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Full Length Research Paper

Effect of soil moisture stress on the growth of *Corchorus olitorius* L.

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Effect of soil moisture stress on the growth of *Corchorus olitorius* L. was investigated using two varieties in the glass house during summer at Tokyo, Japan. Smaller growth was showed in light moisture stress (60 - 50%) and acute moisture stress (40 - 30%) comparing to that of field capacity soil moisture, however the growth in light and acute moisture stress was not much different from each other. Plant height was stunted under soil moisture stress condition. It was caused by shorter inter- nodes. Soil moisture stress affected the growth of inter- nodes. Both varieties of *C. olitorius* were able to grow under heavy soil moisture stress condition (less than 30% of field capacity soil moisture, primary wilting point of plants). The *C. olitorius* has tolerance to soil moisture stress. Application of abscisic acid was not effective for the growth of *C. olitorius* under soil moisture stress condition, because of its tolerance to soil moisture stress. Viscosity of branches in both varieties was larger in heavy soil moisture stress condition. The viscosity in *C. olitorius* seems to be related with soil moisture stress.

Key words: abscisic acid, mucilage, soil moisture, viscosity, yield

INTRODUCTION

Corchorus olitorius L. (Nalta jute or tossa jute) is widely distributed in tropical and sub- tropical region. Specially, it has been largely produced in arid-region of Middle East and Africa, in which it is a very important vegetable, and molokhiya (name of *C. olitorius* in Arabic) soup is very common cooking. *C. olitorius* has mucilage, and it has effect on the cooking taste. Mucilage of *C. olitorius* is reported to be an acidic polysaccharide consisting of gal-acturonic acid, galactose, mannose, glucose and arabi-nose (Tsukui et al., 2004).

C. olitorius , Amaranthus and Okra are important leafy vegetables in West Africa, and the *C. olitorius* production is an annually event in dry season. *C. olitorius* has shown tolerant to soil moisture and NaCl stress (Fawusi et al., 1984; Ayodele and Fawusi, 1989, 1990; Chaudhuri and Choudhuri, 1997).

Distribution of *C. olitorius* in arid-region is thought to be attributed to its tolerance to soil moisture stress. However the characteristics of drought tolerance of *C. olitorius* are not well known. Endogenous abscisic acid (ABA) was known to be related to several environmental stress on the growth of plants (Takahashi et al., 1999). This study is therefore, an attempt to determine the effects of soil moisture stress on the growth of the plants with a view of determining the characteristics of response and the effect of ABA application on the growth of *C. olitorius* under the different soil moisture levels was studied.

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MATERIALS AND METHODS

Experiment 1

The effect of different soil moisture levels on the growth of two varieties *C. olitorius* was investigated in a glass house using cv. Yaya (local variety from Nigeria) and Moroheiya (Sakata Co. Ltd. Japan) at the Tokyo University of Agriculture (TUA), Tokyo, Japan from 3 May to 17 September 2004. Seeds of each variety were sown in the boxes. The seedlings on three leaves were transplanted in the plastic pots of size 20 cm diameter and 60 cm depth already filled with topsoil (soil and sand mixture 7:3) on 25 June. Each plastic pot was supplied with N. P. K. fertilizer at 15 kg element per 100 m^2

In order to determine the water holding capacity of the soil being used and the frequency of water application, the field capacity and the gravimetric moisture contents were estimated using Anderson and Ingram procedure (1993). Based on this method, three watering levels were adopted to establish the following soil moisture conditions: field capacity water level (FCW; >75% of the field capacity), light moisture stress (LMS; 60 - 50%) and acute moisture stress (AMS; 40 - 30%).

Eighteen pots of each variety were used. Six pots of each were kept under each of the LMS and AMS conditions. The rest were kept under FCW condition. The soil moisture level was adjusted after 7 days transplanting to harvest. Plants were harvested, and plant height, number of inter-node, length of inter-node, number of leaf and branch, and their weights were recorded on 17 September 2004.

Experiment 2

The effect of ABA application on the growth of *C. olitorius* under the different soil moisture levels was studied in a glass house at TUA, Tokyo from 3 June to 30 September 2004. The variety Moroheiya was used as experiment 1. Seeds were sown in the boxes, and the seedlings on three leaves were transplanted in plastic pots already filled with topsoil (soil and sand mixture 7:3) on 30 June as experiment 1. Each plastic pot was supplied with N.P.K. fertilizer at 15 kg element per 100 m^2

Two watering levels were adopted to establish soil moisture conditions; FCW and AMS. The soil moisture level was adjusted till harvest as experiment 1. The plants from each soil moisture conditions were foliar sprayed with 1 and 10 mgl^{-1} of ABA by 100 ml per plant every 7 days, ten times from 22 July. Six pots of each ABA treatment with different soil moisture levels were prepared. Control plants were sprayed with water on the same dates and with the same amount.

Plants were harvested and weighed, and plant height, leaf, branch and inter-node were measured on 30 September 2004 as experiment 1.

Experiment 3

The effect of drought condition on the growth, yield and viscosity of leaf and stem of two varieties *C. olitorius* as experiment 1 were investigated in a glass house at the TUA, Tokyo, Japan from 3 May to 8 August 2006. Seeds were sown in the boxes, and the seedlings on three leaves were transplanted in plastic pots already filled with topsoil (soil and sand mixture 7:3) on 29 May as experiment 1. Each plastic pot was supplied with N. P. K. fertilizer at 15 kg element per 100 m^2

Two watering levels were adopted to establish AMS and heavy moisture stress (HMS; less than 30%, as primary wilting point of the plant). Fifty pots of each variety were used. Twenty five pots of each were kept under each of the AMS and HMS conditions. The soil moisture level was adjusted till harvest as experiment 1.

Growth was measured every week from 10 days after planting. Lateral branches (> 20 cm) were harvested and weighed from 12 July to 3 August. Viscosity of plant was measured using harvested stems and leaves from AMS and HMS conditions treatment on 3 August. Main stem, lateral branches and leaves were cut into 2 – 3 mm size by blender, and 5 g of each was put into 50 ml of water, and kept 24 h at 5°C for mucilage extraction (Viscous flow water). Viscous flow water was measured by Viscosity gauge VA-10A, CBC materials co. Ltd, Japan at 25°C with 5 replicates.

RESULTS AND DISCUSSION

The morphological characteristics of two varieties *C. olitorius* under different soil moisture conditions were shown on Table 1 in experiment 1. Shorter plant height in both varieties was observed in AMS and LMS conditions comparing to FCW. Plant height of FCW, LMS and AMS condition in cv. Moroheiya was 171.7, 150.4 and 131.4 cm respectively. Corresponding values in cv. Yaya were 225.1, 183.2 and 166.1 cm respectively. However, number of inter-nodes in main stem was not different among soil moisture conditions in cv. Moroheiya. Fewer internodes were developed in AMS of cv. Yaya. The length of inter- nodes in main stem of FCW, LMS and AMS conditions in cv. Moroheiya was 3.4, 2.9 and 2.5 cm respectively. Corresponding values in cv. Yaya were in 3.3, 2.5 and 2.8 cm respectively. Shorter plant height of both varieties in AMS and LSM conditions was caused by short inter-node length. Soil moisture stress affected the growth of inter-nodes.

Development of number, length and leaf number on first branch was significantly fewer in AMS in the both varieties. Number of first branch in FCW, LMS and AMS conditions in cv. Moroheiya was 45.0, 46.5 and 39.2 respectively. That of variety of cv. Yaya was 47.4, 46.2 and 30.8 respectively. Length of first branch in FCW, LMS and ASM conditions in cv. Moroheiya was 21.6, 16.9 and 12.5 cm respectively, and in case of cv. Yaya was 3.2, 3.2 and 1.9 cm respectively. Only few secondary branches were developed on this experiment, and it was not different among treatments and varieties. Number of leaves on first branch in FCW, LMS and AMS conditions in cv. Moroheiya was 415.3, 427.3 and 327.9 respectively.

Corresponding values in cv. Yaya was 196.6, 222.3 and 100.3 respectively. Smaller mean leaf area on first branch in both varieties was observed in AMS and LMS conditions comparing to FCW. Mean leaf area on first branch in FCW, LMS and AMS conditions in cv. Moroheiya was 3494.9 ± 930.6, 2438.4 ± 159.5 and 1671.5 ± 154.3 cm^2 respectively, and in case of cv. Yaya was 968.4 ± 256.0, 959.4 ± 224.9 and 323.6 ± 157.1 cm^2 respectively. AMS resulted in poor development of number, length and leaf number of branch in both varieties. Growth of first branch may not be affected by LMS condition. Dry matter of root was not much different, and T/R ratio was not different among treatments and varieties as well on that of the soil moisture stress levels.

The growth value of both varieties of *C. olitorius* was retarded by soil moisture stress. This corroborated the findings of the earlier study by Ayodele and Fawusi (1989), in which different response to soil moisture stress was observed between varieties. But, varieties cv. Moroheiya and Yaya showed similar response to soil moisture stress in this experiment. Plant growth in AMS as 40 - 30% is generally difficult for most of leafy vegetables. However, both varieties of *C. olitorius* were able to grow even under the AMS condition. *C. olitorius* was shown tolerance to soil moisture stress. This is again in line with the results of the study by Ayodele and Fawusi (1989).

The morphological characteristics of cv. Moroheiya treated ABA under different soil moisture condition were shown on Table 2 in experiment 2. The plant height, number of node, length of inter- nodes and the development of first branches (number and mean weight) and leaves (number and leaf area) under AMS were smaller than FCW condition as in Experiment 1. No significant difference in plant height was observed between ABA

Table 1. Effect of different soil moisture levels on the growth of two varieties *C. olitorius* (SE).

Variety	Soil moisture level §	Plant height (cm)	No. of node on main stem	Mean length of node on main stem (cm)	No. of branch	Mean length of branch (cm)	No. of leaves on branch	Mean leaf area on branch (cm^2)	Dry matter of root (%)	T/R ratio
Moroheiya	FCW	171.7(7.6) [a]	52(0)	3.4(0.1)	45.0(1.0)	21.6(3.5)	416.3(51.9)	3494.9(930.6)	16.6	3.4(0.7)
	LMS	150.4(26.3)	51(4)	2.9(0.3)	46.5(3.4)	16.9(4.2)	427.3(46.4)	2438.4(159.5)	17.6	3.6(0.3)
	AMS	131.4(23.9)	52(6)	2.5(0.2)	39.2(3.0)	12.5(1.2)	327.9(8.9)	1671.5(154.3)	18.2	3.6(0.8)
Yaya	FCW	225.1(9.7)	68(5)	3.3(0.1)	47.4(3.2)	3.2(0.5)	196.6(51.7)	968.4(256.0)	18.4	4.0(1.0)
	LMS	183.2(15.7)	72(9)	2.5(0.2)	46.2(5.6)	3.2(0.3)	222.3(66.7)	959.4(224.9)	20.6	3.7(0.5)
	AMS	166.1(2.4)	58(2)	2.8(0.1)	30.8(8.2)	1.9(1.1)	100.3(11.1)	323.6(157.1)	18.6	4.3(0.9)

§: Acute moisture stress (AMS), light moisture stress (LMS) and Field capacity water (FCW) conditions; 40 - 30%, 60 - 50% and >75% respectively.
a: Standard error

Table 2. Effect of abscisic acid (ABA) application on the growth of *C. olitorius* under the different soil moisture levels (SE).

ABA treatment	Soil moisture level §	Plant height (cm)	No. of node on main stem	Mean length of node on main stem (cm)	No. of first branch developed	Mean weight of first branch (g)	No. of leaves on first branch	Mean leaf area on first branch (cm^2)
Control	FCW	133.3(23.6) [a]	48.0 (0.6)	3.8 (0.2)	28.7 (1.3)	37.5 (8.3)	385.0(41.7)	2395.5(229.5)
	AMS	75.0(5.7)	36.3 (1.7)	2.1 (0.1)	17.3 (0.6)	6.2 (0.8)	167.3(53.0)	1238.8 (87.0)
1 mgl^{-1}	FCW	125.9 (10.9)	46.7 (2.1)	2.7 (0.1)	25.0 (2.5)	41.9 (14.3)	360.0(67.5)	2844.3(450.6)
	AMS	60.5(7.3)	36.0 (1.2)	1.7 (0.1)	18.3 (0.5)	4.9 (2.2)	157.5(25.7)	1104.6(372.0)
10 mgl^{-1}	FCW	133.2(7.0)	46.7 (1.7)	2.9 (0.2)	28.6 (2.1)	40.6 (14.8)	479.7(57.8)	3817.3(483.7)
	AMS	81.9(12.5)	40.7 (2.0)	2.0 (0.1)	17.7 (0.4)	6.6 (1.4)	156.3(43.0)	1186.7 (68.8)

§: Acute moisture stress (AMS) and Field capacity water (FCW) conditions; 40 - 30% and >75% respectively.
a: Standard error.

treatment and control under FCW condition. As for the plant height under AMS conditions, the higher the ABA concentration, the higher the plant height. Plant height of normal, 1 and 10 mgl^{-1} ABA was 75.0 ± 5.7, 60.5 ± 7.3 and 81.9 ± 12.5 cm respectively. The number of node on the main stem under FCW condition was not different between ABA treatment and FCW. As for the number of inter-nodes in AMS, the higher the ABA concentration, the larger the number of inter-nodes. Number of inter-node in normal, 1 and 10 mgl^{-1} ABA was 36.3 ± 1.7, 36.0 ± 1.2 and 40.7 ± 2.0 respectively. The mean length of inter-nodes on the main stem under FCW conditions, control was longer than ABA treated plant. Mean length of inter-node on main stem in FCW, 1 and 10 mgl^{-1} ABA was 3.8 ± 0.2, 2.7 ± 0.1 and 2.9 ± 0.2 cm respectively. In AMS condition, ABA treatment by 1 mgl^{-1} plant had shorter ones than the others. The FCW, 1 and 10 mgl^{-1} ABA was 2.1 ± 0.1, 1.7 ± 0.1 and 2.0 ± 0.1 cm respectively.

No significant difference in development of branch and leaves were observed in ABA treatment and control under FCW or AMS. Endogenous

Table 3. Effect of acute and heavy soil moisture stress levels on the growth of *C. olitoriu* (SE).

Variety	Soil moisture level §	Plant height (cm)	No. of node on main stem	No. of branch	No. of leaves	Total leaf area on main stem (cm^2)	Total leaf area on branch (cm^2)	Dry matter of roots (%)
Moroheiya	AMS	81.7 (2.3) [a]	20.8 (0.8)	14.8 (0.4)	122.3 (5.3)	64.4 (8.6)	23.1 (5.8)	6.9 (0.8)
	HMS	60.3 (1.3)	18.1 (0.1)	13.1 (0.3)	87.2 (9.3)	32.6 (5.4)	13.1 (3.8)	15.7 (2.4)
Yaya	AMS	71.0 (2.1)	24,4 (0.4)	17.4 (0.4)	219.1 (18.7)	60.6 (9.4)	16.2 (8.5)	11.3 (1.3)
	HMS	50.1 (1.8)	20.1 (0.2)	15.5 (0.8)	109.6 (9.0)	37.1 (5.1)	9.0 (3.5)	17.7 (3.4)

§: Acute moisture stress (AMS) and heavy moisture stress (HMS); 40 - 30% and 30% <.
a: Standard error

Table 4. Effect of acute and heavy soil moisture stress levels on the yield of *C. olitorius.*

Variety	Soil moisture level §	Yield per plant (g)	No. of harvested stems	Weight of harvested leaves (g)	Weight of harvested stems (g)
Moroheiya	AMS	211.7 a	19.8 a	65.0 b	146.7 a
	HMS	33.3 b	7.6 c	11.7 c	21.6 c
Yaya	AMS	182.7 a	18.2 a	78.4 a	104.4 b
	HMS	32.6 b	11.8 b	19.2 c	13.5 c

§: Acute moisture stress (AMS) and heavy moisture stress (HMS); 40 - 30% and 30% <.
Values in each row followed by the same letters are not significantly different (P=0.05).

ABA was known to increase in the plant of chick pea and tomato under soil moisture stress (Nayyar, 2005; Achuo et al., 2006). Exogenous ABA application improved turf performance during drought of kentucky bluegrass (*Poa pratensis* L.) (Wang et al., 2003). Exogenous ABA application is involved in drought, water and soil moisture stress improvement (Takahashi et al., 1999). However exogenous ABA application under AMS was not effect in the morphological characteristics of *C. olitorius* . It seems that ABA application effects cover up by characteristic of the soil moisture stress tolerance in *C. olitorius*.

The effect of AMS and HMS on the growth of two varieties *C. olitorius* at 3 July (before harvesting) was shown on Table 3 in experiment 3. Shorter plant height in both varieties was observed in HMS conditions comparing to AMS condition. Plant height of AMS and HMS conditions in cv. Moroheiya was 81.7 and 60.3 cm respectively. Corresponding values in cv. Yaya was 71.0 and 50.1 cm respectively. As same, the number of inter-node on main stem, number of branch, number of leaves, total leaf area on main stem and total leaf area on branch were smaller in HMS conditions compare to AMS condition in both varieties. Number of inter-node on main stem was not different among soil moisture conditions of cv. Moroheiya in experiment 1. HMS condition as primary wilting point affected on the development of inter -nodes in cv. Moroheiya. Dry matter of roots was increase in HMS condition. It seemed that root development was promoted in HMS condition. Harvested flesh leaves and stems (yield) of two varieties *C. olitorius* under AMS and HMS condition were shown on Table 4 in experiment 3. Yield per plant was declined in HMS conditions comparing to AMS condition. Yield of AMS and HMS conditions in cv. Moroheiya was 211.7 and 33.3 g respectively. Corresponding values in cv. Yaya were 182.7 and 32.6 g respectively. Number of harvested stems of AMS and HMS conditions in cv. Moroheiya was 19.8 and 7.6 respectively. In case of cv. Yaya was 18.2 and 11.8. Weight of harvested leaves of AMS and HMS conditions in cv. Moroheiya was 65.0 and 11.7 g respectively. Corresponding values in cv. Yaya were 78.4 and 19.2 g. Weight of harvested stems of AMS and

Table 5. Viscosity of leaves, main stem and branches under different soil moisture condition of *C. olitorius* (SE).

Variety	Soil moisture level [§]	Viscosity of main stem	Viscosity of branches	Viscosity of leaves
Moroheiya	AMS	1.22 (0.02) [a]	1.21 (0.02)	1.20 (0.03)
	HMS	1.20 (0.03)	1.33 (0.02)	1.23 (0.03)
Yaya	AMS	1.21 (0.02)	1.25 (0.02)	1.22 (0.02)
	HMS	1.24 (0.03)	1.45 (0.16)	1.24 (0.05)

[§]: Acute moisture stress (AMS) and heavy moisture stress (HMS); 40 - 30% and 30% <. a: Standard error.

HMS conditions in cv. Moroheiya was 146.7 and 26.5 g respectively. As for cv. Yaya the values was 104.4 and 13.5 g. HMS condition affected the development of stems and leaves. Development of stems and leaves were not much different in the LMS and AMS conditions from experiment 1 and 2. Primary wilting point of soil moisture strongly stunted the growth of *C. olitorius*. *C. olitorius* for agricultural cultivation would be possible in AMS level.

Viscosity of leaves, main stem and branches under AMS and HMS condition of two varieties *C. olitorius* were shown on Table 5 in experiment 3. Viscosity of main stem and leaves were not different in soil moisture level and varieties. However, viscosity of branches was larger in HMS condition of both varieties. Viscosity of branches on AMS and HMS conditions in cv. Moroheiya was 1.21 ± 0.02 and 1.33 ± 0.02 respectively. Corresponding values in cv. Yaya were 1.25 ± 0.02 and 1.45 ± 0.16 respectively. Results showed that mucilage were increased under HMS condition in the branches. *C. olitorius* was able to grow under heavy soil moisture stress condition, and it has drought resistant. The mechanism on drought resistant or tolerant was not clear in this study. However, the viscosity in *C. olitorius* seems to be related with soil moisture stress.

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