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College of Agriculture Vellayani, Thiruvananthapuram

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PREFACE

Scientific Agriculture played an important role in the process of enrichment of developed countries. Any country seeking to develop its economy has to give significant priority to Agriculture, particularly Scientific Agriculture, and scientific agriculture is intimately associated with climate and weather.

The impact of drought and flood has underlined the urgency of understanding the interrelationships between crops and weather. We have unusual opportunities today to develop crop saving techniques in areas affected by adverse weather conditions and suitable compensatory production programmes in favourable areas. Thus scientific management of monsoon behaviour is becoming feasible. However, to do this in a meaningful manner it is important to understand the effects of weather on the different components of the biosphere. With this in view, the Kerala Agricultural University, College of Agriculture, Vellayani has taken the lead to organize a Workshop on Climate and Development under the sponsorship of the Kerala State Planning Board, Government of Kerala.

I am very much thankful to Dr. P. Rajasekharan, Chief, Kerala State Planning Board for encouraging me to organise a Workshop of this kind so as to make awareness among the scientific community, planners and ultimately the farming community about the importance of weather, the latest methods of weather forecasting and its importance in the current scenario of global agriculture importance. Thanks are also due to our beloved Vice-Chancellor, Sri. K. R. Viswambharan IAS, Dean, Faculty of Agriculture,Dr.K.Harikrishnan Nair and Associate Director of Research (Meteorology)Dr. G.S.L.H.V. Prasada Rao for their keen interest and flagging support. I gratefully acknowledge the benevolence and immeasurable help rendered from Dr. T. N. Balasubramonian, Advisor to National Insurance, Chennai and former Head of Department, Agricultural Meteorology, Tamil Nadu Agricultural University, Coimbatore. I also acknowledge with thanks all the authors who have contributed papers to this Workshop. I thank all the invited speakers, Chairman, Co-chairman and Rapporteur of different technical sessions for taking part in the conduct of technical sessions and actively deliberating on the occasion. Last but not least the hard work and sincere efforts of my collegues at College of Agriculture, Vellayani is also acknowledged.

I am confident that the Workshop will lead to a greater understanding of methods of weather forecasting, its importance and methods of weather management in relation to crop production. The Proceedings of the workshop represents an up-to-date reference of ideas and discussions of the Workshop concerning Climate and Development. On behalf of the organizing committee, I have great pleasure in presenting this Proceedings of the Workshop to the delegates of the National Workshop on Climate and development conducted jointly by the Kerala Agricultural University and the Kerala State Planning Board, Government of Kerala.

The financial assistance received from the Kerala state Planning Board is gratefully acknowledged.

Thiruvananthapuram — L.Girija devi

22.06.2009 — Organising Secretary

Proline may assume greater role in coconut (*Cocos nucifera* L) adaptation to elevated CO_2 and temperature conditions

John Sunoj V.S., S. Naresh Kumar, K.S. Muralikrishna and K.V. Kasturi Bai,Central Plantation Crops Research Institute, Kasaragod, 675124, Kerala

Abstract

Recent reports of IPCC indicate that atmospheric concentration of CO_2 will further rise leading to increased temperatures. As climate change is causing immense impact on plants, it becomes important to understand the adaptation strategies of plants so as to chōose suitable crops or cultivars. A study was conducted with coconut seedlings of three cultivars viz. WCT, LCT, COD, and two hybrids viz., WCT x COD, and COD x WCT, which were grown in Open Top Chamber facility, where CO_2 levels were maintained at 550 and 700ppm and in a separate OTC, temperature was elevated at 2°C above ambient. Apart from these, seedlings were also grown in control chamber and in shade net conditions. After exposure to above treatments for about 2 years, the leaf proline contents were estimated. Results indicated that the elevated CO_2 caused increased accumulation of proline in leaf tissue in spite of maintenance of high leaf water potentials. On the other hand, elevated temperature caused only a slight increase in proline concentration, despite the reduced leaf water potentials. These results suggest greater role for proline in coconut adaptation to high CO_2 concentrations.

Introduction

It is now clear that climate change is a reality (IPCC, 2007). Over the last century, atmospheric concentrations of carbon dioxide increased from a pre-industrial value of 278 parts per million to 379 parts per million in 2005, and the average global temperature rose by 0.74° C. According to IPCC, this is the largest and fastest warming trend that they have been able to discern in the history of the Earth. The IPCC AR4 gives detailed projections for the 21st century and these show that global warming will continue and accelerate. The best estimates indicate that the Earth could warm by 3° C by 2100. Even if countries reduce their greenhouse gas emissions, the Earth will continue to warm. Projections by 2100 range from a minimum of 1.8° C to as much as 4° C rise in global average temperatures. Heavy precipitation events, are expected to rise even with relatively small average temperature increases. Increase in the frequency and intensity of heat waves and heavy precipitation events have already been observed (Meehl et al. 2007). All these changes in climate have profound influence on agriculture.

Recent studies confirm that the effects of elevated CO_2 on plant growth and yield will depend on photosynthetic pathway, species, growth stage and management regime, such as water and nitrogen (N) applications (Kimball et al., 2002). Analyses find that compared to current atmospheric CO_2 concentrations, crop yields increase at 550 ppm CO_2 in the range of 10-20% for C3 crops and 0-10% for C4 crops (Ainsworth et al., 2004; Gifford, 2004; Long et al., 2004) with C3 plants responding more to the atmospheric rise in CO_2 (Ziska, 2003). Elevated atmospheric CO_2 is reported to increase the growth of coconut seedlings grown in open top chambers (Naresh Kumar, 2007). Coconut is a C3 plant and is considered as a source limited crop (Naresh Kumar *et al.*, 2002). Like any crop plant, coconut also responds to the external factors such as nutrients, water, etc. Global climate change is increasingly considered to be the most important external factor which influences plant growth. Simulation studies using Info-Crop-COCONUT model (Naresh Kumar *et al.*, 2008) already reported that climate change likely to increase coconut yields in west coast of India, parts of Karnataka and parts of Tamil Nadu, while reductions are projected in Andhra Pradesh, certain other parts of Karnataka and Tamil Nadu with a caution that the future availability of irrigation water is crucial for obtaining such trends (Naresh Kumar, 2008; Naresh Kumar and Aggarwal, 2009).

It is well established that all plants have evolved many adaptation to grow, develop and reproduce in a narrow range of environmental conditions. Environmental stresses adversely affect these phenomena in various crop plants. Understanding the physiological and biochemical mechanisms that make some varieties tolerant compared to others is fundamental in identifying clearly the recognizable traits for use in breeding programs aimed at developing cultivars adapted to the environmental stress (Laila and Abel 2002). Proline is considered to be one of the strategic molecules in plant adaptation mechanism to environmental stresses. Hence, it is an extensively studied molecule in the context of plant responses to abiotic stresses. Many plants accumulate this compatible solute under water deficit (Aspinall and Paleg, 1981), salinity (Ashraf and Harris, 2004), low temperature (Naidu et al., 1991), high temperature, and some other environmental stresses. Proline accumulation was induced by Cu in rice leaves (Chen et al., 2001) and by low temperature in tobacco (Parvanova et al .2004). Proline protects cell membranes and proteins against the adverse effects of high concentrations of inorganic ions and temperature extremes (Santoro et al, 1992). Proline is one of the important amino acid, which make a substantial contribution towards osmotic adjustment in adaptation to stress (Rabe, 1990) apart from proline dependent scavenging of reactive oxygen species such as hydroxyl radicals (Smirnoff and Cumbes, 1989) and singlet oxygen (Alia et al., 2001). In coconut also, role of proline in osmotic adjustment in the seedlings under severe stress was reported (Kasturi Bai and Rajagopal, 2004). Even though, studies reported that proline is an indicator of plant water status (Lazcano Ferrat and Lovatt 1999), in case of coconut proline is not a good indicator of leaf water status (Kasturi Bai and Rajagopal, 2004). However, it is important to understand the role of proline in plant adaptation to changing environment. Thus, the objective of the study is to understand the accumulation and role of proline in coconut adaptation to elevated CO_2 and temperature.

Materials and Methods

Experiment was conducted in open top chamber (OTC) facility, where elevated CO_2 and temperature are maintained through SCADA (Supervisory Control and Data Acquisition) system, established at Central Plantation Crops Research Institute, Kasaragod, India. Seedlings of three coconut cultivars viz. WCT (West Coast Tall), LCT (Laccadive Tall), COD (Chowghat Orange Dwarf), and two hybrids viz., WCT x COD and COD x WCT were grown in OTC and shade net in a completely randomized design. In two OTCs, seedlings were exposed to 550 ppm and 700 ppm v/v CO_2 concentration for two years. A set of seedlings grown in another OTC, where temperature was maintained at +2 ^{o}C over ambient condition by using hot air blowers, which are also connected to SCADA system. In two OTCs seedlings were grown at ambient CO_2 level (380 ppm), these served as chamber control. Apart from these, a set of seedlings were grown in shade net were seedlings were exposed to ambient atmosphere. These seedlings served as another set of control. All experimental seedlings were provided with vermicompost in uniform doses and soil moisture was maintained by irrigation.

Observation on leaf water potential (Ψ_{leaf}) using Pressure Chamber (Plant Moisture Vessel, SKPM 1400, UK) and proline concentration on all experimental seedlings were recorded on the middle leaflets of the third frond from top. The recordings were done in a bright sunny day between 9 and 11 am. Observations were made on six seedlings in each cultivar under each treatment.

Concentration of proline was estimated in one gram fresh leaves homogenized in 10 mL sulphosalicylic acid and centrifuged at 10,000 rpm for 15 min. From the homogenate 2 mL of supernatant was taken for the estimation of proline as per the method of Bates et al (1973) using acid ninhydrin and L-proline standard (0- 100µg / mL). Spectrophotometric observations were made by reading optical density at 520 nm. All data were statistically analyzed and standard error of mean was calculated.

Result and discussion

Seedlings grown in elevated CO_2 conditions have accumulated more proline as compared that in chamber control seedlings at similar leaf water potentials (Fig. 1) However, the increase was not linear with increase in CO_2 concentrations. On the other hand, proline accumulation in seedlings grown in elevated temperature (but at 380 ppm) did not differ significantly from that of chamber control seedlings even though the leaf water potential in seedlings exposed to elevated temperature was significantly low (Fig 2).

The results indicate that increase in proline concentration in leaf tissue of seedlings grown in elevated CO_2 concentrations is due to high CO_2 effect and not due to water stress as the leaf water potentials of all seedlings (grown in 380, 550 and 700 ppm) were similar. In elevated CO_2 condition increased nitrogen demand will be satisfied by simple organic compound such as free amino acids as additional source of nitrogen (Schimel and Bennett, 2004) and the nitrogen availability is important in carbon sequestration (King et al., 2004) The role of proline as a source of fixed nitrogen contributing to recovery of the plant after relief from the stress has been reported (Blum and Ebercon., 1976). From the above studies it can be assumed that, higher content of proline in coconut seedlings is due to requirement of inorganic nitrogen in the elevated CO_2 condition.

There exists variation in proline concentration among the cultivars and hybrids (Table 1). The tall cultivars viz., LCT and WCT exhibited higher capacity for accumulation of proline. Earlier studies suggest the existence of a correlation between the generation of free radicals and the accumulation of proline under stress (Alia *et al.*,1995). Singlet oxygen quenching activity and hydroxyl radical scavenging activity of proline were observed (Smirnoff and Cumbes 1989; Alia *et al.*, 2001). The accumulation of proline is related to non-enzymatic detoxification of free radicals that are generated excessively under stress. In coconut, higher accumulation of free amino acid takes place under severe stress conditions, where soil moisture content ranged from 3-4% (Kasthuri Bai and Rajagopal, 2000) and during stress period proline contribute to the osmotic adjustment in coconut seedlings, even though in case of coconut proline is not a good indicator of leaf water status (Kasthuri Bai and Rajagopal, 2004). On the other hand studies show that concentration of proline increases in large number of plant species under stress, up to 100 times than normal level (Aziz et al 1998).

Results suggest that the accumulation of proline is limited by availability of carbon skeletons at current atmospheric CO_2 levels as is evident from no significant higher accumulation of proline in seedlings grown at 380 ppm but exposed to high temperature. These seedlings had lower water potentials as well. Possibly this is the reason why earlier studies on coconut did not get a relationship between leaf water potential and proline accumulation. We consider accumulation of proline as an adaptive measure by coconut in elevated CO_2 condition. In climate change scenarios, where rise in temperature is associated with the increased levels of CO_2 in atmosphere, accumulation of high levels of proline as a result of higher CO_2 conditions may prove beneficial for coconut for combating the high temperature stress. Increase of proline content under elevated CO_2 may also serve as the i) nitrogen and amino acid pool, ii) act as a non enzymatic detoxifier of free radicals and iii) help in osmotic adjustment. All these strategies help coconut to adapt to grow in climate change scenarios.

Hence, we conclude that proline is likely to assume a greater role in coconut adaptation strategy to climate change scenarios. This may be used as one of the traits while selecting the genotypes for changing climate.

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Fig.1. Proline concentration (mg/g DW leaf tissue) in coconut seedlings grown at three atmospheric CO_2 (380 ppm, 500 ppm and 700 ppm) concentrations. The leaf water potential of seedlings was similar at ~ -7.2 bars.

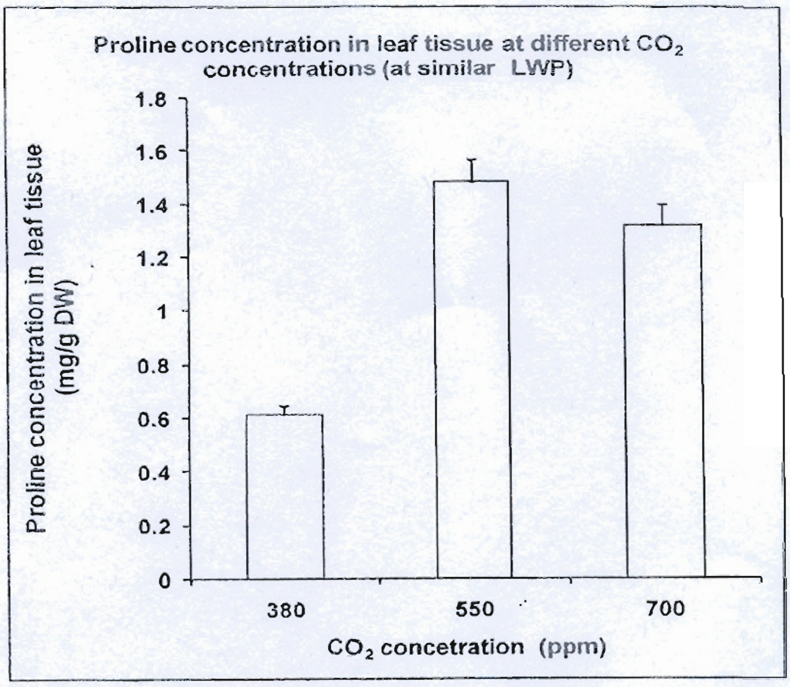

Fig.2. Proline concentration (mg/g DW leaf tissue) and leaf water potential of coconut seedlings grown in different conditions (shade net -SN, control open top chamber (CC) and elevated temperature (+2 °C over ambient temperatures) at atmospheric CO_2 concentrations (380 ppm).

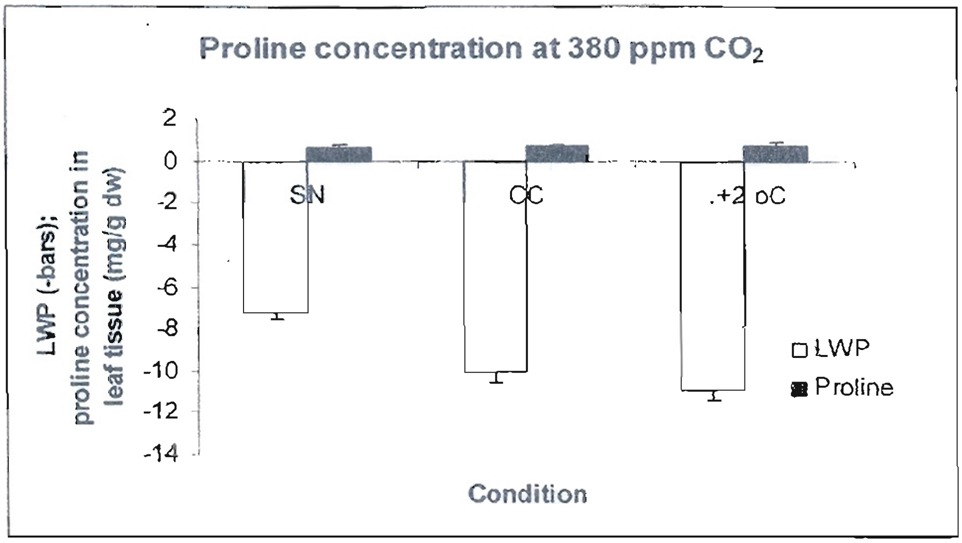

Table Variation in leaf water potential (Ψ_{leaf}) and proline concentration (on dry weight-DW- basis) in coconut seedlings grown under different treatments viz., shade net (SN), CO_2 chamber control (CC), elevated temperature (+2 °C over ambient), 550 ppm elevated CO_2 and 700 ppm elevated CO_2 concentrations.

Cultivars	*Leaf water potential* (Ψ_{leaf})					*Proline (mg proline /g DW leaf tissue)*				
	SN	CC	+2°C	550 ppm CO_2	700ppm CO_2	SN	CC	+2°C	550 ppm CO_2	700 ppm CO_2
LCT	-4.97	-6.19	-9.95	-5.76	-7.54	0.93	0.73	0.76	1.81	1.26
WCT	-4.41	-9.48	-9.99	-6.15	-7.05	0.39	0.66	0.75	1.71	1.09
COD	-8.22	-11.22	-12.05	-10.10	-6.38	0.46	0.69	0.64	1.43	1.09
WCT x COD	-9.11	-11.13	-11.57	-10.98	-6.76	0.70	0.66	0.54	1.17	1.48
COD x WCT	-9.21	-12.28	-10.96	-6.43	-8.35	0.57	0.60	0.83	1.30	1.67
Mean	-7.18	-10.06	-10.90	-7.88	-7.22	0.61	0.67	0.70	1.48	1.32
SEM	1.04	1.07	0.42	1.10	0.34	0.10	0.02	0.05	0.12	0.11

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