

WATER RELATIONS, GROWTH AND OTHER INDICATORS OF PLANT WATER STRESS IN COCOA UNDER DROUGHT

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SUMMARY

Cocoa plants undergo long periods of drought in Southern India affecting growth, metabolism and yield adversely. Among plantation crops, cocoa is regarded as one of the most sensitive to water stress. The water relation components, growth analyses and some metabolic parameters were studied to understand basic mechanisms of drought tolerance in cocoa.

The experimental material consisted of cocoa (*Theobroma cacao* L. var. Forestero) cultivated as intercrop of arecanut palms (*Areca catechu* L.). Observations on growth parameters, water relation components viz. water potential, osmotic potential, turgor pressure, relative water content (RWC); proline, nitrate reductase (NR) activity and chlorophyll contents were collected using standard procedures. Data collected on growth parameters were subjected to growth analysis computations.

The RWC of leaves of rainfed plants were lower than those of irrigated ones. This was accompanied by decrease in leaf water potential and osmotic potential. With progress of drought NR activity and chlorophyll contents declined while proline accumulated in the leaves. The leaf elongation rates were inhibited under drought. This was reflected further in the significant decrease in total dry matter produced, canopy area, relative growth rate and net assimilation rate in droughted plants. In cocoa, it seems probable that ability to tolerate drought results from stomatal regulation which reduces transpirational water loss and high tissue elasticity. The maintenance of leaf turgor accompanied by better metabolic processes further contribute to the drought tolerance ability of some cocoa accessions.

BILAN HYDRIQUE, CROISSANCE ET AUTRES INDICATEURS DU STRESS HYDRIQUE DES PLANTS DE CACAOYER SOUS LA SECHERESSE

RESUME

Les cacaoyers subissent de longues périodes de sécheresse dans le sud de l'Inde, ce qui affecte défavorablement la croissance, le métabolisme et le rendement. Parmi les cultures de plantation, le cacaoyer est considéré comme l'une des plus sensibles au stress hydrique. Les éléments du bilan hydrique, l'analyse de la croissance et certains paramètres métaboliques sont étudiés pour comprendre les mécanismes fondamentaux du degré de tolérance à la sécheresse du cacaoyer.

Le matériel expérimental comportait des cacaoyers (*Theobroma cacao* L. var. Forestero) en culture associée avec des aréquiers (*Areca catechu* L.). L'auteur a rassemblé des données sur les paramètres de croissance, les éléments des rapports hydriques, c'est-à-dire potentiel hydrique, potentiel osmotique, pression turgorique, teneur relative en eau; activité de réductase de nitrate, proline, et teneur en chlorophylle, en se servant des méthodes standard. Les données collectées sur les paramètres de croissance ont été soumises à des calculs d'analyse de croissance.

La teneur relative en eau des feuilles de plants en culture pluviale, était plus faible que dans le cas des arbres irrigués. Ceci s'accompagnait d'une baisse du potentiel hydrique des feuilles et du potentiel osmotique. Les processus d'activité de réductase de nitrate et la teneur en chlorophylle diminuaient lorsque la proline s'accumulait dans les feuilles. Le taux d'allongement des feuilles était inhibé en période de sécheresse. Ceci se reflétait plus tard par les diminutions significatives du total des matières sèches produites, de l'étendue de la frondaison, du taux de croissance relative et du taux d'assimilation nette dans les plants soumis à la sécheresse. Chez le cacaoyer, il semble probable que l'aptitude à tolérer la sécheresse résulte d'une régulation des stomates, qui réduit la perte de l'eau par transpiration et l'élasticité élevée des tissus. Le maintien de la turgidité des feuilles, accompagné de meilleurs processus métaboliques, contribue encore à l'aptitude à la tolérance de la sécheresse de certains nouveau types de cacaoyers.

ESTADO HÍDRICO, DESENVOLVIMENTO E OUTROS INDICADORES DE TENSÃO DE ÁGUA NO CACAU DURANTE A ESTIAGEM

RESUMO

No sul da Índia os cacaueiros estão sujeitos a longos períodos de seca, o que prejudica o seu crescimento, metabolismo e produtividade. Entre as plantas cultivadas, o cacaueiro é considerado uma das mais sensíveis à tensão de água. Os componentes do estado hídrico, análises de crescimento e alguns parâmetros metabólicos foram estudados para compreender os mecanismos básicos da tolerância à seca nos cacaueiros.

O material experimental consistiu em cacau (*Theobroma cacao* L. var. forestero) cultivado em associação com palmeiras areca (*Areca catechu* L.). Fizeram objeto de observações: parâmetros de crescimento, componentes do estado hídrico, como potencial hídrico, potencial osmótico, pressão de turgescência, conteúdo relativo de água (RWC); proline; atividade de redutase de nitrato (NR), e teor de clorofila. Os dados foram coletados segundo métodos padrão. Os dados sobre o parâmetro de crescimento foram submetidos a cálculos de análise de crescimento.

O teor relativo de água em folhas só expostas a chuva foi inferior ao das folhas irrigadas; também o potencial de água da folha e o potencial osmótico foram menores. À medida que a estiagem se prolongava, a atividade NR e o teor de clorofila diminuíram, ao passo que aumentou a quantidade de proline nas folhas. O alongamento das folhas foi inibido pela seca. Outras consequências foram: redução significativa da matéria seca total produzida, da área foliar, da taxa de crescimento relativa e da taxa de assimilação líquida nas plantas sujeitas à seca. Parece que a

capacidade do cacau de tolerar a seca decorre da regulação estomatal, que reduz a perda de água por transpiração e a elevada elasticidade dos tecidos. A manutenção da turgência das folhas, acompanhada de melhores processos metabólicos, contribui também para maior tolerância à seca de algumas variedades de cacau.

RELACIONES DE AGUA, CRECIMIENTO Y OTROS INDICADORES DE TENSION DE AGUA DE LA PLANTA EN EL CACAO EN CONDICIONES DE SEQUIA

RESUMEN

Las plantas de cacao atraviesan por largos períodos de sequía en el Sur de la India, lo cual afecta el crecimiento, metabolismo y rendimiento en forma adversa. Entre los cultivos de plantación, el cacao es considerado como uno de los más sensibles al stress del agua. Los componentes de relación del agua, análisis de crecimiento y algunos parámetros metabólicos fueron objeto de estudio para comprender los mecanismos básicos de tolerancia a la sequía en el cacao.

El material experimental consistía en cacao (*Theobroma cacao* L. var. Forastero) cultivado como intercultivo de palmas de areca (*Areca catechu* L.). Se recogieron observaciones sobre parámetros de crecimiento, componentes de relación del agua como potencial de agua, potencial osmótico, presión túrgica, contenido relativo de agua, proline, actividad de reductase de nitrato y contenidos clorofílicos, usando procedimientos standard. Los datos recopilado sobre parámetros de crecimiento fueron sometidos a cómputos de análisis de crecimiento.

El contenido relativo del agua de las plantas en secano fue inferior que el de las plantas en regadío. Eso fue acompañado de una disminución en el potencial de agua en la hoja y del potencial osmótico. Con el progreso de la sequía disminuyó la actividad de reductase y el contenido clorofílico disminuyó mientras que el proline se acumuló en las hojas. Las tasas de alargamiento de las hojas se vieron inhibidas durante la sequía. Esto se reflejó en la disminución significativa en materia seca total producida en la zona de la copa, tasa de crecimiento relativo y tasa neta de asimilación en las plantas durante la sequía. En el cacao parece probable que la capacidad de tolerar la sequía resulta de la regulación estomatal que reduce la pérdida de agua por transpiración y la alta elasticidad de los tejidos. El mantenimiento de la turgidez de la hoja, acompañada de mejores procesos metabólicos, contribuye además a la capacidad de tolerancia a la sequía de algunas plantas de cacao.

INTRODUCTION

Cocoa which is sensitive to water stress experience periods of drought in Southern India affecting its growth, metabolism and yield adversely. The degree of

drought varies at different locations; the periods extend upto 4-5 months in northern Kerala and coastal Karnataka while relatively shorter in southern Kerala. Cocoa plants are grown as an intercrop of palms in these States of the country (Shama Bhat and Bavappa, 1972).

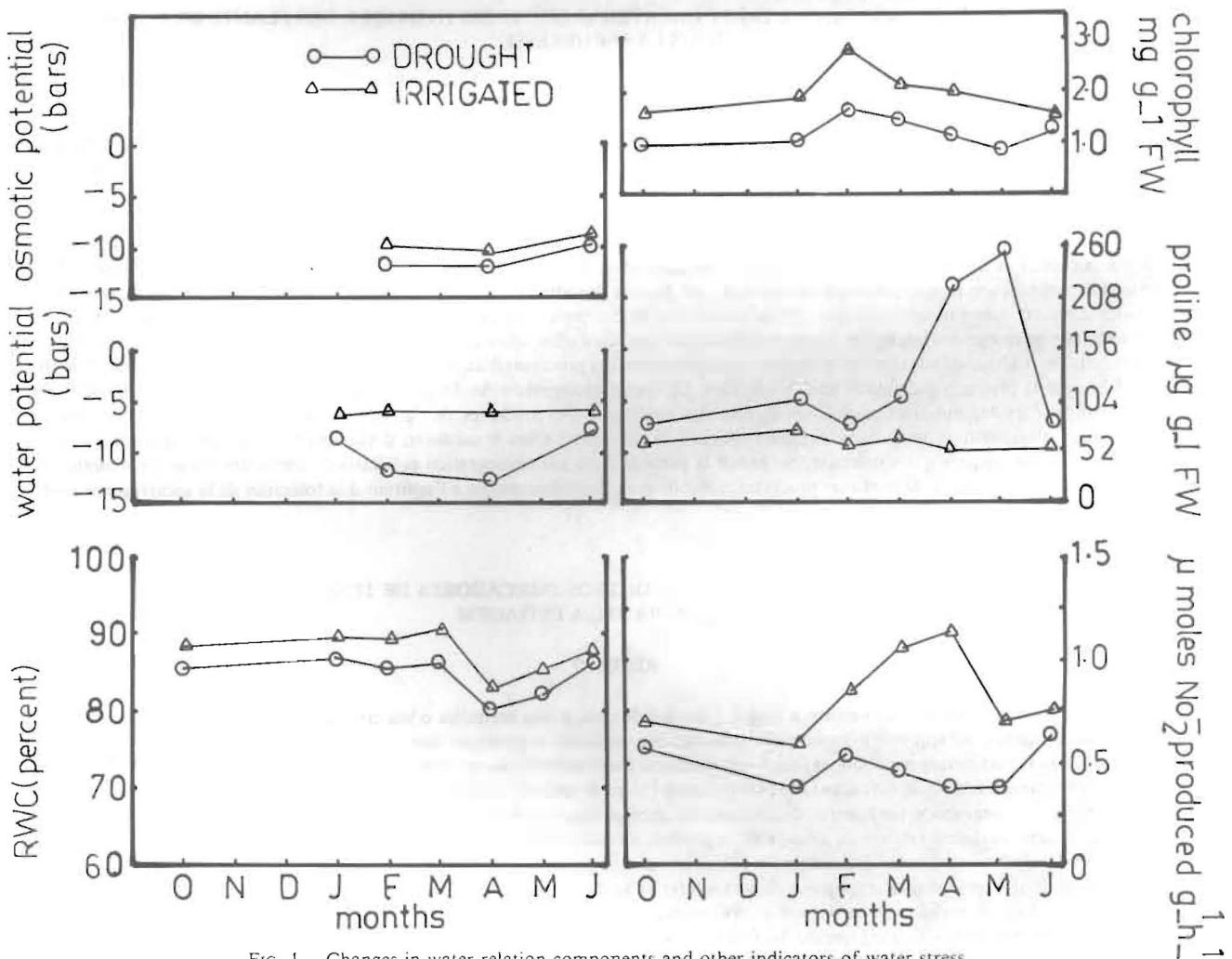


FIG. 1. Changes in water relation components and other indicators of water stress.

The prolonged dry season has been reported to be adversely detrimental to the growth of cocoa in Trinidad, Ghana and Ecuador (Hutcheon, 1977; Orchard, 1984; Wood and Lass, 1985).

Water deficits affect physiological processes to different degrees, the most sensitive being growth and water relation components. In order to extend cultivation of cocoa in India suitable irrigation practices and evolving genotypes for drought tolerance has been taken up at this Institute. This paper deals with the changes in water relations, growth and some sensitive parameters of water stress in response to drought.

MATERIAL AND METHODS

Ten trees each of irrigated and droughted cocoa (*Theobroma cacao* L.) cultivated as an intercrop of arecanut palm were sampled periodically. About 10 leaves (3rd-5th) from each tree were collected for determination. The location, soil and climatic conditions of the Regional Station have been described (Balasimha *et al.* 1985). The RWC, proline, chlorophylls and NR activity were determined by standard methods with slight modifications (Balasimha, 1982). Leaf water potential was measured using pressure chamber (Soil Moisture Equipments Corp., USA). For osmotic potential, the leaves were cut into 1 cm bits, frozen in liquid nitrogen, squeezed through sap extractor into a vial and measured on vapour pressure Osmometer (Wescor Model 5100C). The plants were harvested at regular intervals and growth canopy and dry matter accumulation determined.

RESULTS AND DISCUSSION

During the drying period the unirrigated (drought) cocoa plants had lower RWC, leaf water potential and osmotic potential (Fig. 1). Similar responses of leaf water potential has been reported in other countries where cocoa experiences dry period (Hutcheon, 1977; Alvim, 1967; Orchard, 1984). These water relation and other biochemical parameters did not show appreciable

variations during the season in irrigated plants. There was considerable accumulation of proline in leaves of droughted plants, which may have an adaptive significance. The NR activity also declined with progress of drought, which however recovered with the onset of rains. Because of lack of reducing power caused by water stress the NR activity may be affected (Beevers and Hageman, 1969) and these biosynthetic processes are revived with onset of monsoon. The contents of chlorophylls was lower in droughted plants as compared to the irrigated plants (Fig. 1).

The net result of such drastic changes in leaf water potential components and metabolism is reflected in the adverse effect on growth of cocoa plants (Table 1). The crop growth rates in all the vegetative parts were adversely affected by drought resulting in a decrease in stem girth and total dry weight by about 30% compared to irrigated plants. The canopy area development was even more severely affected i.e. to an extent of nearly 50%.

TABLE I
Mean crop growth rate (CGR) and canopy development

	Stem girth at collar (cm)*	Total dry weight* (kg/plant)	Canopy area* (m ² /plant)	CGR** (Dry weight, g/month)		
				Stem	Leaf	Root
Irrigated	34.7	11.85	16.78	426.2	206.9	14.0
Drought	25.3	8.24	8.24	108.4	129.2	0.12

*Measured when the plants were 50 months old;

**CGR at 40-50 months growth interval

In cocoa the efficient stomatal regulation resulting in reduced transpirational water loss under stress seems to be a major strategy for water conservation (Balasimha *et al.* Unpublished). Under situations where the dry periods are shorter, it is possible to introduce drought tolerant genotypes identified at this Regional Station. However, since this drought adaptive strategy may fail under such areas of longer periods of dry season, there it is necessary to have a proper scheduling of irrigations. The information on water potential and related parameters sensitive to water stress may prove useful in developing suitable irrigation systems.

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