UNIVERSITI PUTRA MALAYSIA

GROWTH, WATER RELATION, YIELD AND CROP QUALITY OF ARABICA COFFEE IN RESPONSE TO WATER STRESS AND DEFICIT IRRIGATION

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By

TESFAYE SHIMBER GESSESE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

This manuscript is dedicated to my beloved parents, Ato Shimber Gessese and W/o Ayelech Degu, to my wife, W/o Sara Alemu and my children, Emnet Tesfaye, Amanuel Tesfaye and Metsenanat Tesfaye.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Coffee (*Coffea Arabica* L.) is the single most important commodity crop that comes after petroleum in the world market. It plays a significant role in the economy of Ethiopia, contributing over 60% of the nation's foreign exchange earnings, 30% of the government's direct revenue, 8% output of the agricultural sector and 4% of the gross domestic production. In spite of the importance of the crop in the country's economy, its average national yield is very low primarily because of traditional production technologies. Apart from hereditary characteristics of the trees, seasonal water stress and recurrent drought are among the major factors which account for low yields of the crop in most coffee growing regions of the country. In the present study, attempt was made to identify water stress tolerant Arabica coffee cultivars and deficit irrigation practices that could improve growth, yield, quality and water use efficiency of the crop under both protected environment and field condition in Ethiopia. Both rain shelter and field experiments were carried out in a randomized complete block design with three replications in the rain shelter and four replications in the field. In the first rain shelter

than NDI for coffee production particularly in areas where water is scarce and dry spells are prolonged. On the other hand, the effect of supplemental deficit irrigation on plant water relations, crop yield and quality was studied in the field using young coffee stands of three cultivars (F-59, 74110 and 75227). Two irrigation treatments, namely, supplemental full irrigation (SFI) and supplemental deficit irrigation (SDI), applied in the conventional way, were compared against rain fed (RF) control. SFI consistently increased soil moisture content, leaf RWC and g_s during the dry period, but there was no difference between the treatments in the main wet season. Besides, SFI significantly increased coffee yield, but the difference between SFI and SDI was not significant and yet SDI had 21 – 24% yield advantage over the RF treatment. On the other hand, overall quality of coffee beans was considerably increased by SDI and RF treatments. Therefore, SDI seems to be more effective than SFI and it can be used as an option next to PRD for coffee production in drier areas.

study, twenty four known cultivars, which are indigenous to the country, were subjected to a soil drying treatment to identify those tolerant genotypes. Variations among the cultivars for mean stress scores, rate of recovery from drought, root to shoot ratio, concentration of inorganic solutes (K, Ca and Mg) in leaves, specific leaf area and survival rate showed that some of the genotypes, such as 74110, 74112 and 8/85, were less sensitive to water stress at seedling stage. On the other hand, in an experiment where three irrigation regimes (well watering, WW, normal deficit irrigation, NDI, and partial root zone drying, PRD) were studied on cultivar F-59 grown in a rain shelter, it was found that NDI and PRD reduced shoot growth, total dry matter production, dry weights of leaves, stem and roots, leaf relative water content (RWC) and stomatal conductance (g_s), but increased root to shoot ratio and irrigation water use efficiency (IWUE) of coffee seedlings. Therefore, it was concluded that PRD is an effective deficit irrigation practice to increase IWUE and decrease irrigation water requirement by 50% without substantial adverse effects on plant growth and development, and it could be practically advantageous in coffee nurseries especially in areas of water scarcity and prolonged drought periods. The same study was carried out in the field to determine the effect of PRD on plant water relations and crop yield and quality of Arabica coffee. Results of the field experiment also indicated that leaf RWC, g_s, fruit growth rate and some yield components were reduced by both PRD and NDI. However, the difference between WW and PRD was not significant for crop yield and yet PRD resulted in over 41% more IWUE than the WW treatment, reduced the amount of irrigation water by 50% and considerably improved both raw and liquor quality of coffee beans. Hence, it was concluded that PRD can be a feasible irrigation strategy, which can save irrigation water, increase IWUE and maintain crop yield, and it appears to be more advantageous

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PERTUMBUHAN, KAITAN AIR, HASIL DAN KUALITI TANAMAN KOPI ARABICA TERHADAP KEKURANGAN AIR DAN PENGAIRAN DEFICIT

Oleh

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February 2006

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Kopi (*Coffea Arabica* L.) merupakan satu-satunya tanaman komoditi terpenting selepas petroleum dalam pasaran dunia. Ia memainkan peranan penting dalam ekonomi Ethiopia, yang menyumbang lebih 60% pertukaran pendapatan bangsa asing, 30% pulangan langsung kerajaan, 8% keluaran sektor pertanian dan 4% pulangan langsung pengeluaran kerajaan. Halangan utama tanaman ini dalam ekonomi Negara adalah purata hasil penduduk yang sangat rendah terutamanya disebabkan oleh teknologi pengeluaran secara tradisional. Ciri-ciri pokok asing yang diwarisi, musim kekurangan air dan kemarau yang berulang merupakan faktor utama yang menyumbang kepada hasil tanaman yang rendah terutamanya tanamna kopi serantai di Negara ini. Dalam kajian ini, usaha dilakukan untuk mengenalpasti kultivar kopi Arabica yang tahan terhadap kekurangan air dan amalan pengurangan pengairan yang dapat memperbaiki pertumbuhan, hasil, kualiti dan keefisienan penggunaan air tanaman dalam keadaan persekitaran terkawal dan di lading di Ethiopia. Kajian di bawah rumah lindungan hujan dan di ladang dilakukan dengan rekabentuk rawak lengkap berblok dengan tiga kali ulangan dalam rumah lindungan hujan dan empat kali ulangan di ladang. Kajian pertama

dijalankan di dalam rumah lindungan hujan, sebanyak 24 kultivar yang diketahui, yang berasal dari negara ini, dikenakan rawatan untuk mengenalpasti genotaip yang tahan terhadap pengeringan tanah. Variasi antara kultivar yang mendapat purata tekanan, kadar pulih semula dari kemarau, nisbah akar ke pucuk, kepekatan larutan inorganic (K, Ca dan Mg) dalam daun, luas daun spesifik dan kadar ketahanan menunjukkan terdapat beberapa genotaip seperti 74110, 74112 dan 8/85, kurang sensitif terhadap kekurangan air pada tahap biji benih. Dalam keadaan lain, satu kajian di mana tiga regim pengairan (pengairan baik, WW, pengairan defisit biasa, NDI dan pengeringan sebahagian zon akar, PRD) dikaji ke atas kultivar F-59 yang ditanam di dalam rumah lindungan hujan dan didapati bahawa NDI and PRD mengurangkan pertumbuhan pucuk, jumlah penghasilan berat kering, berat kering daun, batang dan akar, kandungan relatif air daun (RWC) dan kondultiviti stomata (g_s), tetapi meningkatkan nisbah akar ke pucuk dan pengairan air secara efisien pada biji benih kopi. Oleh itu, disimpulkan bahawa PRD merupakan amalan pengairan deficit yang efektif untuk meningkatkan IWUE dan mengurangkan keperluan pengairan air kepada 50% tanpa kesan kerugian yang banyak ke atas perkembangan dan pertumbuhan tanaman dan ia boleh menjadi amalan yang berfaedah dalam tapak semaian kopi terutamanya dalam kawasan kekurangan air dan tempoh kemarau yang panjang. Kajian yang sama juga dijalankan di ladang untuk mengenalpasti kesan PRD ke atas perkaitan air tanaman, hasil tanaman dan kualiti kopi Arabica. Keputusan kajian di ladang juga menunjukkan kandungan relatif air daun, g_s, kadar pertumbuhan buah dan beberapa komponen hasil berkurangan dengan rawatan PRD dan NDI. Walau bagaimanapun, tiada perbezaan yang bererti antara WW and PRD bagi hasil tanaman dan keputusan menunjukkan lebih 40% lebih IWUE dari rawatan WW, mengurangkan jumlah pengairan air sebanyak 50% dan peningkatan yang tinggi terhadap kualiti bahan mentah dan kualiti minuman biji kopi. Dengan itu, disimpulkan bahawa strategi pengaran secara PRD boleh dilaksanakan untuk menjimatkan pengairan air, meningkatkan hasil tanaman dan ia dilihat lebih banyak memberi faedah berbanding NDI untuk pengeluaran kopi terutamanya dalam kawasan kekurangan air dan jangkamasa kering yang yang panjang. Dalam kajian yang lain, kesan pemberian pengairan yang kurang ke atas perkaitan air tanaman, hasil tanaman dan kualiti di kaji di ladang menggunakan anak benih kopi yang terdiri daripada kultivar (F-59, 74110 dan 75227). Dua rawatan pengairan iaitu pemberian pengairan penuh (SFI) dan pemberian pengairan kurang (SDI) diaplikasikan mengikut kaedah yang biasa diamalkan, dibandingan dengan air hujan (RF) sebagai kawalan. SFI secara tetap meningkatkan kandungan lembapan tanah, kandungan relatif air dan g_s sepanjang jangkamasa kering, tetapi tiada beza secara bererti dengan rawatan dalam musim lembap yang utama. Di samping itu, SFI meningkatkan hasil kopi secara bererti, tetapi perbezan antara SFI dan SDI tidak berbeza secara bererti dengan SDI memperoleh 21-24% faedah hasil lebih daripara rawatan RF. Dengan erti kata lain, kualiti keseluruhan biji kopi telah meningkat dengan banyak dengan rawatan SFI dan RF. Sementara itu, SDI kelihatan lebih efektif berbnading SFI dan ia boleh digunakan sebagai pilihan selain daripada PRD untuk pengeluaran kopi dalam kawasan kering.

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LWP	Leaf water potential
g_s	Stomatal conductance
P_N	Rate of photosynthesis
ABA	Abscisic acid
Ca	Calcium
Mg	Magnesium
K	Potassium
N	Nitrogen
RWC	Relative water content
LER	Leaf elongation rate
DW	Dry weight
TDM	Total dry matter
TLA	Total leaf area
SLA	Specific leaf area
OA	Osmotic adjustment
MPa	Mega paskal
PRD	Partial root-zone drying
WW	Well watering (Well-watered)
NDI	Normal deficit irrigation
DI	Deficit irrigation
FC	Field capacity
SMC	Soil moisture content
IWUE	Irrigation water use efficiency