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EFFECT OF PERCOLATION ON THE WATER USE EFFICIENCY OF PADDY CROP

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LIST OF SYMBOLS

Symbol	
A	The Effective Surface Area
a	Bore area
D	Storage water depth
Dsp	The Spillway height
DR	Drainage
d	Water column height
ET	Evapotranspiration
E	Evaporation
EFR	Effective Rainfall
FB	Freeboard
H	Hydraulic head
Hi	Head of water
h	Pressure head
IR	Irrigation
IE	Irrigation Efficiency
K	Hydraulic Conductivity
l	Length of sample
P	Deep Percolation
PET	Potential Evapotranspiration
Q	Discharge
r_o	The outer radius of bubble tube
r_i	The inner radius of manometer
RF	Rainfall

S	Lateral Seepage
SD	Surface drainage
SW	Standing water
S&P	Seepage and Percolation
S&Pp	Potential Seepage and Percolation
t	Time
WC	Water content
WUE	Water Use Efficiency
z	Gravitational head
ΔS	Changes of Storage Water

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

STUDY ON THE EFFECT OF PERCOLATION ON THE WATER USE EFFICIENCY ON PADDY PLOT

By

RAMLEE BIN JANTAN

SEPTEMBER 1992

Chairman : Professor Madya Kwok Chee Yan

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Attention in this study is focussed on the evaluation of the effect of percolation on Water Use Efficiency computation. In addition, total water use, amount of water supplied, total water requirement at various stages of crop growth and Water Use Efficiency were also determined. Some findings on the factors affecting percolation were also done. Field and Laboratory experiments were conducted through two consecutive seasons. The results obtained in the wet season were 742 mm of water was needed for ET, while water needed for S&P was different between the plots. In the upstream plot S&P was 267.31 mm, in the intermediate plot it was -105.36 mm, and in the downstream plot it was -328.73 mm. The irrigation water supplied was 576.51 mm to the upstream plot, the intermediate plot recorded was 602.01 mm and the downstream plot was 487.58 mm. The precipitation was 515 mm. During the dry season, Evapotranspiration was 670 mm, while S&P was higher than in the wet season. The upstream plot recorded 306.81 mm, the intermediate plot was 108.6 mm and the dowstream plot was -104.53 mm. Irrigation water required during this season was higher. It was 987.81 mm, 864.27 mm and 735.95 mm, respectively for the upstream, intermediate and downstream plots, while precipitation was 151 mm. Water use Efficiency was calculated by a modified equation which is (ET + SW + WC) / (IR + RF). The WUE in dry season ranged from 70% to 90% and in the wet season was 70% to 95%. These results are high when a comparison is made with values of WUE using Wickham's formula.

Abstrak bagi thesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi sebahagian keperluan untuk mendapatkan Ijazah Master Sains.

KAJIAN TERHADAP KESAN PENYUSUPAN KE ATAS KECEKAPAN PENGGUNAAN AIR DI PETAK SAWAH PADI

Oleh

RAMLEE BIN JANTAN

SEPTEMBER 1992

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Fakulti : Fakulti Kejuruteraan

Kajian ini menumpukan penilaian kesan penyusupan ke atas kecekapan penggunaan air di petak sawah padi. Di samping itu juga penentuan jumlah penggunaan air, jumlah air yang dibekalkan, jumlah keperluan air mengikut tumbesaran pokok dan kecekapan penggunaan air dilakukan. Beberapa faktor yang bertanggungjawap ke atas kadar penyusupan juga ditentukan. Kajian yang melibatkan eksperimen di ladang dan di makmal ini dijalankan dalam dua musim penanaman padi secara berturutan. Melalui keputusan yang diperolehi dari kajian ini, pada musim basah (wet season), didapati sejumlah 742 mm air diperlukan bagi Sejatpeluhan (ET) pada setiap petak. Didapati juga jumlah Resipan dan Penyusupan (S&P) berbeza antara petak-petak sawah

dan telah direkodkan sebanyak 267.31 mm air berlaku pada petak di bahagian hulu (upstream), -105.36 mm direkodkan di bahagian pertengahan (intermediate) dan -328.73 mm air di bahagian hilir (dowstream). Pada musim ini juga, jumlah air terbekal adalah 576.51 mm air di petak hulu, 602.01 mm di petak pertengahan dan 487.58 mm di petak hilir. Jumlah hujan yang tercatit adalah 515 mm air. Pada musim kering (dry season) pula, jumlah ET adalah 670 mm air. Jumlah S&P sebanyak 306.81 mm air tercatit di petak hulu, di petak pertengahan adalah 108.27 mm air dan di petak hilir adalah -104.53 mm air dan jumlah ini didapati lebih tinggi dari musim basah. Air pengairan yang diperlukan juga tinggi pada musim ini dan telah direkodkan sebanyak 987.81 mm air, 864.27 mm air dan 735.95 mm air bagi petak masing-masing dan jumlah hujan yang tercatit adalah 151 mm air. Bagi kajian ini, kecekapan penggunaan air telah dikira melalui persamaan berikut: WUE = (ET + SW + WC)) / (IR + RF) dan nilainya didapati pada musim kering iaitu dalam julat 70% ke 90%. Pada musim basah nilainya didapati dalam julat 70% ke 95%. Nilai-nilai ini juga adalah tinggi jika dibandingkan dengan nilai yang diperolehi dari persamaan Wickham.

CHAPTER I

INTRODUCTION

Water is an important input for agriculture production. Plants need water for transpiration and to absorb minerals through the roots into other parts of the plant. The transpiration caused by the vapor pressure gradient between the leaves and atmosphere is loss of water by the plant in the form of vapor into the atmosphere.

Crop water requirements vary with different crops. Paddy being a semiaquatic plant requires more water than most other crops. In order to produce an optimum yield of rice, the water available / supplied must satisfy the Evapotranspiration (ET) needs as well as losses in the paddy field through Seepage and Percolation (S&P) and the standing water requirement. The amount of water required also depends on growth duration, type of soil, topography of land and the stage of the growing crop (De Datta 1981).

In rice irrigation systems, Water Use Efficiency has been used as an index of water utilization in the field. The index shows how efficiently the available water supply is being used. However, most researchers have found that Water Use Efficiency was higher in the dry season but lower in the wet season. An investigation done in Nueva Ecija, Philippines (1975-1980) showed that Water Use Efficiency was nearly 70% in the dry season and 50-70% in the wet season (IRRI annual report 1980). Farmers usually try to save water during the dry season. They ensured an adequate supply of water by improving maintenance of the delivery systems.

Water Use Efficiency is defined as the ratio of the total water requirement to the amount of supplied water. In equation form (IRRI annual report 1978), it is

$$WUE = \frac{ET + (S\&P)}{IR + RF} \qquad [1]$$

where WUE is the Water Use Efficiency, ET is Evapotranspiration, S&P is Seepage and Percolation, IR is Irrigation and RF is Rainfall. All parameters are expressed as depth of water. The efficiency is lower when the summation of Irrigation Water and Rainfall is high compared with total water use. This usually happens in the wet season where rainfall is heavier.

Seepage and Percolation losses are an important component of water crop requirement in paddy. It usually occurs in the submerged condition. Water percolated supplies oxygen as well as fertilizer for the plant. When Equation [1] is used, S&P is responsible for large variation of Water Use Efficiency. When S&P is high, WUE will be high.

In most parts of the tropics, 4 to 5mm/day of ET occurs during the wet season and 6 to 7mm/day during the dry season(De Datta 1981). Like the value of rainfall, both of them cannot be controlled. Only one factor, Irrigation can be controlled.

Statement of Problem.

Many researchers concluded that the Water Use Efficiency could be used as a measure of the economic water utilization. Kampen (1970) in, " Water Losses and Water Balance Studies in Lowland Rice", had published an equation for irrigation efficiency which only considered ET as the total water used. Seepage and Percolation was not taken into consideration.

Wickham (1971) in, "Water Management in the Humid Tropics" stated that the amount of water used was the sum of ET and S&P. He took the reducing depth of standing water as the water used.

Not all the S&P as considered by Wickham is absorbed into the saturated soil or the root zone area but there is also part of the water which is lost as deep percolation. This is especially true for light soils.

Wickham considered all S&P to be water which is effectively used. This is not true as there is always lateral seepage, as well as deep percolation. This results in very high WUE values especially for light soils. This study attempts to evaluate the effect of deep percolation in computing Water Use Efficiency.

Objective

The broad objective of this study is to determine the importance of Percolation losses on the Water Use Efficiency computation on the paddy plots.

Specifically, the objectives are:

i. To determine components of the Water Use including ET and S&P, and amount of water supplied to the plots, namely Irrigation and Rainfall.

ii. To determine the Total Water Requirement and its utilization during the growth stages of the crop.

iii. To determine Water Use Efficiency (WUE) on the paddy plots.

iv. To determine some factors affecting the Percolation of the paddy soil.

v. To determine the extent of the influence of Percolation on Water Use Efficiency.

CHAPTER II

LITERATURE REVIEW

Water Balance

The Water Balance Method, essentially a method of accounting for the volume of water held within a system is often used in upland as well as in lowland irrigation studies. There are three components in the Water Balance Equation such as Inflow, Outflow and Changes of Storage Water.

In lowland rice system, the amounts of Rainfall(RF) and Irrigation(IR), also called the Total Water Supplied are the inflow components (see Equation 2). The field losses by Evapotranspiration(ET), Seepage(S), Percolation(P) and Surface Drainage(DR) are the Outflow components. For an irrigation project, water delivered to the project area, main and secondary canal losses are also considered. A simplified water balance in Equation 2 is used for single plot or field.

$$IR + RF = ET + S + P + DR + \Delta S \qquad [2]$$

Irrigation Water Requirement.

Irrigation is the artificial application of water to soil for the purpose of crop production. It is supplied to supplement the water available from rainfall and the contribution to soil moisture from ground water.

In lowland rice field, large quantities of water are needed for Saturation, Land Preparation, Allowable Standing Water and the ET and S&P losses. An observation of water required in Philippines showed that more than 40% of the total supply was required for land preparation (Kampen 1970). Thavaraj (1975) estimated that water required for saturation varies from 406mm to 508mm in Malaysia. Further analysis showed that if irrigation water was supplied throughout land preparation at the maximum design rate of 22 mm/day, instead of the actual mean discharge of 9 mm/day, the total supply requirement for land soaking could have been achieved in 28 days, 12 days earlier than recorded (IRRI annual report 1977).

Evapotranspiration.

Evapotranspiration (ET) is the combination of two physical processes that cause water loss from field crops. The processes are called Transpiration and Evaporation. Transpiration is a process where the liquid will pass through the roots to the stem of the plant and then it would be transferred into the atmosphere through the leafy part of the plant. Evaporation is the loss of water in vapor form from a soil and Free Water Surface. It is affected by the Meteorological factors such as Solar Radiation, Wind, Relative Humidity and Temperature. These factors also strongly influence the Evapotranspiration rate. The rate will increase with higher solar energy incident on water and plant surfaces (IRRI annual report 1963). In high temperatures, the amount of water evaporated will increase and wind continously sweep away the moisture vapor produced from the wet surface. Its value is higher during lower relative humidity. Plant characteristics including leaf morphology, depth of rooting and growth duration, and soil water regime also affect the ET rate (De Datta 1981). Potential Evapotranspiration (PET) is defined as the rate of ET from a well-watered, close-growing grass crop that completely covers the soil surface and without significant amounts of advective energy from adjacent areas (Penman 1948). One might expect that potential and actual ET under the submerged soil condition of lowland rice would be similar; However, several researchers have reported appreciable difference between the two (Palaysoot 1965).

Actual ET range from 4.8 to 10.6 mm/day, on average 6.2 mm/day, during the dry season. In the wet season, its rate ranges from 1.9 to 7.8 mm/day, about 5.02 mm/day on average (IRRI 1963). The maximum rate normally occurred at heading time and the maximum solar radiation condition. In Malaysia, a first peak of transpiration rate was 3.5 mm/day at the maximum tillering number, increasing to 5.5 mm/day at the heading stage (Sugitomo 1969). After that, it began to decline. This was also recorded at many locations in Thailand, India and Japan (Kung 1965).

Doorenboos and Pruit (1977) recommended four methods of estimating ETo:

i. Penman Method

ii. Evaporation Pan Method

iii. Radiation Method

iv. Blaney-Criddle Method.

The Penman method used data on Temperature, Humidity, Wind and Solar Radiation. The Evaporation Pan method is a direct estimation of the aggregated effects of radiation, wind, temperature and humidity on evaporation from a described open water surface. Two types of pan commonly used in determining the evaporation data are the U.S. Class A pan and the Colorado Sunken pan. The Potential Evapotranspiration is determined by multiplying the Pan Coefficient with the recorded Pan evaporation. Hargreaves (1974) concluded that the Pan Coefficient for grass ranges from 0.65 to 0.80. The Radiation Method requires data of temperature, sunshine, cloudiness and general knowledge of levels of humidity and wind. The Blaney-Criddle method requires only air temperature data and its use is generally not recommended under following conditions: (1) in regions where temperatures remain fairly constant but other weather parameters change; (2) for small islands and coastal areas where air temperature is affected by the sea temperature, which displays little response to seasonal change in radiation; (3) at high altitudes where mean temperatures are low even though radiation is high; (4) in climates with wide variability insunshine hours transition months (example., monsoon or typhoon climates or mid-latitude climates during spring and autumn).

Johnson [1965] concluded that the relationship between ET and Evaporation (E) following the growth stage of paddy crop as;

Vegetative Stage : ET = 1.104(E) + 0.35
Reproductive Stage : ET = 1.145(E) + 0.67
Ripening Stage : ET = 0.88(E) + 0.807 [3]

Kampen [1970] derived the relationship for Wet Season and Dry Season as;

Wet Season : Vegetative Stage : ET = 0.8(E) + 0.3
Reproductive Stage : ET = 0.9(E) + 0.2

Dry Season : Vegetative Stage : ET = 0.8(E) + 0.5
Reproductive Stage : ET =0.9(E) + 0.5 [4]

Water Balance Methods include Catchment Hydrology, Soil Sampling or Lysimetry, as a direct measurement to measure actual Evapotranspiration. The most accurate is by using lysimetry, but it is expensive. It is also called an Evapotranspirimeter which is a tank filled with soil and crops are planted. Its purpose is to measure the amount of water lost by Evaporation and Transpiration. For upland crops, a Weighing Lysimeter is necessary for daily or short time interval measurements. In flooded conditions, particularly in Lowland Rice, the change in water level in the square or circular tank lysimeter is measured to reflect as water losses by ET. A