RESEARCH ARTICLE

# INFLUENCE OF WATERLOGGING, SALINITY AND THEIR INTERACTION ON BIOMASS AND YIELD AND ITS ATTRIBUTES OF PIGEONPEA (*CAJANUS CAJANS* L. MILLSP.) GENOTYPES

**Savita Duhan[1]*, Sunita Sheokand[1], Anita Kumari[1], Sumanbala[1], Nidhi Sharma[2] and Poonam Kumari[1]**

[1]*Department of Botany & Plant Physiology, C.C.S. Haryana Agricultural University, Hisar - 125004 (Haryana)*
[2]*Department of Horticulture, College of Agriculture and Forestry at Rai Technology University, Kadanur - 561204, Bengaluru (Karnataka)*

*Received-27.01.2017, Revised-12.02.2017*

**Abstract:** The Influence of waterlogging, salinity and their interaction on biomass and yield and its attributes was studied in four pigeonpea genotypes (ICPH-2431, PARAS, UPAS-120, H09-33). Plants were raised in in polythene bags filled with half kg soil + FYM manure mixture. Waterlogging, salinity and waterlogging + salinity treatments were given for 8 and 12 days and observations were recorded 1 and 8 days after removal from treatment in 20 and 40 day old plants. A significant decline in percent survival, biomass, seed yield and seed test weight was observed with waterlogging and combined treatment of waterlogging and salinity. Alone salinity resulted in no decline in percent survival and comparatively less decline in biomass, seed yield and seed test weight. All the stresses were found more deleterious when given at later stages. ICPH 2431 performed best among all the genotypes in terms of percent survival, biomass, seed yield and seed test weight.

**Keywords:** Waterlogging, Salinity, Pigeonpea, Biomass, Seed yield

## INTRODUCTION

Pigeonpea is an important pulse crop of South Asia. Being a summer-rainy season crop, pigeonpea is exposed to waterlogging condition during germination and early vegetative growth phases. This is the crucial period, which determines the crop stand and ultimately crop growth and productivity (Kumutha *et al*., 2008). . Waterlogged plants are affected by various stresses, such as limitations to gas, mineral nutrient deficiencies and microelement toxicities (Setter and Waters, 2003; Setter *et al.*, 2009). Seed germination is very sensitive to waterlogging. Decrease in germination ability has been attributed to a shortage of oxygen due to waterlogging (Orchard and Jessop, 1984). About 0.28 million tons loss in pigeonpea has been reported annually due to waterlogging (ICRISAT Report, 2011). In India, where most of world's pigeonpea is produced, around 2.95 million hectares land is also affected by salinity and in Haryana 49.2 thousand hectares is affected by salinity (CSSRI, 2016). High concentrations of salt resulting from natural processes or disarrangement in irrigated agriculture result in inhibition of plant growth and yield (Demiral and Turkan, 2006). Germination of seeds, one of the most critical phases of plant life, is greatly influenced by salinity (Misra and Dwivedi, 2004). Higher level of salt stress inhibits the germination of seeds while lower level of salinity induces a state of dormancy (Khan and Weber, 2008). In recent years, an impressive amount of knowledge has accumulated on plant physiological and molecular responses to salinity or waterlogging stresses. However, studies dealing with the combined effects of these two stresses are much rarer and often controversial (Barrett-Lennard, 2003). Nonetheless, the occurrence of combined salinity and waterlogging stress is increasing throughout the world. This is due to intensive irrigation in agricultural production systems (Smedema and Shiati, 2002), rise of saline water tables (Hatton *et al*., 2003), and seawater intrusion in coastal environments (Carter *et al*., 2006). When combined with waterlogging, salinity can cause even greater damage to plants, so having a major impact on agricultural production (Barrett-Lennard, 2003). Therefore, the present investigations was undertaken to study the independent and interactive effects of waterlogging and salinity on biomass and yield and its attributes in pigeonpea genotypes.

## MATERIAL AND METHOD

Four genotypes were raised in polythene bags filled with half kg soil + FYM manure mixture (3 soil: 1manure v/v), NPK (@20:60:20 kg per ha). Twenty and forty days after sowing the pots were placed in cemented tanks (length 160 cm, breadth 125 cm and depth 65 cm). Waterlogging salinity (30 mM NaCl) and waterlogging + salinity (30 mM NaCl) treatments were given for 8 and 12 days and observations were recorded 1 and 8 days after removal from treatment.

**Statistical Design:** Factorial Randomized Design (4 Replications)

**Survival percentage:** After removal from the treatments the living plants were counted and expressed in the term of percent survival

*Corresponding Author

**Total plant biomass (g):**Three random plants of each genotype were collected from the pots, washed & its root, stem, leaves were separated and wrapped in a paper bag and was kept at room temperature for one day. Then these samples were dried in an oven at 70ºC till a constant weight was obtained.

**Yield and yield components**

**Seed yield per plant (g):** At the time of harvesting, the seeds of each plant were collected separately and weighed. The seeds weight was expressed in grams per plant.

**Test weight (g):** Hundred seeds were counted from each genotype and the weight was recorded in grams. This weight was recorded as test weight.

## RESULT AND DISCUSSION

**Percent survival**

A 40 to 50 % decline was observed in percent survival 1 DAR which further increased to 65 to 90 % 8 DAR (day after removal) from waterlogging (8 days) treatment in 20 days old plants. Twelve days waterlogging treatment was more deleterious and resulted in 50 to 75% decrease in percent survival 1 DAR which further increased to 100% 8 DAR. Salinity treatment alone had no deleterious effect and no decline in percent survival was observed. Waterlogging and salinity treatment in combination was more deleterious resulting in 70 to 80 % decrease in percent survival 1 DAR and 100 % 8 DAR from 8 days treatment. No survival was observed with 12 days waterlogging + salinity treatment 1 and 8 DAR from treatment (Table 5 A). Forty day old plants were more sensitive to waterlogging and waterlogging + salinity treatment resulting in 40 to 80% decrease 1 DAR was which further increased to 100% 8 DAR from 8 days waterlogging. No survival was observed with 12 days waterlogging and waterlogging + salinity treatment 1 and 8 DAR from treatment. No decline in percent survival was observed under salinity treatment also in 40 days old plants (Table 5 B). ICPH-2431 performed best under waterlogging and waterlogging + salinity treatments (8 days and 12 days) followed by PARAS, HO9-33 and UPAS-120 in 20 day as well as 40 day old plants . Kumutha *et al.,* (2008) reported in green gram that tolerant genotype MH96-1 did not show any mortality even after 8 days of waterlogging and recovery while susceptible genotype MH 1K- 24 showed more than 60% mortality during recovery after 8 days of waterlogging. The negative effects of salinity have been attributed to increase in $Na^+$ and $Cl^-$ ions in different plants hence these ions produce the critical conditions that affect plant survival by intercepting different plant mechanisms. Although both $Na^+$ and $Cl^-$ are the major ions which produce many physiological disorders in plants, $Cl^-$ is the most dangerous (Tavakkoli *et al.*, 2010). Not surprisingly, for most genotypes tested, there were adverse interactions between waterlogging and salinity on plant survival. Carter *et al.,* (2006) reported that the regulation of ions uptake and production of organic solutes (i.e. methyl proline) is related to combined salt and flood stress tolerance in some wetland plants.

**Table 1.** Effect of waterlogging, salinity and their combination (8 & 12 days) on survival percent (%) of pigeon pea genotypes

A) 20 DAS

| | 8day* (1 day)** | | | | 12day* (1 day)** | | | 8day* (8 day)** | | | | 12day* (1 day)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Genotype | C | W | S | W+S | W | S | W+S# | C | W | S | W+S# | W# | S | W+S# |
| ICPH 2431 | 100 | 58 | 100 | 35 | 50 | 100 | 0 | 100 | 38 | 100 | 0 | 0 | 100 | 0 |
| UPAS 120 | 100 | 46 | 100 | 19 | 24 | 100 | 0 | 100 | 15 | 100 | 0 | 0 | 100 | 0 |
| H09 33 | 100 | 47 | 100 | 26 | 41 | 100 | 0 | 100 | 21 | 100 | 0 | 0 | 100 | 0 |
| PARAS | 100 | 47 | 100 | 33 | 43 | 100 | 0 | 100 | 26 | 100 | 0 | 0 | 100 | 0 |

B) 40 DAS

| | 8day *(1 day)** | | | | 12day* (1 day)** | | | 8day* (8 day)** | | | | 12day* (1 day)** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Genotype | C | W | S | W+S | W# | S | W+S # | C | W# | S | W+S # | W# | S | W+S # |
| ICPH 2431 | 100 | 40 | 100 | 20 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 0 | 100 | 0 |
| UPAS 120 | 100 | 20 | 100 | 10 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 0 | 100 | 0 |
| H09 33 | 100 | 20 | 100 | 10 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 0 | 100 | 0 |
| PARAS | 100 | 30 | 100 | 20 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 0 | 100 | 0 |

* duration of treatment ** stage of sampling # no survival was observed

**Plant biomass:** Total plant biomass decreased with various treatments (Table 44 A and B). The decline in total plant biomass was 22.3 to 28.1% with W, 1.7 to 8.3% with S when given for 8 days and 5.0 to 15.6% with S treatment when given for 12 days in 20 day old plants. Maximum decline in plant biomass was observed in UPAS 120 with all treatments and minimum decline was observed in ICPH 2431. No plant survived 8 DAR from 8 days combined treatment, 12 days waterlogging and 1 and 8 DAR from 12 days combined treatment in 20 day old pigeonpea plants. Forty day old plants recorded a higher decline of 4.1 to 15.6% and 9.9 to 25.0% in 8 days and 12 days treatment respectively. No survival was observed 8 DAR from 8 days and 1 and 8 DAR from 12 days waterlogging and waterlogging + salinity treatment in 40 day old pigeonpea plants. Maximum decline was observed in UPAS 120 followed by HO9 33, PARAS and minimum in ICPH 2431. Kumutha *et al.,* (2009) also reported in pigeonpea genotypes that total dry matter decreased with different durations of waterlogging, and greater reduction over control was recorded in Pusa 207 (sensitive) than ICP 301 (tolerant). According to Munns, (2002), salt stress decreases growth in most plants and these plants are not able to produce their maximum biomass. Zeng *et al.,*(2013) reported that two weeks of combined salinity and waterlogging treatment significantly decreased plant biomass in two barley genotypes, CM72 and Naso Nijo.

**Table 2.** Effect of waterlogging, salinity and their combination (8 & 12 days) on biomass/plant (g) of pigeonpea genotypes (at harvest)

A) 20 DAS

| **Genotype** | **C** | **W(8)*** | **S (8)*** | **S (12)*** | **Mean** |
|---|---|---|---|---|---|
| ICPH 2431 | 12.1 | 9.4 | 11.9 | 11.5 | 11.2 |
| UPAS 120 | 9.6 | 6.9 | 8.8 | 8.1 | 8.4 |
| HO9 33 | 10.2 | 7.6 | 9.6 | 9.1 | 9.1 |
| PARAS | 11 | 8.2 | 10.6 | 10 | 10 |
| Mean | 10.7 | 8 | 10.2 | 9.7 | |
| C.D. at 5 % | T- 0.55 , G- 0.55, TXG-N.S. | | | | |

B) 40 DAS

| **Genotype** | **C** | **S (8)*** | **S (12)*** | **Mean** |
|---|---|---|---|---|
| ICPH 2431 | 12.1 | 11.6 | 10.9 | 11.5 |
| UPAS 120 | 9.6 | 8.1 | 7.2 | 8.3 |
| HO9 33 | 10.2 | 9.1 | 8.2 | 9.2 |
| PARAS | 11 | 10.2 | 9.2 | 10.1 |
| Mean | 10.7 | 9.8 | 8.9 | |
| C.D. at 5 % | T- 0.55, G- 0.64, TXG- N.S. | | | |

*duration of treatment

**Yield and it's attributes**

**Seed test weight (100 seeds weight):** A decline of 11.0 to 22.7% was observed in seed test weight (Table 45 A and B ) under 8 days W and 6.1 to 12.0% decline was observed under 8 days S treatment which further increased to 8.5 to 33.3% when S treatment was given for 12 day in 20 day old plants. No plant survived 8 DAR from 8 days combined treatment, 12 days waterlogging and 1 and 8 DAR from 12 days combined treatment in 20 day old pigeonpea plants. No plant survived 8 DAR from 8 days combined treatment, 12 days waterlogging and 1 and 8 DAR from 12 days combined treatment in 20 day old pigeonpea plants. The seed test weight decreased from 11.0 to 18.1% with S (8 days) and 14.6 to 40.0% with S (12 days) treatments in 40 day old plants. No survival was observed 8 DAR from 8 days and 1 and 8 DAR from 12 days waterlogging and waterlogging + salinity treatment in 40 day old pigeonpea plants. Maximum decline was observed in UPAS 120 and minimum in ICPH 2431. Vania *et al.*, (2015) reported decline in seed test weight of rye under waterlogging stress. Decrease in seed test weight under salinity treatment was observed in several crops like soybean (Mannan *et al.*, 2013), wheat (Kumar *et al.*, 2012). Ibrahim *et al*., (2007) observed decline in seed test weight in wheat varities when subjected to saline flooding having 50 mM NaCl for 2 days.

**Table 3.** Effect of waterlogging, salinity and their combination (8 & 12 days) on seed test weight/plant (g) pigeonpea genotypes (at harvest)

A) 20 DAS

| **Genotype** | **C** | **W(8)*** | **S (8)*** | **S (12)*** | **Mean** |
|---|---|---|---|---|---|
| ICPH 2431 | 8.2 | 7.3 | 7.7 | 7.5 | 7.7 |
| UPAS 120 | 7.5 | 5.8 | 6.6 | 5 | 6.2 |

| | | | | | |
|---|---|---|---|---|---|
| HO933 | 7.8 | 6.2 | 7 | 6.5 | 6.9 |
| PARAS | 8.1 | 6.3 | 7.4 | 7 | 7.2 |
| Mean | 7.9 | 6.4 | 7.2 | 6.5 | |
| C.D. at 5% | T- 0.70, G- 0.70, TXG- N.S. | | | | |

B) 40 DAS

| **Genotype** | **C** | **S (8)*** | **S (12)*** | **Mean** |
|---|---|---|---|---|
| ICPH 2431 | 8.2 | 7.3 | 7 | 7.5 |
| UPAS 120 | 7.5 | 6.1 | 4.5 | 6 |
| HO9 33 | 7.8 | 6.4 | 5.9 | 6.7 |
| PARAS | 8.1 | 6.9 | 6.7 | 7.2 |
| Mean | 7.9 | 6.7 | 6 | |
| C.D. at 5% | T- 0.71, G- 0.82, TXG- N.S. | | | |

*duration of treatment

**Seed yield per plant:**The seed yield per plant decreased with W and S treatments (Table 46 A and B). The seed yield per plant declined from 27.4 to 61.5% with W, 18.5 to 33.0% with S 1 DAR from S 8 days treatments. Maximum decline in yield per plant was observed in (UPAS 120) 61.5% with W (8 days) and 33.0 % with S (8 days) and minimum decline was observed in (ICPH 2431) 27.4% with W (8 days) treatment and 18.5% with S (8 days) in 20 day old plants. Salinity treatments had more adverse effect on seed yield when given for 12 days with 23.5 to 52.7% decline in 20 day old plants. No plant survived 8 DAR from 8 days combined treatment, 12 days waterlogging and 1 and 8 DAR from 12 days combined treatment in 20 day old pigeonpea plants. A decline of 22.0 to 35.1% was observed in seed yield under 8 days S treatment which further increased to 30.8 to 62.2 under 12 days S treatment in 40 day old plants. No survival was observed 8 DAR from 8 days and 1 and 8 DAR from 12 days waterlogging and waterlogging + salinity treatment in 40 day old pigeonpea plants. Maximum decline was observed in UPAS 120 and minimum decline was observed in ICPH 2431 under S treatment also in 40 day old plants. Vania *et al.*, (2015) reported decline in seed yield per plant of rye under waterlogging stress. Kumar *et al.*, (2012) studied the effect of salinity on yield attributes of wheat genotypes and observed that grain yield per plant significantly reduced by 40 % and 34 % due to salinity > 3 dsm-1. Genotypes K9006, K8434, KRL1-4, K88 and HD 2733 showed better tolerance against higher levels of salinity. Nasher, (2013) reported decline in seed yield under combined waterlogging and salinity.

**Table 4.** Effect of waterlogging, salinity and their combination (8 & 12 days) on seed yield/plant (g) of pigeonpea genotypes (at harvest)

A) 20 DAS

| **Genotype** | **C** | **W(8)*** | **S (8)*** | **S (12)*** | **Mean** |
|---|---|---|---|---|---|
| ICPH 2431 | 5.87 | 4.24 | 4.77 | 4.47 | 4.9 |
| UPAS 120 | 5.26 | 1.98 | 3.5 | 2.45 | 3.4 |
| HO9 33 | 5.43 | 2.2 | 3.78 | 2.56 | 3.6 |
| PARAS | 5.54 | 3.43 | 4.74 | 4.05 | 4.5 |
| Mean | 5.6 | 3 | 4.3 | 3.5 | |
| C.D. at 5% | T- 0.91, G- 0.91, TXG- N.S. | | | | |

B) 40 DAS

| **Genotype** | **C** | **S (8)*** | **S (12)*** | **Mean** |
|---|---|---|---|---|
| ICPH 2431 | 5.87 | 4.56 | 4.04 | 4.9 |
| UPAS 120 | 5.26 | 3.38 | 1.94 | 3.6 |
| HO9 33 | 5.43 | 3.5 | 1.98 | 3.7 |

| | | | | |
|---|---|---|---|---|
| PARAS | 5.54 | 4.23 | 3.13 | 4.4 |
| Mean | 5.6 | 4 | 2.9 | |
| C.D. at 5% | T- 0.91, G- N.S., TXG- N.S. | | | |

*duration of treatment

**CONCLUSION**

This results suggest that waterlogging and salinity in combination is more deleterious to plants of pigeonpea as compared to these stresses alone and resulted in more decline in percent survival, biomass, seed yield and seed test weight both in tolerant and sevsitive genotypes. Salinity alone resulted in minimum decline in percent survival, biomass, seed yield and seed test weight. All the three stresses are more deleterious when given at later stages of growth. ICPH 2431 performed best among all the genotypes in terms of percent survival, biomass, seed yield and seed test weight.

**REFERENCES**

**Barrett-Lennard, E.G.** (2003). The interaction between waterlogging and salinity in higher plants, causes, consequences and implications. Plant and Soil. 253: 35–54.

**Carter, J.L.; Colmer, T.D. and Veneklaas, E.J.** (2006). Variable tolerance of wetland tree species to combined salinity and waterlogging is related to regulation of ion uptake and production of organic solutes. New Phytologist, 169: 123-134.

**CSSRI** (2016). Extent and distribution of salt affected soils in India, Central Soil Salinity Research Institute Karnal, Haryana, India.

**Demiral, T. and Turkan, I.** (2006). Exogenous glycine betaine affects growth and proline accumulation and retards senescence in two rice cultivars under NaCl stress. Environmental and Experimental Botany, 56: 72-79.

**Hatton, T.J.; Ruprecht, J. and George, R.J.** (2003). Preclearing hydrology of the Western Australia wheat belt, target for the future. Plant and Soil. 257: 341-356.

**Ibrahim, K.M.; Wright, D.; Mirbahar, R.B. and Panhwar, M.** (2007). Effects of salinity and waterlogging on ion uptake and growth of wheat varieties. Pakistan Journal of Botany, 39(7): 2535-2540.

**ICRISAT, Half-Yearly Progress Report, June - December** (2011). Selection and Utilization of Water-logging Tolerant Cultivars in Pigeonpea.

**Kumar, R.; Singh, M.P. and Kumar, S.** (2012). Effect of salinity on germination, growth, yield and yield attributes of wheat. International Journal of Scientific and Technology Research, 1(6): 19-23.

**Kumutha, D.; Ezhilmathi, K.; Sairam, R.K.; Srivastava, G.C.; Deshmukh, P.S. and Meena, R.C.** (2009). Waterlogging induced oxidative stress and antioxidant activity in pigeonpea genotypes. Biologia Plantarum. 53(1): 75-84.

**Kumutha, D.; Sairam, R.K. and Meena, R.C.** (2008). Role of root carbohydrate reserves and their mobilization in imparting waterlogging tolerance in green gram (Vigna radiata (L.) Wilczek) genotypes. Indian Journal of Plant Physiology, 33: 735-744.

**Mannan, M. A.; Karim, M. A.; Haque, M. M.; Khaliq, Q. A.; Higuchi, H. and Nawata, E.** (2013). Response of soybean to salinity: II. Growth and yield of some selected genotypes. Tropical Agriculture and Development, 57(1): 31- 40.

**Misra, N. and Dwivedi, U.N.** (2004). Genotypic difference in salinity tolerance of green gram cultivars. Plant Science, 166: 1135-1142.

**Munns, R.** (2002). Comparative physiology of salt and water stress. Plant Cell and Environment, 25: 239-250.

**Nashar, W.Y.E.** (2013). The combined effect of water-logging and salinity on crops yield IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)

**Orchard, P.W. and Jessop, R.S.** (1984). The response of sorghum and sunflower to short term waterlogging. I. Effects of stage of development and duration of waterlogging on growth and yield. Plant and Soil, 81: 119-132.

**Setter, T.L. and Waters, I.** (2003). Review of prospects for germplasm improvement for waterlogging tolerance in wheat, barley and oats. Plant and Soil., 253: 1-34.

**Setter, T.L.; Waters, I.; Sharma, S.K.; Singh, K.N.; Kulshreshtha, N.; Yaduvanshi, N.P.S.; Ram, P.C.; Singh, B.N.; Rane, J.; McDonald, G.; Khabaz-Saberi, H.; Biddulph, T.B.; Wilson, R.; Barclay, I.; McLean, R. and Cakir, M.** (2009). Review of wheat improvement for waterlogging tolerance in Australia and India, the importance of anaerobiosis and element toxicities associated with different soils. Annals of Botany, 103: 221-235.

**Smedema, L.K.. and Shiati, K.** (2002). Irrigation and salinity, a perspective review of the salinity hazards of irrigation development in the arid zone. Irrigation and Drainage Systems, 16: 161-174.

**Tavakkoli, E.; Rengasamy, P. and McDonald, G.K.** (2010). High concentrations of $Na^+$ and $Cl^-$ ions in soil solution have simultaneous detrimental effects on growth of faba bean under salinity stress. Journal of Experimental Botany, 61: 4449-4459.

**Vania, M.G.; Tiago, P.; Emanuela, G.M.; Tiago, Z.A. and Francisco, A.V.** (2015). Effect of soil waterlogging stress on the physiological performance of seeds and on the productivity of rye plants. Agrociencia Uruguay, 19(1): 41-47.

**Zeng, F.; Shabala, L.; Zhou, M.; Zhang, G. and Shabala, S.** (2013). Barley responses to combined waterlogging and salinity stress, separating effects of oxygen deprivation and elemental toxicity. Frontier in Plant Science, 4: 1-13.