Bangladesh J. Bot. 52(1): 71-77, 2023 (March) DOI: https://doi.org/10.3329/bjb.v52i1.65234

EFFECTS ON YIELD AND NUTRIENT CONCENTRATION OF SPINACH (*BASELLA ALBA* L.) AT DIFFERENT SALINITY LEVELS

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Keyword: Salinity, Spinach, Plant nutrient concentration, Biomass

Abstract

Effects of salinity and nutrient concentration were examined for spinach (*Basellaalba* L.) in pot culture at glass house of the Institute of Agricultural Resource and Regional Planning (IARRP), CAAS, Beijing, China during March to April 2018.There were four levels of salinity (*viz.* 0, 4, 8 and 16 dSm^{-1}) as treatment for the trial. The salt stress significantly affected the total biomass weight and the lowest biomass production was found at highest salinity level. Although the photosynthetic rate decreased with increasing salt stress but no significant effect was observed between 12 and 16 dSm^{-1} salinity level. But a noticeable salinity levels up to 8 dSm^{-1} showed a better trend in photosynthesis rate. The total nitrogen in soil reduced from 97.9 to 28.1 mg kg^{-1} when salinity increased to 16 dSm^{-1} and total phosphorus showed similar trend and availability reduced 667.3 to 519.3 mg kg^{-1}. Both nitrogen and sodium became more available for plant in saline condition. The potassium increased from 2811.7 to 5640.3 mg kg^{-1} when salinity level was 16 dSm^{-1} and sodium showed similar trend and availability increased to 1.4 to 3.5 mg kg^{-1}. Nutritional disorder occurs due to salt stress, thus adversely affected on nutrient concentration, uptake and transport in plant and affected negatively on the yield of spinach.

Introduction

In coastal areas salinity is the major problem for crop production due to scarcity of irrigation water. Saline soil is reluctant for agricultural crop production and availability of irrigation water is the major challenge for the farmer for sustainable crop production. In the world about 10% of the land is directly salt-affected and the impact of salinity remain in irrigated land is about 50% (Ruan*et al*. 2010). Effects of salinity to crop are multidimensional where morphological, physiological and metabolic activity disorders occur due to excess salt in soil solution. Water availability in plant root is decreased due to the salinity effects thus occurring water deficit in cells, nutrient deficiencies and ion toxicity. Higher salinity in the soil solution creates very unfavorable situation which ultimately generate oxidative stress thus plant become dry (Orcutt and Nilsen 2000). In agriculture, salinity causes huge loses annually which is about $12 billion and this incident is increasing day by day around the world (Flowers *et al.* 2010).

Within the plant, many cellular compound, substances as well as chlorophyll development in plant mainly depend on nitrogen (Lawlor 2002). Nitrogen deficiency directly affects those important physiological and metabolic activities and stunted plant growth (Lemaitre *et al.* 2008). Important macronutrient phosphorus is also very important in plant physiological activity. Next to nitrogen, potassium affects physiological and biochemical processes of plant growth (Wang *et al.* 2013). Salinity inhibits the most important macronutrient of N, P and K (Halvin *et al.* 2005).

Among the salt sensitive crop, spinach falls in moderate section (Shannon and Grieve 1999) and salinity affects in various way to the spinach starting from the germination, then interrupt root

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and physiological development. Photosynthesis is highly disturbed and stopped due to the salinity in spinach (Kaya *et al.* 2002).

Among the abiotic stress, salinity in one of the most hazards for vegetable crop production and nutritional deficiency is very common due to unusual situation of imbalance nutrients availability in the soil solution. However, research on spinach and its nutritional values affected by salinity is not done much. Therefore, the present experiment was undertaken to observe the effects of salinity on the total biomass production and nutrient concentration of the spinach.

Materials and Methods

This experiment was conducted in small plastic pots at glass house of the Institute of Agricultural Resource and Regional Planning (IARRP), CAAS, Beijing, China during March to April 2018. Spinach seeds were sown in pots containing 250 gm organic soil which was collected from the research Institute that is a ready soil for pot culture and the nutrient concentration of the initial soil (Table 1).

Table 1.Physical and chemical properties of initial soil.

Properties	Amount	Properties	Amount
pH	7.45	Total P (%)	0.325
EC (dSm^{-1})	0.29	Available P (mg kg^{-1})	720
Total C (g kg^{-1})	173	Total K (%)	2.20
Total N (%)	1.183	Available K(mg kg^{-1})	9351
Available N (mg kg^{-1})	40.5	Na (mg kg^{-1})	1.48×10^4

According to the treatments, desire level of salinity (0, 4, 12 & 16 dS m^{-1}) was maintained in the experiment pot. Bottomless pots were used in this study. In each pot, primarily ten seeds were planted and after germination, thinning was done with maintaining four better seedlings after ten days. Randomized complete block design (RCBD) was used and replicated thrice. The temperature during the study ranged from 33 - 45°C.

The germination was counted after ten days, and 45 days later, parameters such as plant height (cm), leaf $plant^{-1}$, dead leaf $plant^{-1}$, root length (cm), biomass weight $plant^{-1}$ (g), photosynthetic rate ($\mu molCO_2mol^{-1}$), etc. were taken into account for data recording. Obviously, the fresh weight of spinach was measured in each and every harvest. Dry weight was measured by drying them in oven (70°C) for 24 hrs. To determine the nutrient concentration, whole plant was used. The digestion was done by nitric acid-hydrogen peroxide and Flame photometer was used for the determination of Na+ and K+ concentrations. Micro-Kjeldahl method (Bremner and Mulvaney 1982) was used for nitrogen determination and phosphorus by colorimetry method (Olsen and Sommers 1982).

Plant parameters such as plant height, Leaf $plant^{-1}$, dead leaf $plant^{-1}$, Root Length, Biomass weight $plant^{-1}$, Photosynthesis rate) and plant analysis data were analyzed by using Statistic 10 program with standard theory (Gomez and Gomez 1984) and different treatments significances were tested at 0.05 level by DMRT.

Results and Discussion

The spinach is fast growing vegetable and salinity inhibited its growth like other crop. The salinity condition is reluctant to crop growth due to its high salt content accumulated in the plants leaves. Excessive salt reduced the growth of new tissue and in the saline condition, increase in salt concentration in the leaf tissue significantly reduce the growth. The plant height of spinach showed significant variation due to the different salinity levels. Obviously the highest plant height was recorded from zero salinity levels (control, no salt stress) and ascendingly decreased with the increase of salinity up to the apex 16 dSm^{-1} (Fig.1). The lowest plant height (8.2 cm) was found in 16 dSm^{-1} salinity level (Fig. 1 and Table 2). The salinity create unfavorable situation for plant growth thus effect on leaf production of spinach and the highest leaf was produced in control treatment as expected and gradually decreased in leaf production as increased in salinity levels.

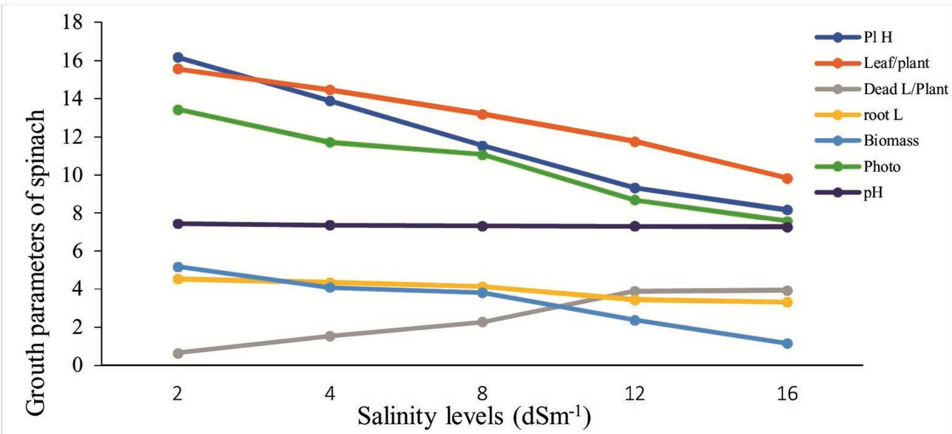

Fig. 1. Effect of salinity levels on the growth parameters of spinach.

Table 2. Effect of salinity stress on growth parameters of Spinach.

Salinity levels (dSm^{-1})	Plant height (cm)	Leaf $plant^{-1}$	Dead leaf $plant^{-1}$	Root Length (cm)	Biomass weight $plant^{-1}$ (g)	Photosynthesis rate ($\mu molCO_2mol^{-1}$)
T_1: 0	16.2a	15.6a	0.6d	4.5a	5.2a	13.4a
T_2: 4	13.9ab	14.5ab	1.5c	4.3a	4.1b	11.7ab
T_3: 8	11.5bc	13.2ab	2.3b	4.1ab	3.8b	11.1b
T_4:12	9.3cd	11.8bc	3.9a	3.4b	2.4c	8.7c
T_5: 16	8.2d	9.8c	3.9a	3.3b	1.1d	7.6c
CV (%)	11.8	12.6	11.6	12.1	9.6	11.5
SE (±)	0.8	0.9	0.2	0.3	0.2	0.7

The number of dead leafs were minimum in the normal situation (No salt stress) but it increased with the raising up of the salinity. The highest dead leaf was obtained from both treatments T_4 and T_5 that produced highest dead leaf (Table 2).

Considering root length, although the first three treatments are similar but T_1 treatment produced long root length. The root length decreased slightly with the increase of the salinity level and up to 8dSm^{-1} salinity the root development was very similar with control. Although the lowest root length was found in T_5 treatment nevertheless, root length showed very strong saline tolerance which is very noticeable.

The biomass weight of spinach is the main yield to be considered which expressed the total crop production. The salt stress significantly affects the total biomass weight and the lowest biomass production was found in highest salinity level. Definitely, the highest biomass weight was produced from no salt stress.

Table 3. Effect of salinity on soil parameters and plant nutrients concentration.

Salinity levels (dSm^{-1})	pH	EC (dSm^{-1})	Available nutrients in soil (mg kg^{-1})			
			N	P	K	Na ($\times 10^4$)
0	7.44a	0.35e	97.9a	667.3a	2811.7c	1.4c
4	7.36a	4.23d	91.3a	596.0b	3985.7b	2.0b
8	7.31a	8.34c	85.4a	578.0bc	4102.3b	2.7b
12	7.30a	12.17b	64.0b	532.0c	5394.7a	2.8a
16	7.26a	16.30a	28.1c	519.3c	5640.3a	3.5a
CV (%)	1.45	3.11	12.9	5.41	10.5	20.8
SE(±)	0.06	0.15	7.8	25.6	376.5	0.4

Disrupting of physiological processes especially photosynthesis in plant due to salt stress. The sodium ions accumulate in intercellular change K:Na ratio during salt stress condition and affect the bio-energetic processes of photosynthesis. The photosynthesis processes is the crucial plant mechanism for the growth and development. Although the photosynthetic rate decreased with the salt tress increase but no significant differences was observed in 12 and 16 dSm^{-1} salinity level which is noticeable and salinity level up to 8 dSm^{-1} showed a better trend in photosynthesis rate.

The saline soil has its different physical and chemical properties compared to normal cultivated land and creates abnormal situation for crop production. The availability of plant nutrients shows a different trend with the different salinity level. The availability of nitrogen and phosphorus show a similar trend of decreasing as salinity level raise up. The nitrogen reduce from 97.9 to 28.1 mg kg^{-1} when salinity change to 16 dSm^{-1} and phosphorus play similar trend and availability reduce to 667.3 to 519.3 mg kg^{-1} .

The sodium and potassium availability increase and show a very similar trend during increasing salinity level. Both these elements become more available to plant in saline condition. The potassium in soil increased from 2811.7 to 5640.3 mg kg^{-1} when salinity change to 16 dSm^{-1} and sodium show similar trend and availability increase to 1.4 to 3.5 mg kg^{-1}.

Salinity is a complex situation and mineral nutrition of crop with salinity can not be described in a straight relationship. Generally nutritional disorder takes place as increasing of the salinity and crop growth tremendously hamper as disrupt of nutrient uptake within soil solution as well as within plant physiological activities. In this experiment, results express that as increasing the salinity reduce the nitrogen uptake and phosphorus in plant. The most important nutrient is nitrogen in plant that amalgamates to synthesis and assimilation for plant growth. The higher salinity diminishes nutrient availability and uptake regularly and might be due to the antagonism between NO_3^- and Cl^-. But results showed that the potassium and sodium uptake increased due to the increase of availability of these elements in soil solution. The increase of sodium ion in soil thus restricted the plant nutrient uptake by limiting the availability of these elements.

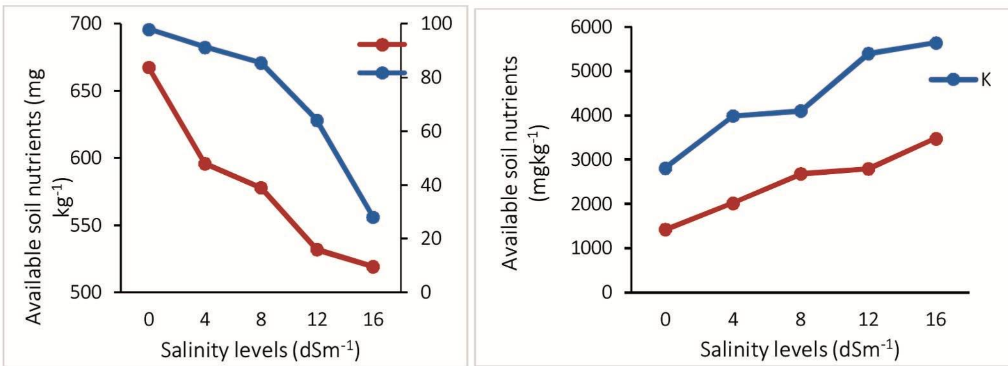

Fig. 2. Effect of salinity levels on the available soil nutrients (N, P, K and Na).

Salinity greatly inhibited the growth of spinach as indicated by reduced shoot fresh weight and dry weight. Salinity creates partial situation as an excess or deficiency in mineral in the soil solution which inhibits shoot growth due to lack of balanced nutrition. The lettuce growth is obstructed due to the presence of calcium ion that salinity enhances (Lazof and Bernstein 1999). Salinity reduce water availability to plant root which decrease leaf water content in spinach and similar result was found in lettuce (Perez-Lopez *et al.* 2013).The growth of spinach was stunted due to reduced photosynthetic rate and it take place as some physiological activity disrupted and existing unfavorable situation in the root zone in saline condition (Taiz and Zeiger 2012).

Table 4.Effect of salinity on plant nutrient concentration.

Salinity levels (dSm^{-1})	Total nutrients in plant (%)			
	N	P	K	Na
0	2.7a	1.1a	8.9c	4.5c
4	2.4ab	1.1a	9.4c	5.7b
8	2.3b	1.0ab	10.2b	6.0ab
12	2.1b	0.9bc	10.3ab	6.2ab
16	2.0b	0.9c	10.8a	6.5a
CV (%)	9.7	8.4	2.8	6.2
SE(±)	0.2	0.1	0.2	5.8

In spinach and lettuce, stomatal and mesophyll conductance reduce under salt stress condition (Delfine *et al.* 1998, 1999, Eraslan *et al.* 2007).These reductions occur due to decrease rate of photosynthesis activities, which indirect affect on biochemical and photochemical capacity of chlorophyll, but fluorescence activity is affected (Delfine *et al.* 1998).

The environmental factor such as humidity, temperature, air pollution and light has an impact on salt concentration in soil solution. Increased amount of salt highly affect the vegetable and inhibit plant growth (Romero-Aranda *et al.* 2001). Excesses amount of salt in the root zone resulted higher amount salt accumulation in the plant specially leaves causing some unusual situation like premature aging. Excesses salt reduces photosynthesis reduce carbon assimilation and hamper the fastest-growing plant part. The salt tolerant genotypes can grow to some extent but in sensitive genotype salt uptake and accumulate easily and rapidly resulting damage of cells and ultimately plant die (Munns 2002). Osmotic stress inevitably occurs in saline condition and it become even major cause that express in leaf first. It is not easy to understand the influence of osmotic effect as well as to identify the toxicity effect on vegetable about a specific ion which is responsible for salinity. Different plants have salt tolerances due to variation of genetic makeup and this capacity is related to the water stress (Munns 2002, Lukovic *et al.* 2009).

Nitrogen biosynthesis nitrogenous organic solutes plants and due to the antagonism effect of chlorine and nitrate ion nitrogen absorption reduce (Parida and Das 2004). The results revealed that nitrogen uptake decreased with the increase of salinity (Fig. 3). Plant growth reduces rapidly due to its unavailability of nitrogen which enhance by salinity (Hu and Schmidhalter 2005).

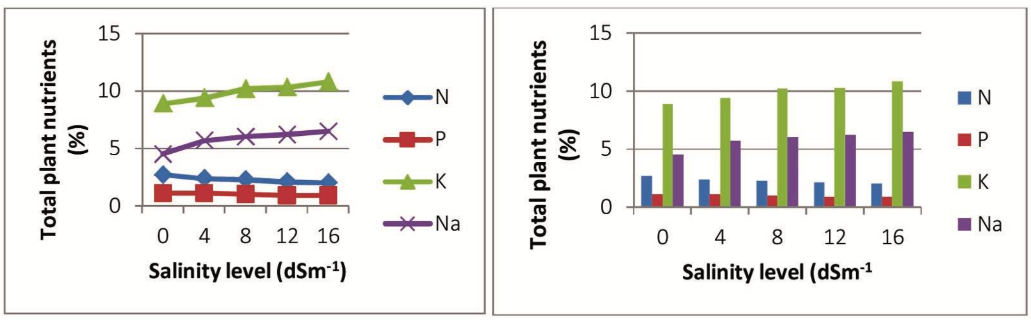

Fig. 3.Effect of salinity levels on the total plant nutrients (N, P, K and Na).

Different plant ability of acclimate salt stress obviously differ and plant that have high tolerance to salinity depends on the morphological, physiological and biochemical characteristics but vegetable especially leafy one has high vulnerability to the salinity. The most common phenomena of salinity are low soil water availability and nutritional disorder affects uptake and transport. The growth of spinach was absolutely inhibited by the increasing level of salinity affecting the fresh weight therefore; reduce the total biomass production.

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(Manuscript received on 15 February, 2022; revised on 17 February, 2023)