,668	0,676137
Chl a	C	369,171	3	123,057	36,0340	0,000000
	V	4,648	2	2,324	0,6805	0,515848
	C-V	35,049	6	5,841	1,7105	0,161738
Chl b	C	114,6971	3	38,2324	9,8940	0,000197
	V	1,3468	2	0,6734	0,1743	0,841130
	C-V	10,0270	6	1,6712	0,4325	0,849888
CATA	C	0,267224	3	0,089075	11,42959	0,000075
	V	0,044922	2	0,022461	2,88210	0,075545
	C-V	0,078554	6	0,013092	1,67994	0,169220
DIA T	C	0,061091	3	0,020364	14,717	0,000012
	V	0,003473	2	0,001736	1,255	0,303176
	C-V	0,001261	6	0,000210	0,152	0,986840
ASC P	C	0,000023	3	0,000008	13,13571	0,000028
	V	0,000000	2	0,000000	0,19575	0,823516
	C-V	0,000005	6	0,000001	1,36648	0,267982
Chl t	C	0,000023	3	0,000008	13,13571	0,000028
	V	0,000000	2	0,000000	0,19575	0,823516
	C-V	0,000005	6	0,000001	1,36648	0,267982

Concentration * varieties: Interaction Concentration-varieties; the effectsdifferenceis significant at p <0.05.

3.3.3. Comparisonbetween the agrophysiological and biochemical parameters of the three tomato varieties as a function of the NaClconcentration

Tables 5a, 5b, 5c and 5d show the mean values of the agrophysiological and biochemical parameters of each tomato variety as a function of the NaCl concentration. The analysis of these tables overall shows that some agrophysiological and biochemical parameters of the varieties are statistically identical (p <0,05) between tomato varieties. Indeed, at the concentration of 0 g / L NaCl (Table 5a), the analysis shows that the agrophysiological and biochemical parameters are statistically identical (p <0,05) with the exception of the root depth which has differences between The three varieties (Petomech, UC82B and Tropimech). As for the concentration of NaCl 2g / L (Table 5b), it appears that the agrophysiological and biochemical parameters studied are statistically identical (p <0,05) for all varieties of tomato. The agrophysiological and biochemical parameters (Table 5c) observed at the 4g / L NaCl concentration showed no significant difference between the parameters except for the ascorbate peroxidase content which differs from one variety to another. At the concentration of 6 g / L NaCl (Table 5d), the analysis showed, contrary to the three concentrations of NaCl mentioned above, that the proline content, the ascorbate peroxidase content and the stem diameter were statistically different (p <0,05) for the studied varieties (Petomech, UC82B and Tropimech). The other parameters studied in this study at this concentration are statistically identical (p <0,05).

Table 5a: Characteristics of the agrophysiological and biochemical parameters of the three varieties of NaCl (0 g/ L)

	Parameters	*Petomech*	*UC82B*	*Tropimech*
	TRE	62,44 ± 8,69 ^{a}	70,88 ± 3,52 ^{a}	66,45 ± 7,39 ^{a}
	PROL	0,35 ± 0,02 ^{a}	0,29 ± 0,05 ^{a}	0,35 ± 0,16 ^{a}
	CARO	8,49 ± 2,09 ^{a}	9,80 ± 2,48 ^{a}	11,48 ± 3,24 ^{a}
	TE	10,73 ± 0,68^{a}	9,41 ± 0,88 ^{a}	9,89 ± 0,73 ^{a}
	SF	50,44 ± 5,67^{a}	47,67 ± 4,04 ^{a}	46,22 ± 6,25 ^{a}
(0g/L) ofNaCl	PRO RA	8,90 ± 0,49 ^{a}	12,36 ± 0,37 ^{b}	11,09 ± 1,03 ^{c}
	NR	157,56 ± 2,34 ^{a}	196,22 ± 16,39 ^{a}	173,22 ± 25,16 ^{a}
	NF	8,22 ± 1,26 ^{a}	9,00 ± 0,58 ^{a}	8,33 ± 0,33 ^{a}
	HT	30,08 ± 5,72 ^{a}	35,18 ± 2,61 ^{a}	33,14 ± 2,74 ^{a}
	Chl a	12,30 ± 2,67 ^{a}	10,05 ± 1,09 ^{a}	11,32 ± 2,92 ^{a}
	Chl b	7,37 ± 3,36 ^{a}	5,72 ± 2,08 ^{a}	5,80 ± 1,71 ^{a}
	CATA	0,20 ± 0,11 ^{a}	0,42 ± 0,24 ^{a}	0,18 ± 0,02 ^{a}
	DIA T	0,41 ± 0,07 ^{a}	0,43 ± 0,06 ^{a}	0,40 ± 0,04 ^{a}
	ASC P	0,00 ± 0,00 ^{a}	0,00 ± 0,00 ^{a}	0,00 ± 0,00 ^{a}
	Chl t	16,30 ± 2,38 ^{a}	21,05 ± 4,38 ^{a}	15,97 ± 5,03 ^{a}

Table 5b: Characteristics of the agrophysiological and biochemical parameters of the three varieties of NaCl (2g/ L)

	Parameters	*Petomech*	*UC82B*	*Tropimech*
	TRE	60,89 ± 3,98 ^{a}	58,27 ± 1,01 ^{a}	61,23 ± 4,33 ^{a}
	PROL	0,52 ± 0,04 ^{a}	0,47 ± 0,08 ^{a}	0,51 ± 0,05 ^{a}
	CARO	7,15 ± 0,76 ^{a}	6,94 ± 2,88 ^{a}	6,92 ± 1,94 ^{a}
	TE	10,55 ± 1,43 ^{a}	8,41 ± 0,84 ^{a}	8,75 ± 1,29 ^{a}
	SF	44,22 ± 2,71 ^{a}	43,55 ± 4,52^{a}	44,67 ± 0,66 ^{a}
2g/L ofNaCl	PRO RA	12,96 ± 5,81 ^{a}	12,70 ± 0,85 ^{a}	11,98 ± 1,86 ^{a}
	NR	127,89 ± 13,67 ^{a}	159,67 ± 22,15 ^{a}	162,56 ± 29,25 ^{a}
	NF	7,00 ± 1,15 ^{a}	8,04 ± 0,67 ^{a}	7,89 ± 0,76 ^{a}
	HT	29,43 ± 0,69 ^{a}	32,11 ± 2,27 ^{a}	32,36 ± 1,86 ^{a}
	Chl a	10,82 ± 2,51 ^{a}	8,23 ± 1,71 ^{a}	9,44 ± 1,91 ^{a}
	Chl b	5,85 ± 3,48 ^{a}	5,37 ± 2,37 ^{a}	4,26 ± 0,43 ^{a}
	CATA	0,17 ± 0,06 ^{a}	0,11 ± 0,10 ^{a}	0,07 ± 0,04 ^{a}
	DIA T	0,34 ± 0,07 ^{a}	0,37 ± 0,00 ^{a}	0,36 ± 0,01 ^{a}
	ASC P	0,00 ± 0,00 ^{a}	0,00 ± 0,00 ^{a}	0,00 ± 0,00 ^{a}
	Chl t	13,97 ± 0,25 ^{a}	13,74 ± 4,35 ^{a}	13,19 ± 1,98 ^{a}

Table 5c: Characteristics of the agrophysiological and biochemical parameters of the three varieties of NaCl (4g/ L)

	Parameters	*Petomech*	*UC82B*	*Tropimech*
	TRE	60,89 ± 3,98 ^{a}	58,27 ± 1,01 ^{a}	61,23 ± 4,33 ^{a}
	PROL	0,52 ± 0,04 ^{a}	0,47 ± 0,08 ^{a}	0,51 ± 0,05 ^{a}
	CARO	7,15 ± 0,76 ^{a}	6,94 ± 2,88 ^{a}	6,92 ± 1,94 ^{a}
	TP	10,55 ± 1,43 ^{a}	8,41 ± 0,84 ^{a}	8,75 ± 1,29 ^{a}
	SF	44,22 ± 2,71 ^{a}	43,55 ± 4,52 ^{a}	44,67 ± 0,66 ^{a}
	PRO RA	12,96 ± 5,81 ^{a}	12,70 ± 0,85 ^{a}	11,98 ± 1,86 ^{a}
4g/l of NaCl	NR	127,89 ± 13,67 ^{a}	159,67 ± 22,15 ^{a}	162,56 ± 29,25 ^{a}
	NF	7,00 ± 1,15 ^{a}	8,04 ± 0,67 ^{a}	7,89 ± 0,76 ^{a}
	HT	29,43 ± 0,69 ^{a}	32,11 ± 2,27 ^{a}	32,36 ± 1,86 ^{a}
	Chl a	10,82 ± 2,51 ^{a}	8,23 ± 1,71 ^{a}	9,44 ± 1,91 ^{a}
	Chl b	5,85 ± 3,48 ^{a}	5,37 ± 2,37 ^{a}	4,26 ± 0,43 ^{a}
	CATA	0,17 ± 0,06 ^{a}	0,11 ± 0,10 ^{a}	0,07 ± 0,04 ^{a}
	DIA T	0,34 ± 0,07 ^{a}	0,37 ± 0,00 ^{a}	0,36 ± 0,01 ^{a}
	ASC P	0,00 ± 0,00 ^{a}	0,00 ± 0,00 ^{b}	0,00 ± 0,00 ^{c}
	Chl t	13,97 ± 0,25 ^{a}	13,74 ± 4,35 ^{a}	13,19 ± 1,98 ^{a}

Table 5d: Characteristics of the agrophysiological and biochemical parameters of the three varieties of NaCl (6 g/ L)

	Parameters	*Petomech*	*UC82B*	*Tropimech*
6g/l ofNaCl	TRE	35,69 ± 5,42 a	45,26 ± 4,10 a	40,78 ± 9,24 a
	PROL	1,21 ± 0,06 a	1,49 ± 0,18 b	1,75 ± 0,22 c
	CARO	2,08 ± 0,60 a	2,01 ±0,69 a	2,62 ± 0,89 a
	TE	7,46 ± 1,90 a	7,86 ± 0,93 a	7,95 ± 0,46 a
	SF	35,11 ± 3,85 a	35,33 ± 3,84 a	35,78 ± 4,22 a
	PRO RA	15,36 ± 1,94 a	13,78 ± 0,92 a	13,86 ± 0,73 a
	NR	122,44 ± 14,54 a	155,67 ± 14,52 a	141,3 ± 38,19 a
	NF	27,38 ± 4,17 a	7,93 ± 0,45 a	6,78 ± 1,83 a
	HT	27,38 ± 4,17 a	27,86 ± 0,33 a	30,61 ± 1,56 a
	Chl a	3,91 ± 0,80 a	2,35 ± 0,49 a	2,64 ± 0,77 a
	Chl b	1,24 ± 0,40 a	2,21 ± 2,03 a	2,21 ± 1,27 a
	CATA	0,04 ± 0,02 a	0,06 ± 0,05 a	0,03 ± 0,01a
	DIA T	0,28 ± 0,02 a	0,32 ± 0,02 b	0,31 ± 0,009 c
	ASC P	0,00 ± 0,00 a	0,00 ± 0,00 b	0,00 ± 0,00 c
	Chl t	4,42 ± 0,97 a	4,31 ± 1,66 a	4,73 ±1,61 a

4. Discussion

The evaluation of the effect of NaCl on the agrophysiological and biochemical parameters of the three varieties of tomato by a chemometric approach revealed that the mean values of these parameters show significant differences between the three varieties of tomato studied from NaCl 2g / L. Indeed, the increase in NaCl content in the different treatments resulted in a reduction in plant height, leaf area and aerial and root biomass of the varieties studied. This effect, which is very common in glycophytes, has previously been observed in other genotypes [11]. The decrease in growth of the vegetative apparatus observed in tomato plants is explained by the fact that NaCl by increasing the osmotic pressure of the medium prevents the absorption of water by the root system. This leads to a reduction in growth, which is the cellular result of a decrease in the number of cell divisions[12]. Reduced growth would result from increased abscisic acid concentration in the aerial part or a reduction in cytokine concentrations. In addition to controlling growth by hormonal signals, growth reduction is the result of resource expenditure in adaptation strategies [13]. These strategies, implemented to maintain homeostasis under stress, are consuming energy and resources that they divert at the expense of growth. According to our results, salt stress caused a delay in plant growth. This results in reduced plant height, decreased leaf area and other morphological parameters up to the death of the plant. These symptoms of toxicity reduced the active surface area for photosynthesis and caused a marked reduction in growth.According to Munnsand Tester (2002)[14], vegetative growth and especially leaf expansion are severely inhibited by saline stress with newly developing leaves and senescence of old ones which accelerate, this is consistent with the results of the work doing by Kara and Brinis (2012)[15], who observe that the reduction of the growth of the aerial parts is an adaptive capacity necessary for the survival of the plants exposed to an abiotic stress. Indeed, developmental delay allows the plant to accumulate energy and resources to combat stress before the imbalance between the interior and exterior of the organism increases to a point where the damage is irreversible.

The physiological approach in this study shows that the chlorophyll a, b and total levels and carotenoids have negatively influenced the salt regime. Salinity has a depressive effect by a reduction in chlorophyll a, b and total[16]. Similar results were obtained by Baghizadeh et al., (2014)[5], which explains that under a salt regime total chlorophylls a, b, and carotenoids have been considerably reduced in two varieties of wheat. Excessive amounts of toxic ions in the leaf tissues of tomato cultivars may behave as a degrading agent for chlorophyll [17]. Thus, the decrease in chlorophyll synthesis may be due, among other things, to a decrease in 5-aminolevulinic acid [18]. NaCl inhibits the synthesis of 5-aminolevulinic acid, a chlorophyll precursor [19]. In addition, plant cultivation in saline solutions is known to damage PSII and photosynthetic enzymes[20]. Saline stress plays a role in decreasing the activity of chlorophyll enzyme responsible for the biosynthesis of chlorophyll pigments [21]. Indeed, the decrease in the rate of assimilation of CO_2 in the leaves is associated with an inhibition of photosynthesis.

NaCl reduces the chlorophyll content even at low concentrations with an increase in the chla / chlb ratio[22]. This study also revealed a decrease in the water content of the leaves and the plant of the varieties of tomatoes studied. Indeed, the increase in the concentration of NaCl leads to a decrease in the hydration of the tissues[23]. The intensification of saline treatment is accompanied by a decrease in the level of hydration. Maintaining a relatively high water content, under salt stress, is a remarkable form of resistance[15]. Studies on wheat and corn show similar results in decreasing relative leaf water content and plant water content [24]. This may be due to the toxicity of Na^+ and / or Cl^- ions accumulated in the cytoplasm at levels exceeding the capacity of tolerance in the vacuole [25].

The results of the biochemical parameters show significant differences in the activities of catalase and ascorbate peroxidase between the control and treated plants. Indeed, a negative correlation was observed when different concentrations of NaCl were applied to these two enzymes. This decrease in catalase and ascorbate peroxidase activity is due not only to the stage of development of the plant but also to the different concentrations of NaCl. These results are consistent with those of other studies. Thus, Naike et al. (2005) [26]observed that the increase in H_2O_2 content in plant tissues was associated with an increase in the applied NaCl dose. According to these authors, the increasing concentrations of NaCl, lead to a decrease in the activity of catalase and ascorbate peroxidase. Research on two Poaceae showed that exposure to salt stress caused a decrease in catalase activity in wheat and rice[27]. This indicates that high salinity generally reduces the activity of catalase regardless of the variety studied. However, our results differ from those of Midaoui et al. (2007)[28], who found that the activity of these enzymes increases with increasing salt concentration. According to their work, catalase is essential for maintaining the redox equilibrium during oxidative stress. It works as a cellular well for H_2O_2 and allows the plant to withstand water or salt stress [27].

In addition, similar results were reported by Ramteke and Karibasppa (2005)[29] in vines. A positive correlation between the intensity of free catalase accumulation and stress tolerance was suggested as an index for determining the potential stress of cultivar tolerance. The main reason for the increase in catalase concentration during salt stress is due to the continuous synthesis of this enzyme during stress[30]. The results obtained during our work indicate that the excess salt causes an accumulation of proline in the plant. Proline, which is usually low in the tissues of plants grown on a salt-free medium and therefore not very water-constraining, is accumulated dramatically in response to salt stress. Several authors have shown that this amino acid is part of the osmoticums that plants synthesize when exposed to water or saline stress [31]. Its role is necessary for osmotic adjustment to balance the osmotic potential of the soil as demonstrated by other studies, including those of O'neill and al. (2006)[32]. On the other hand, a strong accumulation of this amino acid is a sign of metabolic disturbance[33]. In this study, the three varieties have accumulated significant amounts of proline in their leaves to cope with salt stress.

5. Conclusion

The present study investigates the effect of NaCl concentration on the agrophysiological and biochemical parameters of three varieties of tomato by a chemometric approach. The use of a chemometric approach using different statistical techniques could be an aid in understanding the effect of the concentration of NaCl salt on the agrophysiological and biochemical parameters of the three varieties of tomato. This approach used to assess the influence of NaCl on the three varieties of tomato showed a depressive effect on all the morphological, physiological and biochemical parameters. The degree of sensitivity or tolerance depends on the variety, and the intensity of the stress. In sum, from one tomato variety to another according to the different concentrations, the mean values of the agrophysiological and biochemical parameters of the tomato varieties are not significantly different. However, above the 2g / L NaCl concentration, the mean values of the biochemical parameters varied significantly, resulting in differences between the three varieties of tomato studied.

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