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Performance of Chilli Irrigated with Saline Water through Drip System

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Ensuring the quality of irrigation water is crucial for sensitive crops like chillies. In tropical regions, poor-quality water is commonly used for irrigation, where water quality significantly impacts agricultural yields more than water quantity. The experiment attempted to determine the optimal salt level of irrigation water for chilli crop using a drip system. The study was conducted at the Saline Water Scheme, Agricultural College Farm in Bapatla, Andhra Pradesh, India. The study included five different electrical conductivity (EC) levels of irrigation water with four replications, utilizing a randomized block design across three years during the *Rabi*, season from 2021 to 2023. The best irrigation water produced the tallest plant height (79.5 cm) and the highest number of branches plant^{-1} (5.6), comparable to 2 dS m^{-1} EC irrigation. The highest number of green pods plant^{-1} (74.2) and yield (28.5 t ha^{-1}) were achieved under irrigation with the best water. Indicators like green pods per plant were lowest when watered with 8 dS m^{-1} saline irrigation. Saline irrigation did not influence soil pH, but its EC reached the highest when irrigated with 8 dS m^{-1} water. The salt distribution had become more concentrated by the end of the season, with an electrical conductivity of 0.4 to 0.6 dS m^{-1} or higher. In comparison to higher salinity levels, the use of 2 dS m^{-1} EC saline water has demonstrated success with minimal detrimental effects on chilli growth, and yield.

(***Key words:*** *Chillies, Drip irrigation, Electrical conductivity, Growth, Saline water, Yield*)

In coastal tropical agro-ecosystems like India, availability of good quality of water becomes scarce due to high demand for other uses and contamination of fresh water aquifers. Within the season during low rainfall years or months the quality of water had profound influence on the growth, yield, and quality of the produce on crop like chillies which is having high economic importance in global spice trade (Ukkund *et al.,* 2007). In these conditions, salinity problem is much severe in poorly drained soils due to continuous accumulation of salinity load on surface layers during the dry months. Saline environment is one of the most damaging stresses on crop plants and disrupts crop growth and yield (Haque *et al.,* 2014). Salt concentrations in irrigation water and soils exceeding 4.0 dS m^{-1} have an impact on physiological functions. The symptoms are results of a water deficiency produced by the soil's increased osmotic potential (Karolinoerita and Yusuf, 2020).

High salt concentrations and drought stress conditions are frequently to blame for significant losses in agricultural yields worldwide. It is believed that around 20% (45 million ha) of irrigated land, which produces one-third of the world's food, is salt impacted either through saline irrigation or the salts in the soil (Shrivastava and Kumar, 2015). Sustainable chilli production is becoming more challenging in areas where quality and quantity water resources are becoming increasingly scarce. Salinity in the crop root zone has become a serious issue influencing crop growth, and chilli is no exception. Chilli is a crop that has been reported to be moderately sensitive to salinity (Lee, 2006) and requires less than 1920 ppm of dissolved salts in irrigation water for normal growth (Carter, 1994). Salt accumulation on surface soils due to the use of poor-quality irrigation water restrict the plant stature which is similar to plants grown under water deficit conditions (Yildirim, 2010). Salt concentrations exceeding 4.0 dS m^{-1} have an impact on

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physiological functions of many crop species (Divya *et al.,* 2024; Mrudhula *et al.,* 2021). Poor-quality irrigation water increases soil electrical conductivity (Patil *et al.,* 2014; Diya Vincent, 2025). Salinity levels of 3.5 dS m^{-1} or higher significantly reduce seedling emergence, with root growth being more severely affected than shoot growth (Morales *et al.,* 2008). Furthermore, elevated salinity adversely affects overall plant growth, resulting in reduced fruit weight and yield (Gurjinder *et al.,* 2017). The reduction of fresh yield percent under different EC levels of irrigation water (Semiz *et al.,* 2014: Ben-Gal *et al.,* 2008; Navarro *et al.,* 2002) reported by researchers varied due to pre-existing salinity load, climate, and cultivars tolerance. In addition to the above, in chillies quality of water applied was more important than quantity of water (Fallik *et al.,* 2019) for irrigation to attain economic yields.

Drip irrigation had advantageous while using poor quality of water for irrigation in migration of salts in soil away from root zone (Wu *et al.,* 2015; Mrudhula *et al,* 2025). The vertical and horizontal migration pattern of salts reported (Ma *et al.,* 2005; Divya *et al.,* 2024) under low and high rate of emitter flow conditions respectively. Despite an ample amount of literature on plant responses to salinity stress, data on the influence of poor- quality water on chilli crop growth, green pod yield and influence of water EC and pH are limited using drip irrigation. Therefore, to sustaining the green chillies production in the coastal semi - arid areas of Andhra Pradesh, India the present research on the use of different EC levels of irrigation water on green chillies production was formulated.

MATERIALS AND METHODS

The experiment was conducted at the Saline Water Scheme, Agricultural College Farm, Bapatla during the *Rabi* season for three consecutive years from 2021 to 2023. The experiment was laid out in Randomized Block Design with four replications and five treatments *viz.*, T_1: Irrigation with BAW (Best Available Water) of 0.6 dS m^{-1}, T_2: Irrigation with 2 dS m^{-1}, T_3: Irrigation with 4 dS m^{-1}, T_4: Irrigation with 6 dS m^{-1} and T_5: Irrigation with 8 dS m^{-1}. The experimental site was sandy loam in texture, uniform in topography, homogeneously fertile, slightly alkaline (7.4), non-saline (0.3 dS m^{-1}), low in available nitrogen (151 kg ha^{-1}), rich in phosphorus (34 kg ha^{-1}), and potassium (345 kg ha^{-1}). As per the experiment design, the drip irrigation system was set up using 16 mm inline laterals with 2.0 L hr^{-1} discharge emitters spaced at 50 cm. Screen and disc filters were set up following the pumping and fertigation units to strain out impurities from the irrigation water. Waters with varying EC levels (2, 4, 6 and 8 dS m^{-1}) were concocted by mixing seawater of around 34 dS m^{-1} with 0.6 dS m^{-1} of fresh water to reach the right EC level. The seedlings of variety VNR 314 of chilli was planted under drip irrigation. The recommended dose of fertilizer of 120-80-80 kg N-P-K ha^{-1} was applied to the crop. Nitrogen in the form of urea, phosphorus in the form of Di-Ammonium Phospate (DAP) and potassium as Murate of Potash (MOP) were duly applied at the appropriate stages of the crop.

The available nitrogen in soil was determined by the alkaline potassium permanganate method (Subbaiah *et al.,* 1956); the available phosphorus status in soil was extracted by 0.5 *M* $NaHCO_3$ and colour determined by Olsen's method (Olsen *et al.,* 1953); and the available potassium in soil was extracted by a neutral normal ammonium acetate extractant and determined by a flame photometer (Jackson, 1973) and expressed in kg ha^{-1}. The pH of the soil was measured in a 1:2 soil water suspension using a pH meter. After the pH measurement, the suspension was undisturbed overnight to measure EC. The EC (1:2 soil water suspension) of the supernatant was measured by inserting the conductivity cell of the EC Bridge (Jackson, 1973).

Plant height was measured from the bottom of the plant to the tip of the growing point for ten tagged plants before picking and expressed in centimetres. The number of branches of tagged ten individual plants in each net plot was counted, averaged and expressed as the number of branches $plant^{-1}$. The total counts of pods from the ten tagged plants were tallied at harvest and then the average number of pods $plant^{-1}$ was determined. The yield of chilli per treatment was duly noted throughout the entire harvesting period and calculated and expressed in t ha^{-1}. The data generated on various parameters during the investigation were put through the statistical analysis of variance (ANOVA).

The least significant difference (LSD) test was conducted for the scrutinized mean square errors. The procedure provides a single LSD (Least Significant Difference) value at the 5% level of significance, which serves as the threshold for determining whether the difference between any pair of treatment means is statistically significant. Software used for spatial soil salinity distribution was Surfer (https://www.goldensoftware.com). The weather data during the study period was presented in Table 1.

RESULTS AND DISCUSSION

The data presented in Table 2 during the three years of the study indicated that the growth, yield attributes of chilli crop were significantly differed with irrigation water EC levels. During the three years of study mean data reveals that the use of the best available water recorded significantly higher plant height (79.5cm), number of branches plant^{-1} (5.6) and green pods plant^{-1} compared to all other treatments but it was on par with

Table 1. Monthly weather data from 2021 to 2023 during crop growth period

Month & Year	Temperature °C		Relative humidity (%)		Rainfall (mm)	Rainy days
	Maximum	Minimum	Maximum	Minimum		
October, 2021	32.3	23.6	86.1	76.4	39.5	2
November, 2021	29.1	22.7	88.0	83.0	276.0	17
December, 2021	29.9	18.4	87.0	67.0	0.0	0
January, 2022	29.5	18.8	86.0	68.0	60.3	2
Average / Total	30.2	20.9	86.8	73.6	375.8	21
October, 2022	31.4	23.0	87.0	79.0	0.0	0
November, 2022	30.1	20.5	87.0	76.0	49.5	4
December, 2022	30.1	19.9	87.0	79.0	57.1	4
January, 2023	30.3	16.7	86.0	67.0	0.0	0
Average / Total	30.5	20.0	86.8	75.3	106.6	8
October, 2023	34.2	23.8	84.0	69.0	29.3	3
November, 2023	30.7	22.4	86.0	78.0	100.1	7
December, 2023	29.8	19.8	86.0	72.0	286.8	2
January, 2024	29.8	19.3	87.0	71.0	3.1	1
Average / Total	31.1	21.3	85.8	72.5	419.3	13

Table 2. *Effect of water salinity on growth and yield attributes of chilli crop*

Treatment	Plant height (cm)				No. of branches Plant^{-1}				No. of green pods plant^{-1}			
	2021	2022	2023	Pooled data	2021	2022	2023	Pooled data	2021	2022	2023	Pooled data
BAW (1.0)	74.5	86.7	77.4	79.5	5.8	5.6	5.0	5.6	73.5	79.6	69.5	74.2
2 EC_{iw}	72.2	81.5	73.6	75.8	5.0	5.2	4.7	5 .1	70.6	73.5	67.2	70.4
4 EC_{iw}	65.8	73.2	62.4	67.1	4.8	4.7	4.4	4.6	64.7	65.7	60.8	63.7
6 EC_{iw}	58.6	65.5	58.2	60.8	4.6	4.5	3.2	4.1	55.1	57.3	54.7	55.7
8 EC_{iw}	52.5	55.7	53.8	54.0	4.4	4.3	2.6	3.8	43.2	50.7	46.3	46.7
SEm+	1.6	1.9	1.8	1.8	0.3	0.2	0.2	0.3	1.8	2.0	2.3	2.1
CD (5.0%)	4.8	5.9	5.3	5.4	0.9	0.5	0.5	0.7	5.7	6.0	7.2	6.3
CV (%)	5.8	5.4	6.4	5.4	6.2	7.3	7.7	6.5	6.0	6.0	7.9	6.3

2 dS m^{-1} of EC of irrigation water treatment. Increase in irrigation water EC from BAW to 8 dS m^{-1} had resulted drastic reduction in plant height, number of branches plant^{-1} and green pods plant^{-1} to an extent of 32.1, 32.1 and 37.1 percent respectively. The rate of decrease in number of pods plant^{-1} is much higher with increase in EC of irrigation water from 2 to 8 dS m^{-1}. The least number of branches plant^{-1} (2.6) was observed with the use of EC of 8 dS m^{-1} irrigation water. Among the three different *Rabi* seasons, 2023 crop season, recorded highest plant height and number of green pods per plant.

The decrease in plant height with the increase salinity of irrigation water (Ai *et al.,* 2021) could be due to the low osmotic potential of the soil solution, reduced assimilate synthesis and supply of assimilates to the growing parts. The reduction in cell expansion due to osmotic stress caused by salts and altered stomatal functionality (Butt *et al.,* 2021 and Ghorbanpour *et al.,* 2011). Under salinity stress production of excessive reactive oxygen species (ROS) leads to retarded plant growth and development (Kesawat *et al.,* 2023). Plant growth and the number of branches per plant can be reduced due to the effects of salinity-induced oxidative stress, ion toxicity, and water stress, leading to a decrease in the number of branches when using 8 dS m^{-1} EC irrigation water (Niu *et al.,* 2010). The high salt-levels reduced the number of green pods produced by the plant (Priya *et al.,* 2023). This is due to the plant's capacity to carry out various physiological and biochemical processes, such as photosynthesis, water absorption, and nutrient uptake, which can be hindered by salt-stress (Butt *et al.,* 2021).

The yield of green pods ha^{-1} showed significant variation among the different treatments (Table 3). The average yield of green pods ha^{-1} was highest (28.5 t ha^{-1}) when using BAW, comparable to using 2 dS m^{-1} EC water, and significantly superior to rest of the treatments. The lowest mean yield of green pods ha^{-1} (14.7 t ha^{-1}) was observed with the use of 8 dS m^{-1} EC water. Out of the three cropping seasons, the 2021 cropping season had the highest number of green pods ha^{-1}. The yield of green pods ha^{-1} has been gradually decreasing due to the rising salinity levels in irrigation water, with the most significant drop recorded during the 2023 cropping season. On average, the yield decreased by 4.4 per cent when salinity increased from BAW to 2 dS m^{-1}. When the salinity level rose from 2 dS m^{-1} to 4 dS m^{-1}, it led to the most significant decrease in crop yield of 11.1 per cent compared to other EC levels. The salinity levels were plotted against plant height and green pod yield ha^{-1} in a correlation plot, it was shown that salinity levels showed a strong negative correlation with both variables, indicating a high level of agreement of fit (Fig. 1). The highest mean yield reduction (%)

Table 3. *Effect of water salinity on yield of chilli crop*

Treatment	Yield of green pods (t ha^{-1})				Yield reduction (%)			
	2021	2022	2023	Pooled data	2021	2022	2023	Pooled data
BAW (1.0)	29.8	28.6	27.2	28.5	0	0	0	0
2 EC_{iw}	28.6	26.8	26.4	27.3	4.0	6.3	2.9	4.4
4 EC_{iw}	26.2	22.6	23.5	24.1	12.0	21.0	13.6	15.5
6 EC_{iw}	22.3	18.7	19.4	20.1	25.2	34.6	28.7	29.5
8 EC_{iw}	17.5	12.3	14.3	14.7	41.3	57.0	47.4	48.6
SEm+	0.7	0.6	0.8	0.7				
CD (5.0%)	2.0	1.9	2.3	2.1				
CV (%)	5.3	5.6	6.8	5.7				

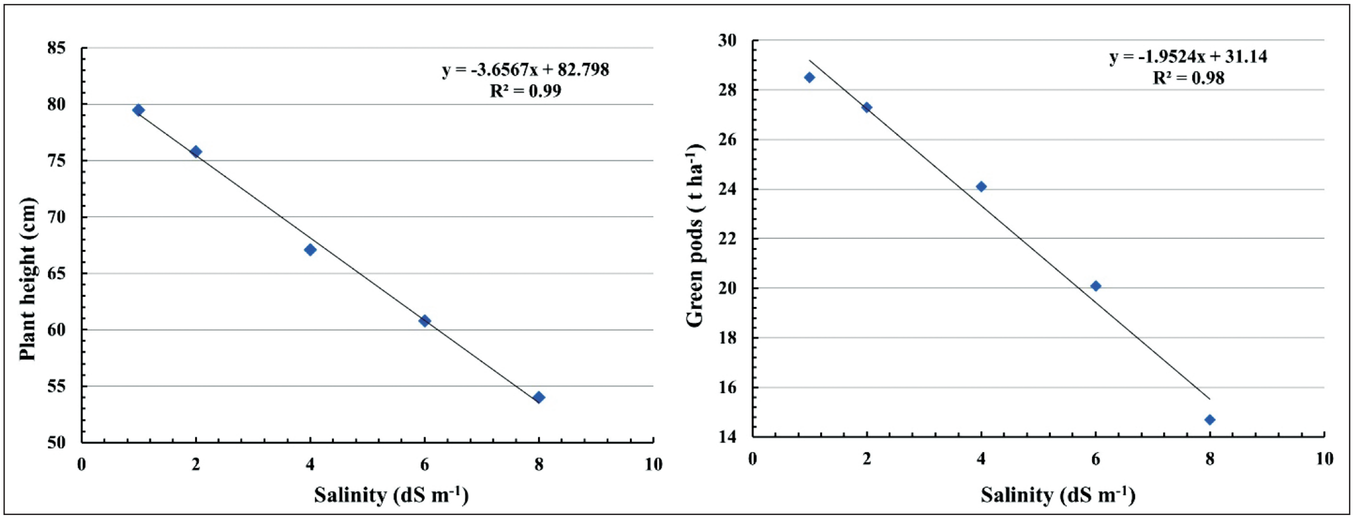

Fig. 1. *Influence of different levels of salinity on plant height (cm) and green pod yield ha^{-1}.*

was observed in the 8 dS m^{-1} EC treatments (48.6 %) in comparison to the treatment using the BAW, while the lowest reduction (%) was seen with the use of 2 dS m^{-1} EC water, suggesting minimal salinity effects on plants.

Increased salinity levels can lead to higher sodium and chloride ion concentrations in plant tissues, potentially causing ion toxicity and damaging plant cells (Isayenkov and Maathuis, 2019). In addition, it was found that the salinity level decreased the concentration of pigments known as carotenoid and chlorophyll, leading to a reduction in photosynthesis and the plant's ability to produce. Increased salinity levels can negatively impact the overall fruit yield of chilli plants. This might be due to the decreasing plant photosynthesis, leading to ion toxicity and reducing water uptake (Razzaghi *et al.,* 2011; Pariyar *et al.,* 2019).

The soils of experiential site had initial salinity ($EC_{1:2}$) of 0.3 dS m^{-1}. With the increase in salinity levels in irrigation water increases the soil $EC_{1:2}$ values and reached at highest soil $EC_{1:2}$ of 2.6 dS m^{-1} with the application 8 dS m^{-1} irrigation water treatment (Table 4). Variability of $EC_{1:2}$ levels was observed in the three cropping seasons and out of which 2021 cropping season recorded highest $EC_{1:2}$ values. Increase in salinity levels of irrigation water from BAW to 2 dS m^{-1} had increased the soil EC of 28.6 per cent which is of highest as compare to other EC levels. After the crop was harvested, there was a slight increase in the soil EC

Table 4. *Soil salinity and pH influenced by the different EC levels of irrigation water*

Treatment	pH				$EC_{1:2}$ (dSm^{-1})			
	2021	2022	2023	Pooled data	2021	2022	2023	Pooled data
BAW (1.0)	7.4	7.1	7.5	7.3	1.4	1.5	1.2	1.4
2 EC_{iw}	7.8	7.3	7.6	7.6	1.7	1.7	1.9	1.8
4 EC_{iw}	8.1	7.6	7.7	7.8	1.9	2.3	2.1	2.1
6 EC_{iw}	8.1	7.6	7.8	7.8	2.2	2.5	2.4	2.4
8 EC_{iw}	8.1	7.6	7.8	7.8	2.4	2.6	2.8	2.6
SEm+	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2
CD (5.0%)	0.5	0.4	NS	0.4	0.3	0.6	0.6	0.6
CV (%)	6.5	5.4	9.6	10.5	6.6	13.2	10.4	9.3

compared to its initial level. The increase in soil EC may be due to the use of saline water, resulting in salt buildup in the soil and reduced salt leaching. At first, when water with different electrical conductivity levels is used for irrigation, the movement of salt from the emitter to the surrounding area along the wetting front can be easily observed.

The mean soil pH data revealed that, the soil pH were increased with increase in irrigation water salinity levels. Use of BAW for irrigation was recorded mean lowest soil pH of 7.3 and increase water salinity from BAW to 2 dS m^{-1} recorded a mean increase in soil pH of 7.6 (4.1%). The highest soil pH was recorded in salinity levels of 4 dS m^{-1} and above where soil pH was recorded as 7.8 (6.8%).

Different EC levels of irrigation induced spatial soil salinity distributionat the beginning and end of the crop season, as shown in Fig. 2 and Fig. 3. Before sowing the chilli crop, the salinity distribution was 0.45 dS m^{-1} within the 20 cm vicinity of the emitter. In the next 10 cm, it increased to 0.5 dS m^{-1}, and up to 60 cm, it reached 0.55 dS m^{-1}. By the end of the season, the salt distribution became more concentrated, extending from the 10 cm radius of the emitter and varying between 0.4 to 0.6 dS m^{-1}. Most of the area displays salt distribution with electrical conductivity ranging from 0.4 to 0.6 dS m^{-1} and higher which was more severe in treatments with high salinity of water. The electrical conductivity varies within specific ranges. Salt development became more concentrated towards the end of the season, with most of the area having an electrical conductivity of 0.8 to 0.95 dS m^{-1}. The use saline water irrigation, low precipitation, and excessive evapotranspiration are primary contributors to salinization during the end of the crop season (Ullah *et al.,* 2021).

CONCLUSION

The results showed that using saline water for irrigation with an electrical conductivity of 8 dS m^{-1} EC had a negative effect on the growth, yield attributes, and yield of chilli than best available water. Based on the present research findings, it can be concluded that saline irrigation water with an electrical conductivity (EC) of up to 2 dS m^{-1} can be safely used for the cultivation of chilli variety VNR 314 in the coastal semi-arid regions of Andhra Pradesh under a drip irrigation system. Irrigation with water of 2 dS m^{-1} EC had minimal adverse effects on chilli plants and produced similar growth, yield attributes, and overall yield comparable

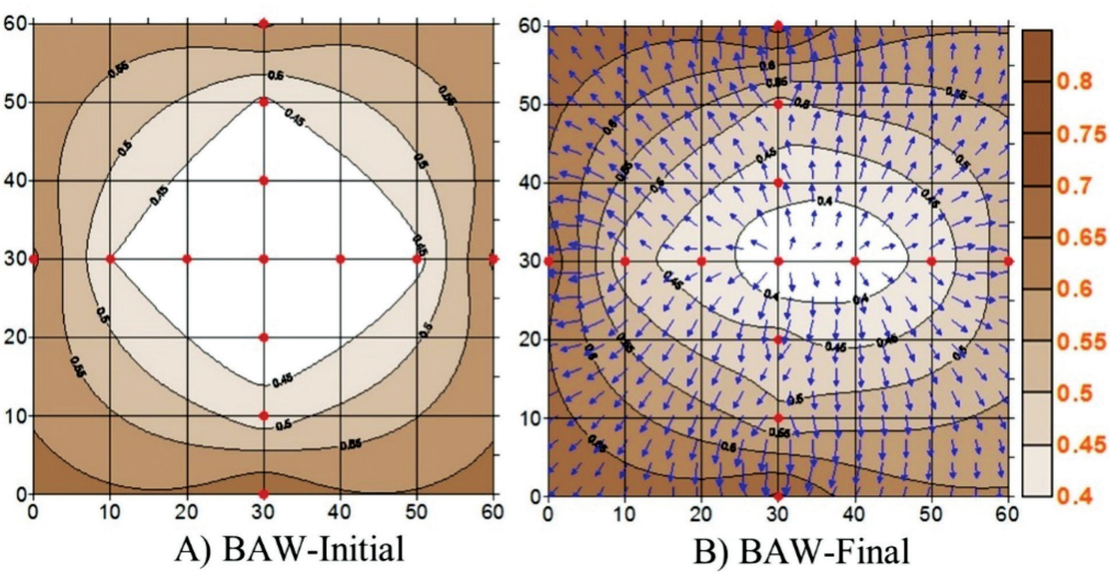

Fig. 2. *Irrigation induced spatial soil salinity distribution; A) Before transplanting as BAW-Initial B) End of the experimentation as BAW-Final*

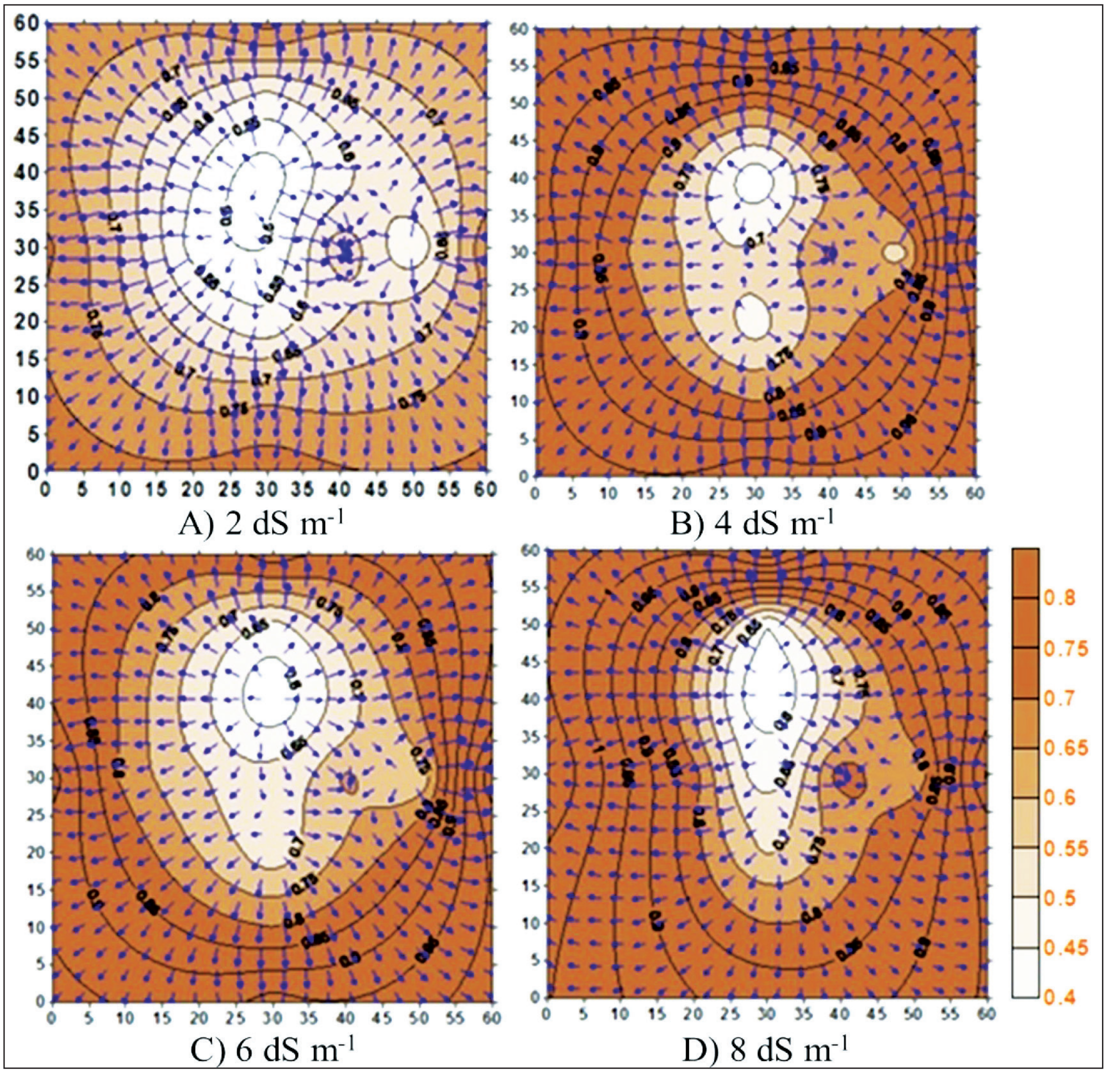

Fig. 3. *Irrigation induced spatial soil salinity distribution A) 2 dS m^{-1} treatment B) 4 dS m^{-1} treatment C) 6 dS m^{-1} treatment D) 8 dS m^{-1} treatment*

to those obtained with the best available quality water. Therefore, the use of saline irrigation water up to 2 dS m^{-1} is recommended for chilli cultivation in these regions without causing significant reductions in crop performance or productivity.

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CONFLICTS OF INTEREST

Authors do not have any conflict of interests to declare.

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