Original Research Article

Effects of watering regimes on growth and yield of *Glycine max* (L.) Merrill (Soybean) varieties

Abstract

Climate change is causing a serious threat to agricultural sector as the major causes of environmental stress influencing plant growth and development. Water stress is one the major environmental stress. In order to evaluate the effects of two contrasting water stress (drought and waterlogging) on the growth and yield of soybean, a greenhouse experiment with 3 varieties of soybean and 5 watering regimes was conducted. Result showed that drought has more significant effect on soybean production than waterlogging. Water stress was observed to reduce plant height, root length, leaf area, number of leaves and number of pods produced in soybean. There is increase in chlorophyll A, chlorophyll B and proline which signify increase tolerance and resistance to water stress. Soil nitrogen fixed was reduced as water stress increases from waterlogging to drought. Result also concluded that watering regime of twice a week producing an average soil water content of 22.02% will be optimum for soybean production.

Keywords: Soybean, watering regimes, drought, waterlogging, chlorophyll content, proline, morphological traits

Introduction

Climate change has recently brought severe environmental factors to living organism. Environmental factors such as rainfall, temperature, soil salinity are becoming more extreme to plants as result of this climate change. Among these, water stress is the most significant. Water is an important compound to all living organisms due to its essential function for respiration and biochemical reactions in living organisms. It participates directly or indirectly in all metabolic process and cellular activities in living activities. Significance of water to plant might be negated in some cases causing water stress. Water stress including drought and waterlogging (flooding) is becoming a significant agricultural problem due to climate change (1). Plants which are sessile organism are mostly exposed to these two extreme water stresses as animals can possibly migrate to other favourable area when the unfavourable environmental factors become extreme in their niche. Responses of plant to stress occur through a number of ways such as anatomical, morphological or physiological responses. Water stress is a major setback to global food production and food security (2) as two – third of crop production in the world are cultivated under water stress (3).

Drought is one of the major abiotic factors leading to high reduction in plant growth and development. It is the leading factor in limiting crop plant production. Lesk et al. (2016) reported that it reduces plant yield by up to 50% in various part of the world. It is probably the most severe stress and major causes of significant losses in growth, productivity and yields of crop plants worldwide (5–7). It affects the physiological, biochemical and molecular processes in plants leading to growth inhibition, stomata closure, decrease in chlorophyll content, inhibition of photosynthesis and protein changes (8,9). Unfortunately, land area affected by drought worldwide has more than doubled from the early 1970’s to the early 2000’s (10). Drought severity is unpredictable and determined by rainfall amount, soil moisture holding capacity and crop evaporative demands (11). Water shortage is expected to increase due to global warming effects increasing evapotranspiration and drought intensity from 1 – 30% by 2100 (Odjugo, 2009; Zhao et al., 2017). Waterlogging are natural water disturbances which have detrimental effects on terrestrial plants (14). Waterlogging mostly affects terrestrial plant roots as its aerobic respiration ceases due to waterlogging, reduces energy rich adenylates causing decline in ion uptake and transport (15). It can cause oxygen stress (hypoxia) or total absence of oxygen (anoxia) in plants root (16). Excess water condition leads to high absorption, low transpiration rate causing build of high tugor pressure in cell elongation region causing maximum swelling of the cells resulting in leggy seedlings (Gray, 2004; Hsiao & Xu, 2000).

Glycine max (L.) Merill (Soybean) is one of the underused crops in Africa including Nigeria. It is an economically legume crop cultivated worldwide. The crop is recently gaining attention due to its high combined vegetable protein (40%) and oil (20%) contents (Banaszkiewicz, 2011; Michelfelder, 2009). Soybean, when processed in to flour, can be used in fortification of the common carbohydrates-based food in the region. It can therefore be used in mediating the problem of protein consumption. The soybean leaves is an edible source of protein source in livestock feed and the roots when planted fixes nitrogen into the soil thereby repairing the soil through its nitrogen fixing capabilities and commonly used in crop rotation. Nigeria produces about 600,000MT of soybean with Kano, Benue, Kadunna and Nasarawa the highest producing states. Its production is adversely affected by environmental stress. Factors such as c availability affect its growth (Mundstock, 2005; Staniak et al., 2023). Water stress is the most common and detrimental factor that significantly limits its production and yield (23,24) as it is sensitive to both waterlogging and flooding which reduce its growth and yield significantly (25). Soybean is sensitive to both water stresses and undergo morphological, physiological and biochemical changes which negatively affects its growth and yield (26). Global climate changes with persistent water stress are frightening reality to the sustainability of soybean production worldwide (27). Soybean production under water stress is dependent on the phonological stages of crop, duration and intensity of water stress (Doss & Thurlow, 1974).

In agricultural settings, drought in crop plant is countered by irrigation while flooding is mediated through drainage. In developing countries like Nigeria, these two technologies are mildly or nonexistent as most farmers practice rainfed agriculture. Irrigation, a popularly used technology amongst the two, when available, water source poses another headache to the farmers. Therefore, coupled with the lack of facilities of both irrigation and drainage in the growing harsh environmental conditions, farmers also face the problem of water scarcity. Deficit irrigation is now encouraged due to fresh water scarcity (29). Soybean producing region is located in savannah region which is subjected to varying extreme harsh condition in this climate change era particularly water stress. This arises due to the erratic and insufficient rainfall which increases drought occurrences and over flooding of river banks as farmlands are located near river banks in a bid to promote water access to crop plant and sometimes, over irrigation leading to flooding of farmland.

Water availability, excess or scarcity, can mean a successful harvest, reduction or total failure in yield. Knowledge of the amount of water needed for optimum growth is therefore necessary for planting time and use of irrigation or drainage where necessary for optimum production. Watering regimes is an economical management strategy to improve time and irrigation water application/drainage as its contribution to irrigation/drainage profitability and water use efficiency (Alordzinu et al., 2021). Effective watering regimes consider many factors such as crop water requirement, crop growth stage, crop species and variety, climatic factors and soil physical and chemical properties which determine its water holding capacity (Alordzinu et al., 2021). Plants use several morphological and physiological adaptive mechanism such as reduction in leaf sizes, hormonal changes or molecular adaptive mechanism to survive prolonged water stress (32). Differences in days of watering produces varying results in soil moisture content and provide a good adaptable way when irrigating soil as the procedure of soil moisture content calculation (33) has soil moisture content have been found tedious by small scale farmers.To overcome food and protein security threat, it is essential to identify best watering regimes for soybean cultivars.The study therefore investigates the best watering regime for optimum performance in soybean cultivation.

MATERIALS AND METHODS

Experimental Site:

The experiment was carried out at the green house of the Department of Botany, Faculty of Science, University of Ibadan, Ibadan, in order to control undesired input of water from external sources. Polythene bags were filled with sandy loamy soil gotten from the University of Ibadan nursery.

Plant materials:

Three varieties of soybean were collected from International Institute for Tropical Agriculture (IITA), Ibadan and are labelled as follows; Variety A - TGX 1987-10F, Variety B - TGX 1835-10E and Variety C - TGX 1987-62F.The soil was watered to field capacity and 3 seeds were planted into each of the pot. Germination and growth of seedlings were allowed for two weeks before imposition of water treatment after germinated seed were thinned to one stand per pot.

Experimental Treatments:

Water stress was simulated by variation in days of irrigation and waterlogging treatment always had soil over-saturated with water without submerging any parts of the plant. The soybean germinated seedlings were subjected to different watering regimes as follows: waterlogging treatment (Wat); once daily (1dy); twice a week (3dy); once a week (1wk) and once in two weeks (2wk). Plants were watered to field capacity on irrigation day until harvest.

Soil Moisture Content (SMC):

Small quantities of soil were taken from each watering regimes into an already weighed crucible and the weight is measured. This is taken as the wet weight (WW). The soil in the crucible was then oven dried at 80^{o}C for 48hrs until a stable weight is obtained. The weight was measured again and taken as the dry weight (DW). SMC was then calculated as follows SMC = $\frac{WW - DW}{DW} \times 100$.

Morphological characters and yield:

Plant Height (PH), Root Length (RL), Leaf area (LA) = (Leaf Length × Leaf Breadth × Correlation factor (0.75) of third trifoliate leaves) were measured with metre rule; Number of Leaves (NL), and Yield (Yd) was measured by counting the matured soybean pod produced by each treatment at the end of the experiment.

Chlorophyll Content:

For chlorophyll content, a fully expanded leaves were detached from plants from each treatment. Prior to extraction, they were rinsed in distilled water to remove any surface contamination. 0.05g of leaf material was weighed out and chlorophyll was extracted with 5mil 80% acetone and made up to 9mil. Each sample was transferred into 15mil centrifuge tubes and centrifuged at1500rpm for 7 min to remove the remaining leafy material. The supernatant was then read with a spectrophotometer at 645nm and 663nm wavelength. Chlorophyll a and chlorophyll b were calculated using Arnon, (1949) method.

Proline Content:

Proline was estimated spectrophotometrically following the method describes by (35). 0.25 g plant material (leaves) was homogenized in 10 mL 3% aqueous sulfosalicylicacid and the homogenate filtered using whatman paper 1. 2 mil acid ninhydrin (prepared by warming 1.2 g of ninhydrin was dissolved in 30 mil glacial of acetic acid and 30 mil of phosphoric acid) was added to 2 mil filtrate in a digestion tube. The solution was placed in a boiling water bath for 90 min and a brick red coloration was observed. 4 mil of toluene was added to the reaction mixture and agitated vigorously. The chromophore containing toluene was aspirated from the aqueous phase and the absorbance read at 520 nm using spectrophotometer. Toluene was used as a blank. The concentration was determined by reference to a standard curve prepared using 0-1 mg L^{-1} proline (sigma) and calculated on a dry weight basis (35).

Total Soil Nitrogen (TSN): Soil collected from each treatment was air dried at room temperature and sieved with 0.5mm sieve. 0.5g of the soil was then weighed into the digestion tube. 5 mil of conc. tetroxoxsulphate vi acid (H_2SO4) and 2 mil of hydrogen peroxide (H_2O_2) was added. A tablet of selenium was added into the soil to act as catalyst. It was put in digestion box at 350°C for 3 hours. After digestion, 10ml of distilled water and 10 ml of 40% sodium hydroxide was added to the solution and placed in the Kjeldahl distillation apparatus for the distillation process. The distillate was collected in receiver containing 0.1N of hydrochloric acid (HCl). The solution were then titrated against 0.1N sodium hydroxide with methyl orange as indicator. Total soil Nitrogen was then calculated using the following formula

Total Soil Nitrogen (%) = $\frac{(Volume\ of\ NaOH\ *\ Normality\ of\ NaOH * 14)}{weight\ of\ sample\ in\ gram\ (0.5g)}$ (36).

Statistical Analysis:

Data were collected in triplicate and processed using Excel 2019 software and the data were expressed as average values ± standard error. SPSS 21.0 statistical analysis software (IBM Corp., Armonk, NY, USA) was used to perform the ANOVA analysis and used to compare treatments and interaction at $\alpha = 0.05$.

RESULTSAND DISCUSSION

Effect of watering regimes on soil moisture content

Table 1: Watering regimes on average soil moisture content

Wat	**1dy**	**3dy**	**1wk**	**2wk**	**ANOVA (Watering Regime) at α = 0.05**
Soil Moisture Content (%)					
41.40 ± 0.48	**37.32 ± 0.55**	**22.02 ± 2.32**	**15.06 ± 2.62**	**9.01 ± 1.94**	**44.995***

Soil moisture content is reflection of the watering regimes application. Good vegetative growth and yield are observed in plants with optimum soil moisture content. Average soil moisture content reduces from 41.40% in waterlogging treatment to 9.01% in once in two-week treatment in the study as shown in table 1. Decreased soil moisture content under drought conditions has been reported in various agricultural system (37) and increase soil moisture content under waterlogging due to poor drainage (38). Increased leaf and soil evaporation during drought contributes to its low soil water content (39). Lee et al. (2017) reported different growth responses in perennial herbaceous plants as soil moisture increased. Waterlogging reduces soybean yield by 17 to 43% and its vegetative growth by 50 to 56% (Oosterhuis, 1990).

Effects of watering regimes on soybean morphological characters and yield

Effects of water stress imposed in soybean are reflected in the morphological traits and yield of soybean. It reduces plant height from 146.33cm, 137.53cm and 156.20cm in daily application to 145.53cm, 132.13cm and 131.80cm in waterlogging treatment and 110.50cm, 104.73cm and 119.53cm in once in two weeks treatment in variety A, B and C respectively (Table 2). Results also indicated that the effect on watering regime is significant on plant height while variety effect was not significant as shown in the ANOVA analysis (Table 3). There is reduction in plant height under water stress (Jaleel et al., 2007; Nemeskéri & Helyes, 2019). Previous study reported soybean seedling height decreased by 4.3% under drought stress (44). Drought stress reduces soybean plant height by limiting photosynthesis and nutrient uptake leading to hormonal imbalance and impaired plant growth (45). Similar effect is exhibited by waterlogging by restricting oxygen availability in plant root and leading to stunted growth (Kaur & Asthir, 2015). Anoxia and drought in plants reduces production and translocation of assimilants
(Khalid Muhammad Fasihand Zakir, 2023).

Root length is an important morphological trait in plant under stress and perform important role in its survival during these periods (Hoogenboom et al., 1987.). Results indicated that root length has the highest length under twice a week treatment with 31.60cm, 32.60cm and 29.40cm and reduced to 17.40cm, 16.40cm and 15.0cm in waterlogging treatment and 17.80cm, 21.20cm and 22.80cm in once in two-week water regime treatment in variety A, B and C respectively (Table 2). Results indicated that both water stresses significantly affect root length while variety was not found to be significant (Table 3). Manavalan et al., 2009 and (50) reported a decrease in soybean root length under drought while (51) and (52) also reported similar results in soybean root length under waterlogging stress. (53) reported that excess water in soil induces root decay, affects root formation and growth of existing roots though root tolerance to anoxia varies among plant species (54). There is also reduction in root characters i.e. length, density and thickness as a result of low water supply . Drought stress increases the root length as the roots searched for water (55). In general, longer root growth has higher resistance ability to water stress condition (56).

Table 2 also shows that leaf area was reduced from 85.19cm^2, 110.27cm^2 and 74.68cm^2 in twice a week water regime to 63.96cm^2, 61.42cm^2 and 53.15cm^2 in waterlogging and 65.67cm^2, 70.61cm^2 and 49.57cm^2 in once in two weeks water treatment in variety A, B and C respectively. Watering regime treatment and varieties were significant on leaf area as indicated in Table 3. Previous research had shown reduction in leaf area in soybean under drought (57) and waterlogging (Kaur & Asthir, 2017) as leaf area is sensitive to water stress since there is increased ethylene production during stress causing leaf growth reduction (59). Decreased cell expansion and leaf growth inhibition under drought is described as a water saving mechanism (60,61). Reduced leaf area in drought has a direct consequence of limiting water losses by reducing stomatal and cuticular transpiration (62). Reduction in leaf area under drought results in decreasing intercepting radiation area resulting in decrease in transpiration (63). Thus, it can be substantiated that long and droopy leaves (*i.e.* with higher leaf angle) results into leaf rolling which is an adaptive response to water deficit in rice(Singh, 2000).

Number of leaves reduced from 9.20, 8.40 and 10.27 of leaves in twice a week water regime application to 7.60, 7.73 and 8.13 in waterlogging treatment and 7.47, 7.60 and 9.20 in once in two weeks water treatment (Table 2). Watering regime plays significant role in number of leaves while varieties was not significant (Table 3). Reduction in number of leaves observed in was more pronounced in drought than waterlogging (65). Results has shown reduction in number if leaves in soybean under drought condition (Zhao et al., 2017). This results from decrease leaf initiation and early senescence and can be drought tolerance mechanism or water conservation strategy under drought (Rivero et al., 2007). Similar observation was reported in the number of leaves of *Conocarpus erectus* under drought (El-Juhany & Aref, 2005). Number of leaves reduction which may be as a result of leaf shedding due to oxygen deficiency (68) was also reported under waterlogging (52).

Fruiting pod is the main yield of soybean plant producing the soybean seeds. Soybean pod yield was reduced under drought from 13, 11 and 12 pods produced under watering twice a week watering regime to 5, 6 and 7 in waterlogging and 3, 3 and 4 pods produced under once in two weeks water regime application in variety A, B and C respectively. Soybean growth and development is affected under waterlogging and drought watering regimes which then reduces the yield as stress increases. Stress factor particularly drought negatively causes sharp decrease of plant yield (Pan et al., 2002.). Yield is reduced under drought stress as reported by previous researches(70,71). Drought leads to reduction in flower initiation, pod set, pod number per plant and pod size (72). Waterlogging causes impaired pollen viability, increased flower abortion and inhibited reproductive development (Pang et al., 2018; Qi et al., 2020).

All morphological traits are affected by the waterlogging and drought factor as seen in table 3 with soybean varieties significant on leaf area only. Good morphological characters and yield result were generally obtained in twice a week treatment with a soil moisture content of 38% across all varieties. In all soybean varieties studied, morphological characters showed a decrease with increase water stress with waterlogging performing better than drought. Decrease in morphological characters and pod might be due to decrease in cell elongation resulting from the inhibiting effect of water stress on growth promoting hormone leading to decrease in cell turgor and eventually leading to suppression in plant photosynthetic efficiency due to closing of stomata and inhibition of Rubisco enzyme (8).

Table 2: Morphological traits and yield of soybean varieties in response to different watering regime

	Wat	**1dy**	**3dy**	**1wk**	**2wk**
Varieties			**Plant Height (cm)**		
A	**145.53 ± 19.65**	**146.33 ± 18.63**	**145.47 ± 15.32**	**134.87 ± 16.14**	**110.50 ± 14.02**
B	**132.13 ± 15.41**	**137.53 ± 16.68**	**134.60 ± 15.37**	**128.00 ± 13.79**	**104.73 ± 14.56**
C	**131.80 ± 16.33**	**156.20 ± 19.16**	**154.20 ± 20.21**	**146.20 ± 21.04**	**119.53 ± 16.40**
Varieties			**Root Length (cm)**		
A	**17.40 ± 1.60**	**29.60 ± 3.46**	**31.60 ± 1.50**	**24.60 ± 0.51**	**17.80 ± 1.85**
B	**16.40 ± 2.42**	**29.40 ± 2.16**	**32.60 ± 2.38**	**25.00 ± 1.22**	**21.20 ± 2.18**
C	**15.40 ± 2.42**	**28.40 ± 1.60**	**29.40 ± 2.84**	**26.60 ± 2.20**	**22.80 ± 2.60**
Varieties			**Leaf Area (cm^2)**		
A	**63.96 ± 2.64**	**76.65 ± 7.86**	**85.19 ± 7.05**	**66.78 ± 6.93**	**65.67 ± 7.03**

B	**61.42 ± 6.50**	**87.27 ± 9.60**	**110.27 ± 8.01**	**105.05 ± 8.82**	**70.61 ± 7.59**
C	**53.15 ± 4.12**	**73.19 ± 8.61**	**74.67 ± 10.63**	**63.05 ± 7.44**	**49.57 ± 4.75**
Varieties			**Number of Leaves**		
A	**7.60 ± 0.97**	**8.00 ± 1.04**	**9.20 ± 1.27**	**8.20 ± 1.23**	**7.47 ± 1.03**
B	**7.73 ± 1.05**	**7.67 ± 1.15**	**8.40 ± 1.16**	**7.67 ± 1.07**	**7.40 ± 1.19**
C	**8.13 ± 1.11**	**9.13 ± 1.06**	**10.27 ± 1.59**	**9.20 ± 1.27**	**8.47 ± 1.18**
Varieties			**Number of Fruiting Pods**		
A	**5 ± 0**	**7 ± 1**	**13 ± 1**	**7 ± 1**	**3 ± 1**
B	**6 ± 1**	**8 ± 0**	**11 ± 0**	**9 ± 0**	**3 ± 1**
C	**7 ± 0**	**9 ± 2**	**12 ± 2**	**8 ± 1**	**4 ± 1**

Wat - Waterlogging, 1dy - Daily watering, 3dy - Twice a week, 1wk - Once a week, 2wk - Once in two weeks

Table 3: ANOVA for soybean morphological traits and yield at p **= 0.05**

Effect	Df	Plant Height	Root Length	Leaf Area	Number of Leaves	Number of Fruiting Pod
Wat. Reg	**4**	**2.04***	**23.45***	**8.87***	**1.62***	**28.56***
Varieties	**2**	**0.89***	**0.13**	**13.50***	**1.34***	**0.61***
Wat. Reg x Varieties	**8**	**0.11**	**0.59**	**1.50***	**0.49**	**0.64**

Effects of watering regime on chlorophyll contents

Table 4: Effects of watering regime on chlorophyll A and chlorophyll B in soybean varieties

	Wat	1dy	3dy	1wk	2wk	ANOVA (Watering Regime) at p = 0.05
Varieties		**Chlorophyll A Content (mg/g)**				
A	**7.64**	**16.19**	**17.01**	**18.47**	**21.97**	
B	**3.98**	**10.50**	**10.71**	**15.73**	**16.39**	**212.73***
C	**5.38**	**15.84**	**15.30**	**16.33**	**18.03**	
Varieties		**Chlorophyll B Content (mg/g)**				
A	**5.29**	**9.26**	**8.76**	**9.42**	**10.98**	
B	**2.80**	**5.77**	**6.51**	**6.62**	**8.38**	**25.54***
C	**4.37**	**8.80**	**6.36**	**7.23**	**9.43**	

Wat - Waterlogging, 1dy - Daily watering, 3dy - Twice a week, 1wk - Once a week, 2wk - Once in two weeks

Water stress causes biochemical and physiological changes in plants thereby affecting plant growth and development. Chlorophyll a is highest at once in two weeks watering regime application with 21.31, 16.39 and 18.03 and lowest under waterlogging treatment with 7.31, 3.98 and 5.05 for variety A, B and C respectively. Chlorophyll b is observed highest also at once in two weeks water regime with 10.18, 8.37 and 9.43 and lowest at waterlogging regime with 5.98, 2.80 and 4.37 for variety A, B and C respectively (Table 4). Variable responses with both increase and decrease were reported on chlorophyll level of plants subjected to droughts and waterlogging stress (Pan et al., 2016) depending on duration and severity of stress with majority of results indicating decline in chlorophyll content (61). Majority Results obtained indicted increase in chlorophyll level of soybean varieties with increase in drought stress. This might be attributed to intermittent subjecting the soybean to water stress and rehydration making the soybean adjusts the chlorophyll level as a means of survival. (Farooq and Hussain, 2012) reported that increasing level of chlorophyll under water stress is a survival mechanism developed in plant (76,77). Increase in chlorophyll in onion under drought stress has also been reported (78).

Effects of watering regimes on proline in soybean varieties

Table 5: Effects of Watering Regime on Proline in soybean

	Wat	1dy	3dy	1wk	2wk	ANOVA (Watering Regime) at p = 0.05
Varieties	Proline Content (µg/g)					
A	948.40	419.20	386.33	1607.20	6558.80	
B	671.40	457.60	402.20	1269.60	6675.60	5677.736*
C	585.20	723.60	577.40	1748.60	6557.20	

Wat - Waterlogging, 1dy - Daily watering, 3dy - Twice a week, 1wk - Once a week, 2wk - Once in two weeks

Adverse environmental stress conditions tend to adjust plant structural conditions and prevent excessive water loss and maintain cell turgidity (79). All soybean varieties studied increased in proline accumulation as water stress increases in soybean. The highest was observed under excessive drought water regime at once in two weeks water regime treatment with 6558.8, 6675.6 and 6557.2 and lowest in daily water regime in varieties A, B, and C respectively and lowest at daily watering regime with 419.2, 457.6 and 505.2 in varieties A, B and C respectively (Table 5). Similar results of proline accumulation under stress have been reported in groundnut (80,81) and chickpea (82). Water stress induces the plants to produce proline to maintain cell turgor pressure (83). Accumulation of proline is a metabolic response of plants under abiotic stress. Increase in its accumulation indicates reduction in negative effects of water stress as it works as osmotic adjustor to stress effect and promote higher cells resistance cells under adverse conditions (84). Proline, an essential amino acid, is a common amino acid accumulated during biotic and abiotic stresses and reported under drought stress (83,85). It is considered as neutral osmolyte and stabilises enzymes and protects cellular structures (86,87). Proline also possesses antioxidant activity and contribute to cellular homeostasis thereby cushioning water stress effects on plants and provides energy source for the stress-recovery process (88,89).

Effects of watering regimes on Total Soil Nitrogen fixation of soybean

Table 6: Effects of watering regime on fixed total soil nitrogen

	Wat	1dy	3dy	1wk	2wk	ANOVA (Watering Regime) at p = 0.05
Varieties	Soil Nitrogen Content (g/kg)					
A	1.47	2.17	1.64	2.80	2.95	
B	1.58	1.79	2.26	2.69	3.27	3.97*
C	1.80	1.86	1.68	3.15	3.25	

Wat - Waterlogging, 1dy - Daily watering, 3dy - Twice a week, 1wk - Once a week, 2wk - Once in two weeks

Soil nitrogen fixed from effect of watering regime on soybean in the soil increased from an initial concentration of 0.9g/kg present the in soil before the start of the experiment to concentration varying from an increase of 1.47g/kg, 1.58g/kg and 1.80g/kg in waterlogging regime which has the lowest values to 2.96g/kg, 3.27g/kg and 3.25g/kg in once in two week water regime application in variety A, B. and C respectively. Nitrogen content fixed was not significant among the variety and treatment. Waterlogging in most cases reduces availability of nitrogen to plants (90) by causing reduction in stomatal conductance due to increase in abscisic acid accumulation (91) thereby reducing root hydraulic conductance (Vandeleur et al., 2005). Formation and growth of root noodles can be affected by factors affecting plant development such as stress.

CONCLUSION

Soybean is a significant worldwide oilseed and vegetable oils from its seed, source of cheap leafy biomass for the livestock industry which also remedy the soil by fixing nitrogen. Its production is adversely affected by environmental stress among which it is more sensitive to water stress. It becomes necessary to irrigate or drain where necessary when it is exposed to stress to produce higher yield in pod, nitrogen fixation and higher biomass. Local farmers tend to not understand water content but easy to recommend days of watering. Soybean is affected by water stress with drought effect more significant than waterlogging. The study helps to understand adaptive mechanism of soybean varieties under varying water stress and can be used to identify useful traits for soybean breeding. From the study, it can be observed that watering regimes of twice a week and once a week to field capacity will be optimum soybean production considering the agricultural and economic value of production. Further study is necessary to replicate and confirm results under field conditions.

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