Research article

Ecology Journal

ISSN (Print): 2708-6356, ISSN (Online): 2708-6364, Website: journal.esbangladesh.org
Ecol. J. (2021) 3 (2) : 169-173

WATERLOGGING EFFECT ON SHORT DURATION SOYBEAN GENOTYPES: PHENOLOGY AND GREENNESS

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Received: 05 October 2021, Revised: 22 October 2021, Accepted: 26 October 2021

ABSTRACT

Stress condition alters the seasonal events and appearance of plants. A field experiment was conducted during January to April 2020 to evaluate the effect of waterlogging on phenology and greenness of short duration soybean genotypes. Twelve genotypes such as BD2334, G00113, G00164, G00067, G00221, BD2331, G00138, G00312, G00058, G00060, G00025 and BU Soybean-1 (check) were tested under 4-days of WL comparing with no WL (control). The experiment was laid out in a split-plot design with three replications. The results indicated that, WL stress reduced plant height and greenness while enhanced lodging. Genotype BD2334 and G00025 displayed better performance in terms of greenness under 4-days of WL stress, while other genotypes showed varying levels of response to WL. Genotype G00113 exhibited better lodging resistance under 4-days WL compared to other genotypes. As a whole, the soybean genotypes BD2334, G00025 and G00133 were found relatively WL tolerance concerning phenology and greenness Therefore, further research including those three genotypes is necessary at the field conditions for developing a WL short duration soybean variety.

Keywords: Soybean, short duration, genotypes, waterlogging

Introduction

Soybean (*Glycine max* L.) is a popular source of protein and phytochemicals (Rao *et al.* 2002). In Bangladesh, the cultivation of soybean was only 5000 ha and concentrated mostly in Noakhali area upto 2005 (Satter *et al*. 2005). Now, the cultivation of this crop has been expanded dramatically to 62500 ha in the districts of Laksmipur, Noakhali, Barishal, Bhola, Chandpur, Patuakhali, Faridpur, and even in the northern Bangladesh (BBS 2020).

The soybean region of the southern part of Bangladesh is mostly affected by different degrees of salinity (Mannan *et al*. 2012, Mondal *et al*. 2013). However, recently due to change in rainfall pattern, which is the consequence of recent climate change, the crop also suffers from excess soil moisture. For example in 2016 there was a cyclone called NADA in early November that caused heavy rains. In the year 2020, the cyclone Amphan hits the southern part of Bangladesh on March 20 and damaged standing crops seriously. Heavy torrential rains in April 2017 and super cyclone Amphan in 2020 damaged soybean crop at the late pod development stage (physiological maturity) in greater Noakhali and Bhola areas. The problem of damaging crop at the later stage of growth due to torrential rain can be resolved to a great extent by developing short duration waterlogging (WL)tolerant soybean variety.

A major feature of soil excess moisture is the depletion of oxygen (Jackson 2005) which results in changes in the metabolism and morphology of plants. Photosynthesis is also inhibited due to stomatal closure, leaf chlorophyll degradation or leaf senescence (Ahmed 2013). WL renders plants more prone to lodging. It also leads to an imbalance between carbohydrate production and consumption, and even plant death when coupled with an accumulation of toxic metabolites under anaerobic respiration. The lack of energy supply hinders plant growth and development, in turn affecting yield and quality (Najeeb *et al.* 2015). Soil flooding caused 18% yield loss in soybean around the world when flooded at late vegetative stage (Komatsu *et al.* 2013).

Generally, longer the duration of hypoxia, greater was the damage on plant productivity (Islam 2008). Since the torrential rains mostly damage soybean at the pod development and physiological maturity stage, short

duration variety with WL tolerance may help to overcome the problem greatly. Therefore, this study was undertaken to evaluate the effect of WL on phenology and greenness of 12 short duration soybean genotypes.

Materials and Methods

A field experiment was conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during January to April 2020. Phenology and leaf greenness of twelve soybean genotypes were evaluated against WL. The tested soybean genotypes were BD2334, G00113, G00164, G00067, G00221, BD2331, G00138, G00312, G00058, G00060, G00025 and BU Soybean-1 (check variety). Water logging treatments were (i). 4-days WL and (ii). no WL (control). The seeds of soybean genotypes were collected from the Department of Agronomy of BSMRAU, Gazipur. Before sowing seeds, the land was prepared by repeated ploughing and cross ploughing with a tractor. Each ploughing was done followed by laddering for breaking clods and leveling land. The weeds and stubbles were removed from the field to obtain a desirable tilth. The experimental field was divided into two blocks, viz. i. WL treatment block and ii. control block. The size of each block was 4.2 m × 4.0 m. Fertilizer doses @ 20, 60, 60, 1.9 and 1.4 kg N-P-K-S-Zn ha^{-1} were applied during final land preparation in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate, respectively (FRG 2018). The soybean seeds were sown on 11th January 2020 in each block maintaining three replications. The seeds were sown in line maintaining planting configuration as 30 cm × 5 cm. For proper germination, light irrigation was given to the field after sowing seeds. The experiment was conducted in a split-plot design where WL was assigned in the main plots and the genotypes in the sub-plot. At three leaf stage, some plants were removed from the field to maintain optimum plant population. Sufficient amount of water was maintained in each plot by supplemental irrigation twice in a week up to maturity of the crop and weeding were done intensively for several times such as 15, 27, 39 and 54 days after emergence to keep the experimental plots weed free. The WL treatment was imposed to the soybean plants at the 50% pod formation stage maintaining a flooding depth of about 4 cm above the soil level and continued for 4 days. Data on different parameters like plant height, days to 1st and 50% flowering, days to 1st and 50% pod formation, soil, plant analysis development (SPAD) value, percent leaf greenness and plant lodging were recorded. The SPAD values were recorded at 2 days interval starting from imposition of WL treatment by using SPAD chlorophyll meter (SPAD-502, Japan). Leaf greenness was determined visually. Lodging was estimated based on visual observation according to IRRI (1988). The data were analyzed by using CropSat 7.2 software to examine the significant variation of different treatments. The treatment means were compared using the DMRT test at 5% level of significance (Gomez and Gomez 1984).

Results and Discussion

Phenology: The effect of WL on plant height and flowering behavior of the soybean genotypes were recorded and presented in Table 1. The results indicated that WL hindered the plant height soybean genotypes except G00067 and G00060. The reduction of plant height under WL condition was more prominent in soybean genotype G00138 than others. This genotype produced the height of 98.86 cm under control condition which reduced to 88.60 cm under WL condition. Similarly, WL stress stuck plant height by 2 to 10% in the rest soybean genotypes. The decrease of plant height on WL may be due to a decrease in oxygen transport and nutrition uptake and resulted in root destruction (Dennis *et al.* 2000). The appearance of 1st and 50% flower as well as 1st and 50% pod formation were not affected by the WL (Table 2). These happened because the WL treatment was imposed during pod formation stage.

Greenness: Soybean response to WL was sensitive and prompt. The symptom of leaf color which varied from green to yellow appeared after 24 hours of WL stress based on observation. This variation was highly correlated with chlorophyll content and hence we investigated leaf chlorophyll content using SPAD value. The SPAD was measured four times to understand the changes in chlorophyll status in the leaves (Table 3). Our result indicated that soybean leaf chlorophyll content significantly decreased due to WL and resulted in leaf color variation. The general SPAD values were decreased due to 4-days WL. Under WL condition, the genotypes BD2334 and G00025 had the highest SPAD, while G00060 had the lowest throughout the measurement period. The SPAD was affected seriously by WL in the genotype G00060. The WL plants showed a trend toward

Table 1. Effect of 4-days waterlogging on plant height and genotypic variations in flowering behavior of tested 12 soybean genotypes

Genotype	PHAF (cm)		DFF (%)		DFPF (%)	
	Control	WL	Control	WL	Control	WL
BD2334	47.20 ghi	45.66 ghi	40.33 bcd	39.00 d	47.33 b-e	46.00 b-g
G00113	25.93 k	23.86 k	40.66 bcd	39.66 bcd	44.33 e-h	43.66 fgh
G00164	55.50 ef	51.70 fg	40.66 bcd	40.00 bcd	47.33 b-e	46.66 b-f
G00067	38.16 j	43.26 hij	40.00 bcd	38.66 d	44.66 d-h	45.00 c-h
G00221	68.93 c	63.53 cd	40.33 bcd	39.00 d	46.66 b-f	44.33 e-h
BD2331	60.93 de	55.13 ef	41.33 abc	39.66 bcd	49.33 ab	46.66 b-f
G00138	98.86 a	88.60 b	38.66 d	38.66 d	42.00 h	43.00 gh
G00312	49.16 fgh	49.03 fgh	40.66 bcd	39.33 cd	45 c-h	43.33 fgh
G00058	26.13 k	22.36 k	43.33 a	41.66 ab	51.00 a	48.33 abc
G00060	37.86 j	40.56 ij	39.33 cd	40.33 bcd	43.33 fgh	46.33 b-g
G00025	40.66 ij	35.76 j	40.00 bcd	39.66 bcd	44.33 e-h	44.33 e-h
BU Soybean-1	61.73 cde	60.66 de	41.66 ab	41.33 abc	49.00 ab	48.00 a-d
CV	8.7		3.0		4.6	

PHAF= Plant height after flooding, WL = Waterlogging (Identified treatment plot for imposing waterlogging), DFF = Days to 1st flowering, DFPF = Days to 50% flowering.

Table 2. Genotypic variation of tested 12 soybean genotypes on days to 1st and fifty percent pod formation

Genotype	DFPF (%)		DFPPF (%)	
	Control	WL	Control	WL
BD2334	60.00 abc	61.66 a	71.33 ab	72.00 ab
G00113	51.33 gh	55.00 d-g	58.33 gh	63.00 c-g
G00164	58.00 a-e	55.33 c-g	68.33 a-d	62.00 d-h
G00067	51.33 gh	52.66 fgh	62.00 d-h	62.33 d-h
G00221	57.66 a-e	53.66 e-h	68.33 a-d	62.00 d-h
BD2331	60.66 ab	58.66 a-d	74.00 a	70.00 abc
G00138	49.00 h	52.33 fgh	55.33 h	61.33 d-h
G00312	52.33 fgh	52.00 fgh	63.00 c-g	59.33 fgh
G00058	55.66 c-g	54.66 d-g	64.00 c-g	63.66 c-g
G00060	52.33 fgh	54.00 d-g	60.00 fgh	58.33 gh
G00025	53.66 e-h	52.66 fgh	62.66 d-g	61.00 e-h
BU Soybean-1	56.66 b-f	56.00 b-g	68.00 a-e	66.33 b-f
CV	5.3		6.7	

WL = Waterlogging, DFPF = Days to1st pod formation; DFPPF = Days to 50% pod formation.

Table 3. Effect of 4-days waterlogging on SPAD value of soybean genotypes

Genotypes	SPAD1		SPAD2		SPAD3		SPAD4	
	Control	WL	Control	WL	Control	WL	Control	WL
BD2334	45.13 a-e	42.69 c-f	43.15 abc	42.94 abc	43.30 c-f	40.84 efg	42.62 abc	35.66 d-g
G00113	47.40 ab	41.99 c-f	48.24 a	47.60 a	45.54 bc	36.05 ij	37.44 c-f	20.51 k
G00164	45.71 abc	40.88 efg	45.34 abc	43.56 abc	45.34 bc	40.92 efg	42.03 a-d	30.10 ghi
G00067	44.04 b-f	43.86 b-f	44.15 abc	42.68 abc	42.73 c-f	40.13 fgh	40.28 bcd	23.56 jk
G00221	45.54 a-d	44.86 a-e	44.44 abc	46.42 ab	47.52 ab	37.04 hij	44.35 ab	29.97 g-j
BD2331	43.93 b-f	42.72 c-f	43.53 abc	43.90 abc	44.70 bcd	40.91 efg	44.35 ab	33.42 e-h
G00138	44.11 a-f	45.17 a-e	43.46 abc	43.55 abc	43.72 cde	37.01 hij	40.97 a-d	29.70 g-j
G00312	42.08 c-f	42.15 c-f	43.42 abc	43.02 abc	42.11 c-f	38.35 ghi	40.42 bcd	28.00 hij
G00058	39.94 fg	40.93 d-g	40.86 bc	39.18 c	35.98 ij	34.46 j	31.74 f-i	26.84 ijk
G00060	37.00 gh	35.22 h	31.34 d	25.43 d	11.17 k	12.84 k	2.65 l	2.11 l
G00025	48.67 a	48.10 ab	48.74 a	47.08 ab	49.34 a	45.14 bc	47.02 a	35.63 d-g
BU Soybean-1	45.81 abc	43.51 b-f	44.65 abc	46.18 ab	42.66 c-f	41.46 d-g	39.00 b-e	21.46 k
CV	5.6		8.8		5.2		12.1	

SPAD = Soil Plant Analysis Development, WL = Water logging.

low SPAD values in adult and young leaves during the stress. Rocío *et al.* (2018) also observed a progressive decline in SPAD values of adult leaves was observed one week after WL was applied and joined by decreases in SPAD values of young leaves at the end of the stress It was also in agreement with previous statements that leaf chlorophyll contents decreased under WL stress (Manzur *et al*. 2009, Yordanova *et al.* 2004, Yordanova and Popova 2001).

Table 4. Effect of 4-day waterlogging on greenness of leaf of soybean genotypes

Genotypes	Greenness (%)	
	Control	WL
BD2334	0.33	3.66
G00113	2.00	5.00
G00164	2.33	6.6
G00067	1.66	7.3
G00221	1.33	6.33
BD2331	0.33	3.60
G00138	2.66	7.30
G00321	1.33	8.00
G00058	1.66	6.00
G00060	9.00	9.00
G00025	0.33	3.00
BU Soybean-1	1.33	7.33

0 = leaf shows 100% greenness, 1 = 90% leaf shows greenness, 2 = 80% leaf shows greenness, 3 = 70% leaf shows greenness, 4 = 60% leaf shows greenness, 5 = 40%leaf shows greenness, 6 = 30% leaf shows greenness, 7 = 20% leaf shows greenness, 8 = 10% leaf shows greenness, 9 = 100% yellow leaf. WL = Waterlogging.

Table 5. Effect of 4-days waterlogging on lodging of soybean genotypes

Genotypes	Lodging score	Lodging (%)
BD2334	3	31.66
G00113	1	3.33
G00164	5	51.66
G00067	5	53.33
G00221	7	68.33
BD2331	3	35.0
G00138	9	90.0
G00321	1	13.33
G00058	1	4.00
G00060	1	4.00
G00025	3	31.66
BU Soybean-1	9	81.66

0 = No plants are lodged, 1 = Less than 20% plants are lodged, 3 = 20%-40% of plants are lodged, 5 = 41%-60% of plants are lodged, 7 = 61%-80% of plants are lodged, 9 = > 80% of plants are lodged

Leaf greenness was measured in top-most fully expanded leaf and adult-basal leaves by eye estimation. This parameter is useful to examine the effects of WL on leaf yellowing, associated with N remobilization and senescence in relation to leaf age among the genotypes (Table 4). In waterlogged condition leaf greenness was high in genotypes G00025 (3%) followed by BD2334 (3.66%) and BD2331 (3.60%). The lowest greenness was observed in G00060 (9%) followed by G00321 (8%). Greenness of adult leaves was significantly lower in waterlogged plants, leading to a detrimental carbon fixation performance at the plant level, and contributing to such a poorer growth (Pang *et al*. 2007, Zeng *et al.* 2013).

Plant lodging: The WL negatively affected soybean genotypes standing nature. Among the genotypes, G00138 (90%) showed the highest lodging followed by BU Soybean-1 (81%), G00164 (68.33%) and the lowest lodging was observed in G00113 (3.33%) followed by G00058 (4%) (Table 5). Genotypes with taller in height are highly prone to lodging in contrast with the genotypes which have shorter plant height as they have the potential to withstand under lodging pressure (Todaka *et al*. 2015). Sterling *et al.* (2018) also found that lodging may occur if the maximum bending moment at the base exceeds soil strength, which is the function of soil parameters and soil moisture contents.

Conclusion

The WL affected the plant height, leaf greenness and enhanced plant lodging of soybean genotypes, though genotypic differences were conspicuous. The genotypes BD2334, G00025 had highest SPAD value and greenness, while G00113 had the lowest lodging in WL treatment. So, genotypes BD2334, G00025 and G00113 were found relatively WL tolerant. Therefore, further research including these three genotypes are necessary at the field conditions for developing a WL short duration variety.

Acknowledgement

We acknowledge greatly the Ministry of Science and Technology for financial support for conducting this study.

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