



International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

www.agronomyjournals.com

2024; 7(5): 222-225

Received: 02-03-2024

Accepted: 04-04-2024

Shahinul Miah

Department of Agronomy,
Bangladesh Agricultural
University, Mymensingh,
Bangladesh

Nasima Bhuiyan

Department of Agronomy,
Bangladesh Agricultural
University, Mymensingh,
Bangladesh

Monzur Ahmed

Department of Agronomy,
Bangladesh Agricultural
University, Mymensingh,
Bangladesh

Rawshan Uddin

Department of Agronomy,
Bangladesh Agricultural
University, Mymensingh,
Bangladesh

Corresponding Author:

Shahinul Miah

Department of Agronomy,
Bangladesh Agricultural
University, Mymensingh,
Bangladesh

Physiological responses of soybean (*Glycine max*) to waterlogging at different growth stages

Shahinul Miah, Nasima Bhuiyan, Monzur Ahmed and Rawshan Uddin

DOI: <https://www.doi.org/10.33545/2618060X.2024.v7.i5c.5122>

Abstract

Leading soybean physiologists have long argued that waterlogging during reproductive stages causes more yield damage than during vegetative growth-but how large is the difference, and what drives it? This research imposed waterlogging for 5 and 10 days at four growth stages (V3, R1, R3, R5) on soybean cv. BARI Soybean-6 at Bangladesh Agricultural University, Mymensingh, during the 2022 kharif season. Chlorophyll content, root dry weight, nodule function, stomatal conductance, and yield components were measured. Ten-day waterlogging at seed fill (R5) caused the largest yield loss (53.7%), while 5-day waterlogging at V3 reduced yield by only 18.2%. Chlorophyll declined by 46.2% and root biomass by 67.0% under 10-day R5 waterlogging. Nodule nitrogenase activity dropped 74.1% at R3 after 10 days of flooding.

Keywords: Soybean, waterlogging, growth stages, chlorophyll, root biomass, nodule activity, stomatal conductance, yield loss, anaerobic stress, *Glycine max*

Introduction

According to Rhine *et al.* ^[1], soybean ranks among the most waterlogging-sensitive grain legumes, yet it is increasingly grown in flood-prone lowlands of South and Southeast Asia where monsoon rainfall can saturate soils for days at a time. Bangladesh alone loses an estimated 12 to 18 percent of potential soybean production annually to transient waterlogging events ^[2].

When soil becomes saturated, oxygen diffusion to roots drops sharply within hours, triggering a shift from aerobic to anaerobic metabolism. Root respiration declines, nutrient uptake slows, and ethylene accumulates in submerged tissues, accelerating leaf senescence ^[3]. For soybean, an additional vulnerability exists: Bradyrhizobium nodules on roots are extremely sensitive to oxygen depletion, and nitrogenase activity can fall by 50 to 80 percent within days of flooding ^[4, 5].

The timing of waterlogging relative to crop phenology determines the severity of damage, but quantitative data comparing stage-specific responses under controlled conditions are limited for tropical soybean cultivars. This research measured physiological and yield responses of soybean to 5- and 10-day waterlogging imposed at four growth stages under field conditions in Bangladesh.

Experimental design

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh (24.75°N, 90.50°E, elevation 18 m) during July–November 2022. A split-plot design with three replications was used, with waterlogging duration (0, 5, and 10 days) as the main plot and growth stage (V3, R1, R3, R5) as the subplot. Each subplot measured 3 × 4 m, bordered by 30 cm raised earthen bunds lined with polyethylene to retain water. Waterlogging was imposed by flooding plots to 5 cm above the soil surface and maintaining this depth for the designated period using a controlled drip inflow. Drainage occurred through outlet pipes after the treatment period ended.

Climatic conditions

The kharif 2022 growing season experienced a mean temperature of 29.3 °C and total rainfall of 1,847 mm. Relative humidity averaged 82 percent. A 14-day dry spell during early September allowed the V3-stage waterlogging treatment to be imposed without confounding natural rainfall. Later treatments coincided with declining monsoon activity in October, requiring supplemental flooding to maintain treatment water levels. Sunshine hours averaged 5.4 hours per day during the reproductive phase.

Material and Methods

Material

Soybean cv. BARI Soybean-6, a medium-duration variety (110–115 days), was sown on July 8, 2022 at 30 × 5 cm spacing. Seeds were inoculated with *Bradyrhizobium japonicum* (strain TAL 379) at sowing. Basal fertilizer was applied at 20-60-40 kg N-P₂O₅-K₂O/ha. The soil was a silty clay loam (Aeric

Haplaquept) with pH 6.3 and organic carbon 1.47 percent.

Methods

Leaf chlorophyll content was measured using a SPAD-502 meter (Konica Minolta) on the third fully expanded trifoliate from the apex, recorded before and immediately after each waterlogging event and at 7-day recovery. Root samples (3 plants per subplot) were excavated at each measurement point, washed, oven-dried at 70 °C, and weighed. Nodule nitrogenase activity was measured by the acetylene reduction assay on detached root systems [6]. Stomatal conductance was recorded using a porometer (Decagon SC-1) between 10:00 and 12:00 h on the day of drainage.

At maturity, plants from a 2 × 2 m area per subplot were harvested for yield components: pods per plant, seeds per pod, 100-seed weight, and grain yield adjusted to 12 percent moisture. Data were analyzed by split-plot ANOVA in Statistix 10 with LSD at $P \leq 0.05$.

Results

Table 1: Effect of waterlogging duration and growth stage on physiological parameters of soybean

Stage	WL days	SPAD	SPAD Δ%	Root DW (g)	Root Δ%	ARA*	ARA Δ%	gs**
V3	0	38.4	-	2.87	-	14.2	-	312
V3	5	34.1	-11.2	2.31	-19.5	9.8	-31.0	247
V3	10	29.6	-22.9	1.74	-39.4	6.1	-57.0	183
R1	5	33.8	-18.9	2.18	-36.1	7.4	-47.9	214
R1	10	27.3	-34.5	1.52	-55.4	4.7	-66.9	156
R3	5	30.7	-21.7	1.87	-40.1	5.8	-59.2	191
R3	10	23.1	-41.1	1.23	-60.6	3.7	-74.1	128
R5	5	28.4	-22.9	1.64	-44.2	4.9	-65.5	167
R5	10	19.8	-46.2	0.97	-67.0	3.1	-78.2	98

*ARA = acetylene reduction activity (μmol C₂H₄/plant/h); **gs = stomatal conductance (mmol/m²/s). LSD ($P \leq 0.05$): SPAD = 2.7; Root DW = 0.23; ARA = 1.4.

All physiological parameters declined with increasing waterlogging duration and later growth stage (Table 1). SPAD values fell by 11.2 to 46.2 percent depending on timing and duration. The most severe impact was on root biomass and

nodule function: 10-day waterlogging at R5 reduced root dry weight by 67.0 percent and nitrogenase activity by 78.2 percent. Stomatal conductance dropped below 100 mmol/m²/s at 10-day R5, indicating near-complete stomatal closure.

Table 2: Yield components and grain yield of soybean under waterlogging at different growth stages

Stage	WL days	Pods/plant	Seeds/pod	100-seed wt (g)	Yield (t/ha)	Yield loss (%)
Control	0	47.3	2.41	12.8	2.18	-
V3	5	41.6	2.34	12.3	1.78	18.3
V3	10	36.8	2.27	11.7	1.52	30.3
R1	5	37.4	2.21	11.9	1.61	26.1
R1	10	29.1	2.08	10.8	1.23	43.6
R3	5	34.2	2.14	11.1	1.47	32.6
R3	10	24.7	1.93	9.6	1.04	52.3
R5	5	38.1	2.07	10.4	1.38	36.7
R5	10	31.4	1.82	8.7	1.01	53.7

LSD ($P \leq 0.05$): Pods/plant = 3.8; 100-seed wt = 0.9; Yield = 0.16.

Grain yield declined by 18.3 to 53.7 percent depending on stage and duration (Table 2). Reproductive-stage waterlogging caused disproportionately larger yield losses than vegetative-stage flooding. Ten-day waterlogging at R5 and R3 produced nearly

identical and the worst yield losses (53.7 and 52.3 percent), driven mainly by reduced 100-seed weight and pod number. Even 5-day flooding at R5 caused 36.7 percent yield loss-double the loss from 5-day V3 waterlogging.

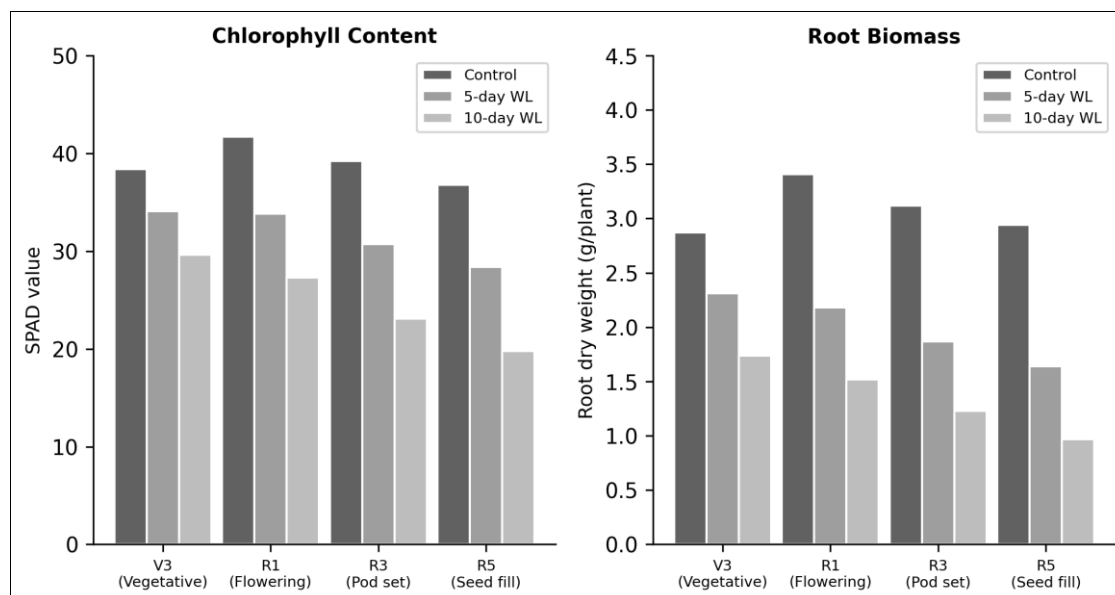


Fig 1: Comparison of chlorophyll content (SPAD) and root dry weight under control, 5-day, and 10-day waterlogging across four soybean growth stages

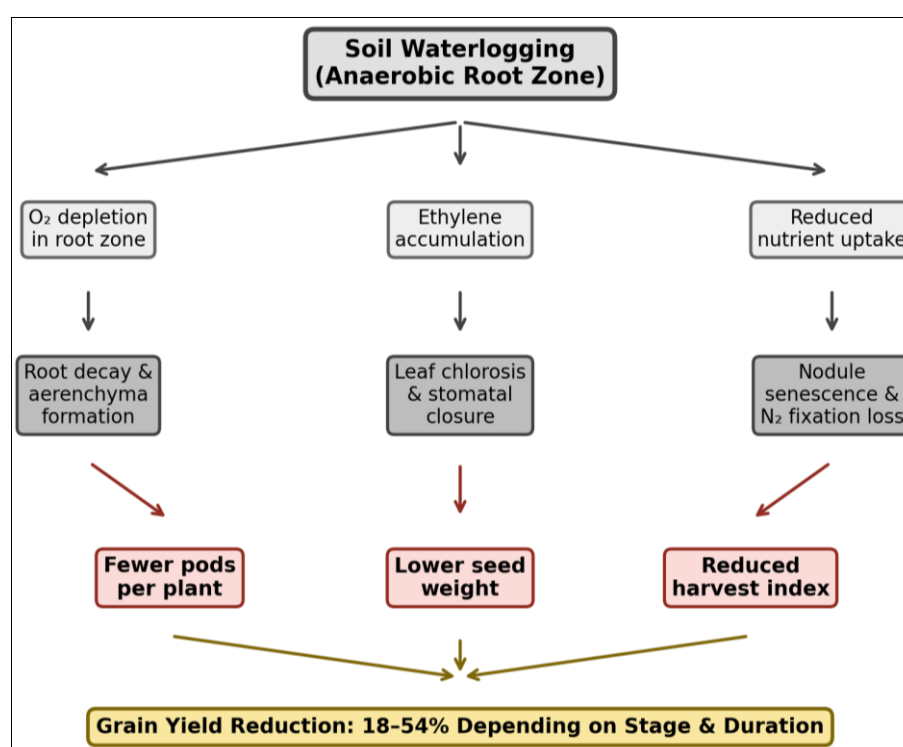


Fig 2: Conceptual model of waterlogging stress responses in soybean, from primary oxygen depletion through physiological damage to yield component reduction

Limitations

This research was conducted over a single growing season at one location, which limits the generalizability of results. Only one soybean cultivar was tested, and genotypic variation in waterlogging tolerance is known to be substantial. The artificial waterlogging method maintained a constant water depth, which may differ from natural flooding events that fluctuate in intensity. Recovery dynamics beyond 7 days post-drainage were not tracked. Multi-season and multi-location validation would strengthen these findings.

Discussion

The greater sensitivity of reproductive stages to waterlogging confirms the pattern described by Linkemer *et al.* [7] and Scott *et*

al. [8], who reported that flooding during pod set and seed fill disrupts assimilate partitioning when demand from developing seeds is at its peak. The 78 percent decline in nitrogenase activity after 10-day R3 waterlogging is particularly damaging because soybean relies on nodule N fixation for 50 to 80 percent of its nitrogen supply during seed fill [9].

Root biomass loss under prolonged flooding reflects both anaerobic decay of existing roots and suppressed new root growth [10]. The formation of aerenchyma, observed visually in waterlogged root sections, may have provided partial adaptation in V3-stage plants, which showed better recovery than reproductive-stage plants [11]. The stomatal closure at R5 likely restricted carbon assimilation during a period when seed filling demands maximum photosynthetic supply [12].

Conclusion

Soybean yield loss from waterlogging ranged from 18 to 54 percent, with reproductive stages (R3, R5) suffering the greatest damage. Ten-day flooding at pod set or seed fill reduced yield by over 50 percent, driven mainly by chlorophyll degradation, root decay, and nodule inactivation. Even short (5-day) waterlogging at R5 caused 37 percent yield loss. Improving field drainage during reproductive stages should be the priority for soybean production in flood-prone areas of Bangladesh. Screening germplasm for waterlogging tolerance at R3 and R5 could identify resilient lines for lowland cultivation.

References

1. Rhine MD, Stevens G, Shannon G, Wrather A, Sleper D. Yield and nutritional responses to waterlogging of soybean cultivars. *Irrig Sci.* 2010;28(2):135-142.
2. Alam MJ, Humphreys E, Sarker MAR. Sunamganj Community-Based Resource Management and Livelihoods Programme. Mymensingh: IRRI-Bangladesh; 2009. p.1-34.
3. Jackson MB, Colmer TD. Response and adaptation by plants to flooding stress. *Ann Bot.* 2005;96(4):501-505.
4. Minchin FR, Pate JS. Effects of water, aeration, and salt regime on nitrogen fixation in a nodulated legume-definition of an optimum root environment. *J Exp Bot.* 1975;26(90):60-69.
5. Bacanamwo M, Purcell LC. Soybean root morphological and anatomical traits associated with acclimation to flooding. *Crop Sci.* 1999;39(1):143-149.
6. Hardy RWF, Holsten RD, Jackson EK, Burns RC. The acetylene-ethylene assay for N₂ fixation: laboratory and field evaluation. *Plant Physiol.* 1968;43(8):1185-1207.
7. Linkemer G, Board JE, Musgrave ME. Waterlogging effects on growth and yield components in late-planted soybean. *Crop Sci.* 1998;38(6):1576-1584.
8. Scott HD, DeAngulo J, Daniels MB, Kirkpatrick TL. Root and shoot growth of soybean in flooding conditions. *Agron J.* 1989;81(4):631-636.
9. Herridge DF, Peoples MB, Boddey RM. Global inputs of biological nitrogen fixation in agricultural systems. *Plant Soil.* 2008;311(1-2):1-18.
10. Henshaw TL, Gilbert RA, Scholberg JMS, Sinclair TR. Soybean response to waterlogging at R5 and R6 growth stages. *J Agron Crop Sci.* 2007;193(6):407-416.
11. Shimamura S, Yamamoto R, Nakamura T, Shimada S, Komatsu S. Stem hypertrophic lenticels and secondary aerenchyma enable oxygen transport to roots of soybean in flooded soil. *Ann Bot.* 2010;106(2):277-284.
12. Oosterhuis DM, Scott HD, Hampton RE, Wullschlegel SD. Physiological response of two soybean cultivars to short-term flooding. *Environ Exp Bot.* 1990;30(1):85-92.
13. VanToai TT, Beuerlein JE, Schmitthenner AF, St. Martin SK. Genetic variability for flooding tolerance in soybeans. *Crop Sci.* 1994;34(4):1112-1115.
14. Ahmed S, Nawata E, Sakuratani T. Effects of waterlogging at vegetative and reproductive growth stages on photosynthesis, leaf water potential and yield in mungbean. *Plant Prod Sci.* 2002;5(2):117-123.