GROWTH AND PHOTOSYNTHETIC CHARACTERISTICS AS AFFECTED BY TRIAZOLES IN *Amorphophallus campanulatus* Blume

R. Gopi**, R. Sridharan, R. Somasundaram, G.M. Alagu lakshmanan and R. Panneerselvam

Annamalai University, Division of Plant Physiology, Department of Botany,

Annmalai Nagar-608 002, Tamil Nadu, South India

Received 7 November 2005

Summary. *Amorphophallus campanulatus* (Elephant Foot Yam) is a rich source of starch, essential amino acids and therefore, used as a vegetable. It is cultivated and utilized in various regions of South India. Triazole compounds are widely used systemic fungicides to control diseases in plants and animals. Many of the triazole compounds have both fungi toxic and plant growth regulating properties. Hence, an attempt was made to study the effect of triadimefon, paclobutrazol, and propiconazole on growth and photosynthetic characteristics of *Amorphophallus campanulatus.* Triazole compounds increased total root length, dry weight, moisture content, chlorophyll and carotenoid contents, intercellular CO_2 concentration, net photosynthetic rate (P_N) and water use efficiency (WUE). On the other hand, petiole length, total leaf area, transpiration rate (T_R) and stomatal conductance were decreased. Among the triazole compounds, paclobutrazol showed higher effectiveness than the other two triazole compounds tested.

Keywords: *Amorphophallus campanulatus*, paclobutrazol, plant growth regulators, propiconazole, triadimefon.

Abbreviations: ABA – abscisic acid, C_i – intercellular CO_2 concentration, Cv –cultivar, CRBD – completely randomized block design, DAP – days after planting, EC – electrical conductivity, FYM – farm yard manure, GA – gibberelic acid, IRGA – infra red gas analyzer, PBZ – Paclobutrazol, PCZ – Propiconazole, P_N – photosynthetic rate, RH – relative humidity, TDM – Triadimefon, T_R – transpiration rate, WUE – water use efficiency

*Corresponding author, e-mail: suriyagopi@yahoo.co.in

INTRODUCTION

Plant growth regulators play a regulatory role in many physiological processes associated with growth and development of plants (Thakur and Thakur, 1993). The triazole compounds are the largest and most important group of systemic compounds developed for control of fungal diseases in plants (Siegel, 1981). They tend to be much more effective than many other plant growth regulators and they generally require relatively low levels of application (Davis et al., 1988, Gilley and Fletcher, 1997). The effects of triazoles on hormonal changes, photosynthetic rate, enzyme activities and yield components have been reported by various researchers (Ye et al., 1995, Zhou and Ye, 1996).

Besides cereals and legumes, the tuber crops are regarded as an important food crop with the highest dry matter production (Kurup and Nambiar, 1993). Elephant foot yam (*Amorphophallus campanulatus* Blume) is one of the very high yielding tuber crop used in certain medicinal preparations recommended for piles and dysentery (Sambamurty and Subramanyam, 1989).

The triazole compounds are mainly used as growth retardants and also stress protectants in many crop plants (Fletcher et al, 2000). However, data on the use of triazole compounds to increase the yield of tuber crops are scanty. Hence, the present study becomes essential to investigate the effect of triazole compounds on the growth and photosynthetic characteristics of *Amorphophallus campanulatus* cv. Pidikarani.

MATERIALS AND METHODS

Plant material

Amorphophallus campanulatus is a robust herbaceous plant with an erect long pseudo stem arising from the underground corm apex bearing a tripartite leaf which is deeply dissected. The root system is fibrous and confined to the top layers of the soil. The corms produced at 60 to 80 DAP. Fresh corms of uniform size were harvested and surface sterilized with 0.2% $HgCl_2$ solution for 3 min with frequent shaking and thoroughly washed in tap water. The field experiments were laid in CRBD with 7 replicates. The pits with a size of 60x60x45cm were dug at a spacing of 90x90cm. The pits were filled with a soil mixture containing FYM, red soil and sand in a 1:1:1 ratio. The plot size was 5 X 4m with 20 pits in each plot. One cormel was planted in each pit and irrigated with bore well water at a 10-day interval. The soil pH was 6.8. Each plant was treated separately with 1L of aqueous solution containing 20 mg triadimefon, 20 mg paclobutrazol and 20 mg propiconazole on 30, 70 and 110 DAP. Treatment was given by soil drenching. During the study the average day and night temperatures were 30±2 °C and 22±2 °C, respectively and the average RH was 70-

80%. The plants were harvested randomly on 80, 160 and 200 DAP for determination of growth and photosynthetic pigments.

Growth parameters

Total root length, petiole length, leaf area and dry weight of root, tuber and leaves were measured. Moisture content was calculated by subtracting the dry weight from the fresh weight.

Photosynthetic pigments determination

Total chlorophyll and carotenoids in the second leaf of the *Amorphophallus* plants were extracted in 80% acetone. The amount of pigments was determined spectrophotometrically after centrifugation at 3000rpm for 10 min (Welschen and Bergkotte, 1994) and calculated according to Lichtenthaler and Wellburn (1983).

Gas exchange measurements

Net photosynthetic rate (P_N), transpiration rate (T_R), intercellular CO_2 concentration (C_i) and stomatal conductance were measured on fully expanded leaves of three individual plants for each treatment at the respective intervals. Gas exchange measurements were done using IRGA (ADC makes model LCA-3). Measurements of P_N, T_R, C_i and stomatal conductance were done at CO_2 concentration (Ca) of 340 μmol^{-1}, leaf to air vapor pressure difference of 2.5 to 3.5 kPa and photosynthetically active irradiance of 1400±50 $\mu mol\ m^{-2}s^{-1}$. Water use efficiency (WUE) represents the ratio of carbon assimilated to water lost by transpiration (Turner, 1986). It was calculated by dividing P_N by T_R (Todorov et al., 1992).

RESULTS AND DISCUSSION

Our results indicated that total root length increased significantly after triazole treatment (Table 1, 2, Fig.1). Among the triazoles, TDM showed the strongest effect, followed by PBZ and PCZ. Triazole treatment was found to increase the root growth in cucumber and this was associated with increased levels of endogenous cytokinins (Fletcher and Arnold, 1986). The stimulatory effect of TDM in rooting may be due to an inhibition of GA synthesis and this effect was entirely blocked by the addition of GA (Vettakkorumakankav et al., 1999, Sankhla and Davis, 1999).

Triazole treatment decreased the petiole length in *Amorphophallus* plants (Table 1, 2, Fig.1). Triadimefon causes several pronounced side effects in plants including the development of shorter and more compact shoots in wheat plants (Fletcher and Nath, 1984) and cow pea (Gopi et al., 1999). The possible reason for the shorter stem could be attributed to the inhibition of cell division and elongation of the subapical

Table1. Triazole-induced changes in growth and photosynthetic parameters of *Amorphophallus campanulatus* on 80th DAP. (values are means of 7 samples, P=0.05 Least Significant Difference)

Parameters	Control	TDM ($20 mg\ l^{-1}$)	PBZ ($20 mg\ l^{-1}$)	PCZ ($20 mg\ l^{-1}$)	LSD (P=0.05)
Total root length [cm $plant^{-1}$]	365.81	644.82	498.3	383.22	17.097
Petiole length [cm $plant^{-1}$]	21.8	18.3	16.8	17.4	0.672
Total leaf area [$cm^2\ plant^{-1}$]	24.03	17.73	16.56	16.7	2.312
Dry weight of whole plants [g $plant^{-1}$]	24.56	49.06	43.52	43.56	1.541
Moisture content of whole plants [g $plant^{-1}$]	109.79	136.16	121.78	128.15	2.318
Total chlorophyll (a+b) [mg g^{-1} FW]	0.11	0.131	0.127	0.12	0.016
Carotenoids [mg g^{-1} FW]	0.018	0.04	0.037	0.033	0.006
Net photosynthesis rate (P_N) [$\mu mol\ CO_2\ m^{-2} s^{-1}$]	9.25	11.24	11.38	11.31	1.39
Transpiration rate(T_R) [$\mu\ mol\ H_2O\ m^{-2} s^{-1}$]	7.92	5.37	5.67	5.98	0.31
Intercellular CO_2 concentration [$\mu mol\ s^{-1}$]	125	145	143	147	10.09
Stomatal conductance [$\mu mol\ H_2O\ m^{-2}\ s^{-1}$]	112.15	94.28	93.92	94.12	7.82
Water use efficiency (WUE) [$\mu mol\ CO_2\ m^{-2} s^{-1} / \mu mol\ H_2O\ m^{-2} s^{-1}$]	1.168	2.141	2.007	1.891	–

meristem (Sachs et al., 1960). It was shown that S-3307 retarded the plant height in rice plants (Izumi et al., 1984). The growth retarding effects of triazoles could probably be due to an inhibition of GA biosynthesis (Fletcher et al, 2000).

Triazole treatment decreased significantly the total leaf area when compared to the respective controls (Table 1, 2, Fig.1). PBZ treatment was found to reduce the total number of leaves and leaf size in citrus (Swietlik and Fucik, 1988) and C*ymbidium sinense* (Pan and Luo, 1994). The inhibition of GA biosynthesis as well as increased ABA content induced by triazole treatment could be the reason for the inhibition of leaf expansion in the triazole-treated *Amorphophallus campanulatus* plants.

Our results showed that both the dry weight and moisture content of roots and tubers were increased when compared to controls. Paclobutrazol and triadimefon treatments increased the root, tuber dry weight and moisture content to a larger extent (Table 1, 2, Fig.1). It was shown that triadimefon treatment increased the dry weight and moisture content of roots in cucumber (Fletcher and Arnold, 1984), radish (Fletcher and Nath, 1988) and peanut (Muthukumarasamy and Panneerselvam, 1997). The mode of action of PBZ in relation to early tuber development can be

Table 2. Triazole-induced changes in growth and photosynthetic parameters of *Amorphophallus campanulatus* on 160th DAP. (Values are means of 7 samples, P=0.05 Least Significant Difference)

Parameters	Control	TDM ($20 mg\ l^{-1}$)	PBZ ($20 mg\ l^{-1}$)	PCZ ($20 mg\ l^{-1}$)	LSD (P=0.05)
Total root length [cm $plant^{-1}$]	452.3	795.7	628.62	492.31	19.512
Petiole length [cm $plant^{-1}$]	37.9	29.21	26.2	27.02	1.154
Total leaf area [$cm^2 plant^{-1}$]	34.58	26.56	25.71	27.31	1.199
Dry weight of whole plants [g $plant^{-1}$]	92.33	170.73	164.82	158.29	6.479
Moisture content of whole plants [g $plant^{-1}$]	290.15	408.09	391.2	391.17	3.878
Total chlorophyll (a+b) [mg g^{-1} FW]	0.145	0.174	0.168	0.167	0.014
Carotenoids [mg g^{-1} FW]	0.023	0.052	0.042	0.039	0.01
Net photosynthesis rate (P_N) [$\mu mol\ CO_2\ m^{-2}s^{-1}$]	18.46	21.68	23.8	21.36	1.45
Transpiration rate [T_R] [$\mu mol\ H_2O\ m^{-2}s^{-1}$]	13.15	9.81	10.36	9.36	1.06
Intercellular CO_2 concentration [$\mu mol\ s^{-1}$]	215	275	269	271	17.08
Stomatal conductance [$\mu mol\ H_2O\ m^{-2}\ s^{-1}$]	82.12	73.95	72.81	73.21	6.72
Water use efficiency (WUE) [$\mu mol\ CO_2\ m^{-2}s^{-1}$ / $\mu mol\ H_2O\ m^{-2}s^{-1}$]	1.403	2.209	2.2	2.282	–

explained by the inhibitory effect of triazoles on GA levels. The lower GA levels as a prerequisite for tuber formation (Hammes and Nel, 1975) increase the ability of partitioning of assimilates to tuberous organ as observed in potato (Deng and Parange, 1988) and gladiolus (Steinitz et al., 1991).

The results of the present study support the observation of Sankhla et al. (1985) and Williamson et al. (1986) for increased leaf dry weight per unit leaf area under triazole treatment in soybean and peach. Triazoles were found to increase the cytokinin content in many plants like pumpkin, oil seed and rape seedlings (Grossmann, 1992).The increased cytokinin levels might increase cell division and thereby lead to increased dry weight in the triazole-treated Elephant Foot Yam plants.

Treatment with triazoles increased chlorophyll and carotenoid contents (Table 1, 2, Fig. 2). Earlier data have shown that TDM treatment increases chlorophyll content in leaves of tomato (Buchenauer and Rohner, 1981), radish (Muthukumarasamy and Panneerselvam, 1997) and cowpea (Gopi et al., 1999). PBZ increased chlorophyll content, fresh weight and leaf area basis and this may be partly due to the observed increase in mass of the root system which is the major site of cytokinin biosynthesis

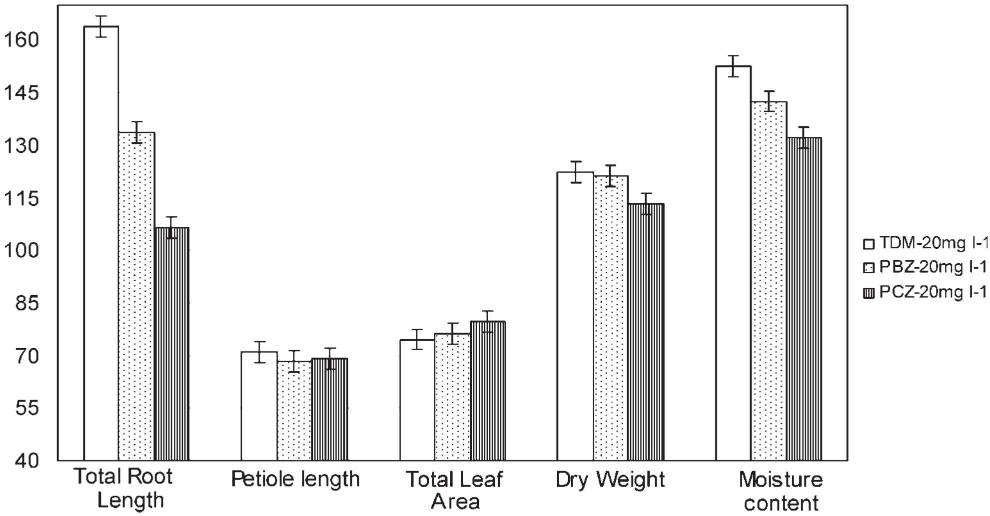

Fig.1. Effect of triazoles on percentage changes in different growth parameters of *Amorphophallus campanulatus* 200 DAP.

(Sopher et al., 1999). The increase in cytokinin levels was associated with stimulated chlorophyll biosynthesis (Fletcher et al., 2000).

Net photosynthetic rate was increased after triazole application (Table 1, 2, Fig. 2). Similar results were observed in PBZ-treated apple (Hong et al., 1995) and triadimefon-treated radish (Panneerselvam et al., 1997). In radish TDM increased P_N along with intercellular CO_2 concentration and stomatal conductance (Panneerselvam et al., 1997).The increased intercellular CO_2 concentration and stomatal conductance may be the reason for the increased P_N in *Amorphophallus* plants. Both increased chlorophyll content and photosynthesis after triazole application were also reported for rice seedlings (Guirong et al., 1995) and bhendi (Sujatha et al., 1999).

The rate of transpiration was lowered in triazole-treated plants at all stages of growth (Table 1, 2, Fig.2). Triadimefon treatment increased the level of ABA content in various plants (Davis et al., 1986, Fletcher and Hofstra, 1988). This in turn induced stomatal closure, thereby decreasing the transpiration rate. A decrease in transpiration rate may have increased the moisture content in the *Amorphophallus campanulatus* plants. Similar results were observed in triadimefon-treated wheat (Sairam et al., 1989) and radish plants (Panneerselvam et al., 1997). Besides, triadimefon treatment increased the ABA content in bean (Asare-Boamah et al., 1986).

Triazole treatment increased the intercellular CO_2 concentration (Table 1, 2, Fig. 2). Similar results were observed in BAS. III W treated maize (Kasele et al., 1995) and *Raphanus sativus* (Panneerselvam et al., 1997). On the other hand, triazole treatment decreased stomatal conductance in *Amorphophallus* plants (Table 1, 2, Fig. 2). Triazole caused partial closure of stomata in mulberry, thereby reducing the T_R

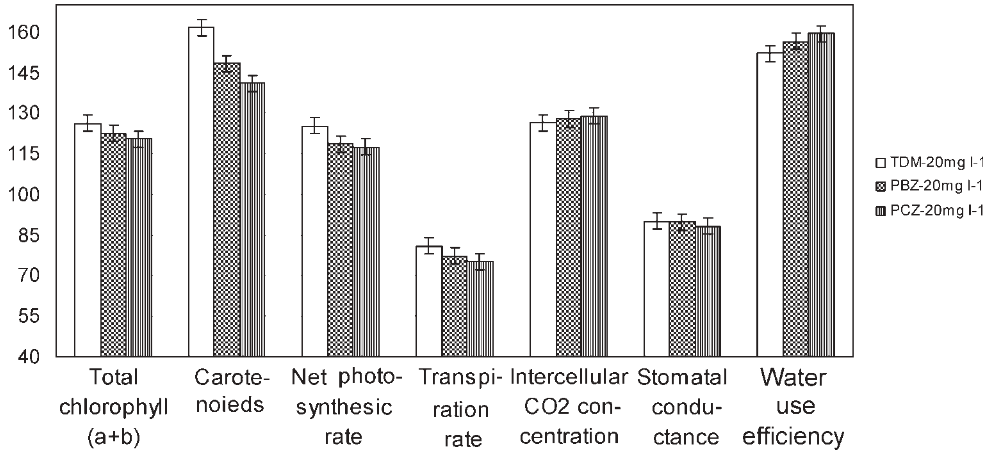

Fig.2. Effect of triazoles on percentage changes in different photosynthetic parameters of *Amorphophallus campanulatus* 200 DAP..

(Sreedhar, 1991) in bean (Asare-Boamah et al., 1986) and oil seed rape (Butler et al., 1988). Our results showed increased WUE in *Amorphophallus* plants (Table 1, 2, Fig. 2). Similar results were reported for TDM-treated sunflower (Wamble and Culver, 1983). PBZ increased the WUE in *Psendotsuga menziesisi* and *Pinus cornata* seedlings (Vanden, 1996). Triazole induced partial closure of stomata and increased intercellular CO_2 concentration. This may be the reason for the increased WUE in the treated plants.

References

Asare Boamah, N.K., G. Hofstra, R.A. Fletcher, E.B. Dumbroff, 1986. Triadimefon protects bean plants from water stress through its effects on ABA. Plant Cell Physiol., 27, 383-390.

Buchenauer, H., E. Rohner, 1981. Effects of Triadimefon and Triadimenol on growth of various plant species as well as on gibberellin content and sterol metabolism in shoot of barley seedlings. Pest. Biochem. Physiol., 15, 58-70.

Butler, D.R., E.Pears, R.D.Child, P.Brain, 1988. Effect of triazole growth retardants onoil seed rape, photosynthesis of single leaves. Ann. Appl. Biol., 114, 331-337.

Davis, T.D., N. Sankhla, A. Upadhyaya, 1986. Paclobutrazol: a promising PGR. In: Purohit, S.S. (ed.) Hormonal regulation of plant growth and development. Agro Botanical Publishers, Bikaner, India, 3, 311-331.

Davis, T.D., G.L. Steffens, N. Sankhla, 1988. Triazole plant growth regulators. In: Janick J. (ed.) Hort. Rev. Timber Press, Portland, Oregon, 10, 63-105.

Deng, R., P.K. Parange, 1988. Effect of paclobutrazol (PP 333) on ^{14}C-assimilate partitioning potato (*Solanum tuberosum* L.). Hort. Sci., 23, 155.

Fletcher, R.A., A.Gilley, T.D.Davis, N. Sankhla, 2000. Triazoles as plant growth regulators and stress protectants. *Hort. Rev.,* 24, 55-138.

Fletcher, R.A., V.Arnold, 1986. Stimulation of cytokinins and chlorophyll synthesis in cucumber cotyledons by Triadimefon. Physiol. Plant., 66, 197-201.

Fletcher, R.A., V. Nath, 1984. Triadimefon reduces transpiration and increases yield in stressed plants. Physiol. Plant., 62, 422-424.

Fletcher, R.A., G.Hofstra, 1988. Triazole as potential plant protectants. In sterol biosynthesis inhibitors in plant production. Eds. D Berg, M Plempel Ellis Horwood Ltd, Cambridge, 321-331.

Gilley, A., R.A. Fletcher, 1997. Relative efficiency of paclobutrazol, propiconazole and tetraconazole as stress protectants in wheat seedlings. Plant Growth Regul., 21, 169-175.

Gopi, R., B.M. Sujatha, S.N. Rajan, L. Karikalan, R. Panneerselvam, 1999. Effect of Triadimefon in the NaCl stressed cowpea (*Vigna ungiculata*) seedlings. Indian J. Agric. Sci., 69, 743- 745.

Grossmann, K., 1992. Plant growth reterents: Their mode of action and benefit for physiological research, In: C.M. Karassan, L.C Van Loon. And D. Vereugdenhil (ed.). Progress in plant growth regulation. Kluwer Academic Publishers, Netherlands pp. 788-797.

Guirong, C.,X.Lin, W.Kaijiun, Z.A.Yan, P.Yijiu, l.Yuming, W.M.Xiang, 1995. The physiological and yield increasing effects of multi-effect triazole treatment of green house rice seedling. Henan Nongye Kexue, No.2, 2-4. (ch, 5 ref). Xinyang Higher Agri. Training School. China.

Hammes, P.S., P.C.Nel, 1975. Control mechanisms in tee tuberization process. Potato Res., 18, 262-272.

Hong, Y., Y. Zhimim, Y.Jingyl, 1995. Biological response of *Hosta plantaginea* to mepiquat chloride and paclobutrazole. J.Nanjing Agricultural Univ.China, 18(3), 18-22.

Izumi, K.,I. Yamaguchi, A. Wada, H. Oshio, N. Takahashi, 1984. Effect of new plant growth retardant (E)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)-1-penten-3-ol (S-3307) on the growth and gibberellin content of rice plants. Plant Cell Physiol., 25, 611-617.

Kasele, I.N., J.F. Shannahan, D.C. Nielsel, 1995. Impact of growth retardants on corn leaf morphology and gas exchange traits. Crop sci., 35(1), 190-194.

Kurup, K.B., Nambiar, 1993. Tuber crops in India, an overview. Indian Horti., 33(3), 4-7.

Lichtenthaler, H., A. Wellburn, 1983. Determination of total carotenoids and cholorophyll *a and b* of leaf extracts in different solvents. Biochem. Soc.Trans., 603, 561-592.

Muthukumarasamy, M., R. Panneerselvam, 1997. Triazole induced protein metabolism in the salt stressed *Raphanus sativus* seedlings. J. Indian Bot. Soc., 76, 39-42.

Pan, R.C., Y.X.Luo, 1994. Effect of PP 333 on growth, development and leaf structure of *Cymbidium sinensis.* Acta Horti. Sinica., 21(3), 269-272.

Panneerselvam, R., M. Muthukumarasamy, L. Karikalan, 1997. Triadimefon enhances growth and net photosynthetic rate in NaCl stressed plants of *Raphanus sativus* L. Photosyn., 34, 605-609.

Sachs, R.M., A. Lang, C.F. Bretz, J.Roach, 1960. Shoot histongensis sub-apical meristematic activity in a canlescent plant and the action of gibberellic acid and AMO-1618. Amer.J.Bot., 47, 260-266.

Sairam, R.K., P.S. Desmukh, D.S. Shukla, K.G., Wasnik, S.R. Kushwaha, 1989. Effect of Abscisic acid and Triadimefon on photosynthesis and nitrate reductase activity during water stress in wheat. Indian J. Plant. Physiol., 32(1), 51-56.

Sambamurty, A.V.S.S., N.Subramanyam, 1989. A text book of economic botany, Willey Estren Lid., New Delhi., India. pp. 294-296.

Sankhla, N., T.D. Davis, A. Upadhyaya, D. Sankhla, R.H. Walser, B.N. Smith, 1985. Growth and Metabolism of soybean as affected by Paclobutrazol. Plant Cell Physiol., 26, 913-921.

Sankhla, N., T.D. Davis, 1999. Use of biosynthesis inhibitors for controlling woody plant growth. Proce. Plant Growth Regul. Soc. Amer., 26, 97-104.

Siegel, M.R., 1981. Sterol-inhibiting fungicides: Effects on sterol biosynthesis and sites of action. Plant Dis., 65, 986-989.

Sopher, R.C., M.Krol, N.P.A. Huner, R.A. Fletcher, 1999. Chloroplastic changes associated with paclobutrazole induced stress protection in maize seedling. Can. J. Bot., 77, 1-12.

Sreedhar, V.M.,1991. Proline accumulation and reduced transpiration in leaves of triazole treated mulberry plant. Indian Bot. Repor., 10,1-5.

Steinitz, B.A., A. Cohen, Z. Golberg, M. Kochba, 1991. Precocious gladiolus corn formation in liquid shake cultures. Plant Cell Tiss. Org. Cult., 26, 63-70.

Sujatha, B.M., R.Gopi, L.Karikalan, S.N.Rajan, R.Panneerselvam, 1999. Effect of triadimefon treatment on bhendi (*Abelmoschus esculantus* (L.) moench.) seedlings under salinity condition. Indian J. of Plant Physiol., 4, 307-310.

Swietlik, D., J.E. Fucik, 1988. Responses of field-grown grape fruit trees to XE-1019 and paclobutrazol. In: R. Geren, K.Meadel (ed.).Proc. VI. Internat. Citrus Conf. Balaban Publ., Philadelphia, pp. 941-946.

Thakur, P.S., A. Thakur, 1993. Influence of triacontanol and mixtalal during plant moisture stress in *Lycopersion esculantum*. Plant Physiol. Biochem., 31(3), 433-439.

Todorov, D.,V. Alexieva, E.Karnanov, D.Velihko, V. Velikova, 1992. Effect of certain dicorboxylic acid monoesters on growth, cholorophyll content, clorophyllase and peroxidase activities and gas-exchange of young maize plants. J.Plant Growth Regul.,11, 233-238.

Turner, N.,1986. In: Advance in agronomy, crop water deficits. A decade of progress. Brady,N.C., (ed.). Academic press, London, 39, 1-43.

Vanden, D.R., 1996. Drought resistance and water use efficiency of conifer seedlings treated with paclobutrazol. New Forests. 11(1), 581-583.

Vettakkorumakankav, N.N., D.Falk, P.Sexena, R.A Fletcher, 1999. A crucial role for gibberellins in stress protection of plants. Plant Cell Physiol., 40(5), 542-548.

Wamble, R.L., E.B.Culver.1983. The influence of paclobutrazol, a new growth regulator on sunflower. J.Amer. Soc., 108,122-125.

Welschen, R., M.Bergotte, 1994. Ecophysiology. Handbook of methods. Department of plant Ecology and Evolutionary Biology, The Netherlands.

Williamson, J.G., D.C. Costom, L.W.Griames, 1986. Growth response of peach roots to soil and foliar applied paclobutrazole. Horti. Sci., 21, 1001-1003.

Ye, Q.F., W.J. Zhou, W.F.Xi., J.Y.Fang, 1995. Effects of S-3307 on levels of endogenous(IAA,ABA and ZT) and physiological of rape seedlings. Acta Agri. Zhejiang, 7, 451-456.

Zhou,W.J., Q.F Ye, 1996. physiological and yield effects of uniconazole on winter rape (*Brassica napus* L.). J. Plant Growth Regul., 15, 69-73.