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Gaytri Soni
 Department of Agricultural,
 Chemistry and Soil Science,
 Junagadh Agricultural
 University, Junagadh, Gujarat,
 India

Dr. SG Savalia
 Department of Agricultural,
 Chemistry and Soil Science,
 Junagadh Agricultural
 University, Junagadh, Gujarat,
 India

Corresponding Author:
Gaytri Soni
 Department of Agricultural,
 Chemistry and Soil Science,
 Junagadh Agricultural
 University, Junagadh, Gujarat,
 India

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

Gaytri Soni and Dr. SG Savalia

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Abstract

Globally salinity is a major 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 faster. Salt has a potentially 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 (V₁: GJP-1, V₂: Vaishali, V₃: BDN-2, V₄: 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 S₁ (Control). The quality parameters like protein content and test weight were found the highest in salinity level S₁ (Control).

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

Introduction

Salinity is one of the major obstacles to increasing production in coastal areas. Salinity stress delays the onset, reduces the speed and will increase the dispersion of germination events, leading to reduced plant growth and crop yield. Soil salinity adversely affects plant growth and development. Soluble salts within the soil ends up in diffusion stress, which ends up in specific particle toxicity and ionic imbalances and also the consequences of those often plant, are ending. Increasing crop salt tolerance could be an extremely enticing 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 assumed to be one among the factors responsible for the reduction of the biomass and yield elements of plants. High concentration of salt within the root zone (rhizosphere) reduces soil water potential and the availability of water. As a result of this, a reduction of the water content leading to dehydration at cellular level and osmotic stress is discovered.

High levels of salts within the soil will usually cause serious limitations to agricultural production. The major factors that contribute to the current drawback are the arid and semi-arid climates and also the use of salty irrigation water. The soil salinity could cause many harmful effects on growth and development of plants at physiological and biochemical level (Gorham *et al.*, 1985; Munns, 2002) [9, 130]. These effects are often thanks to low diffusion potential of soil solution, specific ion effects, nutritional imbalance or a combined result 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) [10, 11, 19] and photoperiod (Omanga *et al.* 1996) [16] emphasized that the result of temperature on the rates of pigeon pea development are often similar in magnitude to those of photoperiod. The optimum range of temperature for proper growth and development of pigeon pea is 18–38 °C, whereas the controlled environment showed that warm (42 °C) and cool (20 °C) temperature delay flower initiation and that the optimal temperature for flowering for early maturing type is close to 24 °C.

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, CaCO₃ 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 treatment 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 P₂O₅ @ 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.*, CaCl₂, MgSO₄, MgCl₂ 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:SO₄ was 4:1. The desired quantity of soil was spread on a polythene sheet in this layer and salt solution of different EC values was 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.



Fig 1: Experiment view at the stage of germination



Fig 2: Overall view of an experiment

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 S₁ (Control) and 47.09 g pot⁻¹ in variety V₄ (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 S₁ (Control) and 144.40 g plant⁻¹ in variety V₄ (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 S₁ (Control). The lowest days to 50% flowering was attained at salinity level S₁ (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 V₄ (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 V₃ (BDN-2). The lowest days to 50% flowering was obtained in variety V₄ (AGT-2). Significantly the highest value of protein content (22.62%) was observed in S₁ (Control), which remains statistically at par with S₂ 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 values 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 60 DAS (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 treatment

Discussion

The accumulation of salts in the root zone reduced absorption of water by roots of groundnut which suppress pod yield (Padole *et al.*, 1993) [17]. The herein reduction in yield due to

salinity effect are in harmony with previous investigations (Nayak *et al.*, 2001) [15] on Indian mustard. Dry weight of shoot decreased as shoot length declined after salinity levels increased, reported by Kaya and Ipak (2003) [12]. The straw

yield was limited during salinity stress primarily by the reduced turgor and limitations of the plant's capacity for osmoregulation study done by Alam *et al.* (2004) [2]. Nautiyal *et al.* (1989) [14] reported that the soils having Na⁺ salinity are not suitable for crops as germination percentage reduced. Anantharaju and Muthiah (2007) [4] reported that germination percentage decreased with an 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) [18]. The reason behind delay in the 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) [5]. High concentrations of sea salts stimulated increased flower shedding which ultimately reduced the effective number of pods (Vadez *et al.*, 2007) [20].

The negative effect of salinity on plants may provoke osmotic potential by salt in the culture medium, so root cells do not obtain the required water from the medium, resulting the production of pods per plant reduced under saline conditions (Golezani *et al.*, 2009) [8]. Reduced number of seeds per capsule under salinity might be due to less translocation of assimilates towards reproductive organ (Ali *et al.*, 2005) [3]. The effect of salt, water stress delayed maturity might lead to shriveled seeds and consequent the lowers test weight (Ahmed, 2009) [1].

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) [6]. 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) [7].

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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