Indian J. Plant Physiol., Vol. 15, No. 4, (N.S.) pp. 396-400 (Oct.-Dec., 2010)

SHORT COMMUNICATION

RESPONSE OF CORIANDER (*CORIANDRUM SATIVUM* L.) TO WATERLOGGING

ANJALI SABALE AND P. B. KALE*

Department of Botany, Shivaji University, Kolhapur-416 004, Maharashtra, India

Received on 29th Aug., 2009, Revised on 18th Dec., 2010

Under waterlogging condition, behaviour of *Coriandrum sativum* L. var. Indoori revealed a significant increase in total soluble sugars and anthocyanins in the leaves which was >100% for four days and >200% for eight days waterlogging. Accumulation of ascorbic acid at eight days waterlogging condition was noticeable. A marked enhancement in reducing sugars and free amino acids (>75 %) was also evident in the waterlogged plants. On the contrary total chlorophylls, carotenoids and flavonoids declined by about 50 % but relative water content, leaf water potential and chlorophyll stability index followed a negligible reduction during stress. Lipid peroxidation (MDA content), superoxide dismutase activity and proline accumulation enhanced with a parallel decline in proline oxidase activity. After relieving the stress, relative water content and leaf water potential remained unchanged but proline and ascorbic acid content decreased. Similarly, proline oxidase, superoxide dismutase activities also recovered and MDA content declined. Total chlorophylls enhanced by 27-35%. These results indicated that the variety is sensitive and susceptible to waterlogging. Ascorbic acid and anthocyanins might function as antioxidant to face oxidative stress while total sugars, proline and free amino acids, as osmoprotectants. Four days waterlogging did not cause much damage to the crop but at eight days waterlogging stress physiological alterations were seen.

***Key words*: Antioxidants, biochemical constituents, *Coriandrum sativum* L., lipid peroxidation, proline oxidase, SOD, waterlogging**

Indoori is a popular variety of *Coriandrum sativum* L. which is well known for its seed quality and grown on a large scale in Rajasthan, Madhya Pradesh, Maharashtra and Gujarat in both kharif and rabi seasons for fruits and green leaves. The crop is sensitive to temperature, rainfall and weather conditions at different growth stages (Chatterjee *et al.* 2001). Coriander is cultivated throughout India in almost every season. The growth and behavior of the crop depends and changes as per the climatic conditions which vary drastically in different parts. Accordingly it may suffer moisture stress, high temperature and sometimes salinity and waterlogging also when rainy season is prolonged. There is no report regarding the response of coriander to waterlogging stress. Under waterlogging condition accumulation of carbohydrates, amino acids, sugars and starch might occur in plants due to inhibition of transport through phloem (Waters *et al*. 1991).Hence in the present study a few enzymes and related biochemicals are analyzed. Response of waterlogged plants after relieving the stress is also recorded.

Healthy fruits of *C. sativum* L. sown in earthen pots filled with soil mixture (Soil: FYM 3:1) and grown upto

*Corresponding author, E-mail: pkale2006@yahoo.com

30 days with normal water supply. Waterlogging treatment was given by filling the pots with water above the soil level and sealing the drain hole. Plants maintained at a normal water supply served as the control. Analysis was done on the next day of treatment.

Relative water content (RWC) and leaf water potential (LWP) were determined as per standard procedure described by Slatyer and Mcllory (1961) and Janardhan and Krishnamoorthy (1975) respectively. Total chlorophylls were estimated following the method of Arnon (1949). Carotenoids were estimated from the same acetone extract prepared for chlorophylls, as per the method given by Kirk and Allen (1965). Total polyphenols were estimated following the method suggested by Folin and Dennis (1915). Reducing and total sugars were estimated according to the method given by Nelson (1944) while Soluble proteins were measured according to the method described by Lowry *et al*. (1951). Anthocyanin and total flavonoids were determined by the method of Mancinelli (1990) and Luximon-Ramma *et al.* (2002) respectively. Free proline, amino acids and ascorbic acid content were measured by the methods given by Bates *et al*. (1973) and Sadasivam and Manickam (1992) respectively. Lipid peroxidation was recorded as described by Carkmak and Hort, (1991).

Proline oxidase activity was measured according to the method of Anthony *et al.* (1979) and Superoxide dismutase activity by the method of Giannopolitis and Ries, (1977). Data were analyzed statistically following the method of Goon *et al.* (1979). Waterlogging was released by removing the seal on the drain hole. After five days plant samples were again analyzed for few parameters.

Water status, pigment content and other biochemical constituents in *Coriandrum sativum* L. exposed to four and eight days waterlogging are presented in Tables 1. A negligible reduction in relative water content and leaf water potential was observed in the leaves during waterlogging. A drastic loss in total chlorophylls was found in eight days stressed plants which accounted for a 70 % decline, but chlorophyll stability index decreased slightly as compared to the control plants. Total carotenoids content and polyphenols level was reduced during waterlogging. Ascorbic acid level was found elevated remarkably during eight days of waterlogging. Similarly a significant enhancement in total sugars and anthocyanins occurred in waterlogged plants. A notable accumulation of proline, amino acids and reducing sugars was also found. Total soluble proteins increased only marginally, but total flavonoids declined drastically in waterlogged plants.

Lipid peroxidase (measured in terms of malondialdehyde MDA) and superoxide dismutase level increased under four and eight days of waterlogging stress. Proline oxidase activity declined and was consistent with elevation of proline level (Fig. 1).

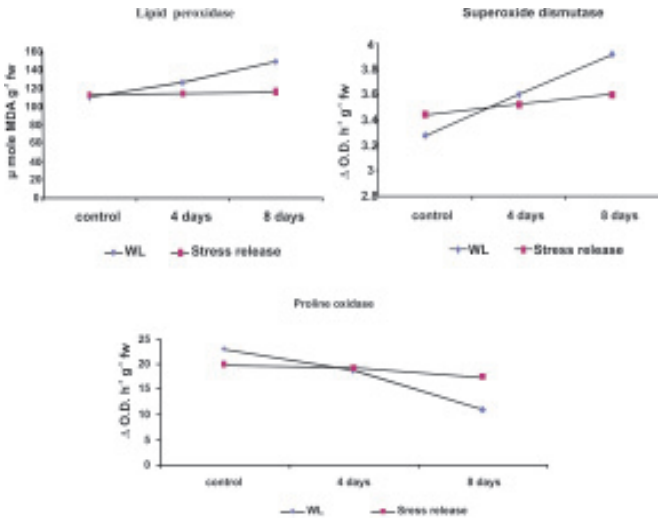

Fig. 1. Effect of waterlogging on lipid peroxidase, superoxide dismutase and proline oxidase activity in *Coriandrum sativum* L. var. Indoori

After releasing the waterlogging a rapid decline in proline and ascorbic acid content occurred. About 27-35% recovery in the total chlorophyll content was observed. Carotenoid content was slightly recovered but total polyphenols attained normal level after releasing the stress (Table 1). Level of MDA returned to its normal value as in control plants after releasing the stress. Thus damage to cell membrane was recovered and MDA content decreased. After release of stress proline oxidase activity increased rapidly in the stressed plants and was nearly similar to that of the control plants. Superoxide dismutase exhibited slightly higher level than control (Fig. 1).

Table 1. Effect of waterlogging on water and Biochemical status in *Coriandrum sativum* L. var. Indoori.

Parameters		Control	4 days WL	8 days WL	C. D. at 5 %
RWC %	WL	95.64	94.45 (-1.24)	87.34 (-8.66)	0.646
	S. R.	95.66	94.57 (-1.13)	87.84 (-8.17)	0.035
LWP (-MPa)	WL	0.772	0.752 (-2.60)	0.709 (-8.16)	0.011
	S. R.	0.773	0.759 (-1.87)	0.754 (-2.46)	0.005
Moisture content %	WL	91.8	91.2 (-0.65)	90.5 (-1.42)	-
	S. R.	91.4	91.2 (-0.22)	90.0 (-1.54)	-
Ascorbic acid (mg $100g^{-1}$ fresh weight)	WL	144.41	161.49 (+11.83)	290.37 (+101.07)	0.005
	S. R.	146.00	155.00 (+6.16)	167.70 (+14.86)	0.004
Free proline (mg $100g^{-1}$ fresh weight)	WL	6.04	8.67 (+43.54)	16.53 (+173.68)	0.006
	S. R.	5.93	6.38 (+7.58)	7.52 (+26.81)	0.003
Total Chlorophylls ($g100g^{-1}$ dry weight)	WL	1.13	0.63 (-44.25)	0.34 (-69.91)	0.019
	S. R.	1.04	0.76 (-26.92)	0.68 (-34.62)	0.119
CSI	WL	0.83	0.72 (-13.25)	0.68 (-18.07)	0.056
Total carotenoids ($g100g^{-1}$ dry weight)	WL	0.103	0.058 (-43.69)	0.046 (-55.34)	0.005
	S. R.	0.094	0.069 (-26.60)	0.062 (-34.04)	0.005
Total polyphenols ($g100g^{-1}$ dry weight)	WL	1.42	1.13 (-20.51)	1.09 (-23.31)	0.002
	S. R.	1.43	1.35 (-5.59)	1.29 (-9.80)	0.001
Reducing sugars ($g100g^{-1}$ dry weight)	WL	0.031	0.046 (+47.92)	0.058 (+85.94)	0.003
Total sugars ($g100g^{-1}$ dry weight)	WL	0.10	0.21 (+110.01)	0.33 (+231.00)	0.007
Total solubleproteins**	WL	2.20	2.30 (+4.55)	2.60 (+18.18)	0.005
Free amino acids ($g100g^{-1}$ dry weight)	WL	1.89	2.81(+48.68)	2.83 (+49.74)	0.032
Anthocyanins @	WL	0.060	0.126 (+110.00)	0.255 (+325.00)	0.006
Total flavonoids #	WL	2.46	0.57 (-76.83)	0.77 (-68.70)	0.013

**$g100g^{-1}$ fresh weight, @O.D.530 g^{-1} fresh weight, # mg of Rutin equiv./g of fresh weight, S. R.- Stress Release, WL- Waterlogging, Values in parentheses indicate percent increase or decrease over control, Each value represents mean of three determinations.

A decline in water status and synthesis of pigments and polyphenols has been reported under waterlogging (Vijayarengan and Dhanavel 2005, Sinha and Chhabra 2006, Lin *et al.* 2006).

Several studies have demonstrated accumulation of proline as a result of waterlogging (Adak and Gupta 2001, Rai *et al*. 2004). A parallel decrease in proline oxidase enzyme which converts proline to glutamate is also observed in the present investigation. Increased soluble protein content which play a significant role in sustaining growth and accumulation of free amino acids due to induced hydrolysis of proteins are evident under waterlogging stress (Asha and Rao 2002, De-Sousa and Sodek 2002). Carbohydrate accumulation followed by anthocyanin synthesis is of common occurrence in plants exposed to oxidative stress (Foot *et al.* 1996). Accumulation of osmotically active solutes such as sugars and amino acids may be responsible for the accumulation of anthocyanins in stressed condition (Tholakalabavi *et al.* 1994).

Ascorbic acid might be functioning as an antioxidant for scavenging free radicals produced during waterlogging. But a drastic reduction was observed in total flavonoids in *Coriandrum* under waterlogging situation. The synthesis of these secondary metabolites might be inhibited under waterlogged environment.

An accumulation of MDA was observed in *Coriandrum sativum* under waterlogging. Production of free radicals is increased under waterlogging conditions causing damage to cell membranes and resulting in rise in lipid peroxidation. Increased lipid peroxidation and accumulation of MDA content due to waterlogging stress is an indication of damage to the membrane system as reported by several workers in various crops (Zhou and Lin 1995, Xiao *et al.* 2005).

Enhancement of superoxide dismutase during waterlogging stress condition and its decline after removal of stress indicated the recovery of plants from stress condition. Induction of superoxide dismutase activity under hypoxia in the roots and leaves of *Hordeum vulgare* has been shown by Kalashnikov *et al.* (1994). High level of SOD might help in minimizing the hazardous effect of ROS in coriander under waterlogging situation. Decline in carotenoids and polyphenols suggested susceptible nature of crop.

The study of different physiological and biochemical parameters in *Coriandrum sativum* L. during waterlogging revealed that the variety is susceptible to waterlogging condition. It can tolerate waterlogging situation upto four days by activating antioxidant enzyme system and synthesizing osmoprotectant solutes. The waterlogging stress of four days did not affect the plant biochemistry to a greater extent, but a longer duration of stress might affect its metabolic set up drastically.

REFERENCES

Adak, M.K. and Gupta, D.K. (2001). Metabolic activities in some rice varieties under submergence stress. *Indian J. Plant Physiol.* **6:** 312-316.

Anthony, H., Huang, C. and Anthony, J.C. (1979). Proline oxidase and water stress induced proline accumulation in spinach leaves. *Plant Physiol.* **63:** 531-535.

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

Asha, S. and Rao, K.N. (2002). Effect of stimulated waterlogging on the levels of amino acids in groundnut at the time of sowing. *Indian J. Plant Physiol*. **7:** 288-291.

Bates, L.S., Warden R.P. and Teare, I. D. (1973). Rapid determination of free proline for water stress studies. *Plant and soil.* **39:** 205-207.

Carkmak, I. and Hort. W.J. (1991). Effect of aluminium of lipid peroxidation, superoxide dismutase, catalase and peroxidase activities in root tips of soybean (*Glycine max*). *Plysiol. Plant*. **83:** 463-468.

Chatterjee, R., Pan S., Datta, S., Bhattacharya, M., Sharangi, A.B. and Chattopadhyay, P.K. (2001). Response of some cultivers of Coriander (*Coriandrum sativum* L.) to different dates of sowing. *South Indian Hort*. **51:** 249-253.

De-Sousa, C.A.F. and Sodek, L. (2002). Metabolic changes in soybean plants in response to waterlogging in the presence of nitrate. *Physiol. Mol. Biol. Plant.* **8:** 97-104.

Folin, O. and Denis. W. (1915). A colorimetric estimation of phenols and phenol derivatives in urine. *J. Biol. Chem*. **22:** 305-308.

Foot, J.P., Caporn, S. J. M., Lee, J.A. and Ashenden, T.W. (1996)**.** The effect of long-term ozone fumigation on the growth, physiology and frost sensitivity of *Calluna vulgaris*. *New Phytologist* **133:** 503-511.

Giannopolitis, C. N. and Ries, S. K. (1977). Superoxide dismutase. 1. Occurrence in higher plants. *Plant Physiol.* **59:** 309-314.

Goon, A.M., Gupta, M.K. and Das Gupta, B. (1979). *Fundamentals of Statistics* Vol. II: pp. 24-34. The World Press Private Ltd., Calcutta, India.

Janardhan, K.V. and Krishnamoorthy, V. (1975). A rapid method for determination of osmotic potential of plant cell sap. *Curr. Sci.* **44:** 390-391.

Kalashnikov, J., Balakhnina, T.I. and Zakrzhevsky, D.A. (1994). Effect of soil hypoxia on activation of oxygen and the system of protection from oxidative destruction in roots

and leaves of *Hordeum vulgare*. *Russian J. Plant Physiol.* **41:** 583-588.

Kirk, J.O.T. and Allen. R.L. (1965). Dependence of chloroplast pigment synthesis on protein synthesis. Effect of actidione. *Arch. Biochem. Biophys. Res. Commun*. **21:** 523-530.

Lin, K.H., Chao, P.Y., Tang, C.M. and Cheng, W.C. (2006). The effects of flooding and drought stresses on the antioxidant constituents in sweet potato leaves. *Botanical Studies.* **47:** 417-426.

Lowry, O.H., Rosenbrough, N.J., Farr, A.L. and Randall, R.J. (1951). Protein measurement with Folin-phenol reagent. *J. Biol. Chem.* **193:** 265-275.

Luximon-Ramma, A., Bahorum, T., Soobrattee, M.A. and Aruom, O.I. (2002). Antioxidant activities of phenolic, proantocyanidin and flavonid components in extracts of *Cassia fistula. J. Agric. Food Chem.* **50:** 5042-5047.

Mancinelli, A.L. (1990). Interaction between light quality and light quantity in the photoregulation of anthocyanin production. *Plant Physiol*. **92:** 1191-1195.

Nelson, N. (1944). A photometric adaptation of Somogyi's method for the determination of glucose. *J. Biol. Chem.* **153:** 375-380.

Rai, R.K., Srivastava, J.P. and Shahi, J.P. (2004). Effect of waterlogging on some biochemical parameters during early growth stages of maize. *Indian J. Plant Physiol.* **9:** 65-68.

Sadasivam, S. and Manickam, A. (1992). Biochemical methods for agricultural science. New Age International (P) Ltd, New Delhi.

Sinha, B.K. and Chhabra, M.L. (2006). Effect of waterlogging and high temperature on gas exchange parameters in Indian mustard (*Brassica juncea* L.) at various growth stages. *Adv. Plant Sci.* **19:** 445-450.

Slatyer, R.O. and Mcllory, I.C. (1961). Practical microclimatology with special reference to the water factor in soil plant atmosphere relationships. UNESCO, Paris.

Tholakalabavi, A., Zwiazek, J.J. and Thorpe, T.A. (1994). Effect of mannitol and glucose-induced osmotic stress on growth, water relations, and solute composition of cell suspension cultures of poplar (*Populus deltoides* var. occidentalis) in relation to anthocyanin accumulation. *In Vitro Cellular and Developmenta Biolog-Plant.* **30:** 164-170

Vijayarengan, P. and Dhanavel, D. (2005). Effect of waterlogging on growth and pigment content of greengram (*Vigna radiata* L. Wilczek). *Adv. Plant Sci.* **18:** 927-929.

Waters, I.P., Kuiper, J.C., Watkin, E. and Greenway, H. (1991). Effects of anoxia on wheat seedlings. I. Interaction between anoxia and other environmental factors. *J. Exp. Bot.* **42:** 1427-1435.

Xiao, Y.P., Kang, W., Xin, J., Mei-Xue, Z.and Zhang, G.P. (2005). Effects of waterlogging on photosynthesis and antioxidant enzyme activities of six barley genotypes with different waterlogging tolerance. *China Agric. Sci.* **4:** 310-316.

Zhou, W. and Lin, X. (1995). Effects of waterlogging at different growth stages on physiological characteristics and seed yield of winter rape (*Brassica napus* L.). *Field Crops Res*. **44:** 103-110.