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Response of Castor Hybrids to Saline Water Irrigation in Pot Culture

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ABSTRACT

The quantity and quality of irrigation water is declining day by day considerably across India. To utilize this available water efficiently, there's a need to grow suitable drought resistant crop cultivars with a greater tolerance to salinity/alkalinity. Hence, a pot culture study was carried out during 2014-15 and 2015-16 to evaluate the response of five popular Indian castor hybrids to irrigation water with varying EC levels of 4.0, 6.0, 8.0 dSm^{-1} and the best quality non-saline water (0.2 dSm^{-1}), in a factorial completely randomized design (CRD) with two replications. The results indicated that among hybrids, PCH-111 (4.48 g plant^{-1}) being at par with DCH-519 (4.24 g plant^{-1}) and DCH-177 (4.25 g plant^{-1}) produced significantly higher seed yield plant^{-1} and was higher by 23.4 and 34.5% over YRCH-1 (3.63 g plant^{-1}) and GCH-7 (3.33 g plant^{-1}). The growth of castor was gradually suppressed with an increase in water salinity. The seed yield plant^{-1} (4.50 g plant^{-1}) was significantly greater with the best quality water (ECw: 0.2 dSm^{-1}) followed by ECw4.0 dSm^{-1} (4.05 g plant^{-1}) beyond which a significant decline in seed yield was registered. Thus, irrigation water salinity of 4.0 dSm^{-1} can be considered as the threshold level for irrigation water for satisfactory growth and yield of castor.The post harvest soil pH, EC and available N were significantly greater with the highest water salinity (ECw: 8.0 dSm^{-1}). Shoot length and dry matter were highly and positively correlated with the seed yield of the castor.

Keywords: *Castor; non-saline water; saline water; seed yield; pot culture; root; shoot*

Introduction

Agriculture is facing twin problems of soil alkalinity on one side and poor quality of irrigation water on the other side and the same may multiply in the near future due to an increase in irrigated area following the commissioning of irrigation projects, renovation of major tanks, mono-cropping, faulty farming practices and failure of monsoon. Furthermore, the irrigation water in arid and semi-arid areas is generally brackish (0.5-5g ltr^{-1} salt) or saline (30-50g ltr^{-1} salt)[13] .An increase in soil and water salinity is reported in more than 100 countries across the world especially Argentina, Australia, Brazil,China, Egypt, India,Iran, Iraq, Mexico, Iraq, Pakistan, Thailand, the former Soviet Union and the USA [20] ; [2] ; [8] . Ever expanding urbanization, industrialization, and climate change may further augment the problem. Though many technologies have been developed to overcome and/or manage problematic soils[16] , minimal efforts were made to better utilize poor quality saline or sodic water. Because of the decline in per capita availability of water from 1816 m^3 in 2001 to 1545 m^3 in 2011 and is expected to be 1340 m^3 and 1140 m^3 by 2025 and 2050, respectively[32]the total water demand is projected to be 1180 billion m^3 in 2050 against the current requirement of 710 billion m^3 in India. Further, the quality of groundwater in India is declining due to pollution and geogenic elements like high fluoride (F) in 13 states, arsenic (As) in West Bengal and iron (Fe) in the north-eastern states, Orissa and other parts of the country, salinity in an area of 19.3 M ha in the canal commands of Haryana, Punjab, Delhi, Rajasthan, Gujarat, Uttar Pradesh, Karnataka, and Tamil Nadu [29] . On the otherhand, in view of the concomitant increase in demand from other sectors, the share of agriculture for irrigation water is likely to be reduced to around 68% of the total water demand from the present share of around 78% [4] . Therefore, water would be the major limiting factor in producing enough food. Hence, there is an imperative need to enhance further exploitation of present poor quality waters (3.2 million ha-m per annum), temporally and spatially to meet the ever growing demand for irrigation water [14] .
Several techniques like molecular breeding for multiple stresses, drainage methods, conjunctive use of good and poor quality waters, and bio-remediation have been identified to manage saline waters, but, are costly and time-consuming and unsustainable.

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In view of these problems and opportunities, "bio-saline irrigation which is irrigating crops with saline water" is an easy and cost-effective approachthatcan be explored.Raising conventional food crops with hyper saline water is not sustainable and profitable, hence, there is a desperate need to utilize this water for non-food crops. Earlier, many researchers reported forest species and roadside plantations like *Atriplex amnicola, A. lentiformis and A. nummularia*, *Acacia ampliceps, Casuarina equisetifolia, Eucalyptus occidentalis and Prosopis juliflora* as salt tolerant and are suitable for regions with soil or water salinity in different countries. Besides, fuel crops, flowers, ornamental crops and aromatic grasses can also be encouraged. Nevertheless, saline-resistant varieties in rice, wheat and mustard were developed and are successfully adopted across different states in India [14] . Furthermore, in urban and peri-urban areas, vegetables are irrigated with poor-quality water, but, it may cause health hazards in human beings in the long run. Saline water when applied strongly affects the growth and yield of crops and increases the osmotic potential of water leading to dehydration, functional disorders and metabolic damage in plants [27] .Castor is a non-edible oil (48-52% oil) crop well known for its rusticity [25] , non-synchronous nature and hardiness, xerophytic and heliophilous nature, tolerance to drought,high yield potential and adapted to arid, semi-arid, tropical and sub-tropical climates with medium to high salt concentrations. Further, it is not only tolerant to salinity but also, better than another wild plant Jatropha and edible plants Indian mustard. It is also a choice crop for phytoremediation of Cd-contaminated soils under salinity due to its ability to bio-accumulate more proline and lower malondialdehyde (MDA) and total soluble protein with less damage to cell membrane [1] .Of late, it has been projected as one of the potential crops for biofuel programs of many countries across the world. Thus, it is a good candidate crop for cultivation with saline irrigation waters. However, there is an imperative need to evaluate and identify cultivars tolerant to saline irrigation water to achieve satisfactory yields [18] ,[24] . Hence, we made an attempt to evaluate popular castor hybrids cultivated across different states in India for their tolerance to saline irrigation water and identify threshold water salinity levels.

Materials and methods

Description of experimental site and treatment details

A pot culture experiment was conducted during 2014-15 and 2015-16 at the Soil Test Crop Response Scheme of Professor Jayashankar Telangana State Agricultural University, Hyderabad, India. This was done to understand the response of five popular castor hybrids *viz.,* PCH-111, GCH-7, YRCH-1, DCH-177, and DCH-519 to four saline irrigation water levels ECw@4.0, ECw@6.0, ECw@8.0dSm-1 and best quality water (ECw@0.2dSm-1). The experiment was carried out in a completely randomized block (CRD) with a 5 × 4 factorial concept and two replications. The sowing of castor seed (six per pot) was done on 12-12-2014 and 23-11-2015 in all the designated pots. Finally, only three healthy plants were maintained per pot till completion of the trial i.e. up to maturity of primary raceme.

Preparation of saline water for imposition of treatments

Approximately 10 kg capacity pots filled with light textured soil were used for the pot culture experiment. As detailed in Table 1, NaCl, $MgCl_2$, $MgSO_4$ and $CaCl_2$ salts were used for the preparation of saline water with ECwof 4.0, 6.0 and 8.0 dSm^{-1} [23] . Thus prepared solutions were given for irrigating the castor bean plants in the pot culture experiment (Table 1). The EC of the best quality water was analyzed to be 0.2 dSm^{-1}. Further, irrigation treatments were imposed at weekly intervals@ 3 litres/pot.

Table 1.Amount of various salts (g) mixed in 100 litres of water to obtain the required EC of saline water used for irrigating the castor bean plants

Salt	EC (d Sm^{-1})		
	4.0	6.0	8.0
NaCl	166.6	227.9	286.4
$MgCl_2$	11.7	51.6	107.2
$MgSO_4$	110.9	172.5	208.2
$CaCl_2$	50.7	87.6	138.6

Sampling and data recording

The data on all growth and yield parameters were recorded at the maturity of the primary raceme (90 days after sowing). Three plants were uprooted and the roots were washed under tap water. The roots, shoots, and leaves were separated physically and were dried at 105°C in a hot air oven for 48 hours and then root weight, and shoot+leaves weight were recorded.

Chemical analysis

The pre and post harvest soil samples were analysed for pH, EC and available K[15], available N [28] and P [19] by following standard procedures. Similarly, N, P and K content in seed and plant samples at harvest were estimated using the procedures suggested by [21] .

Statistical analysis

The data were analysed using RStudio 1.3.959 using agricolae package and draw valid conclusions based on Tukey's HSD (Honest Significant Difference test).

Results and Discussion

Growth, yield traits and seed yield

All the five castor hybrids varied significantly concerning growth, yield traits and seed yield except in the case of root weight and dry matter (Table 2). The YRCH-1hybrid grew significantly taller (20.22 cm) with a greater no. of leaves (20), but, it took more time (65.25 days) to initiate flower bud on primary raceme as compared to other hybrids. Interestingly, all the hybrids performed equally in recording root length which ranged from 17.23 to 18.73 cm.

The yield of castor plants determines the productivity of the hybrid and therefore the viability of its use for commercial purposes. Hence, this parameter is often used to evaluate the tolerance of the crop to salinity. Greater diversity with regard to tolerance to salts does exist among different varieties of castor [10] . In the current study, though, DCH-177 produced significantly greater root weight and shoot length the seed yield produced by it was inferior. Despite significantly less no. of leaves, more no. of damaged leaves per plant and shorter shoots, PCH-111 hybrid gave a significantly higher seed yield (4.48 g $plant^{-1}$). It was 23.4% and 34.5% higher than that of DCH-177 and DCH-519, but, it was at par with YRCH-1 (4.25 g $plant^{-1}$) and GCH-7 (4.24 g $plant^{-1}$). Thus, DCH-177 and DCH-519 were found to be highly sensitive to saline water irrigation. The reason for this could be the efficient translocation of photosynthates from the existing leaves on PCH-111 which might be better than that in other test hybrids.

These results corroborate those reported by [26] who found that different varieties of castor plant presented high levels of yield in high salinities. Nevertheless, the cultivars differed significantly in their sensitivity to salinity. MPA-34 exhibited better performance under moderate salinity levels than BRS Energia and MPB-01[22] . Further, BRS Energia> BRS Gabriela = IAC 028 > LA Guarani were in the order of their tolerance to salinity. Thus, LA Guarani was found highly sensitive and not suitable for regions with saline irrigation [24] .

Castor seedlings irrigated with the non-saline irrigation water (ECw: 0.2 dSm^{-1}) recorded significantly greater seed yield (4.50 $gplant^{-1}$) due to taller plants with longer shoots and higher dry matter over that of ECw of 6 dSm^{-1} (3.60$gplant^{-1}$) and 8 dSm^{-1} (3.74 $gplant^{-1}$), however, it was at par with that of ECw of 4 dSm^{-1} (4.05 $gplant^{-1}$). The traits like plant height, no. of leaves, dry matter and shoot length decreased linearly as a function of an increase in irrigation water salinity beyond 4.0 dS m^{-1}. This might be a consequence of the osmotic effect of dissolved salts, which restrict the osmotic potential of the soil solution and reduced water absorption in plants, resulting in nutritional imbalance and ionic toxicity, or both, due to excessive accumulation of certain ions in plant tissues [11] .Such reports were earlier published by [5] who recorded suppressed growth of the cultivar BRS Energia under water salinity,but, observed better performance under N fertilization. Further, they reported that seed weight from primary raceme was the most sensitive attribute to water salinity and cationic composition,thus, castor seed yield was hampered by irrigation water salinity of 4.5 dS m^{-1}regardless of the cationic nature of the water.As concluded by many researchers, increasing the salinity of irrigation water or nutrient solution delayed the germination by 15 days and flowering [12] , reduced the height, stem diameter and leaf area, number of fruits and seed weight [9] , dry weight of shoot and root irrespective of cultivars tested, however, the impact was more on shoot over root [22] . Many researchers reported greater dry matter production with non-saline water, but, decreased with increasing salinity of irrigation water due to disturbances in the gas exchange with in the plant. According to [6] , irrigation with ECw beyond 0.3 dSm^{-1} reduced dry matter of leaves and stems and fixed irrigation water EC of 2.1 dS m^{-1} as threshold level for cultivation of 'BRS Energia' castor cultivar. On the contrary, [12] reported increased seed yield with increasing water salinity from 2.3 to 4.68 dS m^{-1} in all three hybrids Zoya-856, Olga-864 and Galit K-93 and the highest seed yield of 2.28 ton ha^{-1} at 4.68 dS m^{-1} with Olga-864. [33] recommendeda salinity level of ≤7.1 dS m^{-1} in seedling media for better castor production beyond which the growth, development and physiological responses were greatly repressed. Despite the suppression of vegetative growth due to NaCl> 40 mol m^{-3}, the castor plants produced viable seeds even at 160 mol m^{-3} NaCl[7] .

In the present pot culture trial, greater reduction in seed yield of castor hybrids under increased salinity of water applied could also be explained by suppression of photoinhibition due to inhibition of glycolate oxidase and disruption of photosynthetic metabolism [34] .

Nutrient content

In general, N and P concentrations were higher in seeds than that of dry matter (shoot+leaves), while, it was reverse in the case of K(Table 3).Though castor hybrids did not differ significantly with regard to N, P and K uptake by dry matter, however, their uptake by seed and total uptake was significantly greater with the PCH-111 hybrid(Table 4).

It was mainly owing to higher nutrient concentration.Despite a reduction in growth parameters, PCH-111 removed greater amounts of nutrients from soil and also recorded higher seed yield. It shows the inherent ability of this hybrid to withstand saline water stress and perform better than other hybrids under test.

The uptake of N, P and K either by seed, dry matter or total biomass was significantly higher by the castor plants when irrigated with non-saline water beyond which decline in uptake was linear with an increase in water salinity level(Table 4). The capacity of absorbing total N by castor plants declined by 13.9% with ECw 4.0 dSm^{-1}, 26.1% with ECw 6.0 dSm^{-1}and28.5% with ECw 8.0 dSm^{-1}. Similarly, percent reduction in total P uptake was 23.9%, 40.6% and 51.3%; total K uptake was 28.8%, 49.4 and 56.7%, respectively. Thus, the highest reduction in nutrient uptake was observed under the highest water salinity (8 dSm^{-1}). The reason for this phenomenon could be ascribed to the reduced ability of plant roots to acquire salt-concentrated water due to increased osmotic potential.

Changes in soil electrochemical properties

When compared to initial soil electrochemical values, a slight increase in soil pH was witnessed. This phenomenon may be due accumulation of carbonates and bicarbonates of several cations, such as Ca^{2+} and Na^{+}in the soil [3] . Similarly, an increase in soil EC (from 0.29 to a minimum of 0.61 to 1.34 dSm^{-1})was significant as it was double that of the initial soil value.It increased with salinity level and the highest value was recorded at 8.0 dSm^{-1}. Previous work by [31] has shown that the soil EC followed the pattern of saline water application rate as the plant species can assimilate only a proportion of the available salts. While only a slight decrease in soil available P was observed, no significant change was registered in soil OC and available N and K as compared to that of initial value.With the increase in the salinity of applied irrigation water, the improvement in post-harvest soil available N and K was significant (Table 5). It means castor plants failed to accumulate more amount of nutrients due to high osmotic potential following unfavorable salt concentration which hindered the nutrient uptake. In the treatment which was irrigated with saline water @ 6.0 and 8.0 dSm^{-1},the OC increased slightly. This might be due to higher dehydrogenase activity in the soil irrigated with saline water. The soils irrigated with saline water showed only a slight variation in available soil N and P levels. A significant difference was not observed in soil K among salinity levels and hybrids. However, a slight increase in soil K was observed in the treatment irrigated with saline water @ 6.0 and 8.0 dSm^{-1}.

Though post-harvest soil pH did not differ significantly due to various castor hybrids, but, soil EC values were significantly lower when PCH-111 was grown vis-à-vis other hybrids. It shows the ability of PCH-111 with regard to salt acquisition or inclusion in the plant biomass. Further, the lower amount of nutrients N, P and K were observed in the soil when PCH-111 was grown, but, were higher due to other hybrids. It was due to the capacity of PCH-111 in removing nutrients in larger amounts as compared to other hybrids,under the given level of saline water. Post-harvest OC did not differ significantly due to various castor hybrids though it was slightly under PCH-111 and DCH-177.

Correlation coefficient analysis in castor

The correlation studies revealed the existence of a positive and significant correlation of plant height with total no. of $leavesplant^{-1}$, dry matter, shoot length, and seed yield (Table 6).

[17] also found a positive correlation between plant height and seed yield of castor. Similarly, total no. of leavesplant^{-1} showed a positive and significant correlation with dry matter and shoot length. Further, dry matter had a significant and positive correlation with shoot length. DOIFB was significantly and negatively correlated with root weight. [30] reported that the direct and indirect selection of genotypes with plant height, stem diameter, number of bunches and mass of hundred seeds is promising to select genotypes with high seed yield in castor. The dry matter produced (assimilates) were translocated and partitioned to various plant organs (yield characters).The physiological interrelationship or association between growth and yield is evident in the highly positive correlations observed between growth characters and yield characters in this study.

Conclusions

Based on two year pot culture experiment, it may be safely recommended that the irrigation water having salinity 4.0 dSm^{-1} can be taken as the threshold level above which the growth, development and yield of castor crop was greatly suppressed. Of the five test hybrids, PCH-111, DCH-519 and DCH-177 were found suitable for cultivation under saline irrigation water, however, YRCH-1 and GCH-7 were found unsuitable. A positive and significant correlation was registered for the above-ground parameters like tallness of plants, length of the shoot and dry matter with seed yield of castor. Based on the foregoing results, castor cultivation can be encouraged in arid and semi-arid and gray areas having saline irrigation water which can't be used for irrigating food crops.

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Conflict of Interest: The authors stated that there is no conflict of interest

Future scope of the study: Positively responded castor hybrids to salinity can be cultivated under water scarce rainfed areas with the application of osmolytes or protectants.

Table 2. Effect of saline water irrigation on growth, yield and yield traits of castor hybrids (pooled data of 2014-15 and 2015-16)

Treatments	Plant height (cm)	No. of leaves/ plant	No. of leaves damaged	DOIFB	Root length (cm)	Root dry matter (grams/ plant)	Shoot length (cm)	Shoot dry matter (g/plant)	Seed yield (g/plant)
Hybrid									
PCH-111	18.21	14	3	64.50	17.73	0.21	31.90	12.2	4.48
GCH-7	19.29	18	2	64.63	18.59	0.21	33.45	12.7	4.24
YRCH-1	20.22	20	2	65.25	18.73	0.23	33.79	11.6	4.25
DCH-177	19.84	17	1	61.94	17.53	0.30	34.52	13.0	3.63
DCH-519	17.36	19	2	65.06	17.25	0.25	32.69	14.1	3.33
SEm±	1.12	2	1	0.91	2.11	0.04	0.97	0.19	0.24
Tukey's HSD	1.51	3	1	1.48	NS	0.08	2.11	NS	0.47
Water Salinity (dSm^{-1})									
ECw@4.0	19.28	19	2	63.65	18.44	0.25	33.41	14.1	4.05
ECw@6.0	16.58	18	2	64.60	17.33	0.23	32.17	9.7	3.60
ECw@8.0	18.23	14	2	64.30	18.51	0.24	32.00	9.2	3.45
ECw@0.2	21.85	19	2	64.55	17.60	0.24	35.51	17.3	4.50
SEm±	1.00	2	1	0.69	1.87	0.03	0.95	0.17	0.21
Tukey's HSD	2.10	4	NS	NS	NS	NS	2.41	0.28	0.39
Interaction									
SEm±	2.51	3	1	1.56	3.55	0.08	1.93	0.32	0.49
AXB	4.54	8	NS	NS	NS	NS	NS	NS	NS
BXA	4.27	7	NS	NS	NS	NS	NS	NS	NS
CV%	11.86	22	59	2.28	21.21	33.21	13.99	26.33	11.79

DOIFB: Date of initiation of flower bud

Table 3. Effect of saline water irrigation on N, P and K concentration in castor hybrids (pooled data of 2014-15 and 2015-16)

Treatments	% N		% P		% K	
	Dry matter	Seed	Dry matter	Seed	Dry matter	Seed
Hybrid						
PCH-111	1.20	2.19	0.11	0.20	0.87	0.32
GCH-7	1.18	2.05	0.10	0.17	0.90	0.29
YRCH-1	1.19	2.17	0.10	0.19	0.83	0.31
DCH-177	1.20	2.16	0.10	0.18	0.90	0.28
DCH-519	1.19	2.11	0.10	0.19	0.86	0.29
SEm±	0.01	0.02	0.01	0.01	0.02	0.02
Tukey's HSD	NS	0.03	0.01	0.01	0.03	NS
Water Salinity (dSm^{-1})						
ECw@4.0	1.22	2.19	0.10	0.20	0.90	0.32
ECw@6.0	1.17	2.09	0.10	0.17	0.84	0.26
ECw@8.0	1.13	2.00	0.09	0.14	0.77	0.21
ECw@0.2	1.26	2.27	0.12	0.23	0.98	0.40
SEm±	0.01	0.02	0.00	0.01	0.02	0.02
Tukey's HSD	0.01	0.03	0.01	0.01	0.03	0.02
Interaction						
SEm±	0.02	0.05	0.01	0.02	0.04	0.04
AXB	NS	NS	0.01	NS	NS	NS
BXA	NS	NS	0.01	NS	NS	NS
CV%	1.70	2.27	8.63	10.35	4.74	12.48

Dry matter: Dry weight of shoot+leaves

Table 4. Effect of saline water irrigation on N, P and K removal castor hybrids (pooled data of 2014-15 and 2015-16)

Treatments	**N uptake**			**P uptake**			**K uptake**		
Hybrid	**Dry matter (mg/pot)**	**Seed (mg/pot)**	**Total (mg/pot)**	**Dry matter (mg/pot)**	**Seed (mg/pot)**	**Total (mg/pot)**	**Dry matter (mg/pot)**	**Seed (mg/pot)**	**Total (mg/pot)**
PCH-111	14.85	294.63	309.49	1.40	27.72	29.11	10.60	43.40	54.00
GCH-7	15.29	261.49	276.78	1.35	22.15	23.51	11.76	37.17	48.92
YRCH-1	14.05	277.46	291.51	1.22	24.23	25.45	10.56	40.24	50.80
DCH-177	15.98	236.84	252.83	1.32	20.41	21.73	12.16	32.38	44.55
DCH-519	17.05	212.28	229.33	1.52	18.99	20.51	12.21	29.47	41.68
SEm±	2.15	15.64	15.93	0.20	1.91	1.86	1.31	3.29	3.48
Tukey's HSD	NS	30.90	32.02	NS	2.61	2.60	NS	6.54	4.57
Water Salinity (dSm^{-1})									
ECw@4.0	17.47	265.24	282.71	1.48	24.28	25.76	12.65	39.04	51.69
ECw@6.0	11.63	230.83	242.46	0.96	19.18	20.13	8.35	28.23	36.58
ECw@8.0	10.63	223.97	234.61	0.84	15.64	16.48	7.27	24.17	31.44
ECw@0.2	22.06	306.12	328.17	2.17	31.70	33.87	17.56	54.71	72.26
SEm±	1.92	13.25	14.61	0.18	1.74	1.62	1.25	2.87	3.15
Tukey's HSD	3.45	25.94	26.88	0.25	2.34	2.33	2.37	5.49	4.09
Interaction									
SEm±	4.12	30.42	30.89	0.51	3.66	3.69	2.96	6.55	6.15
AXB	NS	NS	NS	NS	NS	NS	NS	NS	NS
BXA	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	26.40	11.93	11.66	28.57	16.10	15.14	24.36	17.73	13.35

Table 5. Effect of saline water irrigation on post harvest soil electrochemical properties (end of 2015-16)

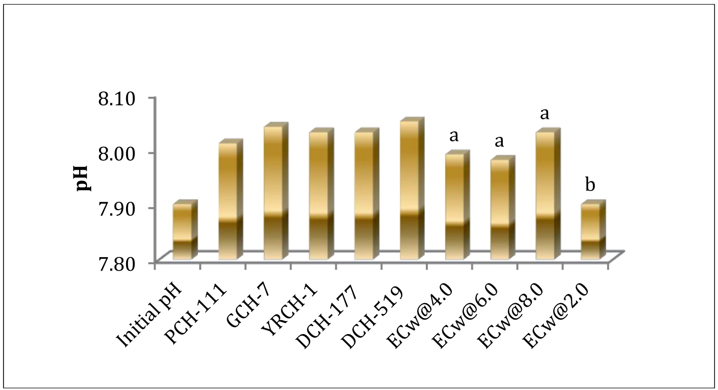
Treatments	pH	EC	OC (%)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Hybrid						
PCH-111	8.01	0.75	0.29[b]	176.56[b]	63.00	582.81[c]
GCH-7	8.04	0.98	0.30[a]	176.94[b]	63.31	585.44[b]
YRCH-1	8.03	0.87	0.30[a]	176.56[b]	64.00	588.06[a]
DCH-177	8.03	1.01	0.30[a]	178.63[a]	63.56	588.69[a]
DCH-519	8.05	0.92	0.29[b]	179.38[a]	63.69	589.25[a]
SEm±	0.04	0.09	0.003	0.74	0.83	1.85
Tukey's HSD	NS	NS	NS	1.01	NS	2.51
Water Salinity (dSm^{-1})						
ECw@4.0	7.99[a]	0.68[c]	0.29	177.15[b]	63.20	586.85
ECw@6.0	7.98[a]	1.00[b]	0.30	178.10[a]	63.75	587.25
ECw@8.0	8.03[a]	1.34[a]	0.30	178.75[a]	63.55	587.70
ECw@0.2	7.90[b]	0.61[c]	0.29	176.45[c]	63.55	585.60
SEm±	0.03	0.06	0.003	0.62	0.82	1.54
Tukey's HSD	0.05	0.11	NS	0.90	NS	NS
Interaction						
SEm±	0.08	0.16	0.01	1.39	1.69	3.55
AXB	NS	NS	0.01	NS	NS	NS
BXA	NS	NS	0.01	NS	NS	NS
CV%	1.02	17.56	3.51	0.79	2.59	0.60

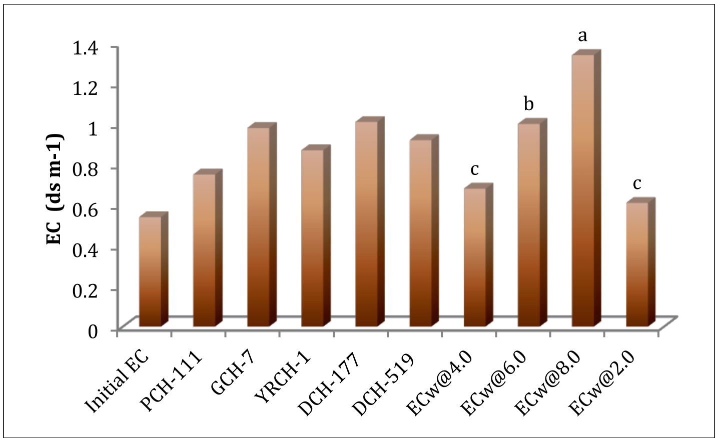
Initial: pH: 7.9 EC: 0.54 OC(%): 0.29; Available N: 178 kg/ha; Available P: 67 kg/ha; Available K: 582 kg/ha

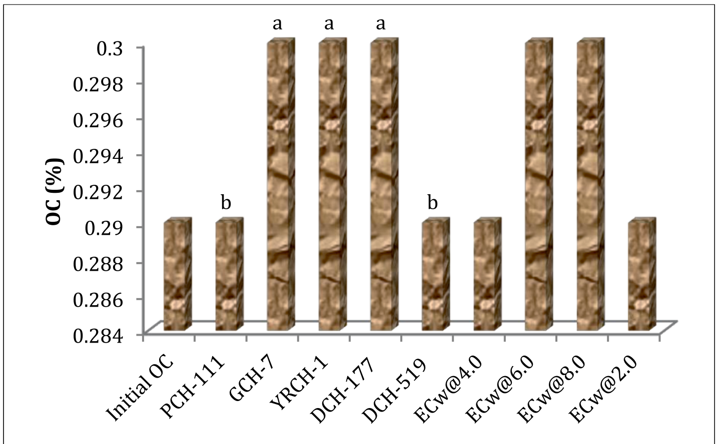
Table 6.Correlation analysis between seed yield and yield influencing traits of castor (Pooled data of 2014-15 and 2015-16)

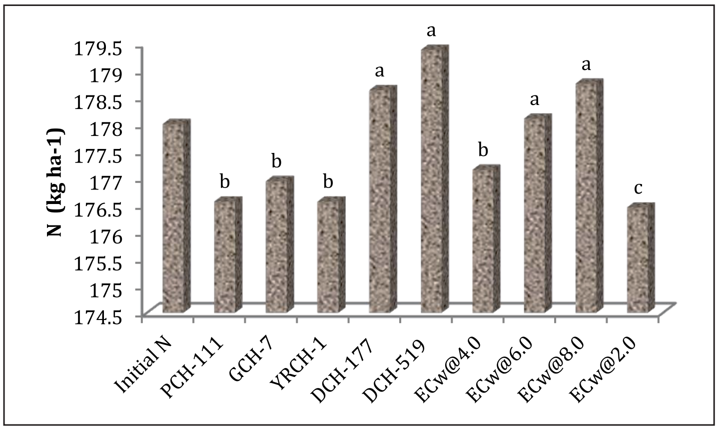
	Plant height (cm)	Total No. of leaves/ plant	No. of leaves damaged	DOIFB	Root length (cm)	Root weight (grams)	Dry matter	Shoot length (cm)	Seed yield (g/plant)
Plant height (cm)	1.000	0.428*	0.128	-0.190	0.299	0.226	0.597**	0.827**	0.389*
Total No. of leaves/plant		1.000	-0.043	0.091	0.046	-0.031	0.445*	0.518**	-0.129
No. of leaves damaged			1.000	0.247	0.123	-0.113	-0.229	-0.217	0.225
DOIFB				1.000	-0.055	-0.462*	-0.085	-0.297	0.185
Root length (cm)					1.000	0.144	-0.029	0.083	0.066
Root weight (grams)						1.000	0.094	0.143	-0.319
Dry matter							1.000	0.637**	0.342
Shoot length (cm)								1.000	0.176
Seed yield (g/plant)									1.000

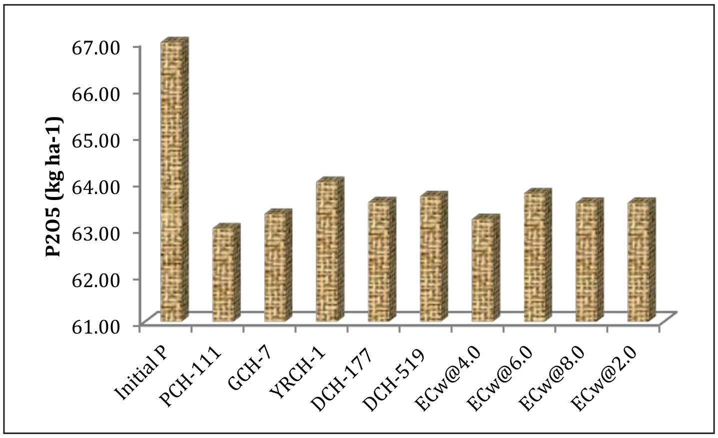
Note: n-2=20-2=18
0.3783 *= Significant at 5% levels of probability, 0.5155 **= Significant at 1% levels of probability











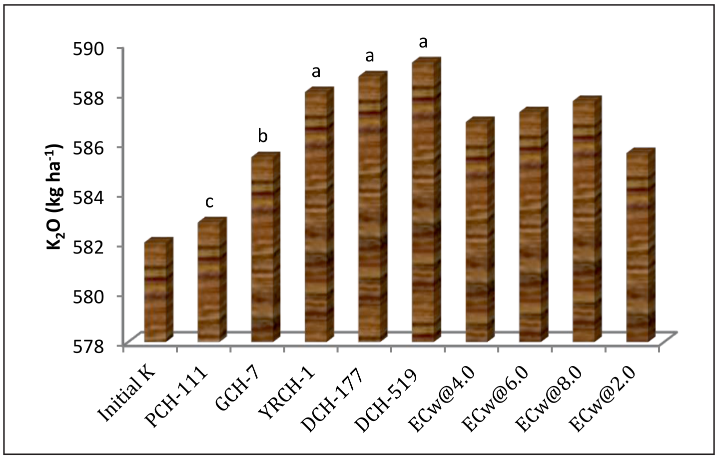


Figure 1.Effect of saline water irrigation on post harvest soil electrochemical properties

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