UNIVERSITI PUTRA MALAYSIA

EVALUATION OF THE MACROS-SAHEL MODEL FOR THE RAINFED PRODUCTION OF CORN (ZEA MAYS L. CV SUWAN I)

RUSHIDAH BT WAN ZAIN

EVALUATION OF THE MACROS-SAHEL MODEL FOR THE RAINFED PRODUCTION OF CORN (*ZEA MAYS* L. CV SUWAN I)

By

RUSHIDAH BT WAN ZAIN

Thesis Submitted in Fulfilment of the Requirements for
the Degree of Master of Agricultural Science
in the Faculty of Agriculture,
Universiti Pertanian Malaysia

April 1993

ACKNOWLEDGEMENTS

The author wishes to convey her sincere gratitude and thanks to Dr. Wan Sulaiman bin Wan Harun, Chairman of the Supervisory Committee, for his guidance and encouragement throughout the course of the programme and his valuable assistance in the preparation and completion of this manuscript. Appreciation is also expressed to Dr. S. Singh and Encik Zakaria bin Wahab for serving this committee.

Thanks are also due to the staff of the Department of Soil Science and the Universiti's Farm Office for their cooperation and approval in using the facilities.

Finally, the author expresses her utmost gratitude to MARDI for awarding the scholarship to pursue this course and to all her friends and colleagues who had contributed to this study while not forgetting her devoted family (Gie, Ee, Eri and Icam) for all the encouragement and sacrifices.

TABLE OF CONTENTS

LIST OF TABLES

LISTS OF FIGURES

Abstract of thesis submitted to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirements for the degree of Master of Agricultural Science.

EVALUATION OF THE MACROS-SAHEL MODEL FOR THE RAINFED PRODUCTION OF CORN (*ZEA MAYS* L. CV SUWAN I)

By

RUSHIDAH BT WAN ZAIN

April 1993

Chairman: Assoc. Prof. Wan Sulaiman bin Wan Harun, Ph. D.

Faculty : Agriculture.

There is an urgent need to cultivate grain corn on a large scale in Malaysia to meet the growing demand. Before attempting to do this a thorough evaluation of environmental effects on the growth and yield of the crop has to be undertaken. One way of doing this is by using simulation models. Therefore the main objective of this thesis is to adapt the MACROS (crop growth) model for the simulation of potential and rainfed production of corn cultivar Suwan I.

A field experiment was set up at Serdang for the establishment of the crop data for corn cultivar Suwan I. The crop data were partitioning of assimilates to the different organs, specific leaf weight constant and crop development rates. They were then used to adapt the MACROS

model for simulating potential yield of corn with the L1D module and subsequently the rainfed yield of the crop, the latter using the SAHEL module for the water balance.

Evaluation with data obtained from Kubang Kranji in Kelantan gave a simulated potential yield of between 8,313 kg ha^{-1} and 9,685 kg ha^{-1} compared to the observed yield of between 7,066 kg ha^{-1} and 8,833 kg ha^{-1}. The simulated growth duration was within -2 to +3 days of the observed. Evaluation for SAHEL was carried out using the data obtained from Serdang. There was no apparent difference in the simulated yield and crop duration when the crops were not irrigated for 7 to 21 days at 42 days after emergence. The observed and simulated rainfed yields were between 5,964 kg ha^{-1} and 6,636 kg ha^{-1} and between 7,657 kg ha^{-1} and 7,659 kg ha^{-1} respectively, while their respective crop growth durations were between 98 days and 100 days, and 101 days. Overall, the MACROS model was able to simulate yield and crop duration accurately for potential production but to a lesser extent the rainfed production.

The MACROS model is very well adapted to the study of behavioural patterns or response to environment changes and crop manipulations. More precise data on other crop data such as the rate of loss of leaf area and basic physiological data pertaining to photosynthesis have to be established in order to improve the model for predicting or simulating absolute yields of specific varieties or cultivar. The model is also potentially capable of predicting yields for any planting dates within a year. Therefore, MACROS can be used by growers to schedule their time of planting and estimate the yield.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia bagi memenuhi syarat keperluan untuk mendapatkan ijazah Masters Sains Pertanian.

PENILAIAN MODEL MACROS-SAHEL UNTUK PENGELUARAN JAGUNG BIJIRIN (*ZEA MAYS* L. CV SUWAN I) DI KEADAAN TADAHAN HUJAN

Oleh

RUSHIDAH BT WAN ZAIN

April 1993

Pengerusi: Prof. Madya Wan Sulaiman bin Wan Harun, Ph. D

Fakulti : Pertanian

Bagi memenuhi keperluan jagung bijirin semasa di Malaysia, penanaman jagung secara besar-besaran perlulah dijalankan. Sebelum meneruskan perusahaan ini kajian pertalian di antara persekitaran dan pengeluaran hendaklah terlebih dahulu dijalankan. Salah satu cara ialah penggunaan model simulasi. Dari itu objektif utama tesis ini ialah untuk menguji kesesuaian model (tumbesaran tanaman) MACROS bagi mensimulat hasil potensi dan dalam keadaan tanpa pengairan bagi jagung bijirin, jenis Suwan I.

Satu percubaan di ladang telah dijalankan di Serdang bagi mendapatkan data-data tanaman jagung. Data- data tersebut ialah pengagihan asimilat ke atas bahagian-bahagian tanaman, angkali berat daun yang khusus dan kadar tumbesaran tanaman. Data-data

tersebut kemudiannya dipadankan kepada model MACROS bagi mensimulat hasil potensi jagung menggunakan modul L1D dan SAHEL bagi hasil di keadaan tadahan hujan.

Penilaian model dengan data-data yang diperolehi daripada Kubang Kranji di Kelantan menunjukkan hasil potensi dari simulasi ialah di antara 8,313 kg sehektar dan 9,685 kg sehektar berbanding dengan hasil sebenar, di antara 7,066 kg sehektar dan 8,833 kg sehektar. Tempoh tumbesaran tanaman yang disimulat pula berbeza di antara -2 hingga +3 hari dari tempoh sebenar. Penilaian ke atas SAHEL pula menggunakan data-data yang diperolehi daripada Serdang. Tiada perbezaan yang nyata pada hasil simulasi bila tanaman tidak menerima air selama 7 hingga 21 hari mulai dari 42 hari selepas disemai. Hasil di keadaan tadahan hujan, sebenar dan simulasi ialah masing-masing di antara 5,964 kg sehektar dan 6,636 kg sehektar. Manakala tempoh tumbesaran sebenar ialah di antara 98 dan 100 hari dan simulasi 101 hari. Pada amnya, model MACROS berupaya untuk mensimulat dengan tepat hasil dan tempoh tumbesaran tanaman untuk pengeluaran jagung berpotensi tetapi kurang berkesan di dalam keadaan tanpa pengairan.

MACROS sangat sesuai bagi mengkaji porla tindakbalas tumbesaran terhadap perubahan persekitaran dan manipulasi tanaman. Data-data yang lebih tepat seperti pertalian di antara kadar kehilangan luas permukaan daun serta data fisiologi seperti fotosintesis hendaklah ditentukan supaya penggunaan model dapat diperbaiki dan dapat pula mensimulat atau meramal hasil mutlak jagung dari jenis atau kaltivar yang khusus. Model ini juga berpotensi untuk meramal hasil jagung bagi mana-mana tarikh tanaman disepanjang setahun. Oleh itu model MACROS boleh dijadikan sebagai panduan untuk menjadual serta mengira hasil yang akan diperolehi oleh pengusaha tanaman jagung.

CHAPTER I

INTRODUCTION

Large scale corn production in Malaysia have to be expanded in order to meet the growing demand parallel to the expansion of the swine and poultry industry. The annual import of corn worth 400 million ringgit (Malaysia, 1988) is expected to increase to one billion ringgit by the year 2000 (MARDI,1990).

Before venturing into large scale production, the crop performance in different locations in relation to the interactive effects between the environment and the crop needs to be evaluated. The most important environmental factor for corn production in Malaysia is rainfall. Inspite of the high average annual rainfall (in excess of 2400 mm), rainfed production of annual crops have not been very successful because of the uneven and unpredictable rainfall distribution. The inconsistent weather conditions pose a great problem to the farmers in estimating the best time to plant their crop and the expected yield. To reduce their risk, farmers plant their crop immediately after the monsoon when moisture is considered to be adequate for seed germination and the subsequent crop growth. The low yield for commercial production of grain corn, reported to be within the range of 0.9 to 3.9 mt ha-1 (MARDI, 1986b), was mainly due to moisture deficits.

The complex interactive effect of the external factors on crop growth can be investigated and best be handled by a systems approach or crop growth simulation models. Crop growth models can be used for quantifying the environmental limits to crop production apart from a broad spectrum of other purposes including an understanding of the plant and its processes (Jones and Kiniry, 1986). Their application not only minimize the costly and lengthy experimentation but also results can be obtained within a short period through computer simulations.

Modelling and simulation studies require readily available weather records. Static models based on soil water budgets from rainfall and evaporation have been used by researchers as a first step in calculating the expected productivity of the agricultural systems under a wide range of climatic conditions. They have been used to develop alternative choices and decision strategies for use under limited available water. Amnuay (1980), Steward and Hash (1982) and Reddy (1983) studied corn yield prediction in rainfed conditions using rainfall and evaporative records for agricultural planning. Recently, dynamic physiologically based models such as MACROS (Penning de Vries *et al.*, 1989) developed after BACROS (Wit, 1978) and SUCROS (Kuelan *et al.*, 1982) have been shown to be effective as growth simulators. The model MACROS was developed for annual crops and is widely used in crop growth simulations for rice, soyabean and wheat.

Objectives of Study

The general objective of the study is to adapt and evaluate the model MACROS for potential and rainfed production of corn cultivar Suwan I. There is insufficient crop data to enable the modelling of the crop in Malaysia. The basic crop data can be grouped, firstly, into physiologically based crop data which are fairly universal and applicable to a wide range of environment. Most of these are available from the literature. The second group are cultivar specific and for Suwan I, are still lacking. Thus the specific objectives of the study are:

1. To establish crop data for cultivar Suwan I for use in the MACROS model (Penning de Vries *et al*., 1989), namely:

    i. Carbohydrate partitioning for growth of leaves (CALVT), stem (CASTT) and storage organs (CASST)

    ii. Crop development rates during vegetative (DRCV) and reproductive (DRCR) phases

    iii. Specific leaf weight constant (SLC)

2. To adapt and evaluate the MACROS model for potential and rainfed yield of corn cultivar Suwan I in Malaysia.

CHAPTER II

REVIEW OF LITERATURE

General

Corn or maize (*Zea mays* L.) has been cultivated for thousands of years. Corn parts first spotted in New Mexico were believed to be about 4500 years old (Berger, 1962). At the time of discovery of the New World, corn was already cultivated in many parts of the American continents, mainly in Mexico, Central America and parts of South America. During the voyages of Columbus, corn was brought to Spain and later spread to other parts of Europe and northern Africa. At the beginning of the sixteenth century corn was brought to India and China. Until today the most important cultivated areas are still in America, in the states of Ohio, Indiana, Illinois and Iowa. The production according to the major regions of the world is shown in Table 1.

The grain is heavily consumed in countries like Portugal, Republic of South Africa, Brazil, Guatamela, Venezuela, India and Mexico where it is served as a special food in the native diets. In the Philippines, corn is a substitute cereal crop for rice for 20 percent of its population.

Table 1

Corn Production in Major Producing Countries

Countries	Corn production (million metric ton)			
	1979-81	1987	1988	1989
U.S.A	192.1 (29.7)	181.2 (24.0)	125.2 (23.6)	191.2 (27.2)
China	60.7 (20.0)	79.5 (20.3)	77.7 (19.6)	75.8 (20.4)
Brazil	19.3 (11.4)	26.8 (13.5)	24.8 (13.2)	26.5 (12.9)
Mexico	11.9 (6.8)	11.6 (6.8)	10.6 (6.5)	9.9 (5.9)
S. Africa	11.2 (4.9)	7.3 (4.0)	7.1 (3.7)	11.7 (3.8)
India	6.5 (5.9)	5.7 (5.6)	8.3 (5.9)	7.8 (5.8)
Philippines	3.2 (3.3)	4.3 (3.7)	4.2 (3.7)	4.5 (3.5)

Figures in parentheses represent total cultivated area for the specified years, in million hectares (Source: FAO Production Year Book, 1989).

Corn is used as raw material for industrial products in dry milling, wet milling, mixed feed manufacturing and distillation and fermentation. Outlets for dry milling are corn meal, corn flour, grits and breakfast cereal. For wet milling, products are in the form of starch, feed, sugar, oil and dextrines. The distillation and fermentation industries manufacture alcohol, acids, glycerol and whisky.

Climatic and Soil Requirements

Corn is planted over a much wider range of climatic conditions than either wheat or rice due to its adaptability. It is an important crop in both the warm temperate and the humid sub-tropical regions of the world. The climatic and soil requirements for the crop are well described by Aldrich *et al.* (1976). It requires a growing season of 100 to 140 days depending on the climate. It is a neutral to short day length crop requiring an average temperature of 18°C to 30°C. The relative humidity during its growth stages should be 40 to 80 percent and at maturation stage, 30 to 40 percent. The crop requires between 500 mm and 800 mm rainfall during its entire growing season (MARDI, 1986a).

The soil requirements for corn in Malaysia are summarized by MARDI, (1986a). It can be grown on a wide variety of soils but performs best on well-drained, deep loam and silt loam containing abundant organic matter and nutrients such as the riverine and marine terraces and flood plains. Developed peat is also fairly suitable for corn cultivation. The crop performance is very poor on muck or peat soils. Corn may be grown on moderately acid soils, but the optimum pH range is from 5.3 to 6.0 with an exchange capacity of 18 to 30 cmol(+) kg^{-1} and 75 % base saturation. The Bray No.2 extractable P for maize should ideally range from 16.4 µg g^{-1} to 20.5 µg g^{-1}. Soil bulk density of 1.3 Mg m^{-3} or less is desirable for corn growth.

Corn Yield in Southeast Asia

Corn yield was reported to vary between locations due to climatic, soil and genetic factors (varieties and hybrids). However, their variations can be minimized by exerting maximum inputs and efficient management practices. In the Philippines, maximum yields of between 8 and 10 mt ha^{-1} have been achieved (Lantin. 1987). In Thailand, Pakistan and Indonesia yields were reported to be 5.8 - 9.0 mt ha^{-1} (Kunta, 1987), 7.1 - 10 mt ha^{-1} (Bahadur, 1987) and 5.4 - 6.2 mt ha^{-1} (Subandi, 1987) respectively. In Malaysia, the reported maximum yield so far was only between 6.0 and 7.1 mt ha^{-1} (Leong ,1988). The low yield recorded in Malaysia could partly be due to the composite cultivar used (Suwan I). The reported yields in other countries were from hybrid cultivars.

The major factors that limit corn yield in the tropics are drought and water logging (Mercado, 1987). Rainfed yields are expected to vary in time and place depending on the amount and distribution of rainfall. Zakaria and Razak (1990) reported that the drought affected yield was between 2.5 and 3.0 mt ha^{-1} whilst for crops affected by both drought and waterlogging the yield was between 0.6 and 1.4 mt ha^{-1}. Drought and waterlogging can cause poor crop establishment and thus reduce the crop population. In Indonesia, farmers make use of early maturing cultivars of 75 to 80 days (Subandi, 1987) to minimize the risk of drought and waterlogging. The yield obtained in this case was less than 3 mt ha^{-1}. In the Philippines, Serranno and Aller (1987) reported yields of 3.5 to 5.7 mt ha^{-1} for partially stressed crop (irrigation witheld for 35 days after planting) and 2.3 - 2.6 mt ha^{-1} for the rainfed crop.

Besides exerting maximum inputs and efficient management practices corn yield in Southeast Asia could also be improved by using high yielding cultivars.

Corn Production in Malaysia

The potential areas for corn cultivation in Peninsular Malaysia can be divided into two categories. The fist category includes all areas under perennial crops and double-cropped rice areas. Cultivation on such land is limited due to the existing crops. The second category is the rainfed rice areas, forest areas, peat swamp forest and idle farm land. The areas are fairly small individually and scattered while planting during the drier periods normally requires irrigation, especially in Perlis, Kedah, Kelantan and Terengganu. Past records and experiences have indicated that drought is a major problem in corn cultivation and plays a major role in grain yield reduction in Malaysia (Lee, 1986).

Although production areas of corn increased annually (Table 2), the supply of grain corn for animal feed is far from sufficient. Imports amount to thousands of tonnes per year worth more than 200 million ringgit (Table 3), mainly from China, Australia, Burma, Thailand and Argentina (Malaysia, 1988). By the year 2000 import is expected to increase to almost a billion ringgit (MARDI, 1990). Local grain production has to be expanded in order to reduce imports and to save foreign exchange.

Table 2

Total Area Grown to Corn in Malaysia

Year	Hectare
1980	5118
1984	4744
1985	4750
1986	4591
1987	5904
1988	6063

(Source: Agriculture, Livestock and Fisheries Statistics for Management. Ministry of Agriculture, Malaysia, 1988).

Table 3

Import of Corn (unmilled) into
Peninsular Malaysia

Year	Quantity ('000 metric ton)	Value (M$ CIF)
1980	418.7	160.4
1981	459.6	181.0
1982	672.9	226.5
1983	742.2	256.6
1984	834.4	293.5
1985	916.3	273.5
1986	944.6	244.7
1987	1,030.9	271.5

(Source: Agriculture, Livestock and Fisheries Statistics for Management. Ministry of Agriculture, Malaysia, 1987).

Water Stress and Corn Growth

Plants require water for the manufacture of carbohydrate, maintain hydration of protoplasm and for translocation of food and mineral nutrients. Internal moisture stress causes reduction both in cell division and elongation, hence growth and final yield.

The combination of high incidence of solar radiation, moderate wind speed and low relative humidities plus the loss of water through the soil-plant system (evapo-transpiration), speeds up moisture stress. At