

Short-term Water Logging on Growth and Yield of Chilli

P. Behera, R. K. Panda, P. Tripathy, R. K. Nayak

Received 11 December 2025, Accepted 9 February 2026, Published on 20 February 2026

ABSTRACT

Waterlogging causes significant damage to chilli crops and is a persistent problem in Odisha. So a net house study was conducted at College of Agriculture, Bhubaneswar, Odisha in *rabi* 2022-23 to examine the response of chilli genotypes to waterlogging stress. In the first phase, eight chilli varieties were tested under varying durations (2, 4, 6, and 8 hours) of waterlogging. Among them, two local genotypes, Barkote and Daringbadi, showed remarkable tolerance, in way of more adventitious roots, lower incidence of leaf yellowing and wilting. Based on these initial observations, a second experiment was conducted using these two tolerant local chilli and the plants were exposed to same waterlogging period. A noticeable decline in the growth and a sudden wilting disorder was recorded to rise in waterlogging period. Both the genotypes produced fewer leaves and exhibited a significant reduction in leaf area under waterlogged conditions

compared to their control plants. Short-term waterlogging triggered an oxidative burst, which corresponded with increased activities of proteins, carbohydrates, and proline, indicating a stress-induced metabolic response. However, prolonged exposure had a detrimental effect on yield attributes. Although both Barkote and Daringbadi showed decreased yield under stress condition, Daringbadi suffered a comparatively greater reduction of 19.8% than Barkote.

Keywords *Capsicum annum*, Waterlogging, Proline, SPAD, Wilt.

INTRODUCTION

Chilli is a fruit of the plants '*Capsicum annum*' belonging to the family of 'Solanaceae' stands among India's most significant commercial crops. The country currently dominates global chilli trade, contributing nearly 56.4% of the total world exports. Cultivated over approximately 7.75 lakh hectares, India achieves an annual production of 14.92 lakh tonnes, with an average productivity of 1.9 t/ha. In Odisha, chilli is typically cultivated during the dry season by local farmers. However, in recent years, erratic rainfall patterns and unpredictable water distribution have posed severe challenges to chilli cultivation. The crop's sensitivity to waterlogging, a condition of water-saturated rhizosphere (WSR), is largely attributed to its shallow root system, which makes it more susceptible than many other crops. During waterlogging, root function is quickly impaired by oxygen deficiency,

P. Behera^{1*}, R. K. Panda², P. Tripathy³, R. K. Nayak⁴

^{2,3}Assistant Professor, ⁴Associate Proessor

^{1,2,3,4}College of Agriculture, OUAT, BBSR-Odisha, India

Email: prgtbehera@gmail.com

*Corresponding author

leading to disrupted physiological processes, plant collapse, and poor recovery potential. Among plant organs, the leaf is reported to be the most sensitive to such stress but can recover up to 81.5% within a week under favorable conditions (Sakagami *et al.* 2019). Certain chilli genotypes and landraces with vigorous root and shoot systems have demonstrated better resilience, maintaining turgor pressure and osmotic balance during short-term flooding episodes. Under waterlogged conditions, plants often experience an oxidative burst, characterized by the accumulation of reactive oxygen species (ROS). This triggers an increase in total soluble proteins, carbohydrates, and proline content, which serve as key biochemical responses to stress. Despite these observations, there remains a significant research gap regarding the physiological and biochemical mechanisms of chilli under waterlogging stress. Hence, the present pot experiment was designed to explore the short-term effects of waterlogging on chilli, focusing on its overall morpho-physiological development and yield.

MATERIALS AND METHODS

The pot experiment was conducted in the net house of College of Agriculture, Bhubaneswar, Odisha, in two sets during the study period. In the first experiment, a total of 80 pots were arranged following a completely factorial randomized design (FCRD) with two replications. Eight chilli genotypes namely BC-28(V1), Barkote (local) (V2), Deogarh (local) (V3), Utkal Ava (V4), Daringbadi (local) (V5), Kenduguda (local)(6), Utkal Ragini (V7), and Utkal Rashmi(V8) were evaluated out of which four released varieties and four local landraces. Plants were subjected to five waterlogging durations of 0 hr (W0), 6 hr (W6), 12 hr (W12), 18 hr (W18), and 24 hr (W24). Healthy seedlings were transplanted at 30 days after sowing, and standard management practices were followed throughout the experiment. Waterlogging treatments were applied at 35 days after transplanting, maintaining a 2 cm water level above the soil surface and root zone for the specified duration. Once each treatment period ended, water was carefully drained through the pot base. Plant responses to waterlogging were monitored for 15 days post dewatering, and adaptability screening scores were recorded based on various visual indicators.

The degree of wilting was assessed using a modified 0–5 scale proposed by (Yeboah *et al.* 2008), where 0 indicate dead plant, 1; 100–75% wilting from tip to base, 2; 74–50% leaf wilting, 3: partial leaf undulation, 4; recurved leaf margins, and 5: completely green plant without symptoms. Adventitious root formation (ARF) under waterlogging stress was visually rated on a 0–3 scale (2), where 0 indicate no ARF, 1: low, 2; medium, and 3: high. The yellow leaf percentage was determined using a 1–6 scale (Mohanty and Ong *et al.* 2003), where 1: no yellow leaves, 2: 10–30% yellow leaves, 3; 30–50%, 4; 50–70%, 5 ; most leaves yellow, and 6: all leaves yellow.

The second experiment was carried out under identical environmental and soil conditions, using the same soil type, fertility status, NPK, and FYM applications as in the first trial. Based on the initial screening, Barkote and Daringbadi were used as two local chilli landrace and subjected to five waterlogging durations (0 hr(W0), 2 hr(W2), 4 hr(W4), 6 hr(W6), and 8 hr(W8)). This experiment followed an FCRD design with four replications and a total of 40 pots. The shorter waterlogging durations were chosen to minimize plant mortality observed in the first screening and to facilitate physiological analyses. Seedlings aged 30 days were transplanted and upon reaching 45 DAT, plants were exposed to waterlogging with 2 cm of standing water above the root zone. Following stress removal, recovery percentage and biochemical parameters such as total soluble protein, total soluble carbohydrate, and proline content were measured at 7day intervals for three consecutive weeks. These estimations followed standard methodologies like Lowry's method for protein (Lowry *et al.* 1951), Anthrone method (Yoshida *et al.* 1976) for carbohydrates, and (Bates *et al.* 1973) for proline. Morphological attributes, yield and harvest-related observations were recorded after plant recovery, and the data were statistically analyzed using the FCRD model with procedures outlined in Statistical Procedures for Agricultural Research" by Gomez, K.A. and Gomez, A.A. (1984).

RESULTS AND DISCUSSION

After dewatering, individual chilli plants were eval-

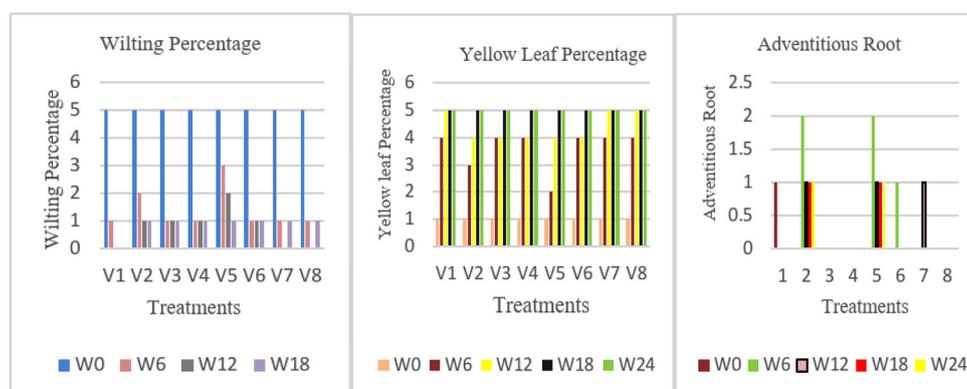


Fig. 1. Effect of waterlogging on wilting, yellowing percentage and adventitious root formation of chilli.

uated for tolerance (Fig 1) between 7 and 21 days following stress removal. The local varieties Barkote and Daringbadi exhibited comparatively better tolerance, characterized by fewer adventitious roots and a yellow leaf percentage ranging from 10–50%, whereas other genotypes showed 50–100% damage. Based on this preliminary screening, Barkote and Daringbadi were selected for further physiological and biochemical studies.

Second experiment

The second phase of the experiment focused on evaluating the physiological and biochemical alterations in the selected genotypes, Barkote (V2) and Daringbadi (V5), under controlled waterlogging conditions. Observations from the preliminary screening indicated very low survival rates when plants were exposed to waterlogging for more than 12 hours. Therefore, a modified treatment regime of 0, 2, 4, 6, and 8 hours of waterlogging was adopted to examine both morphological and biochemical responses in chilli.

Morphological responses

Among plant organs, the leaf proved to be the most sensitive to waterlogging. Parameters such as leaf number, leaf area, chlorophyll content, and plant height were recorded 10 days after dewatering (DAD) (Table 1) and subsequently monitored up to 120 days of plant growth. The results revealed that treatment V2W6 (Barkote-6hr) had the highest leaf number (145), followed by V2W2 (143.3) and V2W8

(136.7), showing an increase of 14.3% and 14.4%, respectively, compared with the control,

Table 1. Effect of waterlogging (120 days) on morphological attribute of chilli genotypes to duration of waterlogging.

Treatments	Plant height (cm)	Number of leaves per plant	Leaf area (cm)	SPAD value	Dry weight (g)
V2W0	72.10	101.33	41.40	12.23	37.13
V2W2	64.20	143.33	48.27	16.23	24.40
	(10.9)	(41.4)	(16.5)	(32.7)	(34.2)
V2W4	63.40	113.33	51.07	32.53	21.50
	(12.06)	(11.8)	(23.3)	(165.9)	(42)
V2W6	69.90	145.00	49.20	16.30	15.90
	(3.05)	(43)	(18.8)	(33.2)	(57.1)
V2W8	67.60	136.67	34.63	15.37	11.80
	(6.2)	(34.8)	(16.3)	(25.6)	(68.2)
V5W0	70.10	135.67	46.37	23.17	37.93
	56.60	121.67	52.97	23.77	24.50
V5W2	(19.2)	(10.3)	(14.2)	(2.5)	(35.4)
	62.40	149.33	61.70	19.07	20.30
V5W4	(10.9)	(10)	(33)	(17.6)	(46.4)
	63.10	166.00	46.27	10.43	14.17
V5W6	(9.9)	(22.3)	(0.2)	(54.9)	(62.6)
	63.37	137.00	45.93	11.50	10.40
V5W8	(9.6)	(0.9)	(0.9)	(50.3)	(72.5)
SE(m)±					
V	1.161	4.739	1.907	0.812	0.339
W	1.835	7.493	3.016	1.284	0.536
VXW	2.595	10.596	4.265	1.816	0.757
CD (0.05)					
V	3.42	13.98	5.63	NS	NS
W	5.41	22.10	8.90	3.79	1.58
VXW	NS	NS	NS	5.36	NS

W0- control, W2- 2hrs, W4- 4hrs, W6- 6hrs, W8- 8hrs of waterlogging, V2- Barkote (local), V5- Daringbadi (local), (-) Figures in Parentheses indicates % increase or decrease over control.

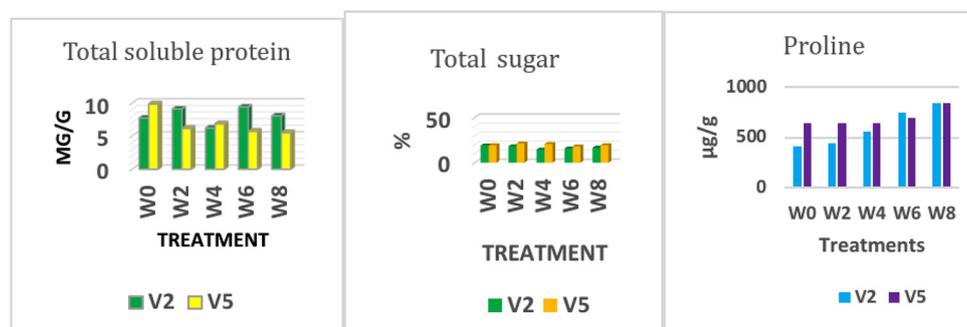


Fig. 2. Effect of waterlogging on total soluble protein, total sugar and proline content of leaf.

A notable reduction in leaf area was observed at 10 DAD in both genotypes, which persisted up to 60 DAD. Beyond this period, leaf area showed a significant increase in most treatments, except in plants subjected to 8 hours of waterlogging, where recovery remained limited. Both Barkote and Daringbadi displayed reduced plant height compared to their controls (72.1 cm and 70.1 cm, respectively). The most sensitive treatments were 4-hour waterlogging in Barkote and 2-hour waterlogging in Daringbadi, showing the lowest plant heights relative to the control. These results align with the findings of (Molla *et al.* 2022), who reported that reduced plant height under waterlogging is a typical stress response mechanism.

The leaf color also changed markedly up to 60 days after dewatering, with plants exhibiting yellowing or deep-green pigmentation, followed by gradual recovery as adaptation mechanisms strengthened. Similar results were noted by (Liu *et al.* 2021), who reported that root hypoxia disrupts substance transport, causing visible morphological symptoms such as leaf discoloration, wilting, or abscission.

Shoot biomass and biochemical responses

Under waterlogging stress, shoot dry weight declined significantly in all treatments relative to the control. The highest values were recorded in Barkote (V2) with 24.4 g, 21.5 g, 15.5 g, and 11.8 g, followed by Daringbadi (V5) with 24.5 g, 20.3 g, 14.1 g, and 10.4 g, indicating reductions of 29.6% and 43.3%, respectively. While the duration of waterlogging had a significant effect, the interaction between variety and

treatment was statistically non-significant.

Analysis of biochemical parameters (Fig 2) revealed significant variation in protein, carbohydrate, and proline content. Total soluble protein levels in Barkote (V2) increased by 17.7%, 21.4%, and 4.6% at 2, 6, and 8 hours of waterlogging, respectively, compared to the control. Conversely, Daringbadi (V5) showed a reduction of 37.2%, 30.4%, 41.8%, and 43.9% at 2, 4, 6, and 8 hours, respectively. These effects were found to be statistically significant for varieties, treatments, and their interactions.

In terms of total soluble sugar, Daringbadi (V5) exhibited a 14.96% higher sugar content than Barkote (V2) at 10 DAD, though the greatest reduction occurred in V5 under 6-hour waterlogging (16.6%). Similarly, proline accumulation recorded at 45 DAD decreased progressively with increasing waterlogging duration in both genotypes, ranging from 10.8% to 46.6% below the control (837.50 µg/g FW). These data also showed significant differences among treatments and genotypes.

Yield response

Consistent with our earlier report on physiological effects of stress related enzymes in chilli under waterlogging condition (Pragati *et al.* 2025) and relative studies on tomato by (Mohanty *et al.* 2020), short-term waterlogging at the early growth stage significantly reduced yield and yield components in chilli. Waterlogging led to a sharp decline in fruit number per plant and overall yield in both genotypes, with Daringbadi exhibiting the most pronounced reduc-

Table 2. Co-relation coefficient between yield and different biochemical parameters.

Character	Yield	Straw yield	Protein	Carbo	Mda
Straw yield	**0.959				
Protein	0.359	0.456			
Carbo	0.236	0.310	-0.169		
Mda	-0.516	-0.411	-0.068	0.030	
Proline	0.135	0.194	0.240	0.150	-0.084

>0.632 significant at 5 % *, 0.765 significant at 1 %**

Table 3. Co-relation coefficient between yield and morphological parameters.

Character	Yield	Straw yield	Pl.ht	Leaf no	Area
Straw yield	**0.959				
Pl.ht	0.335	0.371			
Leaf no	-0.580	-0.539	-0.182		
Area	0.023	0.046	-0.537	0.183	
Spad	0.215	0.285	-0.274	-0.405	0.405

* significant at 5 %, ** significant at 1 %

Table 4. Co-relation coefficient between yield and yield parameters.

Character	Yield	S. yield	Fruits/plant	Avg f.wt	Seed/fruit	Pedicle length	Fruit length
S. yield	**0.959						
Fruits/plant	**0.995	**0.949					
Avg f.wgt	**0.933	**0.897	**0.933				
Seed/fruit	**0.945	**0.909	**0.959	**0.876			
Pedicle length	**0.983	**0.953	**0.983	**0.971	**0.958		
Fruit length	**0.938	**0.913	**0.939	**0.989	**0.919	**0.984	
Fruit Girth	**0.985	**0.958	**0.983	**0.952	**0.959	**0.994	*0.970

*significant at 5 %, ** significant at 1 %

tion. This reduction is likely associated with delayed flowering and poor fruit set, possibly due to ethylene accumulation under hypoxic conditions that induces flower and fruit abscission (Devaux *et al.* 2003). Additionally, reduced photosynthetic activity under stress limits assimilate supply, contributing to lower yield. Consequently, it can be inferred that Daringbadi allocates less energy toward reproductive growth and more toward vegetative recovery during stress, consistent with the findings of (Heeb *et al.* 2005).

Co-relation study

The correlation analysis among morpho-physiological, biochemical, and yield-related traits in relation to

overall yield is presented in the accompanying (Table 2-4). Results indicated that fruit yield exhibited a strong and significant positive correlation with all fruit-associated parameters, including straw yield, average fruit weight, fruit length, fruit girth, pedicel length, number of fruits per plant, and number of seeds per fruit.

Compatible solutes such as proteins, carbohydrates and proline showed a positive association with fruit yield. However, these relationships were statistically non-significant within the scope of the present investigation.

Furthermore, plant yield demonstrated a negative correlation with leaf number, while exhibiting a positive but non-significant relationship with plant height, leaf number, and SPAD value, suggesting that their influence on yield under water logging stress conditions was limited.

CONCLUSION

The study clearly shows that waterlogging stress severely impairs the growth, physiology, and yield performance of chilli plants. Exposure to root hypoxia for extended periods (12–24 hours) proved lethal for most genotypes, with the exception of the local varieties Barkote and Daringbadi, which exhibited partial tolerance and survived up to 12 hours of water stagnation. As the duration of waterlogging increased, a marked decline in metabolic activity was observed, becoming particularly evident beyond 8 hours of exposure. This stress was associated with significant reductions in plant height, flower and fruit production, as well as substantial biochemical

alterations. Furthermore, yield attributes including dry matter accumulation, fruit weight, and overall fruit quality showed pronounced decreases under prolonged waterlogged conditions. Despite these adverse effects, Barkote genotype displayed superior adaptive potential compared to other varieties. Its ability to withstand hypoxic stress conditions suggests the presence of physiological and biochemical mechanisms that mitigate oxidative damage, likely through the regulation of reactive oxygen species (ROS). Thus, Barkote can be considered a promising genotype for developing waterlogging-tolerant chilli cultivars in regions prone to intermittent flooding.

ACKNOWLEDGMENT

The author gratefully acknowledges the support of the Central Instrumentation Facilities, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, for providing access to the laboratory equipment and resources essential for carrying out the biochemical analyses involved in this study.

REFERENCES

- Bates, L. S., Waldren, R. P., & Teare, I. D. (1973). Rapid determination of free proline for water-stress studies. *Plant and Soil*, 39(1), 205–207. <https://doi.org/10.1007/bf00018060>
- Devaux, C., Baldet, P., Joubès, J., Dieuaide-Noubhani, M., Just, D., Chevalier, C., & Raymond, P. (2003). Physiological, biochemical and molecular analysis of sugar-starvation responses in tomato roots. *Journal of Experimental Botany*, 54(385), 1143–1151. <https://doi.org/10.1093/jxb/erg113>
- Gomez, K. A. & Gomez, A. A. (1984). Statistical procedures for agricultural research. New York: John Wiley & Sons, Inc.
- Heeb, A., Lundegårdh, B., Ericsson, T., & Savage, G. P. (2005). Effects of nitrate-, ammonium-, and organic- nitrogen-based fertilizers on growth and yield of tomatoes. *Journal of Plant Nutrition and Soil Science*, 168(1), 123–129. <https://doi.org/10.1002/jpln.200420420>
- Liu, M., Zhang, Q., Xu, J., Bao, M., Zhang, D., Xie, A., & Sun, X. (2021). Effects of waterlogging stress on the physiological characteristics and secondary metabolites of Herbaceous Peony (*Paeonia lactiflora* Pall.). *American Journal of Plant Sciences*, 12(04), 536. <https://doi.org/10.4236/ajps.2021.124035>
- Lowry, O. H., Rosebrough, N. J., Farr, A. L., & Randall, R. J. (1951). Protein measurement with the Folin phenol reagent. *J Biol Chem*, 193(1), 265–275.
- Mohanty, A., Panda, R. K., Rout, G. R., Muduli, K. C., & Tripathy, P. (2020). Impact of short term water logging on flowering, fruit setting, yield and yield attributes in tomato (*Solanum lycopersicum* L. Mill). *Journal of Pharmacognosy and Phytochemistry*, 9(4), 760–763. <https://doi.org/10.20546/ijcmas.2020.907.107>
- Mohanty, B., & ONG, B. L. (2003). Contrasting effects of submergence in light and dark on pyruvate decarboxylase activity in roots of rice lines differing in submergence tolerance. *Annals of Botany*, 91(2), 291–300. <https://doi.org/10.1093/aob/mcf050>
- Molla, M. R., Rohman, M. M., Islam, M. R., Hasanuzzaman, M., & Hassan, L. (2022). Screening and evaluation of chilli (*Capsicum annuum* L.) genotypes for waterlogging tolerance at seedling stage. *Biocell*, 46(7), 1613–1627. <https://doi.org/10.32604/biocell.2022.019243>
- Pragati, B., Rajendra Kumar, P., Pradyumna, T., & Rabindra Kumar, N. (2025). Physiological effects of stress-related enzymes and reactive oxygen species in chilli (*Capsicum annuum* L.) genotypes under waterlogging conditions. *Plant Science today*, <https://doi.org/10.14719/pst.4010>
- Sakagami, J. I., Iwata, Y., Nurrahma, A. H. I., Siaga, E., Junaedi, A., & Yabuta, S. (2019). Plant adaptations to anaerobic stress caused by flooding. In IOP Conference Series: Earth and Environmental Science. *IOP Publishing*, 418, (1), 012080. <https://doi.org/10.1088/1755-1315/418/1/012080>
- Yeboah, M. A., Xuehao, C., Guohua, L., Minghong, G., & Chenwu, X. (2008). Inheritance of waterlogging tolerance in cucumber (*Cucumis sativus* L.) Genetics of waterlogging in cucumber. *Euphytica*, 162(1), 145–154. <https://doi.org/10.1007/s10681-007-9636-7>
- Yoshida, S., Forno, D., Cock, J., & Gomez, K. A. (1976). Determination of sugar and starch in plant tissue. Laboratory manual for physiological studies of rice. Third Edition, chapter 11, 46.