Journal of AgriSearch, 9 (3): 201-207
An Open Access International Peer Reviewed Quarterly

ISSN : 2348-8808 (Print), 2348-8867 (Online)
https://doi.org/10.21921/jas.v9i03.11002

Development of waterlogging tolerant lines of pigeonpea for Eastern India

ANIL KUMAR SINGH, ASHUTOSH UPADHYAYA, ARBIND K CHOUDHRY, KIRTI SAURABH, PAWAN JEET, MONOBURALLAH AND PK SUNDARAM

ABSTRACT

Pigeonpea is very sensitive to waterlogging. At pan India level, approximately 25-30 per cent area of pigeonpea is prone to excess moisture stress. A total of 63 germplasms/genotypes were evaluated along with IPAC-79 as the waterlogging tolerant check under controlled partial submergence condition and under waterlogged field condition for selection of waterlogging tolerant pigeonpea lines. Data were recorded for survivability, days to anthesis, per plant seed yield and maturity period. Pigeonpea genotypes ICAR PP 01, ICAR PP 02 and ICAR PP 03 were found promising. ICAR PP 01 produced highest biomass per plant (746.5g), pods/plant (924.6) and seed yield per plant (151g). The genotype ICAR PP 01 took minimum number of days for anthesis (124 days) and maturity (197days), whereas the check variety IPAC-79 recorded maximum number of days to anthesis (201 days) and maturity (255 days).

Keywords: Pigeonpea, waterlogging tolerance, survivability, biomass, seed yield

ARTICLE INFO

Received on	:	18/07/2022
Accepted	:	07/09/2022
Published online	:	30/09/2022

INTRODUCTION

India is largest producers, consumer and importer of pulses, obviously due to major portion of its population is still vegetarian and heavily depends upon pulses for their dietary protein (Arumugam *et al.*, 2018 and Singh *et al.*, 2015). Pigeonpea is the one of the most important legume/pulses, contributed 7.70% to total world area, and its share to World pulses production is 6.50%. Mostly planted in semi-arid areas, it does well in all environments with the exception of waterlogged soil, excessive moisture, and saline, alkaline soil. It is grown predominantly in 21 nations between latitudes of 14° and 30°, where the average annual rainfall is between 600 and 1500 mm. (Anonymous, 2013 and Choudhary *et al.*, 2020). India is the world's leading producer of pigeonpeas, accounting for two thirds of global production and 80 percent of global area (occupies first place in area). During 2016-17, pigeonpea was grown in 5.34 million ha area, with a production of 4.87 million tonne and the average productivity of pigeonpea was 913 kg/ha (Anonymous, 2018). Eastern state like Eastern part of Uttar Pradesh, Bihar, Jharkhand, Assam, and West Bengal are more prone to water logging or excess moisture as compare to other norther poor southern Indian pigeonpea growing states ((Anonymous, 2016, Choudhary *et al.*, 2011; Singh *et al.*, 2015). This crop is highly susceptible to waterlogging at any stage and frost and excess rain during winter flowering.

About 1.1 million ha of its acreage is affected by excess soil moisture, causing an annual loss of 25-30% (Choudhary *et al.*, 2011; and Choudhary *et al.*, 20120). In addition to affecting pigeonpea during germination, early and late seedling development, and flowering phases, excessive rain, soil moisture, and waterlogging have the ability to harm a crop at any stage of its life cycle (Fukao and Bailey, 2004; Krishnamurthy *et al.*,2012 and Yasin *et al.*, 2019). However, germination, early and late seedling stages are considered to be most critical crop growth, as these stages coincides during peak monsoon period. These three critical stages can be used for screening of tolerant pigeon pea lines for above said traits (Khare *et al.*,2022; Sairam *et al.*,2008 and Bansal and Srivastava, 2012).

Waterlogging is most likely to occur in low-lying locations. Some pigeonpea varieties are sensitive to waterlogging, while others are highly tolerant of it. The main cause of damage is suffocation which the plant has to face due to waterlogging. Oxygen deficiency causes electrolyte leakage due to which the cell is exposed to the outside environment which can also cause peroxidation of lipid and nucleic acid and ultimately death (Kumutha *et al.*, 2008; Sairam *et al.*, 2008). So, any mechanism that can reinstate oxygen supply to stressed tissue can be a major trait for waterlogging tolerance. Lenticels, adventitious roots, and the development of *aerenchyma* are all beneficial in helping waterlogged plants get access to oxygen. In addition to their development, pigeonpea plants undergo a range of biochemical modifications that help them tolerate waterlogging. Increasing reducing sugars, fermentation and glycolysis enzyme activity, as well as antioxidant participation, are examples of biochemical alterations (Asada, 2016; Blokhina *et al.*, 2003 and Chaudhary *et al.*, 2017). Glycolytic enzymes include alcohol dehydrogenase and sucrose synthase. The antioxidant system includes enzymatic and non-enzymatic antioxidants. Superoxide dismutase, catalase peroxidase, ascorbate peroxidase, and glutathione peroxidase are examples of enzymatic antioxidants, whereas ascorbate and glutathione fall under the category of non-enzymatic antioxidant defence system (Blokhina *et al.*, 2003; Bansal and Srivastava, 2012). Empirical evidences suggest that excess rain / soil moisture and waterlogging speed up rapid senescence and cause their shoot tips to droop. It not only reduces the plant height and delays flowering in surviving plants, but it also reduces the number of pods, the number of seeds per pod, and eventually the seed yield (Aarzoo *et al.*, 2017). It has been observed that seed coat thickness, *Aerenchymatous* cells, lenticels and adventitious roots also

ICAR Research Complex for Eastern Region Patna, India
*Corresponding Author E-mail: anil.icarpat@gmail.com

affect tolerance to waterlogging in pigeonpea. However, before they can be utilised as selection criteria in pigeonpea, these features must be validated yet again (Aarzoo *et al*., 2017; Kumutha *et al*.,2008 and Sairam *et al*.,2008). Previous study revealed that excess moisture /waterlogging tolerance is a dominant trait and is governed by a single gene. Therefore, it can easily be transferred by backcrossing to leading varieties, which are sensitive to waterlogging (Duhan *et al*., 2017). One of the key pigeonpea-growing states in India is Bihar. However, the cultivated area with pigeonpea has decreased over time. Due to its extreme sensitivity to waterlogging and ability to endure waterlogging for an extended period of time, one possible explanation for this decline is the lack of a genotype that is appropriate for tolerating excessive moisture (Anonymous, 2018, Choudhary *et al*., 2011 and Perera *et al*., 2011). Approximately 25-30 per cent area of pigeon pea are prone to excess moisture stress. Decent work has been done on the genotype development with respect to excess moisture tolerant. However, with little success, the majority of the study has focused on development of long duration genotypes (Choudhary *et al*., 2011 and Perera *et al*., 2011; Duhan *et al*., 2017). There are few medium- to short-duration cultivars that can withstand excessive /water logging for about 96 hours. An experiment to develop pigeonpea genotypes for high moisture/high rainfall area conditions has been conducted since 2019–20 to address this problem. As a result, a detailed assessment of the pigeon pea lines at the ICAR RCER Patna was carried out with the aforementioned considerations in mind.

MATERIALS AND METHODS

Since water logging is one of the limiting factors to pigeonpea production. To address this issue, an experiment was undertaken after two consecutive years (2019-20 and 2020-21) of evaluation of pigeonpea lines at ICAR Research Complex for Eastern Region (25°35'27'' N, 85°04'54'' E and 51 m AMSL), Patna, India. The evaluation site for this experiment was low lying area surrounded by rice field.

Development of pigeonpea genotypes at ICAR RCER Patna

Promising segregating materials from F_4 progenies of F_1 of selected crosses between (IC33671 x Palamedu local) were further advanced at ICAR RCER Patna, and selection process from each stage were targeted for water logging tolerance, short duration determinate high yielding accession. Parent, IC-33671 is short duration pigeonpea race collected from Maharastra by ICAR-NBPGR Regional Station Akola during 1979. This germplasm was collected from National Gene Bank, NBPGR India. Whereas Palamedu local genotype was collected from Tamil Nadu. It is an early maturing short stature and determinate type pigeonpea genotype during 2014 (Arumugam *et al*., 2018). Segregating population was maintained as open pollinated to induce more variations. The resultant high yielding lines were evaluated for its waterlogging / patrial submergence tolerance, short duration, determinate and high yielding traits. Five pigeonpea lines namely ICAR PP-1, ICAR PP-2, ICAR PP-3, ICAR PP-4 and ICAR PP-5, were identified (Anonymous, 2021).

Three pigeonpea lines (*i.e.*, ICAR PP-01 ICAR PP-02 and ICAR PP-03) tolerant to excess moisture stress were identified after two years of preliminary characterizations and evaluation at ICAR Research Complex for Eastern Region, Patna. Based on the encouraging results of the previous two years, 60 more pigeonpea genotypes from the ICAR- Indian Institute of Pulses Research Kanpur, ICAR-NBPGR Regional Station, Akola, and ICAR-NBPGR New Delhi were evaluated in the field and under controlled conditions (**Table 1**).

Table 1: Pigeonpea genotypes evaluated for partial submergence tolerance

A-95-12	Banda Polo RA	IC 28198
AKP-10/23	Collection No17	IC 28199
AKP-10/40	Collection No11	IC 28201
AKP-10/20	IPAC-79 (INGR20023)	IC 28203
AKP-10/3	ICAR PP-01	IC 28206
AKP-2/3	IPA 203	IC 28207
AKP-AA5/50	NDT-5 Orange	IC 28209
AKP-KR/5/40	NDT-1	IC 28228
AKP-KR/5/45	DT-6	IC 32890
AKP-PNP 8/65	UPAS-120	IC 32955
AKP-PNP 8/71	Maruti	IC 33018
AKP-PNP 8/27	MA-06	IC 33069
AKP-PNP 8/34	MAL-13	IC 33725
AKP-PNP 8/5	PUSA-16	IC 33726
AKP-PNP 8/55	ICP 9521	IC 34504
AKP-PNP 8/74	ICP 9524	ICP 9228
AKP-PNP 8/76	ICP 9555	ICP 9353
AKP-PNP 8/86	ICP 9595	ICP 9397
B-7	ICAR PP-02	ICP 9516
Bahar	ICP 9518	ICAR PP-03
Bahar-1	ICP 9518	ICP 9519

Protocol used for screening of genotypes

Pigeonpea lines were evaluated for its waterlogging tolerance as per the method given below.

Systematic evaluation of pigeonpea lines

Three pigeonpea lines developed by the ICAR Research Complex for the Eastern Region Patna were examined for their ability to withstand waterlogging with 60 other germplasm lines under controlled conditions, and the germplasm lines that performed the best were then tested in the field.

Pigeonpea evaluation under controlled conditions

All together 63 germplasms/genotypes of pigeonpea including three lines of ICAR Research Complex for Eastern Region Patna, namely ICAR PP-01, ICAR PP-02 and ICAR PP-03, were tested along with IPAC-79 (Check line), under controlled submergence environment to evaluate their excess moisture tolerant ability (**Table 1 and Fig. 1a &1b**). Pigeonpea germplasms i. e. IPAC-79 (Registration No. INGR20023), has been registered by ICAR Indian Institute of Pulses Research, Kanpur for their excess moisture tolerant traits. Controlled condition testing and evaluation were done in the artificially established two-foot-deep seepage proof submergence pond.

Each pot was placed in the partial submergence pond with four seedlings or plants of each genotype (Chauhan *et al.*, 2017).

Fig. 1a: Pigeonpea genotypes in pots for evaluation under control conditions

Fig. 1b: Pigeonpea genotypes pot after submergence treatment

Submergence schedule and duration

Selected genotypes of pigeonpeas were tested for submergence tolerance in a controlled environment using 15-day-old seedlings cultivated in pots. Pots containing pigeon pea seedlings were submerged in such a way that at least 5 cm water is maintained for the whole submergence period of each cycle as per the duration prescribed for particular cycle of submergence as mentioned in the **Table 2**. Three different sets of submergence circumstances, ranging from 120 hours (5 days) to 168 hours, were used to test all 63 pigeonpea genotypes (7days). Each set of submergence treatment has two cycles of submergence as per given schedule (**Table 2**). Subsequent second cycle of submergence was imposed to the survived genotypes, after two weeks of first cycle.

Table 2: Schedule of submergence cycle and duration

Subset description	First cycle of submergence	Second cycle of submergence
Subset 1	120 hrs (5 days)	168 hrs (7 days)
Subset 2	168 hrs (7 days)	120 hrs (5 days)
Subset 3	168 hrs (7 days)	168 hrs (7 days)

RESULTS AND DISCUSSION

Data was evaluated to identify better performing accessions over the registered check *i.e.,* IPAC-79 used in the evaluation of water logging tolerance in pigeonpea.

Screening of pigeonpea genotypes against excess moisture tolerance

Pigeonpea survival data were recorded for every cycle and each set of submergence treatment (**Table 3**). Only genotypes with survival rates greater than 50% following the successful completion of the second cycle of submergence were the subject of the data provided (**Fig. 2**). ICAR PP 01 was identified as best performing genotypes under controlled submergence with 81.25% and 68.75% of survival rate after first and second cycle of submergence, respectively, whereas IPAC-79 Check survival shown only 50% survival rate (**Table 3**).

Table 3: Best performing genotypes under controlled submergence (Set 3)

Genotype	First cycle of submergence (168 hrs or 7days)	Second cycle of submergence (168 hrs or 7days)
ICAR RCER PP 01	81.25	68.75
ICAR RCER PP 02	75.0	62.25
ICAR RCER PP 03	70	60.25
ICP 9353	68.75	56.25
ICP 9516	68.75	56.25
ICP 9228	62.50	56.25
ICP 9397	56.25	50.00
IPAC-79 (Check)	56.25	50.00

Fig.2a: Performance pf pigeonpea submergences after first and second cycle of submergence subset 1

Fig.2b: Performance pf pigeonpea submergences after first and second cycle of submergence subset 2

Fig.2c: Performance pf pigeonpea submergences after first and second cycle of submergence subset 3

Fig.2: Screening of pigeonpea genotypes-controlled submergence

Field evaluation of promising pigeonpea line

In the current study, genotypes of pigeonpea were evaluated based on their capacity to withstand repeated exposure to water stress for 168 hours (7 days) of partial submergence separated by two weeks. Best performing pigeonpea genotypes having survival percentage more than 50 under controlled partial submergence (subset 3) has been promote for real field evolution. Pigeonpea genotypes that were discovered to be reasonably tolerant to excessive moisture in a controlled environment were evaluated again in the field for additional analysis and multiplication. Genotypes evaluated under waterlogged field conditions were ICAR PP 01, ICAR PP 02, PP 03, ICP 9353, ICP 9516, ICP 9228, ICP 9397 and IPAC-79 (Check (**Fig. 3**).

Fig. 3: Eavluation of excess moisture tollerent genotypes under filed conditions

Table 4: Biometric of best surviving pigeonpea lines under filed conditions

Genotype	PHT (CM)	Branching (No)	Days to anthesis	Gestation period (Days)*
ICP 9397	97.8	15.9	152	231
ICP 9228	123.6	24.2	143	221
ICP 9353	130.6	26.8	163	237
ICP 9516	111.2	17.3	179	244
ICAR PP 01	137.7	39.6	124	197
ICAR PP 02	83.3	32.3	135	207
ICAR PP 03	99.8	28.5	139	212
IPAC-79	108.5	13.5	201	265
*Date of second picking				

Growth and gestation period of promising genotypes

Data were recorded on plant height and number of effective branching at the time of final harvest. The genotype ICAR PP 02 had the shortest stature (83.3 cm), while the genotype ICAR PP 01 had the tallest height (137.7 cm). In case of branching genotype IPAC-79 has produced only 13.5 branch per plant, however highest number of branches per plant (39.6) was produced by ICAR PP 01 (**Table 4**). Data pertaining to Days to anthesis and Gestation period (Days) revealed that ICAR PP 01 took minimum 124 days and 197days for anthesis and maturity, respectively, whereas check variety IPAC-79 had taken 201 days and 255 for anthesis and maturity respectively (**Table 4**). Present evaluation clearly indicated that ICAR PP 01, ICAR PP 02, and ICAR PP 03 lines completed their effective seed production in a shorter period of time. These lines not only entered anthesis faster, but also finished second pod picking/harvesting in less time. After a fortnight since the first picking, the second pod picking was conducted.

Performance of best surviving pigeonpea lines under filed conditions

The results of evaluating pigeonpea lines in the field showed that genotype ICAR PP 01 produced the maximum biological weight (746.5g), number of pods per plant (924.6), and number of seed per plant (g) (151g). Whereas check variety IPAC -79 produced biological weight of 327.5g, 53.5 no of pod/plant and 17.3 g of seed per plants. IPAC-79 recorded a maximum 100 seed weight of 9.65g , whereas ICAR PP 01 recorded a maximum of 9.58g (**Table 5**).

Table 5: Yield attributes and seed yield of best surviving pigeonpea lines under filed conditions

Genotype	Biological Weight (g/plant)	No of Pods/plant	No of Seed /plant	Pod weight (g/plant)	Seed weight (g/plant)	100 seed weight (g)
ICP 9397	91.3	97.3	195.7	31.6	16.1	9.21
ICP 9228	263.6	333.0	905.4	105.6	62.4	8.86
ICP 9353	240.5	332.0	764.7	114.0	58.8	9.56
ICP 9516	212.9	91.1	229.2	32.2	17.8	9.02
ICAR PP 01	746.5	924.6	2373.8	383.8	151.1	9.58
ICAR PP 02	327.5	904.0	881.5	240.0	107.5	9.31
ICAR PP 03	178.3	397.3	495.7	181.6	96.1	9.23
IPAC-79	327.5	53.5	150.5	22.1	17.3	9.65

Biotic stress observation

It was observed that no significant incidence of diseases or insect pests were documented during the course of experiments in pod culture for all the evaluated pigeonpea lines as well as for biotic stress. However, aphid incidence was noted in IPAC-79, a water-logging resistant line (Fig. 4a). Similar Yellow Vein Mosaic Virus (YVMV) incidences were detected in germplasm line ICP 9228 only during the years 2021–2022, under controlled conditions. All the tested pigeonpea lines were also screened for biotic stress and it was notice that, no major incidence of diseases or insect pests were recorded during the course of investigations in pod culture. However aphid incidence were recorded in water logging resistant line i.e. IPAC-79 (**Fig. 4a**). Similaraly Yellow vein mosaic virus (YVMV) incidence were observed in germplasm line ICP 9228 under filed conditions only **Fig. 4b**) during 2021-22.

Further, systematic multilocation evaluation of these promising pigeonpea lines will carried out at different location in the eastern States of India. For data analysis modified augmented design (MAD) a type 2 data analysis will be employed (You et al., 2013).

CONCLUSION

Based on three years of research screening different pigeonpea lines for their tolerance to waterlogging and excess moisture, it can be said that ICAR PP 01, ICAR RCER PP 02, and RCER PP 03 were superior to other pigeonpea lines tested, including registered check line IPAC-79 developed by ICAR IIPR Kanpur, India, in terms of survival, seed production, gestation period, and biotic stress tolerance as well.

ACKNOWLEDGEMENT

Pigeonpea genotypes use in this study has been supplied by ICAR- Indian Institute of Pulses Research Kanpur, ICAR-NBPGR Regional Station, Akola and ICAR-NBPGR, New Delhi are duly acknowledged.

Fig. 4a: Aphid infestation IPAC-79

Fig. 4b: Yellow vein mosaic virus disease in ICP 9228

REFERENCES

Aarzoo Q, Vijay P and Narsi Ram J. 2017. Response of pigeonpea (*Cajanus cajan* L. millsp.) genotypes under water logging stress. *Int J Agri Sci* **9**(25):4308–4310.

Anonymous. 2013. FAO.2013. https://www.fao.org/faostat/en/

Anonymous. 2021. Annual Report2021-22 ICAR Research Complex for Eastern Region Patna, India pp 121-122

Anonymus.2016. https://nfsm.gov.in/StatusPaper/Pulses2016.pdf

Anonymus.2018. https://agricoop.gov.in/sites/default/files/agristat-glance2018.pdf

Arumugam M, Pillai M A, Jayapradha C, Chaudhary S, Mishra BK, Velayutham G, Verma N, Singh N, Vanniyarajan C, Thangahemavathy, Nagaraja A, Singh AK and Yasin JK. 2018. DG (RG) 55- High yielding short duration dwarf line of pigeonpea. *Journal of AgriSearch* **5** (1): 5-7.

Asada K.2006. Production and scavenging of reactive oxygen species in chloroplasts and their functions. *Plant Physiol* **141**:391–396.

Bansal R and Srivastava JP. 2012. Antioxidative defense system in pigeonpea roots under waterlogging stress. *Acta Physiol Plant* **34**:515–522

Blokhina O, Virolainen E and Fagerstedt KV.2003. Antioxidants, oxidative damage and oxygen deprivation stress: a review. *Ann Bot.* **91**(2):179–194.

Chaudhary S, Singh AK and Yasin JK. 2017. Metallothionein: Protein structure prediction and sequence analyses in pigeon pea (*Cajanus cajan*). *Journal of AgriSearch* **4** (4): 276-279.

Chauhan YS, Silim SN, Rao JK and Johansen CA. 1997. Pot technique to screen pigeonpea cultivars for resistance to waterlogging. *Journal of Agronomy and Crop Science*. **178**(3):179-83.

Choudhary AK, Kumar Rakesh, Saxena KB and Singh AK. 2020. Post-rainy season pigeonpea holds promise for the diversification of cropping systems. *Journal of AgriSearch* **7**(3):115-120.

Choudhary AK, Sultana R., Pratap A, Nadarajan N and Jha UC. 2011. Breeding for abiotic stresses in pigeon-pea. *Journal of Food Legumes.* **24** :165–174.

Duhan S, Kumari A and Sheokand S.2017. Effect of waterlogging and salinity on antioxidative system in pigeonpea plant leaves at different stages of development. *Res Crops* **18**(3):559–568.

Fukao T and Bailey-Serres J.2004. Plant responses to hypoxia—is survival a balancing act. *Trends Plant Sci* **9**:449–456.

Khare D, Rao S, Lakhani JP and Satpute RG. 2002.Tolerance for flooding during germination in pigeonpea. *Seed Research*. **30**:82-7.

Krishnamurthy L, Upadhyaya HD, Saxena KB and Vadez V.2012. Variation for temporary waterlogging response within the mini core pigeonpea germplasm. *J Agric Sci* **150**:357–364.

Kumutha D, Sairam RK, Ezhilmathi K, Chinnusamy V and Meena RC.2008. Effect of waterlogging on carbohydrate metabolism in pigeonpea (*Cajanus cajan* L.), pregulation of sucrose synthase and alcohol dehydrogenase. *Plant Sci* **175**:706–716.

Perera AM, Pooni HS and Saxena KB. 2001. Components of genetic variation in short duration pigeonpea crosses under waterlogged conditions. *Journal of Genetics & Breeding*. **55**(1):21-38.

Sairam RK, Kumutha D, Ezhilmathi K, Deshmukh PS and Srivastava GC.2008. Physiology and biochemistry of waterlogging tolerance in plants. *Biol Plant.* **52**:401–412.

Singh AK, Singh SS, Prakash V, Kumar S and Dwivedi SK.2015.Pulses Production in India: Present Status, Bottleneck and Way Forward. *Journal of AgriSearch* **2** (2): 75-83.

Yasin JK, Chaudhary S, Prasad BN, Pillai A, Verma N and Singh AK. 2019. Role of Lanc like G protein-coupled receptor-2 with BOP and BTB/POZ in stress tolerance and high yielding trait of pigeonpea. *Journal of AgriSearch* **6**(3): 105-112.

You FM, Duguid SD, Dinushika T and Sylvie C. 2013. Statistical analysis and field evaluation of the type 2 modified augmented design (MAD) inphenotyping of flax (*Linum usitatissimum*) germplasms in multiple environments. *Australian J of Crop Sci.* **7**(11):1789-1800.

Citation:
Singh AK, Upadhyaya, A, Choudhry AK, Saurabh Kirti, Jeet Pawan, Monoburallah and Sundaram PK.2022. Development of waterlogging tolerant lines of pigeonpea for Eastern India**.** *Journal of AgriSearch* **9**(3) :201-207