Pak. J. Weed Sci. Res., 18: 427-433, Special Issue, October, 2012

ROOT AND SHOOT GROWTH UNDER FLOODED SOIL IN WILD GROUNDNUT (*Glycine soja*) AS A GENETIC RESOURCE OF WATERLOGGING TOLERANCE FOR SOYBEAN (*Glycine max*)

K. Miura[1], A. Ogawa[1], K. Matsushima[2] and H. Morita[1]

ABSTRACT

Water logging injury is a significant problem in soybean (G. max Merr.) production in Japan, because it is cultivated mostly in the converted paddy field. Wild groundnut (G. soja Sieb. et Zucc.), an ancestor of soybean, is growing around paddy field as a weed throughout the country. In order to evaluate waterlogging injury tolerance as a genetic resource for soybean, root and shoot growth in wild groundnut were investigated under the treatments by raised groundwater level upto soil surface for 21 days at the primary leaf and the flowering stages compared with soybean (cv. Ryuho). At the end of treatment of primary leaf stage, root length density (RLD) increased to 320%, and shoot dry matter weight per plant (DMW) decreased to 31% against no-treatment in wild groundnut, while influences on RLD and DMW were inconspicuous in soybean. It was considered that wild groundnut responded to excess water stress by increasing lateral root with root formation. At the end of treatment of flowering stage, RLD and DMW were not influenced in either species. However, the number of root nodules decreased greater in wild groundnut than in soybean, suggesting the difference in susceptibility to waterlogging injury at the flowering stage between these species. Reduction in leaf chlorophyll content by the treatment was observed continuously until maturity stage only in wild groundnut. At the maturing stage, grain yield in wild groundnut and pod number in soybean were measured to determine recovery from damages by the treatments. In wild groundnut, grain yield was equal to no treatment as well as pod number of soybean, and decreased to 15% by the treatments at the primary leaf and the flowering stages, respectively. However in soybean, pod number decreased to 54% by treatment at the flowering stage. Considering the severe damage in DMW at the end of treatment of primary leaf stage, wild groundnut showed higher ability to recover from the damage by the treatment than soybean. Consequently, it was suggested that waterlogging tolerance in wild groundnut might be related to the amount and the activity of root. Importance of root aerenchyma for waterlogging tolerance in soybean have been reported by many researchers. Therefore root development including aerenchyma formation under flooded condition should be investigated to utilize wild groundnut as a genetic resource of waterlogging tolerance for soybean.

Key words: genetic resource, root length density, soybean, wet injury, wild groundnut.

---

[1]Graduate School of Bioresource Sciences, Akita Prefectural University, Akita, 10-0195, Japan.
[2] Faculty of Bioresource Science, Akita Prefectural University, Akita, Japan.
Corresponding author's email: m12f011@akita-pu.ac.jp

INTRODUCTION

In Japan, soybean (*Glycine max* Merr.) is cultivated mostly in converted paddy field where drainage is inadequate (Araki, 2006), and is damaged occasionally by water logging injury. Wild groundnut (*G. soja* Sieb. et Zucc.), an ancestor of soybean, is growing as a weed throughout the country (Lee *et al.,* 2008) and it has been reported that the plant develops conspicuous aerenchyma in root (Shimamura, 1997) and basal part of stem (Arikado, 1954) under flooded condition, resulting in high waterlogging injury tolerance. There are many reports on waterlogging injury tolerance of wild groundnut mainly from the view point of the anatomy, but there are few reports on the ecological responses. Therefore this study was conducted to evaluate waterlogging injury tolerance of wild groundnut as a genetic resource for soybean in term of the ecological characteristic.

MATERIALS AND METHODS

Seeds of wild groundnut collected at rural area in Akita city and soybean (cv. Ryuho) were sown in plastic container (84 cm long × 63cm wide × 41cm height) filled with andosol on 31st May, 2010. After emergence, seedlings were thinned to ten plants per container. Waterlogging treatments were conducted by raising groundwater level up to soil surface from -30cm for 21 days at the primary leaf stage (W1) and the flowering stage (W2) of each species, respectively. Controls were kept at -30cm of groundwater level throughout the experiment. Root length density, shoot dry weight per plant and number of nodes on main stem were measured at the end of W1, W2 treatments and the maturing stage. Root length density (cm/cm^3) was calculated based on root length in soil monolith (117cm^2 area of base × 20cm depth), divided into 5cm interval. Other measurements included leaf area and length of main stem: end of W1, number of root nodules at the end of W2, branch number at the end of W2 and the maturing stage, leaf chlorophyll content with SPAD-502 (Minolta) at 14, 35, 55, 76, 86, 98, 119, 134 days after sowing. Grain yield of wild groundnut and pod number of soybean were measured at the maturing stage. Because grain yield of soybean could not be measured by bean bug (*Riptortus clavatus*) damage, pod number was measured at the maturing stage. The experiment was conducted with three replications.

RESULTS

Effect of Waterlogging Treatment on Growth and Root Length Density at the Primary Leaf Stage

At the end of primary leaf stage treatment, shoot dry weight, number of nodes on main stem and length of main stem decreased significantly in wild groundnut and number of nodes on main stem decreased in soybean. Waterlogging reduced leaf area by 55% in wild groundnut and 58% in soybean. Leaf area was not influenced by waterlogging treatment in either species (Table-1).

Table-1. Effect of waterlogging treatment on growth at the primary leaf stage (W1).

Species	Treatment	Shoot dry weight (g/plant)	Leaf area (cm^2/plant)	Number of nodes on main stem (/plant)	length of main stem (cm)
Wild groundnut	W1	0.1±0.0 ***	25.9 ± 14.9	2.9±0.2 **	8.6 ± 0.7 ***
	Control	0.3±0.0	58.0 ± 9.6	5.3±0.5	17.6±1.4
Soybean	W1	1.1±0.4	144.5±58.0	3.9±0.4 **	12.4±1.6
	Control	1.8±0.3	346.1±69.7	5.3±0.2	14.1±1.2

Values: Average ± S.E. (n=3), t test: **; p<0.05, ***; p<0.01

At the end of primary leaf stage treatment, root length density at 5-10cm of soil depth increased significantly in wild groundnut while that of soybean was not influenced. At 0-5cm of soil depth, root length density of wild groundnut increased though significance was not obtained by fluctuation among replications. Root length density below 10cm of soil depth was not influenced in both species (Table-2).

Table 2. Effect of waterlogging treatment on root length density at the primary leaf stage (W1).

Species	Treatment	Root length density (cm/cm^3)			
		Soil depth (cm)			
		0-5	5-10	10-15	15-20
Wild groundnut	W1	1.7±0.9	0.9±0.2 **	0.4±0.2	0.3±0.2
	Control	0.4±0.1	0.2±0.1	0.2±0.1	0.2±0.1
Soybean	W1	1.5±0.3	0.9±0.1	0.9±0.4	0.5±0.2
	Control	1.0±0.0	0.9±0.2	1.0±0.2	0.7±0.3

Values: Average ± S.E. (n=3), t test: **; p<0.05

At the end of primary leaf stage treatment, leaf chlorophyll content of both species decreased. However, this decrease recovered earlier in wild groundnut than that of soybean (Figure 1).

Effect of Waterlogging Treatment on Growth and Root Length Density at the Flowering Stage

At the end of flowering stage treatment, there was no influences of waterlogging on the growth in either species (Table 3).

At the end of flowering stage treatment, root length densities were not influenced by treatments at any soil depths. Root nodule number tended to decrease both in wild groundnut and soybean (Table-4).

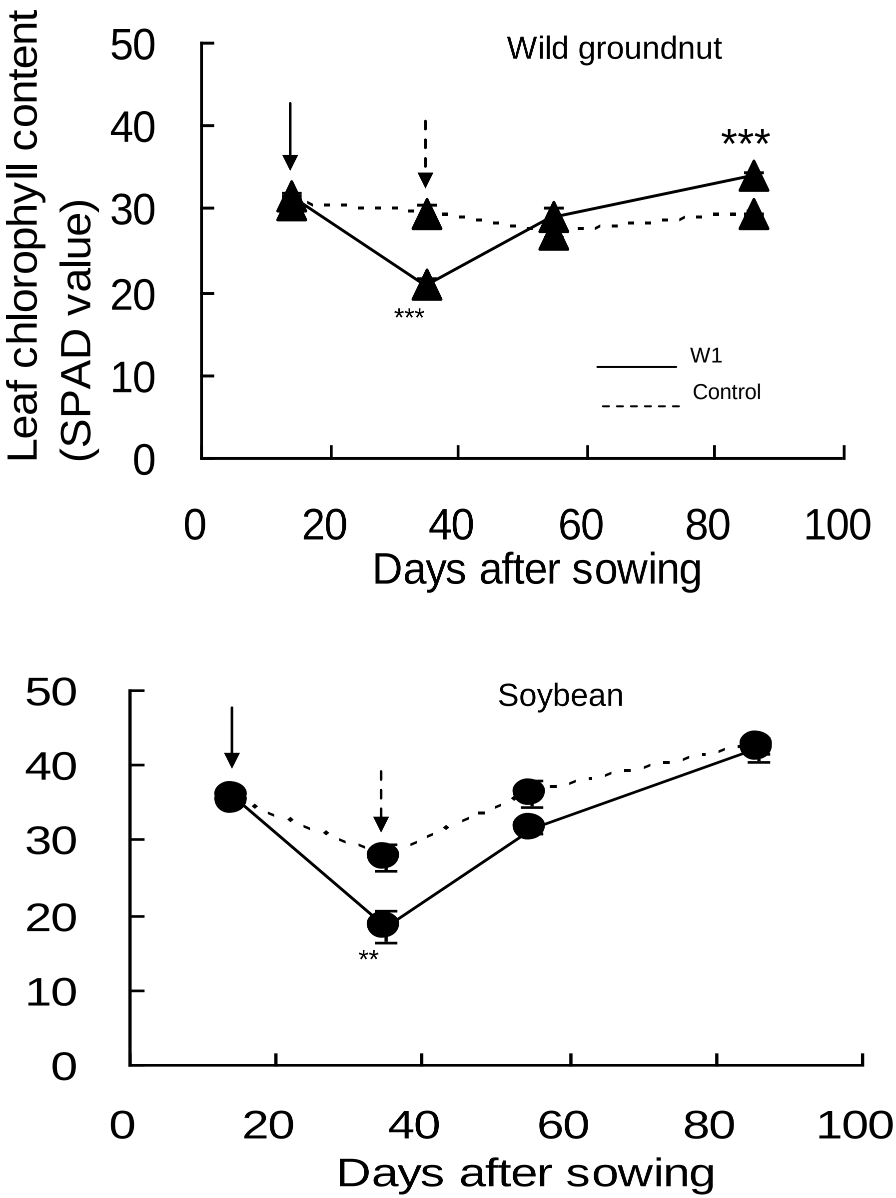

Figure 1. Influence and recovery process in leaf chlorophyll content during and after waterlogging treatment at the primary leaf stage.

→ : Start of treatment, - - → : End of treatment, t test: **; p<0.05, ***; p<0.01

Table-3. Effect of waterlogging treatment on growth at the flowering stage (W2).

Species	treatment	Shoot dry weight (g/plant)	Number of nodes on main stem (/plant)	Branch number (/plant)
Wild groundnut	W2	39.0 ± 5.8	27.3±0.9	23.3±1.3
	Control	38.0±18.2	22.2±4.1	17.1±3.9
Soybean	W2	18.5 ± 2.3	12.8±0.1	7.5 ± 0.6
	Control	21.7 ± 4.3	12.0±1.0	7.0 ± 0.6

Values: Average ± S.E. (n=3)

Table-4. Effect of waterlogging treatment on root length density and number of root nodules at the flowering stage (W2).

Species	treatment	Root length density (cm/cm^3) Soil depth (cm)				Number of root nodule (/plant)
		0-5	5-10	10-15	15-20	
Wild groundnut	W2	4.2±1.5	4.7±1.9	5.4±2.3	5.7±2.3	10.5 ± 4.8
	Control	3.1±1.6	3.8±1.9	4.7±2.4	5.7±2.6	38.2±18.3
Soybean	W2	5.2±0.8	5.7±1.1	5.5±1.9	4.6±1.2	16.3 ± 2.9
	Control	5.3±0.5	5.6±0.0	6.0±1.0	5.0±0.9	26.5 ± 3.4

Values: Average ± S.E. (n=3), t test: ***; $p<0.01$

Leaf chlorophyll content of wild groundnut decreased at the end of flowering stage treatment. Wild groundnuts plants failed to recover chlorophyll contents after the treatment, while soybean plants were recovering well after waterlogging (Figure 2).

Growth, Yield and Root Length Density at the Maturing Stage

At the maturing stage, there were no significant differences in the growth of aerial parts among W1, W2 and control in either species.

Significant reduction in grain yield was observed in W2 of wild groundnut. There were no significant differences in pod number as a yield component of soybean (Table-5).

Increase in root length density at depths of 0-5cm and 5-10cm which was observed at treatment W1 was maintained till the maturing stage though the difference was not significant for either species. Furthermore, tendency of increase in root length density below 10cm of W1 was observed.

DISCUSSIONS

Aerenchyma cells develop in as a strategy of waterlogging tolerance in upland crops (Shimamura *et al.,* 1997). Arikado (1954) found that wild groundnut developed conspicuous aerenchyma cells in basal part of stem in response to waterlogging. In this study, in wild groundnut, root length density near soil surface increased by waterlogging treatment at the primary leaf stage. Wild groundnut showed higher ability to recover from the damages by waterlogging treatment at primary leaf stage such as decrease in dry weight and leaf chlorophyll content than soybean. This ability is considered as waterlogging tolerance in wild groundnut from the ecological viewpoint given by increase of root length density. As development of aerenchyma in root system was not investigated in this study, relationship between the amount of root and the aerenchyma formation in root system should be investigated furthermore to utilize wild groundnut as a genetic resource of waterlogging tolerance for soybean.

Table-5. Growth and yield at maturing stage in wild groundnut and soybean treated with waterlogging treatment at the primary leaf stage (W1) and flowering stage (W2).

Species	treatment	Shoot dry weight (g/plant)	Number of nodes on main stem (/plant)	Branch number (/plant)	Grain yield for wild groundnut (g/plant) Pod number for soybean (/plant)
Wild groundnut	W1	10.3±2.1	29.8±1.6	33.6±4.5	2.1 ± 0.6
	W2	7.7 ± 0.4	21.9±4.7	19.7±5.6	0.3 ± 0.0 *
	Control	9.3 ± 1.4	32.1±2.1	33.1±3.8	1.6 ± 0.5
Soybean	W1	3.9 ± 0.7	11.3±0.9	9.2 ± 1.2	46.1±2.9
	W2	3.7 ± 0.5	12.6±0.3	7.7 ± 0.6	24.5±5.0
	Control	6.5 ± 2.3	13.3±0.8	8.4 ± 0.9	45.5±9.7

Figure: Average ± S.E. (n=3), t test: *; $p<0.1$

Table-6. Root length density at maturing stage in wild groundnut and soybean treated with waterlogging treatment at the primary leaf stage (W1) and flowering stage (W2).

Species	treatment	Root length density (cm/cm^3)			
		Soil depth (cm)			
		0-5	5-10	10-15	15-20
Wild groundnut	W1	4.0±2.1	3.3±0.5	3.8±0.8	4.4±1.0
	W2	1.3±0.2	1.9±0.4	1.3±0.2	2.6±0.9
	Control	2.9±2.7	2.0±1.8	2.2±2.0	2.3±1.5
Soybean	W1	3.8±2.5	2.8±0.6	3.1±0.7	2.9±0.5
	W2	5.4±2.3	4.1±1.3	4.7±1.0	5.2±0.6
	Control	2.8±1.6	4.2±2.5	2.9±1.5	3.8±1.2

Values: Average ± S.E. (n=3)

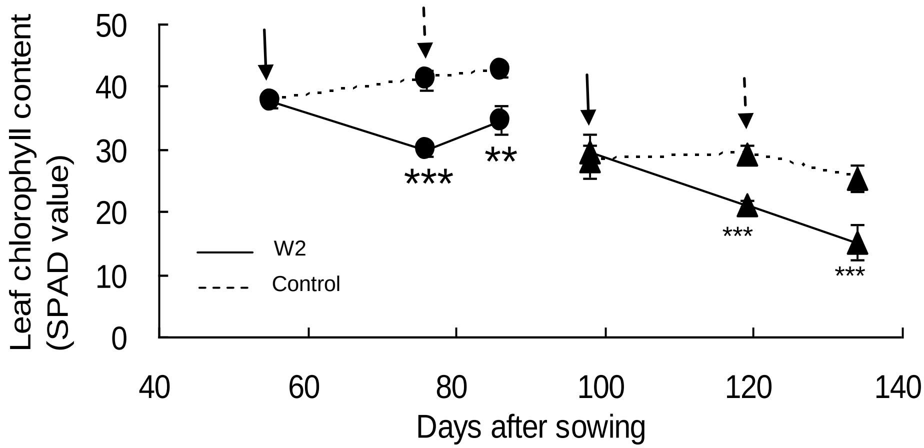

Figure 2. Influence and recovery process in leaf chlorophyll content during and after waterlogging treatment at the flowering stage.

▲: Wild groundnut, ●: soybean,

⟶ : Start of treatment, - - ▸ : End of treatment, t test: **; $p<0.05$, ***; $p<0.01$

REFERENCE CITED

Araki, H. 2006. Water Uptake of Soybean (*Glycine max* L. Merr.) During Exposure to O_2 Deficiency and Field Level CO_2 Concentration in the Root zone. Field Crop Res. 96(1): 98-105.

Arikado, H. 1954. Different Responses of Soybean Plants to an Excess of Water with Special Reference to Anatomical Observations. Proc. Crop Sci. Soc. Japan. 23(1):28-36.

Lee, J. D., J.K. Yu, Y.H. Hwang, S. Blake, Y.S. So, G.J. Lee, H.T. Nguyen and J.G. Shannon. 2008. Genetic Diversity of Wild Soybean (*Glycine soja* Sieb. and Zucc.) Accessions from South Korea and Other Countries. Crop Sci. 48(2):606-616.

Shimamura, S., Mochizuki, T., Inouye, J. 1997. Formation of the Lysigeneous Intercellular Space in Adventitious Roots of Leguminous Species. Japanese J. Crop Sci. 66(2): 208-213. (In Japanese with English summary).