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Original article

Impact of Salinity on the Growth of Potato *Solanum tuberosum* L. Cultivated in Vitro Conditions

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Abstract
Soil salinity is a growing problem worldwide, threatening agricultural productivity. This research has been done to try to solve it by studying the "Impact of salinity on the growth of potato Solanum tuberosum L." cultivated in vitro conditions. In August and September of 2022, this study was conducted in the Faculty of Science laboratory at Omar Al-Mukhtar University in Libya. Seven different concentrations of sodium chloride were used as treatments. The study used a completely unexpected design: NaCl concentrations were as follows: 10 mM, 30 mM, 50 mM, 70 mM, 100 mM, and 120 mM (Control). To cultivate a single-node stem cutting of a single potato cultivar (Spunta), they made use of MS medium treated with these amounts of NaCl. Investigating various growth characteristics, such as plantlet height, number of leaves/plantlets, number of roots/plantlets, and shoot weight, was the goal. There were notable variations across the treatments; as salinity rises, the majority of the studied parameters fall to their lowest values.
Keywords: Salinity, Growth, *Solanum tuberosum* L., in Vitro Conditions.

Introduction

Vegetable crops, characterized by their herbaceous nature and edible parts such as leaves, roots, stems, fruits, or flowers, are cultivated for human consumption. The ability of certain vegetable species to tolerate salinity is of significant importance, particularly in arid and saline coastal regions where freshwater resources are scarce. Cultivating salt-tolerant vegetables addresses food security challenges and offers economic benefits due to their high market value and potential for sustainable agriculture in marginal lands."
[1]. It is becoming more significant for industrial purposes and as a source of vitamins, minerals, and carbohydrates in temperate and tropical regions. Numerous biotic and abiotic factors can affect potatoes [2]. A genetic bottleneck has developed within potato cultivars due to a historically limited intake of variety. To increase their resilience to biotic and abiotic restrictions, it would be expected that potato varieties with novel genetic diversity would be developed [3,4]. Plants have ways to deal with salt stress through different processes that can be grouped into three main types: handling water loss, keeping harmful salt out, and protecting cells from salt damage [5]. When there's too much salt, plants can still grow by managing water loss, keeping their leaves open for air exchange (handling water loss), stopping too much salt from building up in their leaves and shoots (keeping harmful salt out), and moving salt away from important parts of the cell into storage areas to shield the plant's cells from the damaging effects of salinity.
High salinity stress adversely affects plant growth and final productivity by disrupting seed germination, impairing physiological functions, and limiting biomass accumulation, as observed in spinach cultivated under saline conditions [6]. Too much salt disrupts plant functions, harms processes like photosynthesis, breathing, starch breakdown, and nitrogen use, and lowers crop yields [7]. When salt builds up in plant tissues beyond what they can handle, it causes harmful changes in their structure, function, chemical processes, and productivity. These are: (1) a decrease in water availability in the root area, leading to water shortage, (2) detrimental effects on plants of ions such as Na^{+}, and (3) A lack of nutrients produced by reduced mobility or absorption to the shoots [8].
Abiotic and biotic stresses continue to be primary challenges affecting crop growth and productivity, including potatoes. While potato plants are considered sensitive to salinity, their foliage is the most susceptible part to salt stress. Recent studies have shown that high salt concentrations (above 50 mM NaCl) significantly reduce potato yields by impairing physiological functions, disrupting water and nutrient uptake, and inducing oxidative stress, which collectively hinder tuber development and overall plant health [10]. Reduced tuber production, leaves transpiration, tip burn, and leaves burn, limited root water uptake, accelerated plant senescence, and root turning brown and fractures are some of the negative consequences that salt stress has on potato plants [11]. Plant metabolism is altered by salt stress, which results in notable modifications to some biochemical and molecular processes that lower crop yield. One of the most significant abiotic stressors influencing potato growth and yield, particularly in semi-arid growing regions, is salinity, which disrupts plant physiological processes. One of the objectives of the study was to look at how different NaCl salt levels affected the growth of potato plant cultivars grown in vitro. The plant's height, root length, number of roots, and number of leaves will all be

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taken into account. Choosing the optimum agricultural methods to satisfy the market demand for potatoes requires an understanding of how salt impacts potato plants.

Materials and methods

Experimental Design

From August to September of 2022, the current investigation was carried out at the Faculty of Science laboratory at Omar Al-Mukhtar University in Libya. The treatments contained seven different doses of sodium chloride: zero mM (Control), 10 mM, mM, 30 mM, 50 mM, 70 mM, 100 mM, and 120 mM NaCl. This was a completely unexpected design. A single-node stem cutting of a single potato cultivar (Spunta) was cultivated using Murashige and Skoog medium (MS) combined with these NaCl concentrations.

Growth conditions and plant materials

All potato tuber cultivars' sprouting primary shoots were aseptically extracted and cut into nodal pieces. Segments of individual apical shoots were cultivated on semi-solid MS medium. Single nodes (2-5 mm) were separated from shoots that were 4 weeks old and cultured on MS medium. In addition to 9.0 g/L agar as a gelling agent, 30 g/L sucrose was added to the MS medium as a carbon and sugar source. After adjusting the medium's pH to 5.7, it was autoclaved for 20 minutes at 121°C and 15 psi of pressure. For further growth sub-culturing, the cultures were exposed to 2000 lux fluorescent light for 28 days while being incubated at 25±2°C in a 16/8 h light/dark environment.

Table 1. Enumerates the many salt stress methods that are employed to screen different potato cultivars (Spunta).

Treatments	Composition
T1	MS Basal Medium without NaCl (control)
T2	10 mM NaCl in MS medium = 0.58 g/l NaCl
T3	30 mM NaCl in MS medium = 1.75 g/l NaCl
T4	50 mM NaCl in MS medium = 2.90 g/l NaCl
T5	70 mM NaCl in MS medium = 4.06 g/l NaCl
T6	100 mM NaCl in MS medium = 5.80 g/l NaCl
T7	120 mM NaCl in MS medium = 7.20 g/l NaCl

Data recorded

A 28-day (4-week) culture initiation period was followed by the cleaning of plantlets with distilled water and their drying with filter paper. The following parameters were then recorded:
Plantlet height in centimeters - Centimeters of root length - Quantity of plantlet roots - Leaf count of plantlets. The height of 10 plantlets in each treatment was measured, and the average was calculated. The set of 10 plants was selected, taken out of the jars, cleaned in water to eliminate media, then dried on filter paper. After drying. The roots of each plant were measured, and the mean value was calculated. These ten plantlets' root lengths were measured, and the average was recorded. Using a knife, the roots of these ten plantlets were severed from their shoots, and the average weight was noted. Weighing was done on the shoots of these ten randomly selected plantlets.

Statistical Analysis

The collected information was organized in tables for further statistical examination with the aid of Microsoft Excel 356 (version 2022). Duncan's test for post-hoc analysis if ANOVA is significant ($p < 0.05$) [12].

Results and discussion

Plantlet Height

The results indicated that plants grew almost similarly to those under control treatment and were unaffected by the low concentration of salt applied, 10 mM NaCl. The development under high salinity levels was significantly lower when compared with the control (Table 2). Where, for example, it is obvious that raising the salinity level from 0.58 to 7.20 g/l, 10 to 120 mM of NaCl will decrease the length of the shoots of the potato plants compared to control plants.
According to Table 2's in-vitro shoot length data, which shows a mean height of 5.11±0.76, control plantlets grew to a height of roughly 7.59 cm. Plants grew shorter as the salt concentration rose, reaching the lowest value of 1.72 cm in 120 mM NaCl (Figure 1A). This reduction in height is probably because the high salt levels caused stress, making it difficult for the plants to take in water. This then affected their growth in height through the limitation of cell growth [5]. According to our research, plants grew shorter when the salt content rose, which is consistent with other studies' findings for the same and other crops [13]. Salt stress usually causes

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problems with water absorption, making it harder for cells to expand, and we saw this in our research [14]. Since the negative impact on plant height can potentially affect other elements of plant development and health, our findings highlight the importance of these wider consequences [15]. In terms of shoot weight, number of roots per plantlet, and number of leaves per plantlet, salinity displayed a comparable trend. As the salinity increased, fewer leaves were produced per plantlet.

Table 2. An overview of the growth metrics under various salt treatments

Treatment	Plantlet Height (cm)	Count of Leaves/plantlet	Count of Roots/plantlet	Shoot weight
Control (00)	7.59	9.25	9.55	287.8
10 mM	7.51	8.26	8.45	255.1
30 mM	6.01	8.11	7.11	232.8
50 mM	5.11	7.87	6.53	208.9
70 mM	3.24	7.54	5.22	189.5
100 mM	2.91	7.22	3.11	166.9
120 mM	1.72	7.09	2.84	129.5
Average	5.11±0.76	7.87±0.92	6.53±0.53	208.9±21.82

The count of leaves on each plant

Each plant has fewer leaves the more salt there is in the environment. The normal number of leaves on plants was 9.25. At the highest salt level, that is, 120 mM, this number had dropped to 7.09 leaves per plant (Figure 1B). The drop in leaf count indicates that the plant, while under stress, alters its pattern of energy utilization and resource allocation in a way that is detrimental to its growth [16]. The number and size of leaves are important because they determine the photosynthesis ability of a plant. Salt levels stress lowered both the number of leaves and their size, which agrees with earlier studies [13]. This decrease in leaf number or area may be explained by shifting energy utilization and resource allocation of flora under stress. Under stress conditions, plants stop being concerned more about the basic growth of producing leaves and a shoot and allocate resources more directly toward survival strategy mechanisms. By this, short-term survival occurs but is going to cost overall reduced growth in plants and net productivity in general [17].

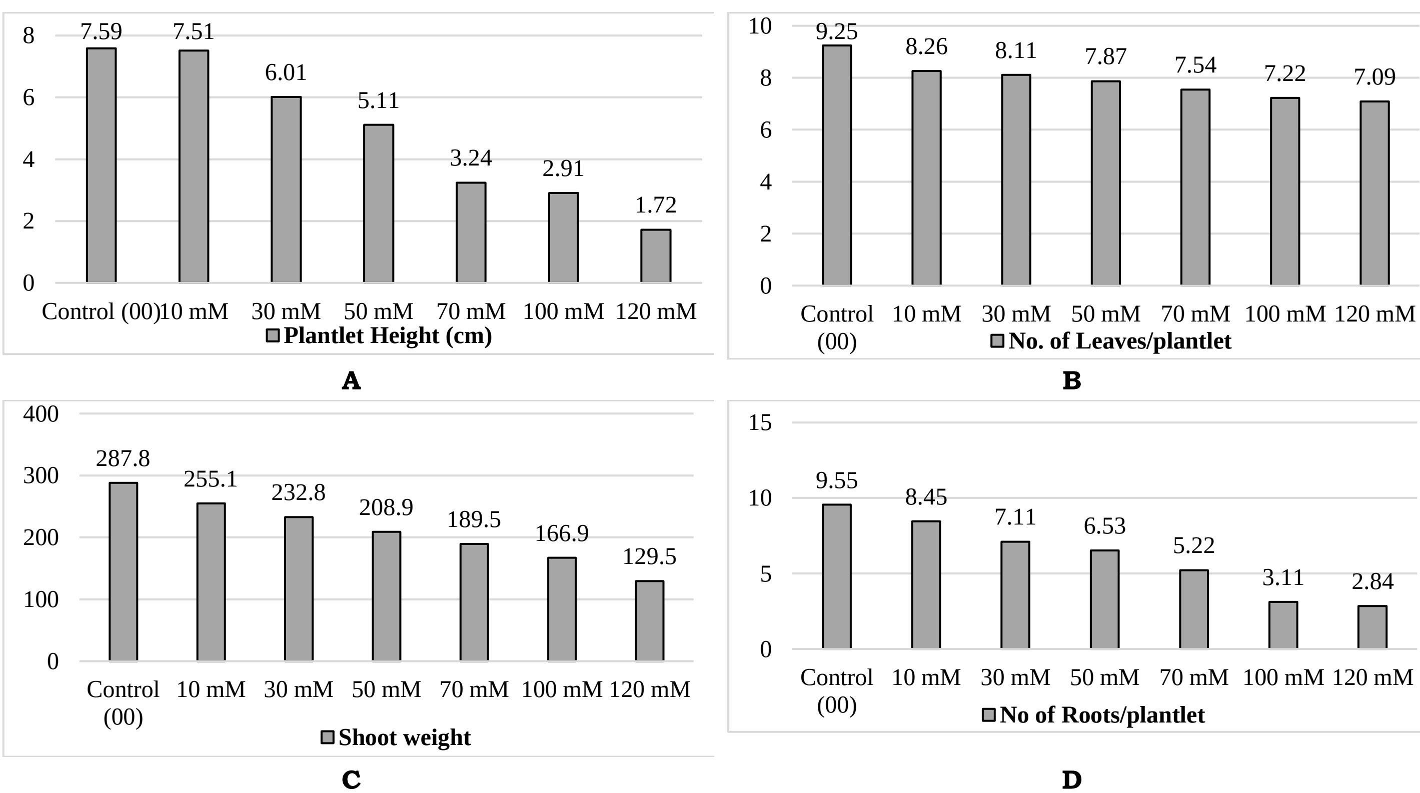

Figure 1. The growth metrics under various salt treatments according to: (a) Plantlet Height (cm) (b) No. of Leaves/plantlet; (c) Shoot weight and (d) No. of Leaves/plantlet.

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The count of roots/plantlets
The average number of root/plantlets was about 9.55. On exposure to high salt levels (120 mM), the number fell to 2.84 (Figure 1D). This decrease in roots may be the consequence of a water and nutrient imbalance brought on by poor cell proliferation in response to the salt stress [13].

Shoot weight
In plants cultivated under normal conditions, the shoot weight was around 287.8 grams. At a high salt level of 120 mM, it dropped to roughly 129.5 grams per plant, with an average of 208.9±21.82 (Figure 1C). When NaCl was added to the MS growing medium, it caused salt stress, which negatively impacted the plantlets of the examined cultivars' ability to grow and develop their shoots and roots. According to this decline may be the consequence of altering balance, water status, mineral nutrition, and photosynthetic efficiency [14]. Several studies have been conducted on salt-sensitive potato genotypes under field and pot conditions [14] and in vitro conditions [16]. Conversely, a high concentration of NaCl prevented new roots from growing. These findings concurred with a prior study on commercial cultivars [18] and potato clones [14].

Conclusion
The study of how salt affects potato plant growth in experimental settings leads to the conclusion that several growth factors drastically decline as salinity rises, and further research in this area is desperately needed.

Conflict of interest. Nil

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الملخص

تعتبر ملوحة التربة مصـــدر قلق متزايد يشـــكل تهديدًا كبيرًا للإنتاجية الزراعية في جميع أنحاء العالم. وفي ظل هذه الخلفية، أجريت الدراســة الحالية لمعرفة "تأثير الملوحة على نمو نباتات البطاطس Solanum tuberosum L. المزروعة في ظروف المختبر. أجريت الدراســـة في مختبر كلية العلوم، جامعة عمر المختار، ليبيا خلال شــهرى أغســطس وســبتمبر 2022م . تم اســتخدام ســبعة تركيزات مختلفة من كلوريد الصـوديوم كمعالجات، وقد اسـتخدمت الدراسـة تصـميمًا غير متوقع تمامًا: صـفر مليمول (مجموعة التحكم)، 10 مليمول، 30 مليمول، 50 مليمول، 70 مليمول، 100 مليمول و120 مليمول كلوريد الصــوديوم. تم اســتخدام وســط موراشــيج وســكوج (MS) المضــاف إليه هذه التركيزات من كلوريد الصـوديوم لزراعة قصـاصـات سـاق العقدة المفردة لصـنف واحد من البطاطس (سـبونتا). الهدف من هذه الدراسـة هو دراسـة معايير النمو المختلفة والتي شـملت ارتفاع الشـتلات وعدد الأوراق/ شـتله وعدد الجذور/ شـتله ووزن البراعم. وقد تم الحصـول على فروقات معنوية بين المعاملات حيث انخفضت معظم معايير الدراسة إلى أدنى قيمة لها مع زيادة الملوحة.

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