LR-5342
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RESEARCH ARTICLE Legume Research- An International Journal

Physiological Characterization of Pigeon Pea Genotypes [*Cajanus cajan* (L) Mill sp.] for Water Logging Tolerance

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10.18805/LR-5342

ABSTRACT

Background: Water- logging stress is one of the important abiotic stress in pigeon pea crop especially in low lying areas in pigeon pea growing states. Being a rainy season crop, pigeon pea is invariably exposed to intermittent water-logging conditions for different durations from germination to early vegetative growth stages, which damage the crop partially and sometime eliminate the entire crop depending on intensity and duration of water stagnation. The present experiment was conducted to study the morphological characters and yield performance of water logging tolerant and susceptible pigeon pea genotypes so that large number of pigeon pea genotypes for water logging tolerance based on morphological and Physiological parameters standardized might be screened.

Methods: As per approved technical programme, the experiment was conducted with 30 pigeon pea genotypes including checks, these were IPAC-79, ICPL-7035, ICPL-20241, ICPL-87051, ICPL-87091, ICP-2376, ICP-5028, ICPL-149, MA-3, MA-6, NDA-1, IPA-15F, Bahar, IPA-203, IPAC-211, IPAC-202, RCM/DD-17, WB-2019/25, WB-2019/26, WB-2019/27, IPAC-212, IPAWL-22-1, IPAWL-22.2, IPAWL-22-3, IPAWL-22-4, IPAWL- 22-5, IPAWL-22-6, IPAWL-22-7, IPAWL -22-8, IPAWL -22-9. Water logging stress was imposed for 24 h-48h-72h having minimum depth of water 12 inches at 30 DAS with 03 replications and a set of all these genotypes were also sown under normal control condition. Morphological Scoring (0-3) at the end of water logging stress was done. and at harvesting yield attributes and yields were recorded.

Result: Morphological Scoring (0-3) at the end of water logging stress showed highest score (0) in genotypes including IPAC-79 (Check for Tolerant) followed by ICPL-87091, ICP-2376, ICPL-20241, IPAC-212, IPAWL-22-7 and IPAWL-22-8 and may be considered as water logging tolerant. Pigeon pea genotypes like ICP-5028, MA-6 and IPAC-202 showed the score of (01) and may be considered as moderately tolerant to water logging stress. Pigeon pea genotypes namely MA-3, NDA-1, IPA-15F, Bahar, IPAC-211, IPA-203, IPAWL-22-6 and IPAWL-22-9 showed moderate score (02) and may be considered as moderately susceptible. The lowest score (03) was recorded in ICPL-87051, ICP-149, RCM/DD-17, WB-2019/25, WB-2019/26, WB-2019/27, IPAWL-22-1, IPAWL-22-2, IPAWL-22-3, IPAWL-22-4 and IPAWL-22-5 and these were at par with ICPL-7035 (Check for susceptibility) and considered susceptible to water logging stress. Development of adventitious roots was observed under water logged condition only and it was recorded highest in genotypes which are water logging tolerant group. In susceptible genotypes no/negligible adventitious roots were found. In yield attributes and yield the reduction % due to water logging stress over normal control was minimum in tolerant/moderately tolerant genotypes whereas, it was found maximum in Susceptible/moderately susceptible group of genotypes.

Key words: Adventitious roots, Genotypes, Morphological scoring, Pigeon pea, Tolerant, Susceptible, Water logging stress, Waterlogging tolerance, Yield.

INTRODUCTION

Pigeon pea [*Cajanus cajan* (L.) Millsp.] is an important pulse crop of India, sown at the onset of rainy season. The country is the largest pigeon pea producer, producing 5.02 million tons from 6.09 million ha (India-stat 2020-21). pigeon pea can be grown in diverse soil types; however, it grows best in well drained fertile soils. Although several improved varieties were released for commercial cultivation across the country, their productivity remains low, 852 kg/ha, which is mainly due to various constraints such as genetic, agronomic, biotic and abiotic factors (Sultana *et al*., 2013). Water-logging stress is one of the important abiotic stress in pigeon pea crop especially in low lying areas in pigeon pea growing states particularly U.P., M.P. Bihar, Chhattisgarh, Jharkhand *etc.* Being a rainy season crop, pigeon pea is invariably exposed to intermittent water-logging conditions for different durations from germination to early vegetative growth stages, which damage the crop partially and sometime eliminate the entire crop depending on intensity and duration of water stagnation. The main cause of damage under water logging is oxygen deprivation, which affect nutrient and water uptake, so the plants show wilting even when surrounded by excess of water. Lack of oxygen shift the energy metabolism from aerobic mode to anaerobic mode. In flooded soils, the gaseous rates of diffusion are 100 times lower than normal (Sairam *et al*.

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How to cite this article: Tiwari, T.N., Dutta, D., Tewari, K. and Laxmi, V. (2024). Physiological Characterization of Pigeon Pea Genotypes [*Cajanus cajan* (L) Mill sp.] for Water Logging Tolerance. Legume Research. 1-9. doi: 10.18805/LR-5342.

Submitted: 23-03-2024 **Accepted:** 20-09-2024 **Online**: 09-12-2024

2009) and respiration of plant roots, soil micro-flora and fauna leads to rapid exhaustion of soil oxygen, thereby causing anaerobiosis. Plants adapted to waterlogged conditions, have mechanisms to cope with this stress such as aerenchyma formation, development of numerous adventitious roots and lenticels, increased availability of soluble sugars, greater activity of glycolytic pathway and fermentation enzymes and involvement of antioxidant defence mechanism to cope with the post hypoxia/anoxia oxidative stress. Gaseous plant hormone ethylene plays an important role in modifying plant response to oxygen deficiency. Studies in details on these aspects and their correlation with water logging tolerance in pigeon pea genotypes is still lacking.

Screening out water logging tolerant pigeon pea genotypes on the basis of their morphological characters including Scoring of water logging injury (0 to 3) at the root zone in plants exposed to water logging and free from water logging, development of aerenchyma cells, lenticels and adventitious roots and yield performance have been the criteria for the selection of pigeon pea genotypes for water logging tolerance. Earlier reports indicated that more than one mechanisms are operating to control water-logging tolerance in plants and such information's are lacking in pigeon pea crop in particular hence, detailed studies are required to understand the tolerance mechanism operating in water logged pigeon pea genotypes. In the proposed project, the efforts have been made to understand the morphological characters and yield performance of water logging tolerant and susceptible pigeon pea genotypes and criteria for screening large number of pigeon pea genotypes for water logging tolerance based on morphological and Physiological parameters standardized during initial study.

MATERIALS AND METHODS

As per approved technical programme the experiments were conducted with 30 pigeon pea genotypes including checks (IPAC-79 (Tolerant), ICPL-7035 (Susceptible), ICPL-20241, ICPL-87051, ICPL-87091, ICP-2376, ICP-5028, ICPL-149, MA-3, MA-6, NDA-1, IPA-15F, Bahar, IPA-203, IPAC-211, IPAC-202, RCM/DD-17, WB-2019/25, WB-2019/26, WB-2019/27, IPAC-212, IPAWL-22-1, IPAWL-22.2, IPAWL-22-3, IPAWL-22-4, IPAWL- 22-5, IPAWL-22-6, IPAWL-22-7, IPAWL -22-8, IPAWL -22-9 in plastic pots of 15 kg capacity during *kharif* season in 2021-22 to 2022-23 at the Research Farm of ICAR-Indian Institute of Pulses Research, kalyanpur, Kanpur with three replication in complete randomized design. Plastic pots were filled with the 15 kg. mixture of well pulverized soil and vermi-compost well before sowing. After maintaining proper moisture in pots five (05) seeds per pot were sown and after germination plants were thinned and 03 plants/pots were maintained. Water logging stress was imposed at 30 days after sowing (DAS) in the existing concrete made tanks of 5 fit depths for 24 hours-48 hours-72 hours with separate sets of pots having all pigeon pea genotypes under study with minimum 12 inches' depth of water regularly and a set of all genotypes were sown in the similar pots and maintained under normal condition at the same site. Morphological Scoring at 0-3 scale **(**0.0-Normal 01-Yellowing of leaves, 02-Yellowing followed by T.W. 03-Yellowing followed by T.W.and P.W.) at the end of water logging stress was done as suggested by (Takele and McDavid 1995; Zaidi *et al*. 2007) with some modification. Morphological characters including scoring of water logging injury (0 to 3) in plants exposed to water logging stress and free from water logging, Leaf senescence, Plant wilting and epinasty, Plants termination, Post-regenerative capacity, Survival % and mortality % were recorded in each set and genotype evaluated in all replications. Study on root anatomy including development of aerenchyma cells and development of adventitious roots and their lengths were observed after retention of water from the experimental pots. Meteorological observations during treatment application including rainfall, minimum and maximum temperature and relative humidity were also observed and given in Table 1. Yield attributes including no. of pods/plant, test weight and grain yield/plant were also recorded at crop maturity.

RESULTS AND DISCUSSION

Water-logging stress is one of the important abiotic stress in pigeon pea crop especially in low lying areas which damage the crop partially and sometime eliminate the entire crop depending on intensity and duration of water stagnation. The main cause of damage under water logging is oxygen deprivation, which affect nutrient and water uptake, so the plants show wilting even when surrounded by excess of water. In the present study the morphological Scoring (0-3) at the end of water logging stress showed highest score (0) in genotypes IPAC-79 (Check for Tolerant) followed by ICPL-87091, ICP-2376, ICPL-20241, IPAC-212, IPAWL-22-7 and IPAWL-22-8 and may be considered as water logging tolerant. These genotypes showed normal plants after 24,48 and 72 hours of water logging stress imposed (Table 2 and Fig 1) and also showed significantly higher adventitious roots number and adventitious root length over susceptible genotypes and respective normal control (Table 3 and Fig 2). These genotypes also showed development of aerenchyma cells in their roots (Fig 3). Morphologically Leaf senescence, epinasty, plant termination was not observed, the average survival percent was 83.40 and average mortality percent

Table 1: Meteorological observations during water logging treatment application.

Meteorological parameters	2021-22	2022-23
Average Maximum Temp.(0^c)	35.50	36.20
Average Minimum temp.(0^c)	26.86	26.40
Average Relative Humidity.(%)	79.99	84.08
Average Rain fall.(mm)	7.00	2.40

was 16.60 only and affected plants were regenerated (Table 4).

Pigeon pea genotypes like ICP-5028, MA-6 and IPAC-202 showed the score of 01 and were normal up to 24 hours of water logging beyond that they showed only yellowing symptoms even after 72 hours of water logging and further they survived well and these genotypes may be considered as moderately tolerant. The adventitious roots with significant number and length were also found in these genotypes. (Table 2 and 3). Morphologically Leaf senescence, epinasty, plant termination was observed in general, but the average survival percent was 66.70 and average mortality percent was 33.30 only and affected plants were regenerated (Table 3). Pigeon pea genotypes namely MA-3, NDA-1, IPA-15 F, Bahar, IPAC-211, IPA-203, IPAWL-22-6 and IPAWL-22-9 showed lower score (02) and may be considered as moderately susceptible against water logging stress. These genotypes showed normal symptoms on 24 hours of water logging and yellowing after 48 hours and at 72 hours temporary wilting was observed. The adventitious roots with significant number and length were relatively less in these genotypes. (Table 2 and 3). Stressed plants showed Leaf senescence, epinasty, plant termination and average survival percent was 48.60 and average mortality percent was 51.40 and the affected plants were regenerated up to some extent (Table 4). The lowest score (03) was recorded in ICPL-87051, ICP-149, RCM/DD-17, WB-2019/25, WB-2019/26, WB-2019/27, IPAWL-22-1, IPAWL-22-2, IPAWL-22-3, IPAWL-22-4 and IPAWL-22-5 which was at par with ICPL-7035 (Check for susceptibility) and susceptible to water logging stress. These genotypes showed yellowing followed by temporary wilting and finally permanent wilting. The adventitious roots were very less in number and their root length was also very poor. Stressed plants showed Leaf senescence, epinasty, plant termination and average survival per cent was 20.80 and average mortality per cent was 79.20 and the survived plants were regenerated very

Table 2: Morphological scoring of pigeon pea genotypes exposed to water logging stress.

Pigeon pea genotypes	24 h	48 h	72 h	Final score (0-3)
1	2	3	4	5
IPAC-79	Normal	Normal	Normal	0.00
ICPL-7035	Yellowing	T.W.	T.W./P.W.	03
ICPL-87091	Normal	Normal	Normal	0.00
ICPL-20241	Normal	Normal	Normal	0.00
ICPL-87051	Yellowing	T.W.	T.W./P.W.	03
ICP-2376	Normal	Normal	Normal	0.00
ICP-5028	Normal	Normal	Yellowing	01
ICP-149	Normal	Yellowing	T.W./P.W.	03
MA-3	Normal	Yellowing	T.W.	02
MA-6	Normal	Yellowing	Yellowing	0'1
NDA-1	Normal	Yellowing	T.W.	02
IPA-15F	Normal	Yellowing	T.W.	02
Bahar	Normal	Yellowing	T.W.	02
IPA-203	Normal	Yellowing	T.W.	02
IPAC-211	Yellowing	Yellowing	T.W.	02
IPAC 202	Normal	Yellowing	Yellowing	01
RCM/DD-17	Normal	T.W.	T.W./P.W.	03
WB 2019/25	Normal	T.W.	T.W./P.W.	03
WB 2019/26	Normal	T.W.	T.W./P.W.	03
WB 2019/27	Normal	T.W.	T.W./P.W.	03
IPAC-212	Normal	Normal	Normal	0.00
IPAWL-22-1	Normal	T.W.	T.W./P.W.	03
IPAWL-22-2	Normal	T.W.	T.W./P.W.	03
IPAWL-22-3	Normal	T.W.	T.W./P.W.	03
IPAWL-22-4	Normal	T.W.	T.W./P.W.	03
IPAWL- 22-5	Normal	T.W.	T.W./P.W.	03
IPAWL-22-6	Normal	Yellowing	T.W.	02
IPAWL-22-7	Normal	Normal	Normal	0.00
IPAWL -22-8	Normal	Normal	Normal	0.00
IPAWL -22-9	Normal	normal	T.W.	02

Morphological Scoring (0.0-Normal 01-Yellowing of leaves, 02-Yellowing followed by T.W. 03-Yellowing followed by T.W.andP.W.)

Fig 1: Morphological symptoms after water logging in pigeon pea genotypes.

Table 3: Development of adventitious roots in pigeon pea genotypes exposed to water logging stress.

Pigeon pea genotypes	No. of adventitious roots (N)	Root length Cm.(N)	No. of adventitious roots (WL)	Root length Cm. (WL)
1	2	3	4	5
IPAC-79	0	8.0	6.5	15.50
ICPL-7035	0	6.0	0.00	0.00
ICPL-87091	0	8.50	7.6	26.50
ICPL-20241	0	8.50	9.4	26.50
ICPL-87051	0	7.0	3.0	5.00
ICP-2376	0	7.5	8.0	21.50
ICP-5028	0	7.5	8.8	20.50
ICP-149	0	5.50	9.2	07.50
MA-3	0	8.5	9.0	22.50
MA-6	0	8.0	6.5	7.00
NDA-1	0	7.0	5.0	13.50
IPA-15F	0	5.5	4.0	9.50
Bahar	0	9.5	6.0	21.50
IPA-203	0	6.5	4.0	12.50
IPAC-211	0	5.5	0.00	04.50
IPAC 202	0	6.3	6.0	14.30
RCM/DD-17	0	3.0	0.00	02.00
WB 2019/25	0	10.50	3.0	10.50
WB 2019/26	0	1.5	0.00	01.50
WB 2019/27	0	2.0	0.00	02.00
IPAC-212	0	11.30	10.0	17.30
IPAWL-22-1	0	6.5	4.0	8.6
IPAWL-22-2	0	7.4	3.0	9.6
IPAWL-22-3	0	7.6	3.0	15.2
IPAWL-22-4	0	9.4	4.0	19.3
IPAWL- 22-5	0	8.5	4.0	8.8
IPAWL-22-6	0	8.0	9.0	26.3
IPAWL-22-7	0	8.8	10.0	18.9
IPAWL -22-8	0	9.2	9.0	21.3
IPAWL -22-9	0	9.0	9.0	26.5
C.D. at 5%			2.16	5.32

poorly to some extent (Table 4). Our results are similar with the findings of Jerald Anthony *et al.* (2024) in maize imposed to water logging at early seedling stage.

Yield attributes including number of pods/plant, 1000 seed weight (Test Weight) and grain yield/plant were significantly decreased under water logging stress when compared with normal condition (Table 5). Reduction in yield and yield parameters were higher in susceptible and moderately susceptible group of genotypes and lowest reduction in yield and yield components was noted in tolerant (37.02) and moderately tolerant (41.20) group of genotypes (Fig 4). Susceptible and moderately susceptible group showed 59.83% and 42.48% reduction over untreated normal control. Under water logging stress germination and early vegetative stages of pigeon pea are more sensitive to water-logging stress as compared to mature plants. Hence, any plant mechanism that can restore the oxygen supply to the flooded tissues will help in the survival of the plants (Singh *et al*.,1986). Crops have to face suffocation throughout their life during water logging due to insufficient of oxygen is a common environmental challenge (Chaudhary *et al.,* 2011). In flooded soils the gaseous rates of diffusion are 100 times lower than normal (Sairam *et al*. 2009) and respiration of plant roots, soil micro-flora and fauna leads to rapid exhaustion of soil oxygen, thereby causing anaerobiosis. According to Marshner (1995) the genotypes which do not adapt to water logging conditions exhibit symptoms of leaf senescence, whole plant wilting and epinasty followed by a rapid decline or even its termination and in the present investigation these symptoms were noted with mostly susceptible and moderately susceptible genotypes. The reductions in survival rate and increase in mortality rate under water logging has been primarily attributed to anoxia/hypoxia (Orchard and Jessop 1984). Simulated water logging imposed at early vegetative stages of green gram reduces

Fig 2: Development of adventitious roots in pigeon pea genotypes.

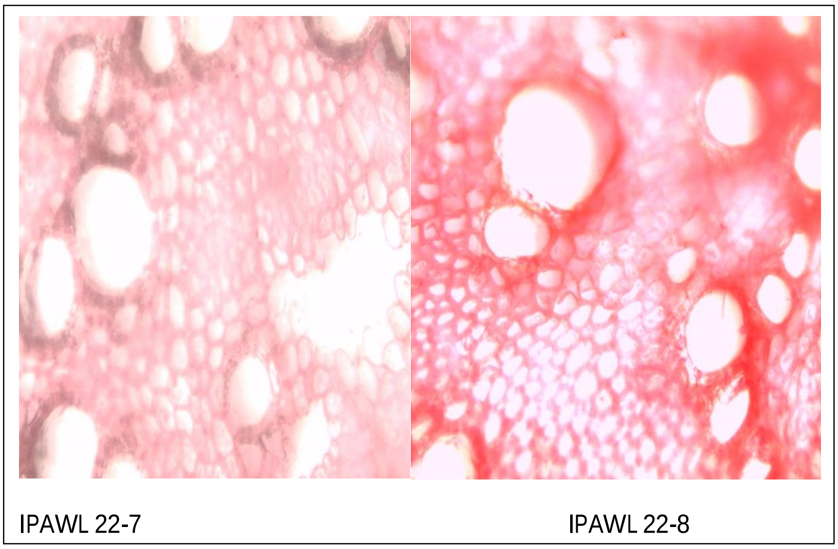

Fig 3: Development of aerenchyma cells in roots of pigeon pea genotypes.

the yield components and yield (Saikia *et al*., 2021) Observations on the development of adventitious roots were recorded in tolerant genotypes after imposing the water-logging treatment and among the tolerant genotypes like ICPL-87091, ICP-2376, ICPL-20241, IPAC-212, IPAWL-22-7 and IPAWL-22-8, the number and length of adventitious roots developed near the root shoot junction were markedly higher over susceptible group. Such adventitious roots were less in number and with small root length or some time absent in Susceptible genotypes like ICPL-87051, ICP-149, RCM/DD-17, WB-2019/25, WB-2019/26, WB-2019/27, IPAWL-22-1, IPAWL-22-2, IPAWL-22-3, IPAWL-22-4 and IPAWL-22-5. These observations showed that tolerant genotypes had adapted to water-logging stress early as compared to other surviving susceptible genotypes. In the present study, the pigeon pea genotypes adapted to water-logging stress developed attributes such as adventitious roots and aerenchyma cells in all tolerant and moderately tolerant genotypes including ICPL-87091, ICP-2376, ICPL-20241, IPAC-212, IPAWL-22-7, IPAWL-22-8, ICP-5028, MA-6 and IPAC-202. These results are similar to those reported by Pourabdal *et al*. (2008) in maize, Thomson *et al*. (1992) and Huang *et al*. (1994) in wheat, Pires *et al*. (2002) and Shimamura *et al*. (2003, 2010) in soybean. The examination of the transverse sections of the samples showed that IPAC-79, ICPL-87091, ICP-2376, ICPL-20241, IPAC-212, IPAWL-22-7 and IPAWL-22-8 and other surviving genotypes had developed aerenchyma cells, while these cells were absent in the susceptible genotypes ICP7035, ICPL-87051, ICP-149, RCM/DD-17, WB-2019/25, WB-2019/26, WB-2019/27, IPAWL-22-1, IPAWL-22-2, IPAWL-22-3, IPAWL-22-4 and IPAWL-22-5. Water-logging is a widespread production constraint for pigeon pea, especially in high rainfall and poorly drained habitats. The significant biological consequence of water-logging is the deficiency (hypoxia) or complete absence (anoxia) of oxygen in the soil; this sets anerobic conditions and restricts the plant growth and development and consequently the seed yield. The tolerant pigeon pea genotypes can adapt to transient water-logging by inducing

Table 4: Morphological characters of pigeon pea genotypes as influenced by water logging stress.

Pigeon pea genotypes	Leaf senescence	Epinasty	Plant termination	Post regen.	Survival%	Mortality%
IPAC-79	Noo	No	No	Yes	88.90	11.10
ICPL-7035	Yes	Yes	Yes	yes	11.11	88.89
ICPL-87091	No	No	No	Yes	77.88	22.12
ICPL-20241	No	No	No	Yes	88.90	11.10
ICPL-87051	Yes	Yes	Yes	No	22.20	77.80
ICP-2376	No	No	No	Yes	88.90	11.10
ICP-5028	Yes	Yes	No	Yes	66.70	33.30
ICP-149	Yes	Yes	Yes	No	33.30	66.70
MA-3	Yes	Yes	Yes	Yes	55.60	44.40
MA-6	Yes	Yes	No	Yes	66.70	33.30
NDA-1	Yes	Yes	Yes	yes	44.40	55.60
IPA-15F	Yes	Yes	No	Yes	55.50	44.50
Bahar	Yes	Yes	No	Yes	55.50	44.50
IPA-203	Yes	Yes	Yes	Yes	44.40	55.60
IPAC-211	Yes	Yes	Yes	yes	44.40	55.60
IPAC 202	Yes	Yes	No	Yes	66.70	33.30
RCM/DD-17	Yes	Yes	Yes	yes	33.30	66.70
WB 2019/25	Yes	Yes	Yes	yes	33.30	66.70
WB 2019/26	Yes	Yes	Yes	yes	33.30	66.70
WB 2019/27	Yes	Yes	Yes	yes	33.30	66.70
IPAC-212	No	No	No	Yes	88.90	11.10
IPAWL-22-1	Yes	Yes	Yes	yes	11.1	88.9
IPAWL-22-2	Yes	Yes	Yes	No	0.00	100
IPAWL-22-3	Yes	Yes	No	Yes	17.77	82.23
IPAWL-22-4	Yes	Yes	Yes	No	11.11	88.9
IPAWL- 22-5	Yes	Yes	Yes	No	0.00	100
IPAWL-22-6	Yes	Yes	No	Yes	22.22	77.78
IPAWL-22-7	No	No	No	Yes	77.88	22.12
IPAWL -22-8	No	No	No	Yes	77.88	22.12
IPAWL -22-9	No	No	No	yes	66.70	33.30

certain built-in mechanisms, rapidly assisting plants in their struggle for survival under excess water stress conditions. Armstrong (1979) demonstrated that the formation of aerenchyma cells, hypertrophied lenticels and adventitious roots facilitate gas diffusion to the roots and thus contribute directly to survival of the plants under water-logging. The common adaptation features of plants to water-logging condition are development of numerous adventitious roots and lenticels with the formation of aerenchymatous cells (Shimamura *et al*., 2010). Some insight on the mechanisms of water logging tolerance in pigeon pea, using water-logging tolerant and susceptible pigeon pea genotypes identified earlier by Sultana *et al*. (2012). Thus, based on survival data for two years, seven water-logging tolerant (IPAC-79(Check), ICPL87091, ICP2376,ICPL-20241, IPAC-212, IPAWL22-7 and IPAWL22-8), three moderately tolerant (ICP-5028, MA-6 and IPAC-202), eight moderately susceptible (MA-3, NDA-1, IPA-15 F, Bahar, IPAC-211, IPA-203, IPAWL-22-6 and IPAWL-22-9) and twelve sensitive (ICP7035 (Check), ICPL-87051, ICP-149, RCM/DD-17, WB-2019/25, WB-2019/26, WB-2019/27, IPAWL-22-1, IPAWL-22-2, IPAWL-22-3, IPAWL-22-4 and IPAWL-22-5) genotypes were identified. Observations on number of live plants before and after water-logging were recorded to estimate per cent plant survival. In addition, visual scores on plant senescence were also recorded after draining the water. Scoring for senescence was done using a 0 to 3 scale (0.0-Normal 01-Yellowing of leaves, 02-Yellowing followed by T.W. 03-Yellowing followed by T.W. and P.W) following some modification as reported by Takele and McDavid 1995; Zaidi *et al*., 2007). Early pigeon pea varieties are more sensitive as compared to medium and late and the risk of crop failure or yield losses due to short term water logging (Castanon-Cervantes *et al.,* 1995). Water logging during June September pigeon pea growing season is caused by irregular and prolonged rains and represents an important production constraint and is becomes a serious problem (Matsunaga *et al.,* 2005).

Table 5: Influence of water logging stress on yield attributes and yield of pigeon pea genotypes.

Pigeon pea	Pod NO./Plant		Test weight (g.)		Grain yield/plant (g.)	
genotypes	Normal	Water logged	Normal	Water logged	Normal	Water logged
IPAC-79	332	298	99.4	97.2	16.4	10.81
ICPL-7035	156	83	54.4	50.0	25.5	12.67
ICPL-87091	120	102	61.6	58.6	14.60	7.28
ICPL-20241	98	87	84.2	81.4	14.35	8.32
ICPL-87051	224	154	90.2	84.6	14.00	1.20
ICP-2376	212	188	69.8	65.8	18.66	14.02
ICP-5028	274	252	56.4	54.2	28.86	24.14
ICP-149	99	88	53.2	50.5	8.25	5.24
MA-3	302	274	92.1	90.1	25.00	16.90
MA-6	300	271	94.2	92.2	35.00	15.20
NDA-1	310	290	94.10	92.0	18.50	10.10
IPA-15F	266	245	58.8	54.4	33.78	8.35
Bahar	217	206	75.6	70.2	32.56	28.60
IPA-203	222	210	74.8	70.0	26.30	18.32
IPAC-211	97	91	55.2	51.8	22.58	13. 60
IPAC 202	218	202	64.8	61.6	18.70	9.20
RCM/DD-17	196	180	68.7	64.0	6.35	4.30
WB 2019/25	84	64	40.8	36.2	40.2	15.60
WB 2019/26	87	61	44.6	41.1	32.8	16.00
WB 2019/27	92	82	48.0	43.5	8.18	2.12
IPAC-212	116	107	55.2	53.2	11.46	9.46
IPAWL-22-1	66	31	80.57	70.21	11.50	3.59
IPAWL-22-2	64	31	90.55	70.94	18.60	8.30
IPAWL-22-3	147	76	120.25	100.26	31.20	11.43
IPAWL-22-4	171	84	90.75	80.19	24.10	13.33
IPAWL- 22-5	38	11	90.85	80.22	12.70	02.40
IPAWL-22-6	43	15	90.92	80.23	11.90	02.70
IPAWL-22-7	174	94	80.38	70.26	17.44	10.50
IPAWL -22-8	164	84	90.57	80.01	21.20	12.00
IPAWL -22-9	168	82	40.36	30.80	15.30	8.40
C.D.at 5%	8.76		2.02		1.21	

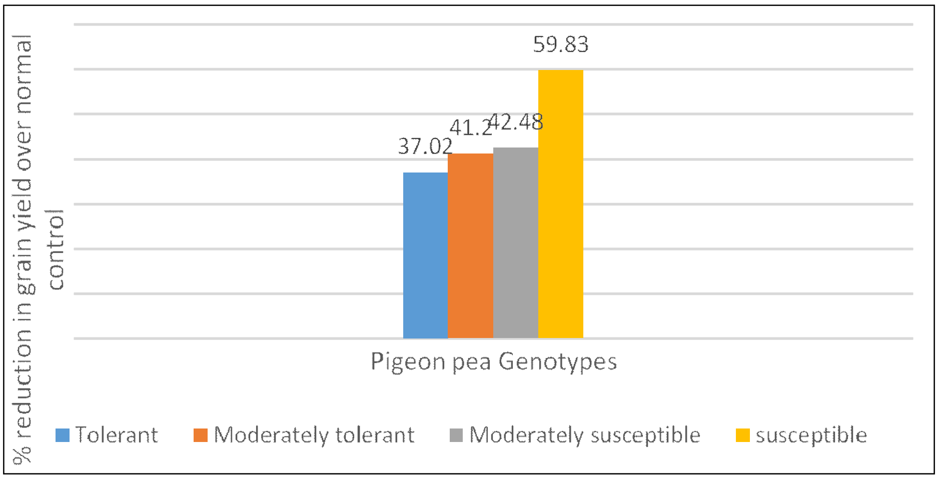

Fig 4: Effect of water logging stress on grain yield in pigeon pea genotypes.

Greater tolerance in the late maturing group is likely to be related to the availability of more time for further recovery from the sub-lethal water-logging stress (Khare *et al*. 2002). Besides this, Hou and Thsenge (1991) in soybean and Khare *et al*. (2002) in pigeon pea also correlated flooding tolerance of genotypes with their dark seed coat colour; which was attributed to the presence of greater amounts of tannins in the genotypes. In field peas testa colour and its integrity was also found strongly associated with water logging tolerance (Shahin *et al.* 2019) However, in the present investigation no such strong correlation with seed coat colour was observed. The physiological and morphological traits identified in this study would be utilized for further breeding programme in developing tolerant lines as also suggested by Kennedy *et al.* (1992) and Meena *et al.* (2014a). The findings of Marshner (1995) and Orchard and Jessop (1984) suggested that the genotypes which do not adapt to water logging conditions exhibit symptoms of leaf senescence, whole plant wilting and epinasty followed by a rapid decline or even its termination and reductions in survival rate under prolonged water logging has been primarily attributed to anoxia/hypoxia are also observed in the present investigation which supports our findings. The effect of water logging stress on yield related traits in pigeon pea genotypes was also assessed in this experiment. Water logging stress negatively influenced the growth, development and yield by reducing plant height, number of branches, per plant, number of seed per pod, test weight and final economic grain yield. Reduction in these traits is associated with decreased photosynthetic efficiency under stress and plant height and this may be due to decline in cell growth and expansion that limits the overall plant architecture under water logging stress. our findings are also supported with finding of Kumar *et al*. 2020, Basavaraj *et al*. (2023) and Zhengyuan *et.al.* (2023). Further the scope of application of Nano technology in enabling plants to overcome water logging stress is yet to be tried (Mohd kafeel *et al.,* 2023).

CONCLUSION

Conclusively the identified water logging tolerant genotypes (ICPL87091, ICP2376, ICPL-20241, IPAC-212, IPAWL22-7 and IPAWL22-8)) and traits responsible (low leaf senescence, epinasty, mortality and higher plant survival percent, development of efficient adventitious roots and aerenchyma cells in roots) imparting tolerance against water logging stress may be utilized for further breeding programme for water logging tolerance in pigeon pea crop.

Connflict of intrest

All authors declared that they have no conflict of intrest.

REFERENCES

Armstrong, W. (1979). Aeration in higher plants. Advances in Botanical Research. 7: 225-332.

Castanon-Cervantes, O., Lugo, C., Aguilar, M., Gonzalez-Moran, G. and FanjulMoles, M.L. (1995). Comp. Biochem. Phys. A. 110: 139-146.

Basavaraj, P.S., Jadish Rane, K.M., Boraiah, Prakash Gangashetty and C.B. Harisha (2023). Genetic analysis of tolerance to transient water logging stress in pigeon pea [*Cajanus cajan* (L). Millspaugh]. Indian Journal of Genetics. Plant Breed. 83(3): 316-325.

Chaudhary, A.K., Sultana, R., Pratap, A., Nadarajan, N. and Jha, U.C. (2011). Breeding for abiotic stresses in pigeon pea. Journal of Food Legumes. 24(3): SSs165-174.

Hou, F.F. and Thseng, F.S. (1991). Studies on the flooding tolerance of soybean seed: varietal differences. Euphytica. 57: 169-173.

Huang, B., Johnson, J.W., Nesmith, D.S. and Bridges, D. C.(1994). Root and shoot growth of wheat genotypes in response to hypoxia and subsequent resumption of aeration. Crop Sci. 34: 1538-1544.

India Stat. (2021). https://www.indiastat.com/data/agriculture/land-use-classification/data-ye.

Jerald Anthony, C., Esteban, Nenita, B. and Baldo (2024). Effect and recovery of maize (*Zea mays* linn) to water logging imposed to early seedling stage. Agricultural Science Digest. 44 (3): 414-420. doi: 10.18805/ag.DF-500.

Kennedy, R.A., Rumpho, M. and Fox, T.C. (1992). Anaerobic metabolism in plants. Plant Physiology. 100: 1-6.

Khare, D., Rao, S., Lakhani, J.P. and Satpute, R.G. (2002). Tolerance for flooding during germination in pigeon pea. Seed Res., 30: 82-87.

Kumar, Sultana, R., Kumar, R.R. and Kirti, M. (2020). Characterization of pigeon pea genotypes for water logging tolerance based on morpho-physiological and molecular traits. Current J., Appl. Sci. Technol. 38(12): 21-33.

Meena, K.C., Rao, S., Rao, S.K., Gontia, A.S. and Singh, S.K. (2014a). International Journal of Agriculture, Environment and Biotechnology. 7(3): 455-463.

Matsunaga, R., Ito O., Johansen, C. and Rao, T.P. (2005). Japanese Journal of Tropical Agriculture. 49(2): 132-139.

Marschner, H. (1995). Mineral Nutrition of Higher Plants. Second edition. London, Academic Press Limited:889 str.

Mohd, K.A.A., Bengu, T.U., Sumera, J., Fazilt, V., Abdullah, A.A., Munir, O., Mahammad, I. (2023). Application of nano technology in enabling plants to overcome water logging stress. Agriculture Reviews. 44(3): 289-299. doi: 10.18805/ag.R-2581

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 Soil. 81: 119-132.

Pires, J.L.F., Soprano, E. and Cassol, B. (2002). Morph physiological changes of soybean in flooded soils. Pesquisa Agropecuaria Brasileira. 37: 41-50.

Pourabdal, L., Heidary, R. and Farboodnia, T. (2008). Effects of different flooding periods on Some Histochemicals of *Zea mays* L. Seedlings. Plant Sci. Res. 1(1): 8-12.

Saikia, B., Prakash, K. and Ranjan, D. (2021). Effect of Simulated water logging condition imposed at early vegetative growth on final yield in Green gram (Vigna radiate). Legume Research. 44(10): 1226-1232.

Shahin, M., Zaman, U., Imran, m., Parwinder, k., Fedirico, M., Ribalta, and William Erskine (2019). Water logging tolerance at germination in field pea: Variability, genetic control and indirect selection. Frontiers Plant Science,30 July 2019. https://doi.org/10.3389/fpls.2019.00953.

Shimamura, S., Mochizuki, T., Nada, Y. and Fukuyama, M. (2003). Formation and function of secondary aerenchyma in hypocotyl, roots and nodules of soybean (*Glycine max*) under flooded conditions. Plant Soil. 251: 351-359.

Shimamura, S., Yamamoto, R., Nakamura, T., Shimada, S.and Komatsu, S. (2010). Stem hypertrophic lenticels and secondary aerenchyma enable oxygen transport to roots of soybean in flooded soil. Ann. Bot. 106: 277-284.

Singh, K., Sharma, S. P., Singh, T. K. and Singh, Y. (1986). Effect of waterlogging on growth, yield and nutrient concentration of black gram and green gram under subtropical condition of Varanasi. Ann. Agr. Res. 7: 169-177.

Sultana, R., Vales, M.I., Saxena, K.B., Rathore, A., Rao, S., Rao, S.K., Mula, M.G. and Kumar, R.V. (2012). Waterlogging tolerance in pigeon pea (*Cajanus cajan*(L.) Millsp.): genotypic variability and identification of tolerant genotypes. J. Agril. Sci. ISSN1469-5146.

Sultana, R., Vales, M., Saxena, K., Rathore, A., Rao, S. and Kumar, R. (2013). Waterlogging tolerance in pigeonpea (*Cajanus cajan* (L.) Millsp.): Genotypic variability and identification of tolerant genotypes. The J. Agric. Sci. 151(5): 659-671.

Sairam R.K., Kumutha D., Ezhilmathi K., Chinnusamy V. and Meena R.C. (2009). Waterlogging induced oxidative stress and antioxidant enzyme activities in pigeon pea. Biologia Plantarum. 53(3): 493-504.

Takele, A. and Mcdavid, C.R. (1995). The response of pigeon pea cultivars to short durations of waterlogging. African Crop Sci. J. 3(1): 51-58.

Thomson, C.J., Colmer, T. D., Watkin, E.L.J. and Greenway, H. (1992). Tolerance of wheat (*Triticum aestivum* cvs. Gamenya and Kite) and triticale (*Triticosecale* cv. Muir) to waterlogging. New Phytol. 120: 335-344.

Zaidi, P.H., Maniselvan, P., Yadav, P., Singh, A.K., Sultana, R., Dureja, P., Singh, R.P. and Srinivasan, G. (2007). Stress-adaptive changes in tropical maize (*Zea mays*L.) under excessive soil moisture stress. Maydica. 52: 159-171.

Zhengyuan, X., Lingzhen, Y., Qiufang, S., Gouping, Z. (2023). Water logging tolerance in plants.https;//doi.org/10.1016/j.jia.2023.12.028.