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Effects of salinity stress on growth and photosynthetic activity of common basil plants (*Ocimum basilicum* L.)

Wpływ działania stresu solnego na wzrost i aktywność fotosyntezy roślin bazylii pospolitej (*Ocimum basilicum* L.)

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ABSTRACT

The study evaluated basil plants' response (var. Sweet Green) to increased concentrations of sodium chloride (NaCl) and macro- and micronutrients in the medium. The following variants were used: ½ Hoagland nutrient solution containing NaCl (0, 80 and 160 mM) and 4/2 Hoagland solution with 0 mM NaCl. Biometric and physiological parameters were measured 20 days after saline application. The application of 160 mM NaCl in nutrient solution caused the suppression of basil plants' growth. The height of plants was decreased by 22% and the length of the roots was less by 60%. Control plants had 68% greater leaf area than those grown in the medium with 160 mM NaCl. Compared to the control, basil grown in ½ Hoagland solution with 80 mM NaCl and 4/2 Hoagland solution with 0 mM NaCl had leaf area reduced by 43.4% and 48.2%, respectively. A single plant's highest fresh weight was found in the control variant (17.78 g) and the lowest in the ½ Hoagland solution with 160 mM NaCl (5.14 g). A negative effect of 160 mM NaCl in solution on the leaf gas exchange of salt-treated plants was found. At the same time, no negative influence of salinity on the content of photosynthetic pigments was found. The addition of NaCl into Hoagland solution did not affect the maximum photochemical efficiency (F_v/F_m) but modified the actual activity of Photosystem II (PSII). Increasing the concentration of macro- and microelements in the nutrient solution (4/2 of Hoagland and 0 mM NaCl) had a significantly lower negative effect on the growth and photosynthetic activity of basil plants.

Keywords: salinity, Hoagland nutrient solution, leaf gas exchange, water potential, chlorophyll fluorescence

STRESZCZENIE

Badania obejmowały ocenę reakcji roślin bazylii pospolitej (odmiany Sweet Green) na podwyższone stężenie chlorku sodu (NaCl) oraz makro- i mikroskładników pokarmowych w pożywce. Zastosowano następujące warianty doświadczalne: ½ pożywki Hoaglanda zawierająca NaCl (0, 80 i 160 mM) oraz 4/2 roztwór Hoaglanda zawierający 0 mM NaCl. Parametry biometryczne i fizjologiczne mierzono 20 dni po zastosowaniu zasolenia. Zastosowanie 160 mM NaCl w pożywce spowodowało zahamowanie wzrostu roślin bazylii. Wysokość roślin była mniejsza o 22%, a długość korzeni o 60%. Rośliny kontrolne miały o 68% większą powierzchnię liści niż rośliny uprawiane na pożywce z 160 mM NaCl. W porównaniu z kontrolą, bazylia uprawiana w roztworze ½ Hoaglanda z 80 mM NaCl i roztworze 4/2 Hoaglanda z 0 mM NaCl miała zmniejszoną powierzchnię liści odpowiednio o 43.4% i 48.2%. Istotnie najwyższą świeżą masę pojedynczej rośliny stwierdzono w wariancie kontrolnym (17.78 g), a najniższą w roztworze ½ Hoaglanda z 160 mM NaCl (5,14 g). Stwierdzono negatywny wpływ 160 mM NaCl w roztworze na wymianę gazową roślin. Jednocześnie nie stwierdzono

negatywnego wpływu zasolenia na zawartość barwników fotosyntetycznych. Wprowadzenie soli NaCl do pożywki Hoaglanda nie wpłynęło na maksymalną wydajność fotochemiczną (F_v/F_m), zmodyfikowało jednak faktyczną aktywność fotoukładu II (PSII). Zwiększone stężenie makro- i mikroelementów w pożywce (4/2 Hoaglanda i 0 mM NaCl) miało istotnie mniejszy negatywny wpływ na wzrost i aktywność fotosyntetyczną roślin.

Słowa kluczowe: zasolenie, pożywka Hoglanda, wymiana gazowa, potencjał wody, fluorescencja chlorofilu

INTRODUCTION

Basil is an annual plant with morphology specific to the *Lamiaceae* family (Paton et al., 2005; Khair-ul-Bariyah et al., 2012; Egata et al., 2017). This species is considered economically useful because of its basic natural characteristics as essential oil producer (Lawrence, 1993). Basil is used in pharmacy for diuretic and stimulating properties and in cosmetics for its smell (Khatri et al., 1995).

According to Capecka (1998) and Svecova and Neugebauerova (2010) the basil plants' height ranges from 14.3 to 46.0 cm. Maboko and Du Plooy (2013) and Skorina and Sacziwko (2015) obtained higher plants of 50.2 to 84.0 cm depending on the cultivar. Green-leaved basil grown in Poland reaches an average height of 17.8 to 40.7 cm (Majkowska-Gadomska et al., 2017; Jadczak, 2007). Additionally, basil biometric studies showed that the plant diameter ranges from 15.3 to 15.8 cm (Jadczak, 2007). According to Egata et al. (2017) fresh leaves' weight ranges from 31.1 to 344.4 g. Jadczak (2007) found that the weight of basil plants grown in Western Poland ranged from 23.5 to 31.3 g per plant, while the weight of fresh basil grown in Egypt – from 18.0 to 158.2 g (Nassar et al., 2013). In the research conducted by Egata et al. (2017), the weight of air-dried leaves collected from basil plants ranged from 4.0 to 60.6 g and depended on its genotype. In 2005 and 2006, air-dried leaves of basil grown in Finland (Mikkeli) weighted respectively 126.0 and 267.0 g/m^2 for cv. 'Kasia' and 131.9 and 295.0 g/m^2 for cv. 'Wala' (Seidler-Łożykowska et al., 2008). Chang et al. (2008) showed that the average basil leaf area reached 110.4-237.1 cm^2 for the first pair of true leaves and 356.0-700.0 cm^2 for the third pair of true leaves. This diversity may result from differences in genotype, environmental impact, or horticultural practice (Egata et al., 2017; Singh et al., 2018).

Currently, about 20% of arable lands in the world and about half of all irrigated lands are exposed to salinization, one of the most important abiotic factors limiting crop yields (Zhu, 2001; Stepien and Klobus, 2006; Tarchoune et al., 2010). Most plants grown in a saline environment exhibit growth inhibition, a reduction in the size and number of leaves and roots, with the limitations of the aboveground organ growth being greater than the limitations of the root growth (Taiz and Zeiger, 2002). Salt stress affects plants' physiological and biochemical processes and significantly reduces their yield (Khan and Panda, 2008; Center et al., 2016). Salinity is mostly triggered by an excess of sodium chloride (NaCl) or sodium sulfate (Na_2SO_4) in the water used for plant irrigation (Tarchoune et al., 2012). This problem is particularly important for species not resistant to salinization or cultivated in a dry climate (Demiral and Türkan, 2005; Bernstein et al., 2009; Tarchoune et al., 2010; Tarchoune et al., 2012).

In the case of basil, salinity reduces the plant's ability to absorb water from the substrate and decreases its growth rate, as described by authors from different regions of the world (Munns, 2002; Kaymakanova and Stoeva, 2008; Golpayegani and Tilebeni, 2011, Heidari, 2012). The high concentration of hydrochloric acid salts in the rhizosphere reduces water's potential in the soil and water availability. This in turn causes dehydration at the cellular level and osmotic stress (Lloyd et al., 1989; Stepien and Klobus, 2006; Kaymakanova et al., 2009; Center et al., 2016). Salinity may also lead to cell membrane destabilization and inability to absorb minerals, resulting in reduced biomass and plant yield (Golpayegani and Tilebeni, 2011; Amuthavalli and Sivasankaramoorthy, 2012; Menezes et al., 2017). The increased concentration of hydrochloric acid salts also reduces the photosynthetic ability due to osmotic stress and partial closure of stomata leading to

reduction of intercellular CO_2 concentration (Drew et al., 1990). Reduced photosynthesis activity under salt stress is also attributed to non-stomata factors. There is ample evidence that salinity affects photosynthetic enzymes and photosynthetic pigments (Stepien and Klobus, 2006). Since Photosystem II (PS II) was found to be sensitive to unfavorable environmental factors, research was also undertaken on its activity in plants growing in salinity. Many studies indicate that salinity can damage PS II (Jimenez et al., 1997, Stepien and Klobus, 2006), but there are also data indicating its high photochemical activity (Lu et al., 2002), which may be an indicator of plant tolerance to stress, including salinity.

The study evaluates selected biometric and physiological parameters of basil (*Ocimum basilicum* L.) plants, cv. Sweet Green, grown in the substrates with increased sodium chloride (NaCl) concentration and macro- and micronutrients. This is particularly important when growing herbs (including basil) in pots, where the maintenance of optimal conditions in the substrate determines the success of the cultivation.

MATERIAL AND METHODS

The experiment was carried out in October-November 2017. The study used "Sweet Green" basil (seeds from Thomson & Morgan) cultivated in a growth chamber under controlled conditions: photoperiod 14/10 hours (light/dark), light intensity (PAR) 300 µmol/m^2/s PPFD, temperature 25/15 °C (day/night) and relative air humidity 65-70%. In the phase of two pairs of true leaves, the seedlings were transplanted into pots, 12 cm in diameter, filled with perlite and ½ Hoagland solution (Hoagland and Arnon, 1950). Then the plants were cultivated for four weeks. In the second week, the number of plants was reduced to a single plant per pot. At the same time, the plants were divided into the experimental variants: ½ Hoagland solution and NaCl (0, 80 and 160 mM); 4/2 Hoagland solution with 0 mM NaCl (Figure 1). Each variant was set in three replications with six plants.

After 20 days of growth in the presence of increased salt concentrations, the whole plants were harvested (Figure 2).

Figure 1. Growth chamber with basil plants. A - ½ Hoagland's solution and 0 mM NaCl (control); B - ½ Hoagland's solution and 80 mM NaCl; C - ½ Hoagland's solution and 160 mM NaCl; D- 4/2 Hoagland's solution and 0 mM NaCl

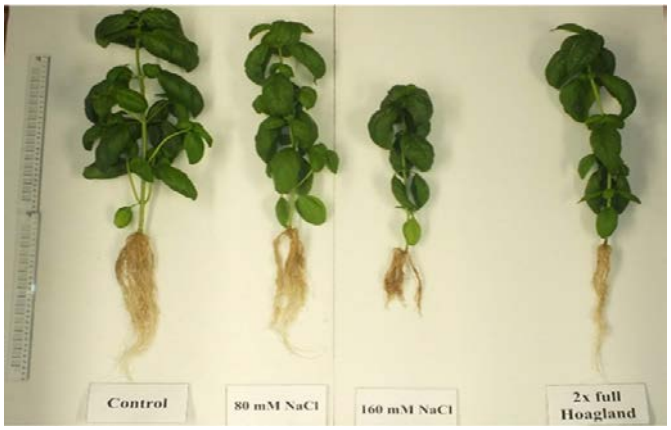

Figure 2. Basil plants after harvest

Fresh weight and dry weight (Krełowska–Kułas, 1993) of plants were assessed. The average length of all roots was measured. The leaf area was measured with an electronic area meter NEO-3 (TU-Sofia). The leaf gas exchange parameters were determined using a portable LCA-4 analyzer (ADC, England). Photosynthetic pigments were measured by a spectrophotometric method, and the content of the pigments was calculated according to Lichtenthaler (1987). The leaf water potential was determined using a pressure chamber EL 540-305 (ELE-International Ltd., Hemel Hempstead, England). Chlorophyll fluorescence parameters (in dark and light adapted leaves) were determined with the pulse amplitude modulation fluorimeter MINI-PAM (Walz, Effeltrich, Germany) on the same plants that were used for gas exchange measurements. Minimal fluorescence (F_0), was measured in dark-adapted leaves using modulated light (<0.15 μmol/m^2/s). Maximal fluorescence (F_m) was evaluated after 0.8 s saturating white light pulse (>5500 μmol/m^2/s) in the same leaves. Maximal variable fluorescence (F_v=F_m–F_0) and the photochemical efficiency of Photosystem II (F_v/F_m) for dark adapted leaves were calculated. Photochemical (qP) and non- photochemical (qN) quenching parameters were determined according to Schreiber et al. (1986) and Van Kooten and Snel (1990). The efficiency of electron transport (Y) and the rate of electron transport (ETR) were calculated according to Genty et al. (1989).

Biometric measurements and physiological analyses were performed on four plants from each replication.

Finally, ANOVA was used to assess the significance of differences between means using Tukey's test for randomized blocks in a single-factor experiment, and half confidence intervals at the significance level P<0.05 were calculated. Statistical calculations were made using Statistica 13 software (StatSoft Polska Sp. z o.o.).

RESULTS

High salt concentrations in Hoagland solution (160 mM) significantly reduced plant height (by 22%) and the growth of root system (by 61%) – see Table 1. Leaf area was greatly reduced (383.5 cm^2) compared to control variant (1186.0 cm^2). Plants grown in Hoagland's solution with 80 mM NaCl and those with higher concentrations of macro- and micronutrients were less affected.

The significantly highest fresh weight of a single plant (17.78 g) was found in the control variant. The considerably lowest fresh weight (5.14 g) was found for ½ Hoagland solution and 160 mM NaCl (Table 2). Comparing the weight of leaves, shoots and roots showed that it was significantly highest for leaves (17.66 g) and the lowest for the plant root system (4.19 g). It was proven that the interactions of the factors studied in the experiment (salt concentration and morphological part of the plant) significantly affected fresh weight of a single plant, and revealed the greatest fresh weight (28.35 g) for the leaves of the control plants, and the lowest fresh weight (8.01 g) for the control roots. It was found a higher yield of leaves in the three remaining salt concentrations and a lower yield of the other organs.

There were no statistical differences in the dry weight of plants subjected to different salt concentrations. We determined greater dry weight for the root system (55.53%) and smaller for shoots and leaves (22.02 and 17.51%, respectively). There was no significant influence of the interactions of the experimental factors on the dry weight of basil.

It is noteworthy, however, that the percentage of leaves in a single plant's weight was the highest (65.20%) in basil grown in ½ Hoagland solution and 160 mM NaCl, and the lowest (53.35%) in control plants.

Table 1. The influence of salinity stress on the height plants, the length of the root system and area of plant leaves of sweet basil

Salt concentration	Plant height (cm)	Root system length (cm)	Leaf area (cm^2)
½ Hoagland's solution and 0 mM NaCl (control)	41±1.41	31±6.36	1 186.0±251.31
½ Hoagland's solution and 80 mM NaCl	40±2.83	25±4.24	671.1±160.3
½ Hoagland's solution and 160 mM NaCl	32±0.71	12±2.83	383.5±47.16
4/2 Hoagland's solution and 0 mM NaCl	40±0.71	28±1.41	615.3±1.91
Average	38.3±0.35	24.3±0.53	713.96±91.59
$HSD_{P<0,05}$	2.750	17.125	668.28

± standard deviation, HSD - honestly significant difference

Table 2. The influence of salinity stress on fresh, dry weight and share of the leaf mass in the fresh weight of the plant

½ Hoagland's solution and 0 mM NaCl (control)	Shoots	16.97±3.24	7.86±7.51	53.35
	Leaves	28.35±1.91	35.13±14.69	
	Roots	8.01±2.5	33.29±19.82	
Average for control		17.78±2.55	25.43±14.01	
½ Hoagland's solution and 80 mM NaCl	Shoots	7.36±0.43	13.61±0.64	56.30
	Leaves	14.86±2.47	8.35±1.15	
	Roots	4.12±1.35	42.81±23.12	
Average for ½ Hoagland's solution and 80 mM NaCl		8.78±1.13	21.59±7.11	
½ Hoagland's solution and 160 mM NaCl	Shoots	3.50±0.6	38.02±6.55	65.20
	Leaves	10.04±0.3	16.19±5.88	
	Roots	1.88±0.18	77.24±0.24	
Average for ½ Hoagland's solution and 160 mM NaCl		5.14±0.16	43.82±0.31	
4/2 Hoagland's solution and 0 mM NaCl	Shoots	7.54±0.28	28.6±19.04	62.74
	Leaves	17.38±1.05	10.36±2.33	
	Roots	2.78±0.25	68.80±23.81	
Average for 4/2 Hoagland's solution and 0 mM NaCl		9.23±0.17	35.92±0.81	
Average for:	Shoots	8.84±0.92	22.02±1.4	-
	Leaves	17.66±0.76	17.51±1.33	-
	Roots	4.19±1.07	55.53±16.75	-
$HSD_{P<0,05}$ for:	A	2.547	n.s.	-
	B	2.547	18.445	-
Interaction	A/B	2.547	18.445	-

± standard deviation, n.s. – non-significant statistical difference, HSD - honestly significant difference

The salinity influenced gas exchange in basil leaves (Table 3). The measurements showed a decrease of the net photosynthesis (P_N), stomata conductance (g_s) and transpiration (E) along with the increase of sodium chloride concentration in the substrate. Significantly higher net photosynthesis was found in control plants (9.46 µmol $(CO_2)/m^2/s$), and the lowest using ½ Hoagland's solution and 160 mM NaCl (3.6 µmol $(CO_2)/m^2/s$). A similar effect occurred in the case of transpiration and stomata conductance.

The leaf gas exchange of plants grown in Hoagland's solution with 80 mM NaCl and those with higher concentrations of macro- and microelements was less affected.

The applied salting reduced slightly the water potential, which is a measure of plant cells' ability to absorb water. Compared with the control variant, Ψ_l values were lower in the plants grown at ½ Hoagland solution with NaCl and at 4/2 Hoagland solution.

The analysis of photosynthetic pigments in salt-treated basil plants showed an increase in chlorophyll a content by 22–23% in the plants grown in the presence of sodium chloride (80 mM and 160 mM), and a decrease of 5% at 4/2 Hoagland solution with 0 mM NaCl (Table 4). When using NaCl (80 mM and 160 mM), a total carotenoids content and chlorophyll a/b ratio increased compared with the control plants.

Table 3. The influence of salinity stress on the height plants, the length of the root system and area of plant leaves of sweet basil

Salt concentration	P_N	E	g_s	Ψ_l
½ Hoagland's solution and 0 mM NaCl (control)	9.46	1.96	0.15	-0.68
½ Hoagland's solution and 80 mM NaCl	7.55	1.56	0.13	-1.19
½ Hoagland's solution and 160 mM NaCl	3.6	0.54	0.03	-1.39
$^{4/2}$ Hoagland's solution and 0 mM NaCl	5.78	1.12	0.07	-1.12
Average	6.8	1.29	0.10	-1.09
$HSD_{P<0,05}$	0.997	0.165	0.012	n.s.

P_N – Net photosynthetic rate (µmol$(CO_2)/m^2/s$); E – Transpiration rate (mmol$(H_2O)/m^2/s$); g_s – stomata conductance (mmol $/m^2/s$); Ψ_l – water potential (MPa); n.s. – non-significant statistical difference, HSD - honestly significant difference

Table 4. The content of photosynthetic pigments (mg/g FW) in basil leaves exposed to salinity stress

Pigments	Salt concentration					
	½ Hoagland's solution and 0 mM NaCl (control)	½ Hoagland's solution and 80 mM NaCl	½ Hoagland's solution and 160 mM NaCl	$^{4/2}$ Hoagland's solution and 0 mM NaCl	Average	$HSD_{P<0,05}$
Chl a	1.61	1.99	1.94	1.53	1.77	0.352
Chl b	0.65	0.71	0.67	0.53	0.6	n.s.
Chla+b	2.25	2.70	2.61	2.06	2.41	0.462
Total carotenoids	0.52	0.65	0.63	0.53	0.58	0.119
Chl a/b	2.53	2.82	2.88	2.87	2.78	n.s.
(Chla+b) / total carotenoids	2.88	3.08	2.80	2.54	2.82	n.s.

n.s. – non-significant statistical difference, HSD - honestly significant difference

Table 5. Chlorophyll fluorescence parameters in basil leaves subjected to salinity stress

Salt concentration	Leaves adapted in dark conditions			Leaves adapted in light conditions			
	F_0	F_m	F_v/F_m	Y	qP	qN	ETR
½ Hoagland's solution and 0 mM NaCl (control)	254	1308	0.806	0.254	0.446	0.655	32.8
½ Hoagland's solution and 80 mM NaCl	252	1313	0.809	0.200	0.401	0.629	24.7
½ Hoagland's solution and 160 mM NaCl	289	1245	0.768	0.207	0.359	0.626	25.9
4/2 Hoagland's solution and 0 mM NaCl	255	1297	0.803	0.232	0.417	0.639	28.6
Average	263	1290	0.796	0.223	0.405	0.63	28.0
$HSD_{P<0,05}$	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

F_o - minimal fluorescence, F_m – maximal fluorescence, F_v/F_m – photochemical efficiency of PSII, Y – quantum yield of electron transport, ETR - electron transport rate, qP - photochemical quenching, qN - non-photochemical quenching; n.s. - non significant statistical difference, HSD - honestly significant difference

There was no significant influence of salinity on the chlorophyll fluorescence parameters in basil leaves (Table 5). The sodium chloride at concentration of 160 mM led to a simultaneous slight increase in initial fluorescence (F_o) and a decrease in maximum fluorescence determined after leaf adaptation in the dark (F_m). However, this did not significantly cause a decrease in photochemical efficiency (F_v/F_m), which was 0.768. The addition of 160 mM NaCl into Hoagland solution showed a decrease of 20% in the proportion of energy driven to the photosynthetic pathway (qP), while 80 mM NaCl decreased qP with 10%. Yield (Y) decreased by an average of 20%. The non-photochemical quenching (qN) in the leaves of these plants was at the level of control. Concerning electronic transport rate (ETR) the plants from the medium with NaCl were affected and presented an average reduction of 20%.

DISCUSSION

Numerous studies noted that increased salt concentration in nutrient solution results in morphological changes and/or differences in plant biometric parameters, such as the number of leaves, length of the root system, plant height and leaf area (Munns, 2002; Hafsi et al., 2007; Delavari et al., 2010; Tarchoune et al., 2010; Menezes et al., 2017). Osmotic effects of salt trigger water shortages in the plant affecting plant biometric parameters (Munns, 2002; Munns et al., 2006). Delavari et al. (2010) showed that with the increasing salinity of the medium (0, 100 and 200 mM NaCl), basil plants grew lower than control plants.

In the present work, basil plants cultivated with ½ Hoagland's solution with the addition of 160 mM NaCl were much lower than other studied objects.

Increased substrate concentration (4/2 Hoagland solution and 0 mM NaCl) had a positive effect on plant height only on the first date of biometric measurements (fifth day). Plants were then on average by 27% higher than those growing in the control medium and media with salt (80 mM NaCl and 160 mM NaCl). Subsequent measurements did not confirm this trend (unpublished data).

In most plants, NaCl presence in the substrate inhibits plant growth, reduces their size and the number of leaves and roots. The growth limitations of aboveground organs are greater than those of roots (Taiz and Zeiger, 2002). The current study confirmed that pattern for basil plants. Control plants had the longest root system (31 cm) and basil grown using ½ Hoagland solution with 160 mM NaCl had the shortest roots (12 cm). Control plants had 68% greater leaf area than those grown in the medium with a higher salinity level (160 mM NaCl). Basil cultivated in ½ Hoagland solution with 80 mM NaCl and 4/2 Hoagland

solution with 0 mM NaCl showed a significant reduction in leaf area compared with the control.

Tarchoune et al. (2010) showed that after 15 days in the presence of 50 mM NaCl, the leaf area in cv. 'Genovese' basil reached 632.0 cm per plant vs. 712.0 cm in control plants. In other studies, Tarchoune et al. (2010; 2012) showed a lower fresh yield of plants exposed to 50 mM NaCl than in control plants. After 15 days of treatment with 50 mM NaCl, the leaf area in cv. 'Genovese' basil amounted to 632.0 cm per plant, while it was 712.0 cm per plant in the control. After 30 days of salt stress, the weight was 25.97 g for individual plants treated with 50 mM NaCl and 33.74 g for control plants. The authors showed a weight reduction of 50% in the leaves and 77% in the stems and root system compared to control plants.

The salt in the medium usually reduced the fresh weight of shoots, leaves and roots. When studying the influence of salt stress on the dry weight of Genovese basil plants Tarchoune et al. (2010) determined the dry weight of 1.03 g per plant after 15 days of exposure to 50 mM NaCl and of 1.18 g per plant for control plants. Meanwhile, Ning et al. (2015) determined dry weight in the roots and stems (0.21–0.34 and 2.85–0.94 g per plant, respectively) in basil grown in seawater (at concentrations of 0, 5, 10, 20, 40).

In the present study, the highest fresh weight of a single plant (17.78 g) was found in the control variant. The lowest fresh weight (5.14 g) was found in ½ Hoagland solution with 160 mM NaCl. No statistically significant differences were found for the tested salt concentrations in the dry weight of basil shoots, leaves and root system. Greater dry weight was determined for shoots and the root system when the plants were treated with ½ Hoagland solution with 160 mM NaCl than in the other variants. The leaves from the control plants had the highest dry weight. Various changes in biomass accumulation in response to salinity in plants of three cultivars of ornamental amaranth were also reported by Wrochna (2007). On average, by 55.53% greater dry weight was determined in the root system, by 22.02% in the shoots and by 17.51% in the leaves. By comparing the results of this experiment it was shown that the percentage of leaves in the herb weight increased under salinity.

The most important process that is affected in plants, growing under saline conditions, is photosynthesis. Photosynthesis under salinity can be directly reduced through a decrease in CO_2 assimilation and diffusion from the stomata to mesophyll cells (Flexas et al., 2007), and indirectly through oxidative stress that impairs the photosynthetic apparatus (Chaves et al., 2009). In this study, there was an evident decrease in photosynthetic activity in basil plants subjected to salinity. Increasing salt level progressively decreased P_N. The stronger inhibition of P_N at the higher salinity dose (160 mM NaCl) – by 72%, could result from the stomata closure (by 80%). Decreased g_s resulted in reduced transpiration activity. Stomata closure is an effective mechanism for the economical use of water and the limitation of the harmful salt ions uptake. At the same time, however, the decrease in stomata conductance also affects the photosynthesis activity (Hasegawa et al., 2000).

The negative influence of salt stress on the intensity of photosynthesis was also observed by Wasilewski et al. (2015) in a study in spring barley, Gawlik et al. (2014) in soybean and Kaymakanova and Stoeva (2008) in the bean.

Water status is sensitive to salinity and therefore is dominant in determining the plant response to this stress (Stepien and Klobus, 2006). The present research showed that the water potential, which is a measure of the ability of plant cells to absorb water, decreased considerably in the plants grown at ½ Hoagland solution with NaCl and at 4/2 Hoagland solution because most likely salinity increased cellular water loss.

In the study of Tarchoune et al. (2012), water potential (Ψ_l) in the basil was -0.84 MPa for plants grown in the presence of 25 mM Na2SO4, which was higher than -0.89 MPa at 50 mM NaCl. The water potential determined in KRL wheat (salt-tolerant) was -0.60 MPa at 50 mM NaCl and -0.77 MPa in plants exposed to a higher salt concentration of 100 mM NaCl (Mandhania et al., 2006).

Photosynthetic pigments are one of the important internal factors, which can limit photosynthesis activity. The analysis of photosynthetic pigments in salt-stressed basil leaves showed that Genovese basil contains on average 17.6 mg/g FW of chlorophyll *a*, 4.9 mg/g FW of chlorophyll *b* and 1.2 mg/g FW of total carotenoids (Tarchoune et al., 2012). In the case of 'Red Rubin' and 'Tigullio' basil grown in the control conditions (plants watered with tap water with the addition of H_2SO_4), the content of total pigments was 9.8 µg/mg FW and 9.2 µg/mg FW of chlorophyll *a+b* (Landi et al., 2014). A study by Menezes et al. (2017) proved an increase in chlorophyll *a* and chlorophyll *a/b* ratio at the concentration of 0, 40, 60 and 80 mM NaCl.

This research showed an increase in chlorophyll a content by 22–23% in the plants grown in the presence of sodium chloride (80 mM and 160 mM), and a decrease of 5% at 4/2 Hoagland solution with 0 mM NaCl (Table 4). When using NaCl (80 mM and 160 mM), a total carotenoids content and chlorophyll *a/b* ratio increased when compared with the control plants. The effect of salinity on photosynthesis can be direct through a decrease in CO_2 assimilation and diffusion from the stomata to mesophyll cells (Flexas et al., 2007), and indirect through oxidative stress which impairs the photosynthetic activity (Chaves et al., 2009). This study demonstrated that the photosynthesis intensity decrease was mainly due to a reduction in stomata conductance. The decrease in CO_2 assimilation did not depend on photosynthetic pigments, the levels of which increased when plants were grown at ½ Hoagland solution with NaCl.

There was no significant effect of salinity on the fluorescence parameters of chlorophyll in basil leaves. The photochemical efficiency expressed by F_v/F_m was in the range of 0.768-0.809. The optimal F_v/F_m value found in healthy leaves is 0.75–0.83 (Bolhàr-Nordenkampf and Öquist, 1993). This was indicating that, in this case, no functional disturbances in Photosystem II, which is the most sensitive indicator of abiotic stress in plants. A similar effect was described in the work of Tarchoune et al. (2012). Medium salinity (50 mM NaCl) did not affect chlorophyll fluorescence parameters in light- and dark-adapted leaves of Genovese basil. The maximum photochemical efficiency (F_v/F_m) reached was 0.82, thus indicating no functional disturbances in PSII.

The addition of NaCl into Hoagland solution showed a slight decline of quantum efficiency of electron transport (Y), which is a measure of the total photochemical efficiency of Photosystem II under photosynthetic steady-state conditions. Photochemical quenching (qP) presented similar behavior to yield (Y). The non-photochemical quenching (qN) in the leaves of these plants was at the level of control, which proves the lack of energy dissipation through non-photochemical processes.

Since qP indicates the proportion of open reactive centres PSII while qN - heat dissipation, the salinity used did not significantly affect the primary photochemical reactions and the loss of energy excited under heat. Studies by some authors show that salt stress damage photosystem II (Stepien and Klobus 2006), but other literature reports indicate high photochemical activity, which can measure plant tolerance to salt stress (Lu et al., 2002).

CONCLUSION

The present study showed that NaCl in Hoagland nutrient solution inhibited the growth and leaf gas exchange of young basil plants. The values of the studied parameters decreased with increasing concentration of sodium chloride. At the same time the addition of NaCl into Hoagland solution did not affect the maximum photochemical efficiency (F_v/F_m) but modified the actual activity of PSII. Increasing the concentration of macro- and microelements in the nutrient solution (4/2 of Hoagland and 0 mM NaCl) had a significantly lower negative effect on the growth and photosynthetic activity of basil plants.

In conclusion, it can be stated that the photosynthetic apparatus of the studied plants was characterized by tolerance to salinity in the range of the concentrations used.

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