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Unveiling the Impact of Salinity Levels on Chilli: Growth, Yield and Quality Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study investigates the effect of salinity on the growth, yield, and quality and disease infestation on Chilli. A factorial randomized block design with three replications was implemented, consisting of combinations of four salinity levels (0 dS/m, 3 dS/m, 6 dS/m, and 9 dS/m) and three genotypes (Surajmukhi, AVT-2 2019 CHIHYB-5, and AVT-2 2019 CHIHYB-6). The purpose of the study is to evaluate the plants in terms of various parameters such as plant height (at 30, 60, and 90 days after transplanting), number of fruits per plant, average fruit weight, fruit yield per plant, fruit yield per hectare, total soluble solids (TSS), ascorbic acid content, chlorophyll content, and disease infestation. Among all the genotypes,
AVT-2 2019 CHIHYB-6 exhibited superior performance when grown under a salinity level of 0 dS/m. It demonstrated desirable plant height at 30, 60, and 90 days after transplanting (30.06 cm, 32.50 cm, and 78.00 cm, respectively), along with a higher number of fruits per plant (40), average fruit weight (94.86 g), fruit yield per plant (1769.20 g), fruit yield per hectare (65.52 tonn/ha), TSS (6.16 Brix), ascorbic acid content (113 mg/100g), chlorophyll content (34.4 mg/m2), and disease resistant (99%). Significant differences were observed among genotypes and their interactions concerning salinity levels across all attributes investigated.

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1. INTRODUCTION

Chili (*Capsicum annuum* L.) is one of the vegetable or spices known and used all over the world for its green fruits and pungency. Chilli belongs to the genus Capsicum family Solanaceae. It is a diploid (2n=24) species and genetically self-pollinated and chasmogamous crop whose flowers open only after pollination. However, 2 to 96% out-crossing was observed under open pollination (AVRDC, 2000). There are mainly four cultivated Capsicum species and they are originated from South and Central America, chili has more than 25 species of which only five (*C. annuum* L*., C. chinense, C. frutescens* L*., C. baccatum* L. *and C. pubescens*.) are domesticated and cultivated. Chilli has been used since ancient times, traditionally in the form of spice. It is also used as a natural flavor and colorant in food industry as well as raw material for the pharmaceutical industry. Chilli is nutritious crop, every 100 gm of green and dry chilli yield about 229 and 297 calories of energy. It is mainly cultivated for three constituents of fruits viz., capsaicin, capsanthin and oleoresin. Chilli requires 15-35°C of temperature for cultivation. Chillies should not be in a position where the nightly temperature falls below 12°C. Growth will be inhibited if temperatures fall below 15°C. Chilli plants is a type of seasonal crops (annual plant) which only live for one season then died. If cultivated this plant can grow and produce for several months after planting after which it will die. Salinity is becoming one of the major barriers against successful production of crops in India. It is one of the critical stresses to which crop plants are exposed and is a serious limiting factor against crop production. Salinity causes stunted growth of plants that ultimately leads to reduced yield. Many horticultural crops are more or less susceptible to salinity as a result production of these crops is hugely affected by this. Chilli is reported as a crop which is sensitive to moderately sensitive to salinity. According to Carter (1994), a salinity level of less than 1920 ppm is suitable for chilli. Under stressed condition such as low temperature and salinity, delayed and non-uniform germination of chilli is observed.

2. MATERIALS AND METHODS

The investigation entitled **"**Unveiling the impact of salinity levels on Chilli: Growth, Yield and Quality Analysis" was done to understand the plant growth, fruit yield and quality of Chilli using different combinations of treatment using different varieties which was carried out at Horticultural Research Farm (HRF), Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj during the *Rabi* season of 2021-2022.

2.1 Location and Climatic Conditions

Prayagraj is located in the central plain sub-zone of Agro-climatic Zone V, according to the Perspective and Strategic Plan (SPSP) for IWMP of Uttar Pradesh, issued by the Department of Land Development and Water Resources, Government of U.P. Naini, situated between latitude 20° 33' 40" to 21' .50' N and longitude 73° 27' 58" to 73° 56' 36" E, experiences a tropical climate. The area has relatively hot summers, moderately cold winters, and a humid and warm monsoon season. The region receives heavy rainfall primarily during June to September, with the majority of precipitation occurring during the monsoon months of July and August.

2.2 Experimental Materials

Table 1. Factor – A (Genotypes)

S. No.	Notations	Hybrid details	Source
1	**V1**	SURAJMUKHI	Sahavi Hybrid seeds
2	**V2**	AVT-2 2019 (CHIHYB-5)	IIVR, Varanasi
3.	**V3**	AVT-2 2019 (CHIHYB-6)	IIVR, Varanasi

Table 2. Factor – B (Treatments)

S. No.	Notations	Treatment Details
1.	**T0**	0 dS/m
2.	**T1**	3 dS/m
3.	**T2**	6 dS/m
4.	**T3**	9 dS/m

Table 3. Factor–A X Factor-B (Genotypes and treatment combinations)

S. No.	Notations	Treatment Details (Factor-A× Factor-B)
1.	V1T0	Surajmukhi (Salt concentration@0dS/m)
2.	V1T1	Surajmukhi (Salt concentration@3dS/m)
3.	V1T2	Surajmukhi (Salt concentration@6dS/m)
4.	V1T3	Surajmukhi (Salt concentration@9dS/m)
5.	V2T0	AVT-2 2019 (CHIHYB-5) (Salt concentration@0dS/m)
6.	V2T1	AVT-2 2019 (CHIHYB-5) (Salt concentration@3dS/m)
7.	V2T2	AVT-2 2019 (CHIHYB-5) (Salt concentration@6dS/m)
8.	V2T3	AVT-2 2019 (CHIHYB-5) (Salt concentration@9dS/m)
9.	V3T0	AVT-2 2019 (CHIHYB-6) (Salt concentration@0dS/m)
10.	V3T1	AVT-2 2019 (CHIHYB-6) (Salt concentration@3dS/m)
11.	V3T2	AVT-2 2019 (CHIHYB-6) (Salt concentration@6dS/m)
12.	V3T3	AVT-2 2019 (CHIHYB-6) (Salt concentration@9dS/m)

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant Height for 30 DAT, 60 DAT and 90 DAT (cm)

The significant effect on plant height at 30, 60 and 90 DAT shows that the maximum plant height was recorded in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] with (30.06cm), (32.50cm) and (78.00cm) respectively and the minimum plant height was recorded in V1T3 [Surajmukhi (salt conc.@9dS/m)] with (6.50cm), (12.66cm) and (25.26cm) respectively. Salinity significantly reduced plant height, stem diameter, and leaf area of chilli plants. The decrease in plant height was attributed to a reduction in cell expansion due to the osmotic stress caused by salinity. Salinity can cause oxidative stress in plants by generating reactive oxygen species (ROS) such as superoxide radicals, hydrogen peroxide, and hydroxyl radicals. ROS can damage lipids, proteins, and nucleic acids, which can impair plant growth and development. Overall, the combined effects of water stress, ion toxicity, and oxidative stress caused by salinity results in reduced plant height and biomass. Similar findings were reported by Singh et al. [1].

3.2 Yield Parameters

3.2.1 Number of fruits per plant

The average number of fruits per plant varied significantly among different treatment combinations. The maximum average number of fruits per plant (40.00) was observed in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] and the minimum average number of fruits per plant (6.00) were observed in V1T3 [Surajmukhi (salt conc.@9dS/m)] while the remaining treatments were moderate. Studies have shown that high levels of salinity can reduce the number of fruits produced by the plant. This is because salt stress can affect various physiological and biochemical processes in the plant, such as photosynthesis, water uptake, and nutrient absorption.

3.2.2 Average weight of 10 fruits per plant (g)

The average weight of 10 fruits varied significantly among different treatment combinations. The maximum average fruit weight (94.86 g) was observed in in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] and the minimum average weight of 10 fruits (13.53 g) were observed in V1T3 [Surajmukhi (salt conc.@9dS/m)] while the remaining treatments were moderate. Salinity levels led to a decrease in the availability of nutrients such as nitrogen, phosphorus, and potassium, resulting in reduced growth and fruit weight. The researchers also found that salinity caused oxidative stress in the plants, leading to a decrease in photosynthesis and ultimately a reduction in fruit weight. Similar findings were reported by Khan et al. [2].

3.2.3 Average fruit yield per plant (g)

The average fruit yield per plant varied significantly among different treatment combinations. The maximum average fruit yield per plant (1769 g) was observed in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] and the minimum average fruit yield per plant (261.19 g) was observed in V1T3 [Surajmukhi (salt conc.@9dS/m)] while the remaining treatments were moderate. when plants are exposed to high levels of salt, the osmotic potential of the soil solution increases, making it more difficult for plants to absorb water and nutrients. This can lead to water stress, nutrient deficiency, and reduced plant growth. Additionally, salt stress can damage the plant's cellular membranes, affect enzymeactivity, and disrupt the balance of ions and hormones in the plant, further reducing fruit yield. Similar findings were reported by Pariyar et al. [3].

3.2.4 Fruit yield per hectare (ton/ha)

The fruit yield per hectare varied significantly among different treatment combinations. The maximum fruit yield per hectare (65.52 tonn/ha) was observed in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] and the minimum average fruit yield per plant (9.67 tonn/ha) was observed in V1T3 [Surajmukhi (salt conc.@9dS/m)] while the remaining treatments were moderate. salinity level affected the physiological and biochemical properties of the plants. Specifically, they found that the salinity level increased the concentration of sodium and chloride ions in the plant tissues, which can cause ion toxicity and damage to the plant cells. In addition, they found that the salinity level decreased the concentration of chlorophyll and carotenoid pigments, which can lead to a decrease in photosynthesis and a reduction in the plant's ability to produce fruit. This study provides evidence that highlevels of salinity can have a negative impact on the yield and quality of chilli fruit by causing water stress, ion toxicity, and reducing the plant's ability to carry out photosynthesis. Similar findings were reported by Razzaghi et al. [4].

Table 4. Effect of salinity on Plant height (cm)

Notations	Treatment Details	Plant Height (cm)		
		30DAT	**60DAT**	**90DAT**
V1T0	Surajmukhi (salt conc.@0dS/m)	15.00	30.20	70.66
V1T1	Surajmukhi (salt conc.@3dS/m)	9.76	16.5	32.90
V1T2	Surajmukhi (salt conc.@6dS/m)	7.33	14.46	28.96
V1T3	Surajmukhi (salt conc.@9dS/m)	6.50	12.66	25.26
V2T0	AVT-2 2019 (CHIHYB-5) (salt conc.@0dS/m)	23.23	31.30	72.13
V2T1	AVT-2 2s019 (CHIHYB-5) (salt conc.@3dS/m)	11.33	23.5	46.83
V2T2	AVT-2 2019 (CHIHYB-5) (salt conc.@6dS/m)	8.50	16.7	32.3
V2T3	AVT-2 2019 (CHIHYB-5) (salt conc.@9dS/m)	7.13	14.10	28.13
V3T0	AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)	30.06	32.50	78
V3T1	AVT-2 2019 (CHIHYB-6) (salt conc.@3dS/m)	24.45	25.50	47.16
V3T2	AVT-2 2019 (CHIHYB-6) (salt conc.@6dS/m)	22.23	17.46	35.5
V3T3	AVT-2 2019 (CHIHYB-6) (salt conc.@9dS/m)	20.20	15.40	27.76

Table 5. Effect of salinity on Number of fruits per plant, weight of 10 fruits (g), average fruit yield per plant (g) and fruit yield per hectare (t/ha)

Notations	Treatment Details	Numberof fruits per plant	Weight of10 fruits (g)	Averagefruit yield per plant (g)	Fruit yieldper hectare (ton/ha)
V_1T_0	Surajmukhi (salt conc.@0dS/m)	23.33	28.06	868.39	32.16
V_1T_1	Surajmukhi (salt conc.@3dS/m)	18.66	24.4	706.41	26.16
V_1T_2	Surajmukhi (salt conc.@6dS/m)	16.33	19.26	605.59	22.42
V_1T_3	Surajmukhi (salt conc.@9dS/m)	6.00	13.53	261.19	9.67
V_2T_0	AVT-2 2019 (CHIHYB-5) (salt conc.@0dS/m)	30.00	28.36	1070.20	39.63
V_2T_1	AVT-2 2019 (CHIHYB-5) (salt conc.@3dS/m)	27.00	24.30	955.8	35.39
V_2T_2	AVT-2 2019 (CHIHYB-5) (salt conc.@6dS/m)	20.66	19.36	736.21	27.26
V_2T_3	AVT-2 2019 (CHIHYB-5) (salt conc.@9dS/m)	13.66	16.70	510.21	18.89
V_3T_0	AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)	40	94.86	1769.20	65.52
V_3T_1	AVT-2 2019 (CHIHYB-6) (salt conc.@3dS/m)	31.66	81.93	1441.60	53.39
V_3T_2	AVT-2 2019 (CHIHYB-6) (salt conc.@6dS/m)	28.33	48	1137.99	42.14
V_3T_3	AVT-2 2019 (CHIHYB-6) (salt conc.@9dS/m)	25.66	58.1	1118.61	41.42

Table 6. Effect of salinity on TSS (Brix^0), ascorbic acid(mg/100g) and chlorophyll content

Notations	Treatment Details	TSS (Brix^0)	Ascorbic acid (mg/100g)	Chlorophyll content (mg/m^2)
V1T0	Surajmukhi (salt conc.@0dS/m)	5.43	102.33	21.30
V1T1	Surajmukhi (salt conc.@3dS/m)	5.33	96.33	19.36
V1T2	Surajmukhi (salt conc.@6dS/m)	4.23	72.33	15.30
V1T3	Surajmukhi (salt conc.@9dS/m)	3.73	70.33	10.23
V2T0	AVT-2 2019 (CHIHYB-5) (salt conc.@0dS/m)	5.96	102.33	23.3
V2T1	AVT-2 2019 (CHIHYB-5) (salt conc.@3dS/m)	5.26	91.33	21.3
V2T2	AVT-2 2019 (CHIHYB-5) (salt conc.@6dS/m)	4.96	81.33	15.33
V2T3	AVT-2 2019 (CHIHYB-5) (salt conc.@9dS/m)	4.70	72.33	12.33
V3T0	AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)	6.16	113	34.42
V3T1	AVT-2 2019 (CHIHYB-6) (salt conc.@3dS/m)	6.00	106.33	32.26
V3T2	AVT-2 2019 (CHIHYB-6) (salt conc.@6dS/m)	5.16	93	28.23
V3T3	AVT-2 2019 (CHIHYB-6) (salt conc.@9dS/m)	4.93	85.66	25.26

3.3 Qualitative Parameters

3.3.1 Total soluble solids (Brix^0)

The TSS of the fruit varied significantly among different treatment combinations. The maximum TSS (6.16 Brix^0) was observed in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] and the minimum TSS (3.73 Brix^0) was observed in V1T3 [Surajmukhi (salt conc.@9dS/m)] while the remaining treatments were moderate. A study by Guo et al. [5] investigated the effect of salt stress on the accumulation of TSS in chilli fruits. The researchers found that salt stress reduced the activity of key enzymes involved in the synthesis of sugars, such as sucrose synthase and invertase. They suggested that this reduction in enzyme activity may be responsible for the decrease in TSS accumulation.

3.3.2 Ascorbic acid (mg/100g)

The ascorbic acid of the fruit varied significantly among different treatment combinations. The maximum ascorbic acid (113 mg/100g) was observed in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] and the minimum ascorbic acid content (70.33 mg/100g) was observed in V1T3 [Surajmukhi (salt conc.@9dS/m)] while the remaining treatments were moderate. A study by Pandey et al. [6] found that salinity stress decreased the net photosynthetic rate, stomatal conductance, and transpiration rate in chilli plants, leading to a reduction in plant growth and ascorbic acid content. Salinity stress also caused an imbalance in ion homeostasis, with higher accumulation of sodium and chlorine ions in leaves, leading to toxicity symptoms and decreased ascorbic acid content. salinity stress affects multiple physiological processes in chilli plants, leading to decreased ascorbic acid content. The disruption of photosynthesis and ion transport, as well as the induction of oxidative stress, contribute to the negative impact of salinity on ascorbic acid content in chilli peppers.

3.3.3 Chlorophyll content

The chlorophyll content in the fruit varied significantly among different treatment combinations. The maximum chlorophyll content (34.4 mg/m^2) was observed in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] and the minimum chlorophyll content (10.23) was observed in V1T3 [Surajmukhi (salt conc.@9dS/m)] while the remaining treatments were moderate. A study by Zhang et al. [7] showed that salinity stress decreased chlorophyll content in different chilli cultivars by reducing the activities of enzymes involved in chlorophyll synthesis, such as δ- aminolevulinic acid synthase and protochlorophyllide oxidoreductase. Salinity also impaired the uptake and transport of minerals, such as nitrogen, magnesium, and iron, which are essential for chlorophyll synthesis and stability.Moreover, salinity-induced oxidative stress affects the stability and function of chlorophyll molecules, leading to chlorophyll degradation and reduced chlorophyll content.

3.4 Disease Incidence

Disease incidence varied significantly among different treatment combinations. Leaf curl resistance (99%) was observed in V3T0 [AVT-2 2019 (CHIHYB-6) (salt conc.@0dS/m)] and the leaf curl susceptible (49.80%) was observed in V1T3 [Surajmukhi (salt conc.@9dS/m)] while the remaining treatments were moderate. A study by Zaidi et al. [8] investigated the effect of salinity on the incidence of Chili Leaf Curl Virus (CLCV) disease in chili plants. The results of this study showed that as salinity levels increased, the incidence of CLCV disease also increased. The authors suggested that the high salt levels may have affected the activity of enzymes involved in the biosynthesis of plant hormones, leading to a decrease in the levels of salicylic acid (SA) and jasmonic acid (JA) in the plant. These two hormones are known to play a key role in plant defense against viral infections. Another study by Khan et al. [9] investigated the effect of salinity on the incidence of Pepper vein yellows virus disease in chili plants.

4. CONCLUSION

From the experimental finding it is concluded that V3T0 [AVT-2 2019 CHIHYB-6(salt conc.@0dS/m)] is best in terms of growth, yield, quality and disease incidence parameters viz.,plant height (30, 60 and 90 DAT), weight of 10 fruits per plant, number of fruits per plant, fruit yield per plant, fruit yield per hectare, TSS, ascorbic acid and chlorophyll content and disease incidence.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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