Effect of simulated soil salinity conditions and varieties of pigeon pea (*Cajanus cajan* L.) on growth, yield and yield attributes

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Abstract: Globally salinity is the problem in arid and coastal areas. Due to climate change soil salinization is spreading drastically and because of availability of lack of freshwater, it is spreading worldwide more rapidly. Salt has potential harsh impact on leguminous crops, which ultimately decreases straw yield, seed yield, growth parameters and protein content. In the present study, the effect of five salinity levels (Control, 40, 60, 80 and 100 meq l^{-1}) and four pigeon pea varieties (V_1: GJP-1, V_2: Vaishali, V_3: BDN-2, V_4: AGT-2) were measured on seed yield, straw yield, different growth parameters and protein content. Application of different levels of salinity significantly affected growth, yield attributes and yield, quality, uptake of nutrients, available nutrients and soil properties after harvest of pigeon pea crop. The results showed that the highest value of germination %, days to 50 % flowering, plant height, number of branches plant^{-1}, pod length, number of pods plant^{-1}, number of seed pod^{-1}, seed and straw yield were observed with salinity level S_1 (Control). The quality parameters like protein content ant test weight were found the highest in salinity level S_1 (Control).

Keywords: Pigeon pea, salinity levels, growth, yield, yield attributes and quality
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1. Introduction

Salinity is one of the major obstacles for increasing production in coastal areas. Salinity stress delays the onset, reduces the rate and increases the dispersion of germination events, resulting in reduced plant growth and crop yield. Soil salinity adversely affects plant growth and development. An excess of soluble salts in the soil leads to osmotic stress, which results in specific ion toxicity and ionic imbalances and the consequences of these can be plant demise. Increasing crop salt tolerance is a highly attractive approach to overcoming the salinity threat.

Therefore, salinity is one of the majorly affecting abiotic factors limiting crop productivity. This is attributed to the fact that Na^+ competes with K^+ for binding sites essential for cellular function and the latter implication of these two macronutrients in salinity is thought to be the one of the factors responsible for the reduction of the biomass and yield components of plants. High concentration of salt in the root zone (rhizosphere) reduces soil water potential and the availability of water. As a result of this, reduction of the water content leading to dehydration at cellular level and osmotic stress is observed.

High levels of salts in the soil can often cause serious limitations to agricultural production and land development. The main factors that contribute to this problem are the arid and semi-arid climates and the salt load in the water used for irrigation. The soil salinity may cause several deleterious effects on growth and development of plants at physiological and biochemical level (Gorham *et al*., 1985; Munns, 2002). These effects can be due to low osmotic potential of soil solution, specific ion effects, nutritional imbalance or a combined effect of all these factors.

In India, pigeon pea crop has four distinct maturity groups *viz.*, early (120-140 days), mid-early (141-160 days), medium duration (161-180 days) and long duration (>180 days). Pigeon pea phenology is strongly affected by temperature (Hodges 1991, Jones *et al*. 1991, Ritchie and NeSmith 1991) and photoperiod (Omanga *et al*. 1996) emphasized that the effect of temperature on the rates of pigeon pea development can be similar in magnitude to those of photoperiod. The optimum range of temperature for proper growth and development of pigeon pea is 18–38^{o} C, whereas in the controlled environment showed that warm (42^{0}C) and cool (20^{0}C) temperature delay flower initiation and that the optimal temperature for flowering for early maturing type is close to 24^{0}C.

2. Resources and Research methods

A pot experiment was conducted during *kharif* - 2019-20 at the Department of Agricultural Chemistry and Soil Science, College of Agriculture, JAU, Junagadh. The experiment soil was silty clayey in texture and alkaline in reaction with pH 8.08, EC 0.30 dS m^{-1}, $CaCO_3$ 33.00 % and CEC 35.20 cmol (p^+) kg^{-1}. The soil was low in available nitrogen (180.10 kg ha^{-1}) and medium in phosphorus (48.00 kg ha^{-1}), high in available potassium (407.00 kg ha^{-1}), low in available sulphur (21.38 mg kg^{-1}), medium in available iron (7.64 mg kg^{-1}), high in available zinc (1.17 mg kg^{-1}), medium in available manganese (2.95 mg kg^{-1}) and high in available copper (0.57 mg kg^{-1}).

The experiment consists of 20 treatments combinations comprising five levels of salinity and four levels of varieties under the Factorial CRD design. The required quantity of N @ 20 kg ha^{-1} and P_2O_5 @ 40 kg ha^{-1} applied to all the pots as basal dose in the form of urea and DAP, respectively. The desired soil salinity was artificially prepared by dissolving pre-determined quantity of salt in a measured quantity of water (*i.e*. on the basis of saturation percentage of soil). The salts used were *viz*., $CaCl_2$, $MgSO_4$, $MgCl_2$ and NaCl were used for preparing solution and required quantity of salts. The proportion of cations *i.e*. Na:Ca:Mg was 5:1:2 and anions as Cl:SO_4 was 4:1. The desired quantity of soil was spread on a polythene sheet in this layer and salt solution of different EC values were sprayed and soil were covered with polythene sheet for two days. Ten seeds of pigeon pea were sown in each pot at a depth of 2 to 3 cm on the 12th July 2019. Only the required quantity of water was applied to avoid leaching during first and second irrigations.

Figure 1: Experiment view at the stage of germination

Figure 2: Overall view of an experiment

3. Results

The value of seed yield (Table 1) was significantly affected by salinity levels and found to be reduced with each unit increment in level of salinity. The highest value of seed yield 59.01 g pot^{-1} was achieved under salt concentration level S_1 (Control) and 47.09 g pot^{-1} in variety V_4 (AGT-2). The straw yield (Table 1) of pigeon pea was significantly decreased with increased salt concentration. The highest value of straw yield 151.72 g pot^{-1} recorded with salinity level S_1 (Control) and 144.40 g plant^{-1} in variety V_4 (AGT-2). The highest germination %, plant height (at 45 DAS, 60 DAS and at harvesting stage), number of branches plant^{-1} at harvest, pod length, number of pods plant^{-1}, number of seeds pod^{-1}, test weight were found in salinity level S_1 (Control). The lowest days to 50 % flowering was attained at salinity level S_1 (Control). Different varieties also significantly affected the growth parameters. The highest value of germination percentage, number of branches plant^{-1} at harvest, pod length, number of seeds pod^{-1}, test weight were attained in variety V_4 (AGT-2). While the highest plant height (at 45 DAS, 60 DAS and at harvesting stage), number of pods plant^{-1} were recorded in variety V_3 (BDN-2). The lowest days to 50 % flowering was obtained in variety V_4 (AGT-2). Significantly the highest value of protein content (22.62 %) observed in S_1 (Control), which remain statistically at par with S_2 level (40 meq l^{-1}).

Table 1 Effect of salinity levels and varieties on seed and straw yield of pigeon pea

Treatments	Seed yield (g pot^{-1})	Straw yield (g pot^{-1})
Salt concentration(Salinity) (S)		
S_1: Control	59.01	151.72
S_2: 40 meq l^{-1}	48.83	146.77
S_3: 60 meq l^{-1}	44.10	141.47
S_4: 80 meq l^{-1}	38.92	134.98
S_5: 100 meq l^{-1}	33.75	125.14
S.Em. ±	**0.65**	**1.92**
C.D. (P=0.05)	**1.85**	**5.48**
Variety (V)		
V_1: GJP-1	42.82	133.61
V_2:Vaishali	44.42	141.34
V_3:BDN-2	45.37	140.71
V_4: AGT-2	47.09	144.40
S.Em. ±	**0.58**	**1.72**
C.D. (P=0.05)	**1.65**	**4.91**
S x V Interaction		
S.Em. ±	**1.29**	**3.84**
C.D. (P=0.05)	**NS**	**NS**
C.V. %	**4.98**	**4.75**

The highest mean seed yield (44.86 g pot^{-1}) was recorded by variety AGT-2 followed by BDN-2 (41.85 g pot^{-1}) and Vaishali (40.96 g pot^{-1}) shown in Table 4. The pigeon pea variety AGT-2 recorded value of different salt tolerance criteria like higher mean salinity index (71.96 %), higher mean seed yield (44.86 g pot^{-1}), minimum yield decline (37.97 %) at 10.0 dS m^{-1} and for 50 % yield reduction at $EC_{2.5}$ (11.72 dS m^{-1}).

Table 2 Effect of salinity levels and varieties on growth and yield attributing characters of pigeon pea

Treatments	Yield attributing characters									
	Germination (%)	Days to 50 % Flowering	Plant height at 45 DAS (cm)	Plant height at 60DAS (cm)	Plant height at harvest (cm)	No. of branches $plant^{-1}$ at harvest	Pod length (cm)	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	Test weight
Salt concentration (Salinity) (S)										
S_1: Control	89.18	149.08	65.60	85.60	148.22	22.33	4.48	21.71	4.15	10.96
S_2: 40 meq l^{-1}	81.38	152.00	64.63	84.72	147.07	22.25	4.45	20.69	3.94	10.02
S_3: 60 meq l^{-1}	73.26	154.75	59.59	80.67	142.47	21.33	4.42	20.28	3.85	9.78
S_4: 80 meq l^{-1}	64.88	157.25	59.38	79.38	140.83	19.33	4.17	19.71	3.49	9.71
S_5: 100 meq l^{-1}	57.08	158.17	43.08	67.08	126.43	19.17	3.97	19.55	3.42	8.80
S.Em. ±	**1.36**	**2.16**	**1.24**	**1.39**	**2.57**	**0.43**	**0.13**	**0.39**	**0.08**	**0.21**
C.D. (P=0.05)	**3.89**	**6.18**	**3.56**	**3.98**	**7.35**	**1.23**	**0.36**	**1.11**	**0.22**	**0.59**
Variety (V)										
V_1: GJP-1	67.36	167.87	52.36	75.03	137.39	19.20	4.20	22.11	3.50	9.01
V_2: Vaishali	71.36	150.47	56.36	76.36	138.52	20.67	4.04	20.39	3.77	9.76
V_3: BDN-2	76.76	152.47	63.22	86.62	148.14	21.40	4.35	20.46	3.82	9.83
V_4: AGT-2	77.14	146.20	61.88	79.94	139.96	22.27	4.61	18.58	3.99	10.82
S.Em. ±	**1.22**	**1.93**	**1.11**	**1.25**	**2.30**	**0.38**	**0.11**	**0.35**	**0.07**	**0.19**
C.D. (P=0.05)	**3.48**	**5.53**	**3.18**	**3.56**	**6.57**	**1.10**	**0.32**	**0.99**	**0.20**	**0.53**
S x V Interaction										
S.Em. ±	**2.72**	**4.33**	**2.49**	**2.78**	**5.14**	**0.86**	**0.25**	**0.78**	**0.15**	**0.41**
C.D. (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
C.V. %	**6.44**	**4.86**	**7.37**	**6.07**	**6.32**	**7.13**	**10.23**	**6.61**	**7.02**	**7.31**

Table 3 Effect of salinity levels and varieties on quality parameters of pigeon pea

Treatments	Protein content (%)
Salt concentration(Salinity) (S)	
S_1: Control	22.62
S_2: 40 meq l^{-1}	21.93
S_3: 60 meq l^{-1}	21.15
S_4: 80 meq l^{-1}	20.82
S_5: 100 meq l^{-1}	20.74
S.Em. ±	**0.49**
C.D. (P=0.05)	**1.39**
Variety (V)	
V_1: GJP-1	21.57
V_2: Vaishali	21.32
V_3: BDN-2	21.47
V_4: AGT-2	21.45
S.Em. ±	**0.44**
C.D. (P=0.05)	**NS**
S x V Interaction	
S.Em. ±	**0.9756**
C.D. (P=0.05)	**NS**
C.V. %	**7.88**

Table 4 Salt tolerance criteria of pigeon pea varieties based on yield

Varieties	Mean seed yield (gm pot^{-1})	Mean salinity index (%)	Reduction at EC 10.0 (dS m^{-1}) over control (%)	$EC_{2.5}$ (dS m^{-1}) for 50% yield decline	Regression equation (Y = a + bX)
V_1: GJP-1	39.25	69.79	45.73	10.75	Y = 60.9920 – 3.0578 X r^2 = 0.9444**
V_2: Vaishali	40.96	70.01	42.36	11.12	Y = 62.2860 – 2.97 X r^2 = 0.9524**
V_3: BDN-2	41.85	70.16	39.52	11.60	Y = 62.0920 – 2.7812 X r^2 = 0.9172**
V_4: AGT-2	44.86	71.96	37.97	11.72	Y = 66.3728 – 3.0032 X r^2 = 0.8783**

** Mean salinity index = mean of 4, 6, 8 and 10 / Control tratment

4. Discussion

The accumulation of salts in the root zone reduced absorbtion of water by roots of groundnut which suppress pod yield (Padole *et al.,* 1993). The herein reduction in yield due to salinity effect are in harmony with previous investigations (Nayak *et al.,* 2001) on Indian mustard. Dry weight of shoot decreased as shoot length declined after salinity levels increased, reported by Kaya and Ipak (2003). The straw yield was limited during salinity stress primarily by the reduced turgor and limitations of plants capacity for osmoregulation study done by Alam *et al.* (2004). Nautiyal *et al.* (1989) reported that the soils having Na+ salinity are not suitable for crop as germination percentage reduced. Anantharaju and Muthiah (2007) reported that germination percentage was decreased with increase in salinity levels due to a decrease in water uptake.

The delayed flowering may simply be a case of slow growth of floral parts thus taking more days to become an open flower after floral induction reported by Promila and Kumar (1982). Reason behind delay in flowering period of pigeon pea might be sensitivity of crop with saline condition and higher rainfall occurred in monsoon season 2019. Increasing levels of salinity were found to markedly suppress the plant height, which may be due to an increase in the soil salinity which decreases the uptake of nitrogen and phosphorus which had a direct effect on the plant growth and ultimately on the plant height and branches per plant (Anjum *et al.,* 2005). High concentration of sea salts stimulated increased flower shedding which ultimately reduced the effective number of pods (Vadez *et al.,* 2007).

The negative effect of salinity on plants may provoke osmotic potential by salt in the culture medium, so root cells do not obtain required water from the medium, resulting the production of pods per plant reduced under saline condition (Golezani *et al.,* 2009). Reduced number of seeds per capsule under salinity might due to less translocation of assimilates towards reproductive organ (Ali *et al.,* 2005). The effect of salt, water stress delayed maturity might lead to shriveled seeds and consequent the lowers test weight (Ahmed, 2009).

Under saline conditions, reactive oxygen species (ROS) are commonly generated and accumulated by which oxidative damage occurs in biomolecules such as proteins, resulting in cell death later in the process reported by Arefian *et al.* (2014). Reduction in seed set starts before the very beginning of fruit development due to failure of fertilization and abortion of the fertilized ovules when salts are present in soil (Asha and Dhingra, 2007).

5. Conclusion

It was concluded that the growth, yield and yield attributes and quality parameters decreased with increasing salinity levels of irrigation water. Pigeon pea variety AGT-2 was found more salt tolerant compared to other varieties. The sequential order of salinity tolerance for pigeon pea varieties was observed AGT-2 > BDN-2 > Vaishali > GJP-1.

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