AAB BIOFLUX
Advances in Agriculture & Botanics-
International Journal of the Bioflux Society

Cleome gynandra L. (C_4 plant) shows higher tolerance of salt stress than its C_3 close relative, *C. viscosa* L.

[1]Jarunya Kulya, [2]Watanachai Lontom, [2]Sumontip Bunnag, and [2]Piyada Theerakulpisut

[1]Department of Biology, Faculty of Liberal Arts and Science, Roi-Et Rajabhat University, Roi-Et 45120, Thailand; [2]Applied Taxonomic Research Center, Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand.
Corresponding author: P. Theerakulpisut, piythe@kku.ac.th

Abstract. The effect of salt stress on some physiological and anatomical parameters in two species of *Cleome*, *C. gynandra* (C_4 plant) and *C. viscosa* (C_3 plant) was investigated. Seedlings were grown in potted soil in greenhouse for 3 months, before being subjected to salinity stress. Salinity was induced by adding sodium chloride solution at the concentration of 75 mM for 15 days. Growth and physiological parameters were recorded every three days after addition of NaCl. The results showed that salinity caused slightly higher reduction in plant height of *C. gynandra* than *C. viscosa.* A small reduction in chlorophyll content was observed in *C. viscosa* after 15 days of NaCl treatment. Proline content in roots, stems and leaves of both species was generally unaffected by NaCl treatment. The amount of hydrogen peroxide, malondialdehyde and electrolyte leakage increased in response to NaCl. These parameters, which indicate secondary oxidative stress response, were more affected in *C. viscosa* than *C. gynandra*. Significant reductions in leaf thickness, petiole and root diameters, and root vascular cylinder were observed in NaCl-treated plants of *C. viscosa* compared to control plants. The results suggested that *C. gynandra* was more tolerant of salt stress compared to *C. viscosa.*
Key words: C_3 plant, C_4 plant, *Cleome*, salt stress, electrolyte leakage.

Introduction. *Cleome* (Capparaceae), a genus closely related to *Arabidopsis*, contains species spanning a developmental progression from C_3 to C_4 photosynthesis and provides a potentially excellent new model plant to increase the understanding of C_4 photosynthesis (Marshall et al 2007). The C_3 plant, *Cleome viscosa* and the C_4 plant, *C. gynandra* are utilized as vegetables in some tropical countries and have many medicinal applications often in rubifacient and irritant preparation (Songsak & Lockwood 2002). The essential oil extracted from the seeds of *C. gynandra* is occasionally used as an insecticide (Edeoga et al 2009). In general, C_4 plants are distinctive from C_3 plants in having a particular leaf anatomy due to the presence of: (i) a well defined bundle sheath; (ii) chloroplast dimorphism; (iii) two carboxylation pathways; (iv) negligible photorespiration due to CO_2 concentrating mechanism in bundle sheath cells (Nayyar & Gupta 2006). Moreover, C_4 plants have advantages when limitation on carbon acquisition is imposed by high temperature, drought and salinity stress while C_3 plant is relatively inefficient because oxygen competes with CO_2 for the active sites of Rubisco enzyme and some of the fixed carbon is lost by photorespiration (Voznesenskaya et al 2001).

Salinity is one of the major environmental factors limiting crop production. Saline environment imposes three major kinds of stress on plants: osmotic stress, specific ion toxicity and nutrient deficiency thus affecting a range of physiological processes involved in cell metabolism (Munns 2002). Many studies indicate that salt stress leads to secondary stress i.e. the production of active oxygen species (AOS) such as superoxide (O^-_2), hydroxyl radicals ($OH^\bullet$), hydrogen peroxide (H_2O_2), and singlet oxygen ($^1O_2$), a process referred to as oxidative stress (Jungklang et al 2004). Gambarova & Gins (2008) who studied the characteristics of plants with C_3 and C_4 photosynthesis during salinization

reported that wheat (C_3) and amaranth (C_4) plants displayed a different sensitivity and response of the antioxidant systems to the effect of salt stress. Amaranth plants, unlike wheat, were able to detoxify the superoxide radicals with the participation of the enzyme superoxide dismutase and amarathin, to effectively oppose the accumulation of active oxygen species and to reduce the tension of lipid peroxidation processes. Not only the physiological processes are affected by salt stress, but some anatomical structures of stressed plants are also changed. Raising the concentration of NaCl in hydroponic solution resulted in greater leaf succulence and greater mesophyll thickness for bean, cotton and *Atriplex* (Longstreth & Nobel 1979). Recently, Junghans et al (2006) discovered that the salt-resistant *Populus euphratica* and salt-sensitive *P. x canescens* showed decreases in vessel lumina associated with increases in wall strength in response to salt. Most of comparative studies on C_4 and C_3 plants responding to abiotic stress were done with plants in the same family (Nayyar & Gupta 2006) or differ in taxonomic levels (Gambarova & Gins 2008). However, studies on responding to salt stress of closely related C_3 and C_4 plants which belong to the same genus is still meager. The purpose of this study is to compare physiological and anatomical responses of *C. gynandra* (C_4 plant) and *C. viscosa* (C_3 plant) to salt stress.

Material and Method. Seeds of *C. gynandra* and *C. viscos*a were germinated in potted soil and maintained in greenhouse under natural photoperiod and temperature. Three-month-old seedlings were then subjected to NaCl stress by watering with 75 mM NaCl solution for 15 days. The controlled plants were treated with tap water. During the period of NaCl stress, plant height was measured at days 0, 3, 6, 9, 12 and 15. For physiological analysis, fresh samples of roots, stems and leaves were taken on days 6 and 15 after salinity treatment. Fresh samples were immediately used for determination of electrolyte leakage, for other physiological parameters samples were frozen in a -20 °C freezer for later analyses.

Chlorophyll content was determined according to Arnon (1949). Approximately 0.1 g of sampled tissues were extracted in 10 mL of 80 % acetone and filtered through filter paper. After recording the volume of filtered extract, the absorbance of the filtrate was estimated at 645 nm and 663 nm.

Free proline content was determined by using the method of Bates et al (1973), sampled tissues (0.1 g) were homogenized in 3 % sulfosalicylic acid and filtered through filter paper. After addition of acid ninhydrin and glacial acetic acid, the resulting mixture was heated at 100°C for 1 h. in water bath. Reactions were stopped by placing the tubes on ice bath. The mixture was then added with toluene, and the absorbance of fraction with toluene aspired from upper liquid phase was read at 520 nm. The proline concentration was determined from the standard curve and calculated on a fresh weight basis (μg g^{-1}FW).

Malondialdehyde (MDA) content was determined using the thiobarbituric acid (TBA) method (Health & Packer 1968). Sampled tissues (0.1 g) were cut into small pieces, added with 1.4 mL of distilled water, and mixed by a vortex mixer. Thiobarbituric acid reagent (1.5 mL of 0.5% TBA in 20 % TCA) was added. The mixture was heated at 95 °C for 25 min and then quickly cooled in an ice bath. After centrifugation at 10000 x g for 10 min, the absorbance of the supernatant was read at 532 and 600 nm. The correction for unspecific turbidity was done by subtracting the absorbance at 600 nm from the absorbance at 532 nm. MDA content was calculated according to its extinction coefficient of 155 mM^{-1} cm^{-1}. The concentration was expressed as nmol g^{-1} FW.

Electrolyte leakage was assessed as described by Dionisio-sese & Tobita (1998). Fresh samples were washed with deionized water. Sampled tissues (0.1g) were cut into small pieces, placed in closed vials containing 10 mL of deionized water, and incubated at 32°C for 2 h. After that, electrical conductivity of the solution (EC_1) was determined. Samples were then autoclaved at 120 °C for 20 min and the electrical conductivity (EC_2) was obtained after equilibration at 25 °C. The electrolyte leakage (EL) was defined as follows: EL (%) = (EC_1/ EC_2) x 100.

Hydrogen peroxide (H_2O_2) content was determined according to Velikova et al (2000). Sampled tissues (0.5 g) were homogenized at 4 °C with 5 mL of 0.1% (w/v)

trichloroacetic acid. The homogenate was centrifuged at 12,000 x g for 15 min and 0.5 mL of supernatant was added to 0.5 mL of 10 mM potassium phosphate buffer (pH 7.0) and 1 mL of 1 M potassium iodide. The absorbance of reaction mixture was read at 390 nm. The H_2O_2 content was calculated from a standard curve and expressed as μmol g^{-1} FW.

For anatomical studies, fresh leaf blades and petioles (from the fully expanded leaves at the third internode from the top), stems (the middle part of the stem) and tap roots (0.5 cm below ground) were collected from both control and NaCl-treated plants at day 15 of salinity stress. These specimens were fixed in 70% FAA. The fixed materials were dehydrated, embedded in paraffin and sectioned transversely using a rotary microtome at 10 μm thickness following a method of Thammathaworn (1995). The sections were deparaffinized, rehydrated and stained with 1% safranin followed by 1% fast green and mounted with DePeX mounting medium. The thickness of leaf blade, the diameters of petiole stem and tap root, and the wideness of mesophyll, petiole's vascular bundle and root's xylem were investigated under light microscope.

The experiment was carried out in 2 x 2 x 3 factorial in completely randomized design with 5 replications. Significant differences of means of physiological parameter measured between species were determined by independent sample t-test; and those between treatments, and those among sampling dates were determined by Duncan's multiple range test (DMRT) at $p \leq 0.05$.

Results. NaCl stress had an inhibitory effect on plant growth causing 31.35% and 27.31% reduction in height of plants, exposed to NaCl for 15 days, in *C. gynandra* (C_4 plant) and *C. viscosa* (C_3 plant) respectively (Figure 1). During the earlier period up to day 6 of stress, the overall morphology of both species was not different from the controls. After 10 days of stress, the first sign of salt stress symptoms appeared in *C. viscosa* including the yellowing and wilting of lower leaves starting from the lowest node. On day 15, the stress symptoms progressed so that the leaves up to the fourth node from the top yellowed and those at the lower nodes started to drop off. Most leaves of *C. gynandra*, however, remained green; only those at the lowest node became yellow.

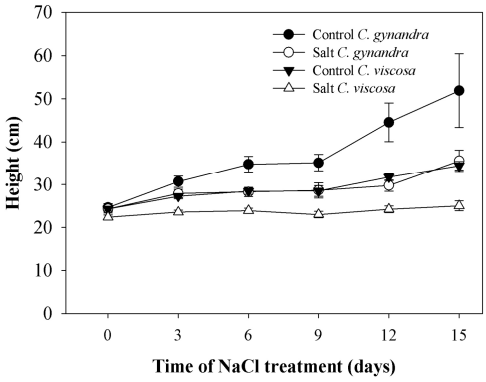

Figure 1. Effects of NaCl stress on plant height of *C. gynandra* and *C. viscosa* after addition of 75 mM NaCl solution to the culture soil for 6 and 15 days. Bars indicate means ± SE of 5 replications.

In both plant species, there was a slight non-significant increase in chlorophyll content of the third leaf from the top after 6 days of exposure to NaCl. At 15 days after stress treatment there was only a slight reduction in chlorophyll in *C. gynandra* leaves in stressed plants compared with the controls, whereas greater reduction was was observed in *C. viscosa* (Figure 2). Both species of *Cleome* did not significantly accumulate proline, a common osmolyte, in any of the tissues investigated (Figure 3).

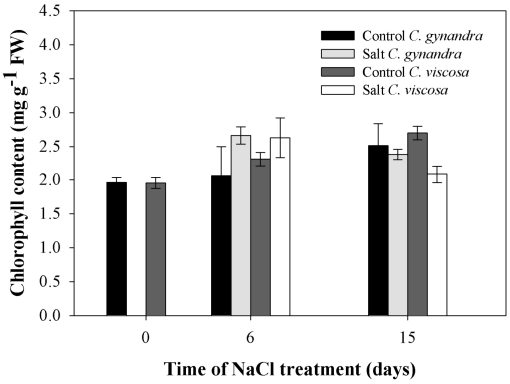

Figure 2. Effects of NaCl stress on chlorophyll content of *C. gynandra* and *C. viscosa* after addition of 75 mM NaCl solution to the culture soil for 6 and 15 days. Bars indicate means ± SE of 5 replications.

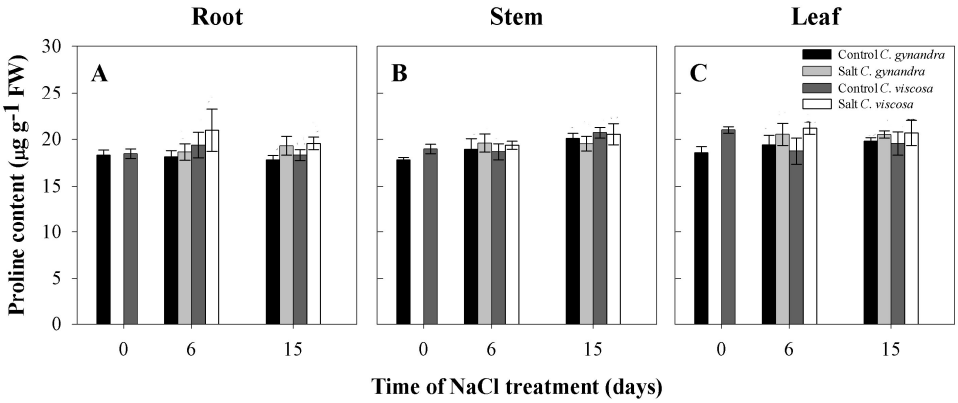

Figure 3. Effects of NaCl stress on the amount of proline in root (A), stem (B) and leaf (C) of *C. gynandra* and *C. viscosa* after addition of 75 mM NaCl solution to the culture soil for 6 and 15 days. Bars indicate means ± SE of 5 replications.

Salinity treatment caused marked increase in electrolyte leakage values, an indicator of cellular membrane integrity, in all types of tissue. The most profound effect was observed in roots, stems and leaf tissues of *C. viscosa* after 15 days under salt stress (Figure 4 A-C).

Sharp increase (100% increase from control) in hydrogen peroxide, an indicator of oxidative stress, was observed only in leaves of *C. viscosa* after 15 days in salinity stress (Figure 4 F), whereas the amount in leaves of *C. gynandra* increased only slightly (9.24%). Pattern of response in term of hydrogen peroxide content in roots and stems are inconsistent compared to that in leaves. In general, tissues of *C. viscosa* tended to accumulate more H_2O_2 in response to NaCl than *C. gynandra*.

Sodium chloride stress caused an increase in the amount of malondialdehyde, an indicator of lipid peroxidation process, in all tissues tested in both plant species. Leaf tissue normally has several folds higher amount of MDA than root and stem. The most significant increase in MDA content (54.72% higher than control) was observed in leaf tissue of *C. viscosa* after 15 days in NaCl treatment (Figure 4 I), whereas MDA in the leaf of *C. gynandra* increased only slightly. Similar observation was found in stem tissues (Figure 4 H).

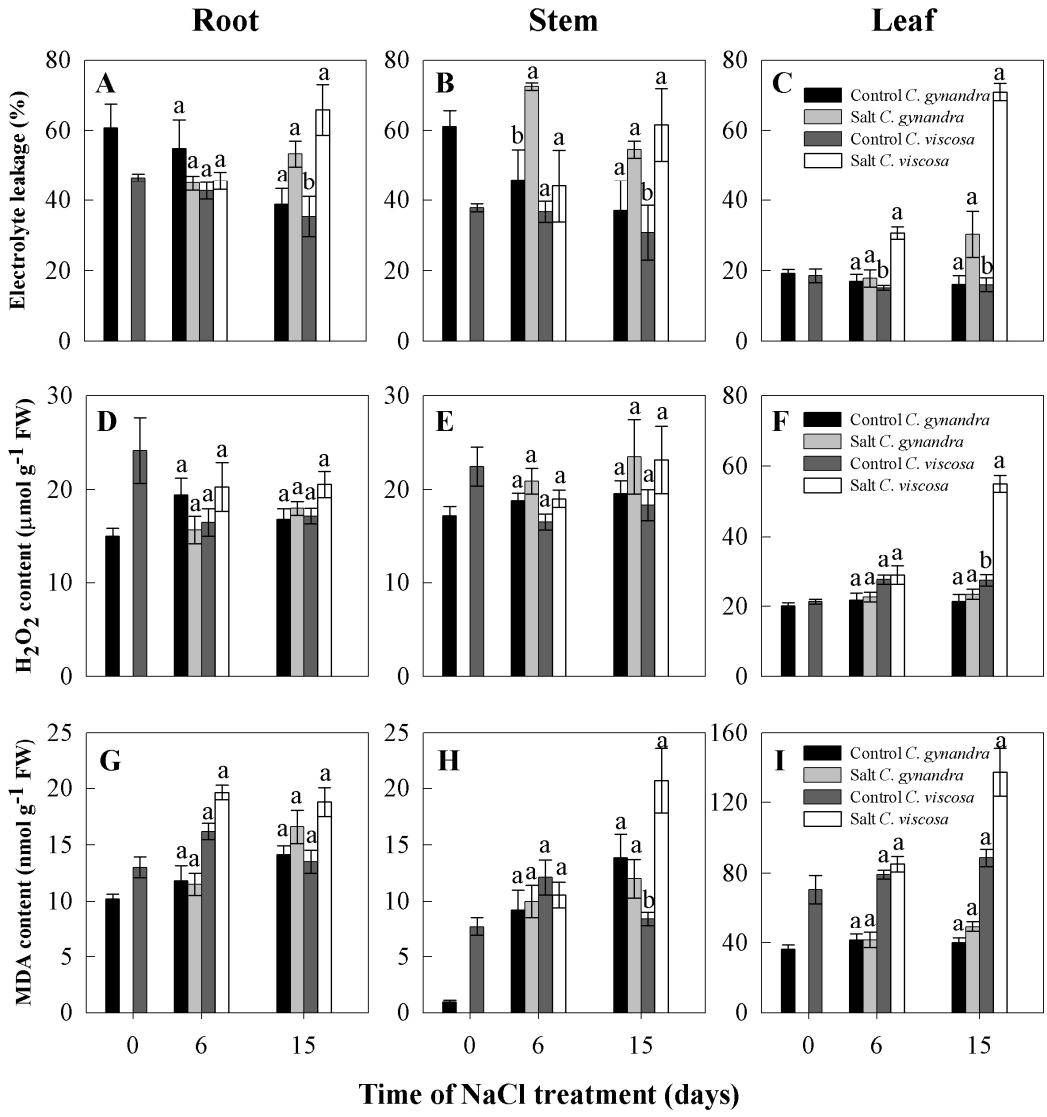

Figure 4. Effects of NaCl stress on the levels of electrolyte leakage (A-C), hydrogen peroxide (D-F) and malondialdehyde (G-I) in root, stem and leaf of *C. gynandra* and *C. viscosa* after addition of 75 mM NaCl solution to the culture soil for 6 and 15 days. Bars indicate means ± SE of 5 replications.

Salt stress for 15 days imposed more negative effects on anatomical structures of *C. viscosa* than those of *C. gynandra*. The dimensions of four anatomical features of *C. viscosa* were significantly decreased in salt-stressed C_3 plants including leaf thickness, petiole and root diameters and diameter of root vascular cylinder (composing mainly of secondary xylem). On the other hand, most anatomical features of *C. gynandra* were unaffected by salt stress except for the decrease in the width of the stem cortex (Table 1).

Discussion. It can be concluded that *C. gynandra* (C_4) was more tolerant of salt stress and less suffered from secondary oxidative stress than *C. viscosa* (C_3) as indicated by smaller increase in the amount of H_2O_2, MDA and electrolyte leakage. Stepien & Klobus (2005) also observed the lower level of lipid peroxidation in maize (C_4) than wheat (C_3) under salt stress, which was due to higher activity of antioxidative enzymes. Sudhakar et al (2001) who studied the effect of NaCl stress on two genotypes of mulberry found that MDA content was high in sensitive variety, while the tolerant variety showed no change in

Table 1

Effect of NaCl stress on some anatomical characteristics of *C. gynandra* and *C. viscosa*

*Anatomical characteristics**	*C. gynandra* (C_4)		*C. viscosa* (C_3)	
	Control	75 mM NaCl	Control	75 mM NaCl
Leaf thickness (µm)	178.75±10.68a	178.12±11.33a	110.00±5.68a	95.62±3.44b
Petiole diameter (µm)	860.00±22.73a	857.50±25.96a	717.50±11.81a	682.00±7.07b
Diameter of petiole vascular bundle (µm)	200.00±7.07a	195.00±11.90a	142.50±4.78a	137.50±6.29a
Stem diameter (mm)	5.50±0.295a	5.41±0.13a	3.56±0.24a	3.50±0.094a
Width of stem cortex (µm)	532.00±39.68a	415.00±30.13b	306.25±48.27a	260.25±38.69a
Root diameter (mm)	4.63±0.54a	4.38±0.22a	4.06±0.12a	3.16±0.13b
Diameter of root vascular cylinder (mm)	2.39±0.037a	2.290±0.074a	2.081±0.029a	1.218±0.128b

* For each species, mean ± SD of the control and salt-treated group for each parameter followed by the same letter are not significantly different at $p < 0.05$. (n=6)

MDA content, lower amount of electrolyte leakage and high activity of antioxidative enzymes. Zhang & Kirkham (1996) reported that sunflower (*Helianthus annuus* L., C_3) had much higher MDA contents than sorghum (*Sorghum bicolor* (L.) Moench, C_4), indicating that sunflower membranes are more injured by oxidative stress than sorghum under drought stress. Sreenivasulu et al (1999) reported the effect of NaCl on lipid peroxidation of two genotypes of *Setaria italica* L. They found that the tolerant cultivar (Prasad) had lower MDA content than the susceptible one (Lepakshi) during salt stress. Chaparzadeh et al (2004) who studied long term salt-induced oxidative stress in marigold (*Calendula officinalis* L.) reported that high salinity caused reductions in growth parameters, lipid peroxidation and hydrogen peroxide accumulation. Maize shoots under stress showed higher water potential, osmotic adjustment and less electrolyte leakage than wheat shoots (Nayyar 2003). Nayyar & Gupta (2006) reported the effect of water stress in wheat (*Triticum aestivum*, C_3) and maize (*Zea mays*, C_4). They discovered that moderate and high stress levels caused more damage to wheat as compared to maize. This was accompanied by more loss of water and chlorophyll in wheat relative to maize at these stress levels. The oxidative damage in terms of malondialdehyde and H_2O_2 content was markedly higher in wheat as compared to maize at moderate and high stress levels.

Proline accumulation in plants occurs after a wide range of abiotic stress including salt, drought, high temperature, low temperature, anaerobiosis and UV radiation and the levels of accumulation varies from species to species (Verbruggen & Hermans 2008). Although, accumulation of proline in shoots and roots is a common physiological response to NaCl stress found in many halophytes and glycophytes (Sairam & Tyagi 2004), no significant accumulation of proline was observed in *Cleome* spp. under the condition of this study. Kumar et al (1984) reported that *C. gynandra* (C_4) was more resistant to water stress than *C. speciosa* (C_3) because leaf osmotic potential of *C. speciosa* was more decreased than *C. gynandra*. Moreover, proline content of *C. speciosa* was higher than *C. gynandra* under stress condition.

NaCl stress affected not only the physiology but also the anatomy of stressed plants. The present study indicated that NaCl induced differential anatomical changes in

leaf of both species of *Cleome*. However, it was evident that leaf and root tissues of *C. gynandra* were more tolerant of salt stress than *C. viscosa*. The petiole diameter and thickness of *C. gynandra*'s leaf were unaffected, while those of *C. viscosa* were significantly reduced. Longstreth & Nobel (1979) found that raising the concentration of NaCl in hydroponic solutions resulted in greater leaf succulence and thickness for bean and cotton. Such salt-induced succulence could lower the resistance to CO_2 uptake and thus increase photosynthetic rates by increasing the amount of internal leaf surface area across which gaseous exchange can occur per unit leaf area. Moreover, NaCl significantly inhibited growth of *C. viscosa* by reducing root diameters (22% reduction) and root vascular cylinder diameter (41% reduction). These root anatomical features in *C. gynandra* were only slightly reduced. Salinity also affected root growth of cotton seedlings causing a reduction in the width of the cortex (Kurth et al 1986).

Conclusion. Results from physiological and anatomical studies indicated that *C. gynandra* (C_4) was more tolerant of salt stress and less suffered from secondary oxidative stress than *C. viscosa* (C_3). A better understanding of the mechanism involved in the responses and adaptation of plants to salinity may help the introduction of environmental and genetic manipulations aimed at increasing crop salinity resistance.

Acknowledgements. Financial support made available to the first author by Graduate School, Khon Kaen University, Khon Kaen, Thailand is gratefully acknowledged.

References

Arnon D. I., 1949 Copper enzymes in isolated chloroplasts polyphenoloxidase in *Beta vulgaris*. Plant Physiol **24**:1-15.

Bates L. S., Waldren R. P., Teare I. D., 1973 Rapid determination of free proline for water stress studies. Plant Soil **39**:205-207.

Chaparzadeh N., Lucia D'Amico M., Khavari-Nejad R., Izzo R., Navari-Izzo F., 2004 Antioxidative responses of *Calendula officinalis* under salinity conditions. Plant Physiol Biochem **42**:695-701. DOI:10.1016/j.plaphy.2004.07.001

Dionisio-sese M. L., Tobita S., 1998 Antioxidant response of rice seedlings to salinity stress. Plant Sci **135**:1-9. DOI: 10.1016/S0168-9452(98)00025-9

Edeoga H. O., Omosun G., Osuagwu G. G. E., Mbaebie B. O., Madu B. A., 2009 Micromorphological characters of the vegetative and floral organs of some *Cleome* species from Nigeria. Am Eurasian J Sci Res **4**:124-127.

Gambarova N. G., Gins M. S., 2008 Characteristics of oxidative stress of plants with C_3 and C_4 photosynthesis during salinization. Russ Agric Sci **34**:77-80.

Heath M. C., Packer I., 1968 Photoperoxidation in isolated chloroplast I kinetics and stoichiometry of fatty acid peroxidation. Arch Biochem Biophys **125**:189-198.

Junghans U., Polle A., Düchting P., Weiler E., Kuhlman B., Gruber F., Teichmann T., 2006 Adaptation to high salinity in poplar involves changes in xylem anatomy and auxin physiology. Plant Cell Environ **29**:1519–1531. DOI: 10.1111/j.1365-3040.2006.01529.x

Jungklang J., Sunohara Y., Matsumoto H., 2004 Antioxidative enzymes response to NaCl stress in salt-tolerant *Sesbania rostrata*. Weed Biol Manag **4**:81- 85. DOI: 10.1111/j.1445-6664.2004.00123.x

Kumar U. D. J., Saraswathy R., Das V. S. R., 1984 Differential performance of *Cleome gynandra* L. (C_4) and *C. speciosa* L. (C_3) under water stress and recovery. Environ Exp Bot **24(4)**:305-310.

Kurth E., Cramer G. R., Lauchli A., Epstein E., 1986 Effects of NaCl and $CaCl_2$ on cell enlargement and cell production in cotton roots. Plant Physiol **82**:1102–1106.

Longstreth D. J., Nobel P. S., 1979 Salinity effects on leaf anatomy consequences for photosynthesis. Plant Physiol **63**:700-703.

Marshall D. M., Muhaidat, R., Brown, N. J., Liu, Z., Stanley, S., Griffiths, H., Sage, R. F., Hibberd, J. M. 2007 *Cleome*, a genus closely related to Arabidopsis,

contains species spanning a developmental progression from C_3 to C_4 photosynthesis. The Plant J **51**:886-896.
Munns R., 2002 Comparative physiology of salt and water stress. Plant Cell Environ **25**: 239-250. DOI: 10.1046/j.0016-8025.2001.00808.x
Nayyar H., 2003 Accumulation of osmolytes and osmotic adjustment in water-stressed wheat (*Triticum aestivum*) and maize (*Zea mays*) as affected by calcium and its antagonists. Environ Exp Bot **50**:253-264. DOI:10.1016/S0098- 8472(03)00038-8
Nayyar H., Gupta D., 2006 Differential sensitivity of C_3 and C_4 plants to water deficit stress: association with oxidative stress and antioxidants. Environ Exp Bot **58**:106-113. DOI: 10.1016/j.envexpbot.2005.06.021
Sairam R. K., Tyagi A., 2004 Physiology and molecular biology of salinity stress tolerance in plants. Curr Sci **86**:407-421.
Songsak T., Lockwood G. R., 2002 Glucosinolates of seven medicinal plants from Thailand. Fitoterapia **73**:209-216.
Sreenivasulu N., Ramanjulu S., Ramachandra-Kini K., Prakash H. S., Shekar-Shetty H., Savithri H. S., Sudhakar C., 1999 Total peroxidase activity and peroxidase isoform as modified by salt stress in two cultivars of fox-tail millet with differential salt tolerance. Plant Sci **141**:1-9. DOI: 10.1016/S0168-9452(98)00204-0
Stepien P., Klobus G., 2005 Antioxidant defense in the leaves of C_3 and C_4 plants under salinity stress. Physiol Plant **125**:31-40. DOI: 10.1111/j.1399-3054.2005.00534.x
Sudhakar C., Lakshmi A., Giridarakumar S., 2001 Changes in the antioxidant enzyme efficacy in two high yielding genotypes of mulberry (*Morus alba* L.) under NaCl salinity. Plant Sci **161**:613-619. DOI:10.1016/S0168- 9452(01)00450-2
Thammathaworn A., 1995 Handbook for Microtechnique in Biology. Department of Biology, Faculty of Science, Khon Kaen University.
Velikova V., Yordanov I., Edreva A., 2000 Oxidative stress and some antioxidant systems in acid rain-treated bean plants protective role of exogenous polyamines. Plant Sci **151**:59-66. DOI:10.1016/S0168-9452(99)00197-1
Verbruggen N., Hermans C., 2008 Proline accumulation in plants: a review. Amino Acids **35**:753–759. DOI: 10.1007/s00726-008-0061-6
Voznesenskaya E. V., Franceschi V. R., Kiirats O., Freitag H., Edwards G. E., 2001 Kranz anatomy is not essential for terrestrial C_4 plant photosynthesis. Nature **414**:543-546. DOI:10.1038/35107073
Zhang J., Kirkham M. B., 1996 Enzymatic response of the ascorbate-glutathione cycle to drought in sorghum and sunflower plants. Plant Sci **113**:139-147. DOI: 10.1016/0168-9452(95)04295-4

Received: 15 April 2011. Accepted: 29 May 2011. Published online: 30 May 2011.
Authors:
Jarunya Kulya, Department of Biology, Faculty of Liberal Arts and Science, Roi-Et Rajabhat University, Roi-Et 45120, Thailand.
Watanachai Lontom, Applied Taxonomic Research Center, Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand.
Sumontip Bunnag, Applied Taxonomic Research Center, Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand.
Piyada Theerakulpisut, Applied Taxonomic Research Center, Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand, e-mail: piythe@kku.ac.th
How to cite this article:
Kulya J., Lontom W., Bunnag S., Theerakulpisut P., 2011 *Cleome gynandra* L. (C_4 plant) shows higher tolerance of salt stress than its C_3 close relative, *C. viscosa* L. AAB Bioflux **3**(1):59-66.