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Water Deficit and Irrigation in Oil Palm: A Review of Recent Studies and Findings

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ABSTRACT

The role of water deficit in oil palm is discussed in this paper. Factors such as evapotranspiration, relative humidity and vapour pressure deficit affect the carbon assimilation process and oil palm growth in general. Various irrigation techniques have been tried to overcome this water deficit and some of the results are discussed.

ABSTRAK

Peranan defisit air dalam pertumbuhan sawit dibincangkan dalam artikel ini. Faktor-faktor seperti sejat-transpirasi, kelembapan banding-an dan tekanan wap defisit mempengaruhi proses asimilasi karbon dan pertumbuhan sawit amnya. Pelbagai kaedah pengairan telah dicuba untuk mengatasi defisit air dan beberapa keputusan yang diperoleh turut dibincangkan.

Keywords: water deficit, evapotranspiration, drip irrigation.

INTRODUCTION

Malaysia, though having a high average rainfall of over 2000 mm per annum, still has in certain regions, an uneven distribution. In the northern states of the Malaysian Peninsula, particularly in Kedah, water deficit occurs for three months or so each year. This condition may cause adverse effects on the yield of oil palm, which originated from the damp and wetter regions in West Africa. Oil palm requires a *relative humidity* (RH) of more than 45% for optimal transpiration. In fact, there have been instances where the presence of a high water table would mean that the crop is never short of water even during dry periods. The water supply for palms comes from rain or underground sources. In an oil palm plantation, Squire (1984) found a spatial distribution of throughfall of rain due to the influence of the trunk. Mean throughfall was 78% with 22% of the rain intercepted. Studies by Chang and Rao (1983) showed that the oil palm intercepts about 20% of rainfall by its apex, bunches and frond bases. The remaining rain reaches the soil and is taken up by the roots into the palms through the transpiration process.

WATER DEFICIT

Evapotranspiration is the sum total of evaporation and plant transpiration. Transpiration is a continuous process caused by the evaporation of water from the leaves of palms on one hand and its corresponding uptake by roots in the soil, on the other (Kramer, 1983). When evapotranspiration exceeds the precipitation (rainfall or irrigation) rate, a water deficit occurs. The soil water deficit is the amount of available water removed from the soil within the crop's active rooting zone. It is the actual amount of water required to refill the root zone to bring the soil moisture levels back to field capacity, which is the percentage of water remaining in the soil two or three days after the soil has been saturated and free drainage practically ceased. This percentage may be expressed in terms of weight or volume. When a water deficit occurs, the plants may suffer stress. The potential evapotranspiration is the amount of water that could be evaporated or transpired at a given temperature and humidity when water is not limiting. Water is a major constituent of plant tissue and is a mode of translocation for metabolites and minerals within the plants and it is essential for cell enlargement through increasing its turgor pressure. With a water deficit, many of the physiological processes associated with growth are affected and a severe deficit may cause plant death. The effect of water deficit varies with the degree and duration of water stress and the growth stage of the oil

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palm. The leaf area may decrease and this will eventually reduce the amount of light intercepted. A reduced leaf water potential will close the stomata and the plants will lower their transpiration which is caused by a rise in leaf temperature and thereby reduce the biochemical processes. This will lead to disturbance in the source and sink partitioning.

A study by Ling (1979) in central Peninsula Malaysia found that evapo-transpiration in oil palm may reach up to 160 mm mth^{-1}. Dufrene (1989) found that the maximum evapotranspiration rates were 4-5 mm day^{-1} or 120-150 mm mth^{-1}. Thus, to replace this deficit, irrigation should be applied at about 5 mm day^{-1}, or equivalent to 350 litres $palm^{-1}$ for a planting density of 143 palms ha^{-1}.

Severe limitations to oil palm growth occur when the RH is 30%-34%, while below 30% may cause very severe limitation to growth (Kumar, 1997). Even well watered palms as described by Corley (1973) have been found to close their stomata during midday when the sun is brightest and this may cause a loss of 10% in the potential yield. Even with ample irrigation, the atmospheric stress from low RH and high temperatures that give rise to a high vapour pressure deficit (VPD) may affect carbon assimilation. This has been proven by Henson (1991) who showed that oil palm stomata closed during a high VPD, even when the soil moisture is not limiting.

The soil water deficit can be calculated in various ways. One of the best methods is to use pan evaporation or Penman's estimate of evaporation, multiplied by the crop factor, derived from direct measurement of the crop evapotranspiration. The crop factor is used to estimate how much water a plant can extract. The crop factor of oil palm is 0.7 (Kumar, 1997). The potential evapotranspiration (PE) is obtained by the product of the pan evapotranspiration and crop factor. For example, if the pan evaporation is 5 mm day^{-1}, then the PE is 3.5 mm day^{-1}.

IRRIGATION

Due to the different conditions in different regions in the Malaysian Peninsula, such as in Sintok, Kedah (*Figure 1*), palms may suffer a water deficit of up to three months or more. Therefore, it is vital to correct such deficits. The objective of irrigation is to compensate for the rainfall shortage so that water is no longer a plant growth-limiting factor. The rate of application will depend on the amount of water and its distribution. The timing of irrigation is best determined from measurement of the plant water status based on stomatal behaviour and the application rate by the soil water deficit (Chan, 1979).

One of the ways to alleviate a water deficit is to set up a drip irrigation system. The drip system applies water in small quantities directly to the rooting zone. It allows adjustment of the water supply to demand at any time and at the same time, limits the loss through percolation. Most drip systems require water at only a low pressure of 1.0-1.5 kg cm^{-2} compared to 3.5 kg cm^{-2} in standard irrigation (Kumar, 1997). The disadvantage of this system is that it requires thorough checking of the drippers, especially for operation after a long pause. With surface drip irrigation, the upper 150 mm soil layer is much more hydrated than with subsurface drip irrigation (Srinivas, 1996).

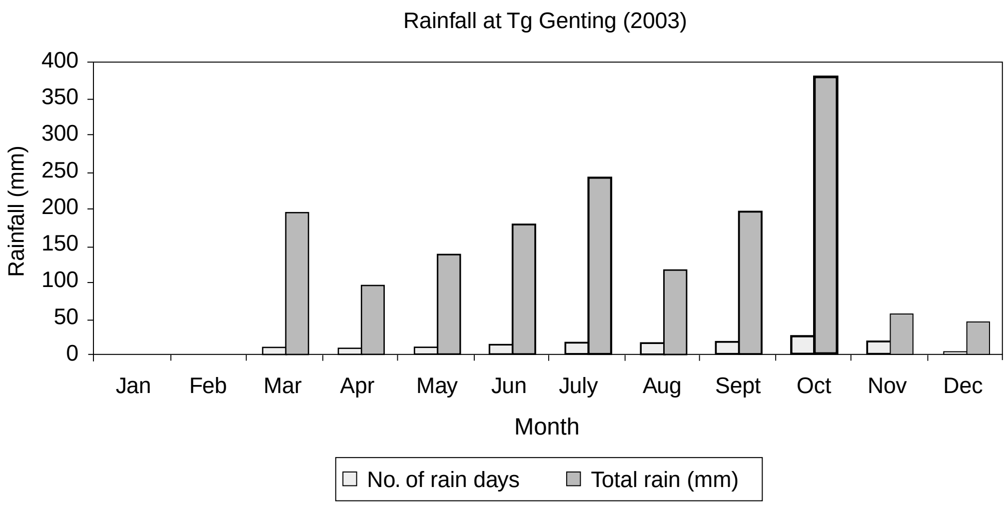

Figure 1. Rainfall at Tanjung Genting, Sintok, Kedah (2003).

How Much Water to Irrigate?

One of the problems in irrigation practices is to decide how much water to irrigate. By using the data from the pan evaporation (E-pan) and meteorogical instrument, say 4.0 mm day^{-1}, it means that the evapotranspiration is equivalent to 4.0 litres m^{-2} day^{-1}. At a planting density of oil palm of 148 per hectare, each palm occupies 10 000 m^2/148 = 67.6 m^2. Thus for these palms, only a portion of 67.6 m^2 is occupied. With an estimate of canopy radius about 3.0 m, this is equivalent to 42% of the allotted area being occupied. Therefore, each palm requires 67.6 m^2 x 0.42 x 4 litres m^2 day^{-1} = 113.6 litres day^{-1} (Henson, 2004). This amount of water should be irrigated to compensate the water requirement. The time taken to irrigate will depend on the flow rate, as it will rely on the water pump efficiency.

Water Balance in Oil Palm

Irrigation scheduling using the water balance concept is based on estimating the soil water content. In the field, daily evapotranspiration (ET) amounts are withdrawn from the storage in the soil profile. Any rainfall or irrigation is added to storage. Irrigation is needed when the water balance calculations of soil water drop below minimum level. Water balance in oil palm is done by assessing the total water demand, *i.e.* water losses by surface runoff, deep percolation and evaporation, including transpiration by the palms and ground vegetation, and to draw up a balance against total water input by precipitation and irrigation if applicable.

For a given volume of soil and plant environment, the water balance equation (Kee *et al.*, 2000) is as follows:

$$\Delta S = P + I - ET - R - D$$

where ΔS = change in soil moisture.
P = precipitation.
I = irrigation.
ET = evapotranspiration.
R = surface runoff.
D = drainage.

RECENT WORKS ON THE EFFECTS OF WATER DEFICIT ON YIELD AND IRRIGATION

Over the past three decades, various researchers have studied the effects of water deficit on palm growth and yield. Water stress decreases yield through increased inflorescence abortion and a lower sex ratio as observed by Turner (1976). In water stress, the stomata close and leaves begin wilting in most plants. The minimum photosynthetic activity occurs resulting in a low carbohydrate status. This will turn the inflorescences into males, as they require less nutrition to develop. When the carbohydrate status recovers, more female inflorescences will be produced. Past research on irrigation based on a water requirement of 4-5 mm day^{-1} had little success in ameriolating the trough yields which might have been due to insufficient water and nutrient (Chan, 1979; Corley and Hong, 1981; Chan *et al.*, 1985; Kee and Chew, 1991).

Anon (1969) estimated the yield reduction at various annual moisture deficits. Maillard *et al.* (1974) identified the effects of severe droughts on oil palm. They noticed numerous closed spears, broken green leaves, dried out leaves, toppled spears and at times, death of palms. Water deficit also affected the oil content of the fruit bunches. There was also lower oil/mesocarp in normally ripe bunches, preventing complete ripening. In more serious cases, numerous fruits dried up and extraction rates were reduced by 30%-40% for several weeks (Kumar, 1997).

In a small scale drip irrigation study in Benin, there was a 140% increase in yield from 9-year-old oil palm, from 12.5 to 30 t ha^{-1} yr^{-1} fresh fruit bunch (FFB) (Lim, 1988). Both bunch number and bunch weights were increased. The drip system also improved potassium uptake by the palms. Ochs and Daniel (1976) did an irrigation trial in Ivory Coast and obtained about 225% more FFB yield.

Experiments by Guthrie Plantations in Negeri Sembilan produced about 17% more oil palm yield using drip, 11% more using furrow and 8% more using jet irrigation. However, irrigation only increased bunch number but not bunch weight (Chan, 1979). The increase in yield was due to a higher peak yield with no effect on the trough yield. Production remained low in the trough period even with irrigation. The needs for nutrients and irrigation during the yield trough have to be studied further.

Later, Corley and Hong (1981) reported a 5% yield increase with irrigation using hose on 12-year-old palm, on Ulu Tiram and Harimau soil series in central Johor. The FFB yield increased from 24.7 to 25.8 t ha^{-1} yr^{-1}.

Sime Darby Plantations in Northern Johor also conducted a 42-ha irrigation study drip irrigation, fertigation and POME application. After the fifth to seventh year, there was an 8% increase in FFB using drip irrigation, 9% with fertigation and 19% with POME application.

Another interesting irrigation study was done in southern Thailand by Tittinutchanon *et al.* (2000) in a seasonally dry (December-April) area with average cumulative annual water deficit of 214 mm over the last six years. In the first trial, two rates of drip irrigation were applied 150 and 300 litres palm^{-1} day^{-1} or 2.1 and 4.3 mm rainfall per day. In the second trial, four methods of irrigation drip, sprinkler, micro spray and contour furrow were tested at three different rates - 120, 240 and 360 litres palm^{-1} day^{-1}, or 1.7, 3.4 and 5.1 mm day^{-1} (*Table 1*). The irrigation was first applied at the seventh year of field planting. It was found that irrigation at 4-5 mm day^{-1} gave a significant increase in bunch number per palm but not in mean bunch weight. The dry season caused higher inflorescence abortion and lower bunch number, irrigation increased the bunch number. Irrigation was only applied when the cumulative water deficit (rainfall minus evaporation, calculated daily) exceeded 30 mm. The FFB yield increase was about 6 t ha^{-1} yr^{-1}. A significant response to irrigation was observed in three out of seven years. There were significant differences in oil/bunch ratio from the palms irrigated by the different methods. Drip and micro spray irrigation gave higher oil/bunch than furrow and sprinkler irrigation.

Drip irrigation in Ouidah, Benin was applied by Chaillard *et al.* (1983) using polyethylene tubes discharging into irrigation rills dug parallel to the rows of palms. It was aimed to produce a mean yield of 18 t ha^{-1} FFB at maturity. The yield in 1981-1982 was 20.6 t ha^{-1} FFB in the first section with a residual water deficit in the sex differentiation period of 280 mm. In the second section, with a residual water deficit of 360 mm, the yield was only 13.9 t ha^{-1} FFB. Thus, it is possible to obtain over 18 t ha^{-1} FFB applying irrigation of 5 mm daily. Unfortunately, the trial had no control.

A lysimeter study at Sg Tekam, Pahang showed the daily potential ET of a mature palm over the year to be 5.5- 6.5 mm day^{-1} (Foong and Lee, 2000). In the dry season, the potential ET for an immature oil palm was about 5.5-6.0 mm

TABLE 1. YIELD (t FFB ha^{-1} yr^{-1}) WITH DIFFERENT IRRIGATION METHODS

Irrigation	Rate of irrigation (litre palm^{-1})	Yield (t ha^{-1})				
		1996	1997	1998	1999	Mean
Unirrigated (control)	0	17.4	12.7	16.0	32.1	19.5
Sprinkler	120	23.7	14.2	17.3	34.1	22.3
	240	23.0	14.8	22.6	30.4	22.7
	360	23.4	14.9	18.4	30.2	21.8
Drip	120	22.4	14.2	18.8	29.2	21.2
	240	23.7	17.4	19.4	33.5	23.5
	360	27.9	25.8	20.3	32.5	26.6
Furrow	120	21.3	16.6	19.1	34.4	22.9
	240	29.5	19.9	20.3	32.8	25.6
	360	22.7	17.3	22.3	31.4	23.4
Microsprayer	120	24.3	17.4	17.8	30.5	22.5
	240	27.1	21.7	19.0	27.0	23.7
	360	23.6	20.9	19.6	26.0	22.5
Mean (all methods)	120	22.9	15.6	18.3	32.0	22.2
	240	25.8	18.4	20.3	30.9	23.9
	360	24.4	19.7	20.2	30.1	23.6
Dry season rain, 2 years earlier (mm)	–	341	198	234	465	309.5

Source: Tittinutchanon *et al.* (2000).

day^{-1} and 7.0-8.0 mm day^{-1} for a mature palm. With adequate water and fertilizer, the lysimeter palm produced a FFB yield of 59 t ha^{-1} and a total oil yield of 15 t ha^{-1}. Irrigation did not affect the seasonal yield fluctuation. Heightening the peak yield and some raising of the trough yield were seen, but this could have been due to the trial being fertilized well. In most cases, the bunch number rather than the bunch weight was more affected by the irrigation (Chan, 1979; Foong and Lee, 2000).

CONCLUSION

Water deficit hinders palm growth and yield. Thus, proper irrigation is needed to solve or minimize this problem. However, irrigation has its limits. It is very difficult to apply over large areas and therefore not easy to ensure its cost-effectiveness. The yield of oil palm depends very much on its water supply during sex differentiation of its inflorescences; *i.e.* about 28 months before bunch harvest. Sufficient water is thus vital for good yield. Irrigation system should be well maintained so that water can be applied as soon as a water deficit occurs. Routine and regular inspections of the inlet and the lines are necessary to ensure that all the palms receive a regular water supply as expected. In practice, irrigation for oil palm would be preferably applied in flat areas suffering periodic dryness and near to a water source.

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