UNIVERSITI PUTRA MALAYSIA

EFFECT OF IRRIGATION INTERVALS ON EVAPOTRANSPIRATION AND GROWTH OF PAPAYA

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By

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LAG	Months before harvest
ET	Evapotranspiration
RH	Relative humidity

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

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July 1994

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Faculty: Engineering

Papaya a crop with potential for expansion is sensitive to drought and waterlogging. Although in Malaysia irrigation is provided to supplement the uneven rainfall distribution, reliable data on crop evapotranspiration are required to design a proper irrigation system so as to apply the correct amount of water at the right time.

An experiment was conducted to determine the actual evapotranspiration (ET) of papaya plant and the effect of irrigation intervals on crop growth. Papaya seedlings were transplanted into containers and observed for about 38 weeks under glass. They were irrigated through emitters at irrigation intervals of 1, 2, 4 and 8 days.

ET varied between the four treatments. The daily-irrigated plants gave the highest ET, an average of 5.9 mm/day, and those with an 8-day interval, the lowest, an average of 3.1 mm/day. The plant height, number of leaves and girth measurements did not show a marked difference. However, flowering occurred only in plants subjected to daily and 2-day irrigation intervals and not in the other treatments.

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

KESAN JARAK PENGAIRAN KE ATAS PENYEJATPELUHAN DAN PERTUMBUHAN POKOK BETIK

Oleh

AESHAH ISMAIL

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Betik ialah satu tanaman yang berpotensi untuk dikembangkan di mana pertumbuhannya akan terganggu di dalam keadaan kemarau atau air bertakung. Di Malaysia pengairan adalah untuk menampung taburan hujan yang tidak serata. Untuk merekabentuk satu sistem pengairan, maklumat asas seperti penyejatpeluhan pokok diperlukan agar pokok-pokok yang disiram menerima air secukupnya pada masa yang diperlukan.

Satu ujikaji telah dijalankan untuk menentukan penyejatpeluhan sebenar pokok betik dan kesan jarak pengairan terhadap pertumbuhan pokok. Anak benih ditanam di dalam tangki yang terlindung dari hujan dan diperhatikan selama 38 minggu. Pokok-pokok menerima air melalui penitis pada jarak pengairan 1, 2, 4 dan 8 hari.

Nilai penyejatpeluhan didapati berbeza di antara keempat-empat rawatan. Pokok yang disiram setiap hari memberi nilai yang paling tinggi, purata 5.9 mm/hari,dan yang disiram setiap 8 hari yang terendah, purata 3.1 mm/hari. Didapati tiada perbezaan ketara di dalam ketinggian pokok, bilangan daun dan ukurlilit batang pokok bagi keempat-empat rawatan. Walau bagaimanapun, hanya pokok-pokok yang disiram setiap hari dan setiap 2 hari berbunga manakala yang lainnya tidak berbunga.

CHAPTER I

INTRODUCTION

The fruit industry in Malaysia has great potential for expansion particularly to meet the demand for domestic fresh fruit, export and processing. Demand for Malaysian fruits has increased both locally and overseas; overseas demand for fruits such as pineapple, guava, papaya, banana, mango and mangosteen is increasing annually. Export of fresh fruits is increasing by an average of 28% per annum (Abu Bakar, 1988). The fruits that are exported are mainly durian, star fruit, papaya, watermelon and banana.

The area under fruit cultivation has increased but mostly at smallholder level. Of late the private sector, through diversification programmes, has ventured into large-scale fruit cultivation. However, the growth of the industry is hampered by an inconsistent and inadequate supply of high quality fruits.

Malaysia is situated between latitudes 1 to 7 degrees North. There is only a small seasonal variation of solar radiation, thus the temperature and length of day are quite uniform throughout the year. The most variable element of the climate of Peninsula Malaysia is rainfall; its seasonal and regional differences are large enough to affect agricultural production (Nieuwolt, 1984).

Malaysia receives more than 2500 mm of rain annually with some regions receiving up to 4000 mm rain. Overall, water resources appear to be abundant but they are unevenly distributed chronologically and geographically; there is surplus and also shortage of water. The average annual rainfall that Malaysia receives on the land mass amounts to 990 billion cubic metres, of which 35% returns to the atmosphere as evaporation and transpiration, 57% goes as surface runoff and 7% goes to recharge groundwater (Keat, 1986). On a global average, loss by evapotranspiration (ET) is about 57% of the annual precipitation (Budyko et al., 1962).

Most differences in agroclimatic conditions in the country are related to rainfall. In agricultural production, it is important to know when dry periods occur. There are two main dry periods: around January to March and June to July. Agricultural droughts - defined as periods when rainfall supplies less than half of the water requirements (Nieuwolt, 1982) - may last as long as 4 months in the northwest and northeast of the country; they decrease in duration away from the coast and towards the south.

Water is a fundamental requirement in crop productivity. A limited water supply and inefficient water management may limit optimum yield production even in the humid tropics. Plants require great amounts of water to replace that lost by transpiration as the plant size increases.

The response of fruit crops to water regimes is different from field crops; hence irrigation management differs. The main factors are the importance of the reproductive stage in growth and fruit production, and the cumulative response of fruit trees to moisture regimes on a long-term basis.

The total amount of water required by fruit trees varies with the climatic conditions under which they are grown, with their age and size (growth stage) and with the depth and type of the soil and rooting habits of the trees. The growth stage of crops influences the aerodynamic roughness and the proportion of the ground covered.

The length of the irrigation season and the timing of irrigation depend on the rate of water use by the tree, its growth stage, bloom and fruit-setting, fruit development and time of harvesting (Bielorai et al., 1973). Underestimation of crop water use will lead to an under-designed irrigation system resulting in lower yield while over-irrigation (due to overestimation) could also lead to yield deficits because of the effect of poor aeration in the root zone.

Papaya growth and productivity are greatly affected by climatic conditions. It performs well in regions of even rainfall distribution without dry spells. It is sensitive to standing water; 48 hours immersion is fatal to the tree (Purohit, 1981). Crops like cassava, pineapple, banana and papaya are most affected by excess rainfall while other perennials are not easily damaged.

Water deficit in the plants develops when water absorbed by the roots cannot compensate for the transpiration loss. During moisture stress growth is suspended, resuming when it is over. As water stress is imposed on the plant, respiration rate first increases then decreases as the plant adapts to stress. The rate of photosynthesis declines noticeably after a reduction of about 30% in the water content of the leaves and ceases when 60% of leaf moisture is lost (Chang, 1968).

The effect of drought on perennials can be immediate or long term (irreversible). Although it can be immediate in terms of vegetative growth, it may be 3 years or more before this effect is visible in the fruit crop yields (Jackson, 1977). Some fruits require a certain amount of stress at the end of the growing season to help them to mature, but severe stress may cause the fruits to shrivel or become smaller.

A serious yield reduction can occur if water shortage occurs at certain critical growth periods. The most critical period is during flower formation and fertilisation for pollen production. At a critical period, the effect is greater on growth or yield than on transpiration. However, at a non-critical time, water shortage reduces total transpiration but the effect on yield is small.

Objectives

One of the basic factors in the determination of crop water requirements is crop evapotranspiration (ET). Accurate and reliable ET data are needed to predict crop water requirements, distribution and peak demand of an irrigated area especially if water is scarce. Timing (when and where) and quantity of water are important to allow for water depletion because root growth is confined to the frequently wetted soil volume. During dry periods, supplemental irrigation is necessary to alleviate water stress as it affects crop growth, yield and quality, either in the short or long term (irreversible).

This study aims to

- determine the actual ET for papaya and
- observe the effect of irrigation intervals on papaya plant growth, namely height, number of leaves and girth.

CHAPTER II

LITERATURE REVIEW

Agronomy of Papaya Plant

Papaya (*Carica papaya* L.) is a tropical fruit. It is a diecous and is either a male, female or hermaphrodite plant. It is a fast-growing, non seasonal tree, with the potential to produce fruits throughout most months of the year under good management practices. Ripe papaya fruit is very refreshing, high in vitamins A, B_1, B_2, and C, minerals and papain (a proteolytic enzyme which helps in digestion).

Papaya plants can grow on any soil provided it is well drained and does not dry out quickly, but grow best on light pervious soils rich in humus. A sandy soil needs to be conditioned with organic manure, well fertilised and adequately irrigated. Most Malaysian soils have an optimum soil pH of 6.0 to 6.5; to obtain this, 3-4 tons/ha of lime is required (Raveendranathan, 1986).

Seeds are best sown in polybags at the rate of 3 to 4 seeds per bag in the nursery, although seeds can also be sown directly in the field or in the nursery then transplanted from ridges. Culling is done at the 4-leaf stage so that only one healthy plant is left per bag. After 6 weeks in the nursery, the plants are transplanted in the field at a planting distance of 1.8 m x 2.7 m. Flowering starts about 22 weeks from seed sowing and the first harvest, 21 weeks from flowering. The yield per tree is 25 to 40 fruits depending on soils, climate and cultivation practices (Purohit, 1981). The plants are considered uneconomic after about 2 1/2 to 3 years. Although papaya is non-seasonal, it does show distinct production peaks in its cropping cycle. The peaks normally occur at every 3- monthly intervals.

First peak	10 - 11th month period
Second peak (highest yield)	13 - 14th month period
Third peak (less distinct)	18 - 20th month period

Plant Water Relationship

Water is a major constituent of plant protoplasm, comprising as much as 95% of the total weight of the plant. It takes part in a number of chemical reactions as in photosynthesis and is a product of respiration. It acts as a solvent for many substances. It is also responsible for maintaining turgidity of cells and plants as a whole and serves as a medium for dissolved substances to move between cells and in the xylem and phloem.

Perennial lowland crops have similar water requirement, between 80% and 100% of potential evapotranspiration throughout the year. They differ in tolerance to dry periods. Crops like cassava and pineapple are relatively insensitive to droughts while oil palm, banana and pepper cannot bear dry periods until they have developed a deep root system. Some crops like sugarcane and cashew nut need a dry season for good production. Coffee, cocoa, durian, mango and citrus need a short dry period of 1-2 months to initiate flowering. Mild stress can enhance flower bud initiation (Kriedmann, 1986). In the highlands, climatic conditions are slightly different; rainfall is higher, less variable and of lower intensity, temperatures are lower and relative humidity is higher. Potential ET and water requirements of crops decrease rapidly with elevation.

In perennials, the response to water conditions at any stage of development depends on conditions in previous stages and years. If poor conditions prevail in one stage, subsequent good periods will not overcome the problem (Jackson, 1977). During the fruiting stage, water requirements are usually reduced, but this is more pronounced during the dry fruiting stage than the wet fruiting stage (Chang, 1968). Mature trees are generally less sensitive to moist conditions than young trees.

Most of the water taken in through the roots is transpired. Maize plants transpire over 98% of all the water absorbed; only 0.2% is used in photosynthesis, the rest is retained in the plant (Miller, 1938). The rate at which roots can take up water from the soil depends on the length of absorbing roots in the soil, the volume of the soil they can permeate and the rate that water moves from the body of the soil to the roots. The rooting depth of a crop in a given soil depends on the water regime; frequent irrigation encourages shallow rooting.

The extent to which damage to plants occurs is influenced by their physiological age, the degree of water stress and the species concerned. Various parts of plants and different physiological processes react differently to moisture stress, and any single factor cannot be used in isolation as a plant indicator. The ability to recover when water shortage ceases also differs. Since for different crops different parts are marketed (leaf, fruit, stem, tuber or roots), there is a need to distinguish between vegetative growth, total yield and marketable yield. Generally the growth rate of vegetative organs is more sensitive to water shortage than that of reproductive organs. Similarly, fresh weight is more affected by water shortage than dry weight (Salter and Goode, 1967). Cereals are very sensitive to moisture shortage during the formation of reproductive organ and flowering.

The plant reproductive cycle consists of three stages namely flowering, fruit enlargement and ripening. The flowering phase largely determines the number of ripe fruits but not size. The second phase determines the fruit size and involves large amounts of carbohydrates and water being transported into the fruit. The third phase is the ripening stage.

During reproductive growth, carbohydrate is essential. Growth of flowers and fruits involves a rapid accumulation of dry matter and water. The vascular system of large fleshy fruits must be well developed to fascilitate the carbohydrate distribution to the growing tissues. Fruit contains about 50% to more than 90% water depending upon the fruit type and stage of development. Reproductive growth generally causes reduced vegetative growth. The root system is affected and indirectly the plant becomes sensitive to drought. It can result in a pronounced plant water stress when only moderate stress occurs in the soil. Root growth of a pea variety decreases sharply after flower initiation and some older roots die (Salter and Drew, 1965). Any specific effects like water deficit during the early stages of the reproductive cycle will probably affect the final yield. For example, when water deficit has reduced the number of fruits, it is probably due to water stress during flowering, and a decrease in fruit size is caused by water deficit after flowering when the fruit is enlarging.

It is water deficit in the plant, not soil moisture, which influences photosynthesis, absorption rates (from the soil) and transpiration. A moist soil with a high transpiration rate (due to evaporative demand) can cause plant-water deficit. Insufficient water to replace that lost by transpiration commonly causes plant death. The magnitude of water stress measured in the soil is different from that in the tissues of the tree. Plant-water deficit causes stomata to close, hence reducing both transpiration and carbon dioxide intake, the latter in turn limits photosynthesis. The dry matter composition can result in leaves becoming more xerophytic, cell walls more thickened and an increase of cutin deposits outside their epidermal cells.

Papaya requires water during the early stages of growth and prolonged drought. Lack of moisture generally retards plant growth and causes flower abortion or fruitlets leading to sterile phases or fruiting skips along the trunk. Flower abortion may also be due to high temperatures during drought. Flower production of papaya is most active during the rainy period.

Ong and Kwok (1983) found that climatic factors (rainfall, sunshine, temperature and dry spells) which commonly affect papaya yield are maximum temperature at LAG 4-4 1/2 (4-4 1/2 months before harvest) and dry spells at LAG 0-1 1/2 (0-1 1/2 months before harvest) which are adverse to fruit yields. On the other hand, with cool temperatures and wet conditions, hermaphrodite flowers may revert to femaleness (carpellody of stamens). This leads to formation of misshapen fruits which are not marketable (Chan, 1984).

A very moist or poorly drained soil causes collar rot or root rot. The life of papaya plants is shortened, growth is retarded or flowers do not develop into fruits. The effect of insufficient water is similar but slower and causes less death. Fertilisation rate is low and fruits may easily abort. Poor crop management will result in non-uniform growth of stem diameter, smaller shoots, fewer and smaller leaves, short petiole and root rot. Flowers do not develop into fruitlets. Fruits abort or are smaller than normal, with less flesh.

The number of flowers in apricots subject to water stress decreases as a result of fewer nodes bearing flowers (Jackson, 1969). The number of flower buds is also reduced and the time of differentiation is delayed. Fruits from late-developing flowers have longer stems and smaller stones than normal; the fruits are smaller and mature several weeks later (Brown, 1953). Valencia and Washington navel oranges experience the highest rate of flower bud and leaf abscisson 3 days after a hot dry spring day (Erickson and Brannaman, 1960).

Water stress most adversely affects yield of cereals during the periods of internode elongation just before flowering, ear emergence from the leaf sheath, and flower opening (Salter and Goode, 1967). In some plants like pepper (Kaufmann, 1968) water stress increases fruit set number during the first week of flowering; durian and mango need a period of water stress to induce flowering. Regularly irrigated coffee plants and bamboos growing in moist soil do not flower, but irrigation or precipitation after a drought results in flowering (Alvim, 1960, 1964). Fibre content of bush bean pods is increased by about 20% if water stress occurs after flowering; percentage of dry matter also increases. A greater decrease in fresh