

Irrigation Management in Oil Palm

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1. Introduction

Oil palm (*Elaeis guineensis* Jacq.) is a native of West Africa and is known to be the highest edible oil yielding perennial crop (4-6 t/ha/year) which produces two distinct oils, i.e., palm oil and palm kernel oil. As on 2012, various Expert Committees constituted by Ministry of Agriculture, Government of India have identified a total of 19.30 lakh hectares in eighteen states of the country as suitable for oil palm cultivation. So far, an area of 2.30 lakh ha has been covered under oil palm. The FFB yield obtained by progressive farmers of Andhra Pradesh and Karnataka, under optimum management conditions, are between 20 and 25 tonnes of FFB per ha per annum i.e., 4-5 tonnes of oil per ha per annum from fourth year onwards. Traditionally, oil palm is grown in areas, where the annual rainfall exceeds 2000 mm and yields are always high in countries like Malaysia and Indonesia, which have high and uniform rainfall as compared to countries like Nigeria, Republic of Benin, *Cote d'Ivoire* which have marked dry seasons. Trials conducted in India with supplementary irrigation have shown positive response to growth and yield.

In India, oil palm is promoted as an irrigated crop, as the rainfall is much less than 2000 mm in most of the cultivated regions and rainfall is not evenly distributed, leaving a few dry months. It is estimated that around 150 mm of water per month is required for oil palm to meet evapo-transpiration demands. Under Indian conditions, several months in a year have little or no rainfall, while a few months have abundant rainfall. Months, which receive less than 150 mm rainfall or do not have sufficient water reserves in root zone, are termed as deficit months. When sufficient water is not available for evapo-transpiration, the oil palm, like any other plant, regulates the transpiration losses through stomata closure. Once the stomata are closed, the photosynthetic activity will be affected, which in turn impairs growth and yield.

Irrigation management is one of the most critical aspects in oil palm cultivation. Irrigation is adopted to supplement the soil water reserve at the root zone and thereby meet the evapo-transpiration demands of the crop. Deficit or surplus of water would create stress to oil palm and adversely affect its yield. Irrigation without any deficit is considered optimum for oil

palm, which means that irrigation should be given at such rates and frequencies, so that water is readily available for the plants with minimal losses. To realize its full yield potential, irrigation should be given to ensure adequate moisture in the soil throughout the year in tandem with other agronomic practices.

2. Symptoms associated with water deficits

General symptoms

Indicators of water deficits in oil palm are:

- Accumulation of unopened leaves (spear leaf)
- Bending of lower whorl of leaves
- Yellowing of leaves and appearance of necrotic zones at the tip of leaflets
- Drying of lower leaves and bending/ breaking of rachis
- Bunch failure



Bending of lower whorl of leaves

Young seedlings and juvenile palms

- Non - opening of younger leaves
- Inward leaf curling i.e., rolling of leaflets
- In extreme cases, yellowing and subsequent necrosis of older leaves



Unopened spear leaves

Mature palms

- Non-opening of spear leaves
- Rolling of leaflets of mature leaves
- Wilting and drying of leaflets
- Suppression in formation of female inflorescences and increase in male inflorescences
- Abortion of female inflorescences



Breaking of leaves

3. Moisture sensitive stages

Effect of a drought period on yield components occur with long time-lags (2-3 years) because drought-sensitive processes such as floral sex determination or early inflorescence (anthesis) abortion take place months or years before the maturity of a given bunch.

Two sensitive phases of drought in oil palm are sexual differentiation (approx. 30 months before harvest) and abortion (approx. 10 months before harvest). The second drought-sensitive phase may coincide with the photoperiod sensitive phase, making their distinction difficult.

Moisture stress at these stages will lead to production of male flowers resulting in decreased yields. Irrigation at these stages can effectively mitigate the adverse effect of water deficits on bunch production.



Floral abortion



Bunch failure

4. Relationship between water deficits and yield

Stage	Water deficit (mm/year)	Symptoms	Yield loss (%)
1	< 200	Not a serious problem	0 – 10
2	200-300	Non opening of immature and younger leaves, defective old leaves	10 - 20
3	300-400	Increased unopening of younger leaves and defective leaves, drying of older leaves	20 - 30
4	400-500	Unopened immature leaves and dried leaflets	30 - 40
5	> 500	Young leaves may not open, leaf bud cracks and breaks	> 40

5. Estimation of soil water deficits based on rainfall

The difference between rainfall and evaporation indicates the soil water deficits. The water deficits for a period can be calculated by using the following equation:

$$D = R + P - PE$$

Where D = Water deficits; R = Theoretical reserve; P = Rainfall;
PE = Potential Evapotranspiration

In the absence of either pan evaporation figures or sufficiently detailed meteorological data, the method developed by IRHO, France (now CIRAD-CP) can be used. In this method, it is assumed that, for the months with 10 or more rainy days, evapotranspiration is 120 mm and for months with less than 10 rainy days, evapotranspiration is equal to 150 mm. Using this method, water deficits has been calculated at a place in West Godavari district of Andhra Pradesh as 792 mm using the rainfall average data of 50 years.

6. Calculation of water requirement of oil palm based on CF

Water requirement of a crop is the quantity of water required by the crop in a given period of time for its optimum growth under field conditions. It is a function of rainfall, soil water reserves and evapo-transpiration. Water requirement varies from place to place depending on climatic conditions like sunshine hours, temperature, relative humidity, wind velocity etc. This is the best available method to estimate crop water requirement from direct measurement of evapotranspiration. In this method, pan evaporation or Penman's estimate of evaporation is multiplied by an appropriate "crop factor".

Water use of crops is very closely related to evaporation. In fact, crop water use is composed of evaporation of water from the soil surface and transpiration of water through the leaves. Combined together, these two factors are named as evapotranspiration. While evaporation is easily measured, transpiration is not. Therefore, it is much simpler to relate the crop evapotranspiration to daily evaporation via a crop factor. A crop factor is related to the percent of ground covered by the crop canopy and therefore will vary depending on the crop stage. For an adult oil palm, 0.7 is considered as "crop factor".

The following simple method of calculation has been devised based on the evaporation rates prevailing in the area especially during summer months:

Evaporation from open pan : 6.70 mm

Crop factor : 0.7

Potential evapotranspiration (PE) = Pan evaporation x Crop factor

= 6.70 x 0.7 (Crop factor being assumed as 0.7)

= 4.69 mm/day

= 46,900 l/day/ha (1 mm of rainfall is equal to 1 l/sq. m)

Since 143 palms are accommodated in one hectare area, the quantity of water per palm per day works out to be 328 l.

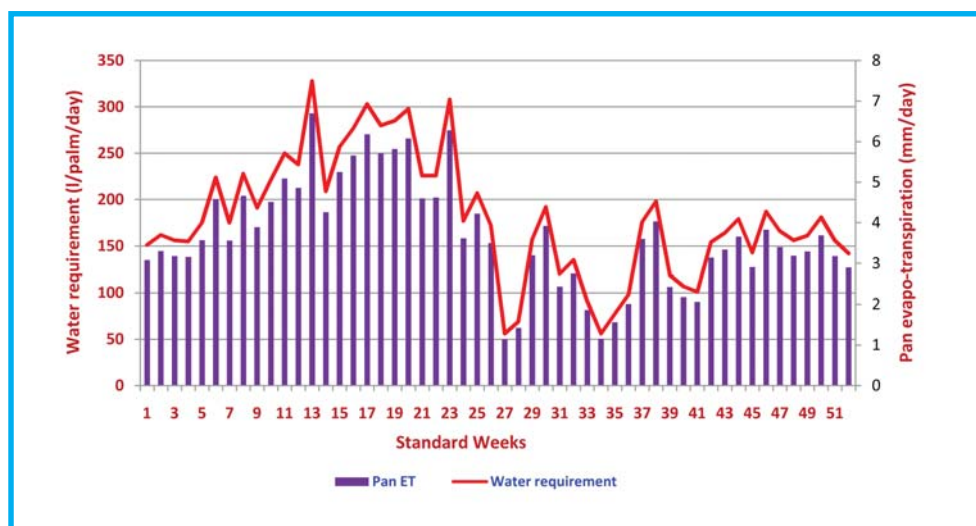
Water holding capacity at not less than 70 % of the field capacity is acceptable and will not affect the FFB yield of oil palm significantly.

Therefore, the minimum quantity of water to be applied will be:

$4.69 \text{ mm} \times 70\% = 3.283 \text{ mm/day}$ or 32,830 l/ha/day or 230 l/palm/day

By providing irrigation regularly at the above quantities coupled with proper nutrient management, FFB yield of 20 tonnes/ha/year could be ensured.

Water requirement for adult oil palm grown under Pedavegi, West Godavari district, Andhra Pradesh (Canopy area - 70 sq. m)



Water requirement (WR)

Water requirement of banana, oil palm and sugarcane is perceived to be very high as they need adequate soil moisture throughout the year for good growth and production. However, as compared to sugarcane and banana, oil palm requires less water for its optimum production.

Water requirement of oil palm, banana, sugarcane and rice

Crop	WR (lakh litres/ha/year)
Oil palm	67.35
Banana	120.00
Sugarcane	133.00
Rice*	300.00

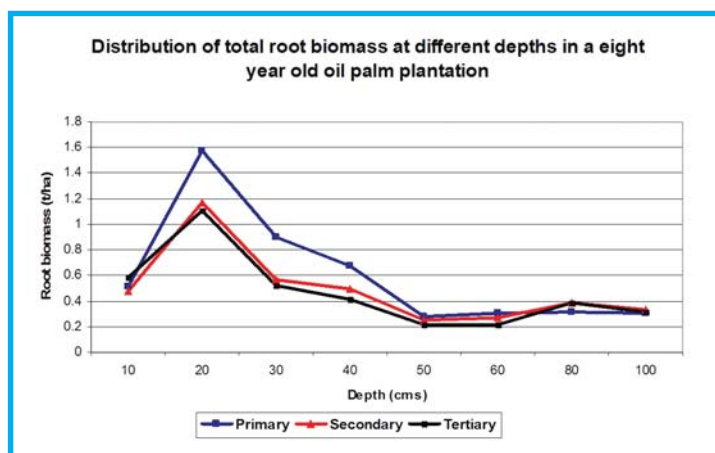
* for two crop seasons in a year

7. Root distribution

The moisture pattern along with root biomass distribution in the different irrigation methods (basin, drip and jet) in juvenile oil palm plantations grown under irrigated conditions was reported by Reddy *et al* (2002). The root density was more in palms irrigated with jet system followed by drip and basin. The maximum concentration of roots was in 10-40 cm depth at 0.5 m distance from the palm irrespective of the irrigation methods and decreased with increase in depth. The feeder roots were high in palms irrigated with jet system followed by basin and drip methods. The root distribution pattern in relation to soil moisture content indicated that most roots were present in the zone (10-40 cm), where the moisture content was less indicating that the uptake of water by the roots.



In another study, Suresh *et al* (2003) reported that root biomass was maximum at 10-20 cm depth followed by 20-30 and 30-40 cm depth and there was a constant decline of root biomass from 40 cm downwards till 100 cm. The total root biomass at the entire root zone of 100 cm in an eight-year-old oil palm plantation was estimated to be 12.57 t/ha. The density of roots was maximum at 2 m distance from palm base and decreased with the distance from palm base.



Hence, absorbing roots in adult palms spread up to a maximum distance of 2.00 m from the trunk and to a depth of 40 cm from the surface. For higher water and nutrient use efficiency, irrigation and fertilizers should be applied up to 2 m from the palm trunk. Vertical development of root system largely depends upon sub soil water table.

8. Irrigation techniques

It has been widely recognized in the field that yield levels from oil palm could greatly improve with the institution of organized irrigation methods. Estimates show that a well organized irrigation system, whether basin, micro jet or drip irrigation, that can deliver 6.5mm of water per day can increase productivity by 20 per cent.

Basin / Furrow method of irrigation is the simplest and useful where land is leveled and abundant supply of water is assured all the year round. Water use efficiency in this method will be low because of high water losses



Basin irrigation



Sprinkler irrigation



Drip irrigation

in conveyance and evaporation. Micro jet method may be better than the basin/furrow method in that they reduce conveyance losses, but evaporation losses could be high. Drip system has the advantage of keeping the root zone in moist condition and thus reducing conveyance, percolation and evaporation losses. This is one of the most cost effective and

environmentally conscious ways of irrigating oil palm. Palms irrigated with drip system recorded maximum FFB yield and higher bunch number as compared to palms irrigated with micro jet system.

Most of the areas in India where oil palm cultivation is envisaged are also prone to low atmospheric humidity during the winter and summer months. As oil palm requires high atmospheric humidity, this low humidity results in high vapour pressure deficit prompting the closure of stomata thereby reducing the photosynthetic activity, even under well irrigated conditions. Further, the percentage of feeder roots is high in micro jet method followed by basin and drip methods. Considering these advantages, micro sprinkler/jet irrigation may prove more suitable to achieve better yields under our conditions but with a lesser water use economy as compared to drip system.

9. Irrigation management

Oil palm requires sufficient irrigation for higher productivity. Insufficient irrigation causes stress in plants leading to less number of leaves and reduced yield (due to more male flowers). Water requirement depends upon age of the plantation, soil type and potential evapotranspiration (PET) prevailing in the locality. PET is calculated based on the temperature, relative humidity and wind velocity of a particular area. Oil palm plantations (>4 years) grown in light soils (PET 3.0 mm) requires around 210 liters of water per palm per day. As PET increases, plants require more quantity of water due to reduced water holding capacity of the soil.

In Pedavegi, West Godavari District, Andhra Pradesh, the average PET during summer is 3.1-3.8 mm and the water requirement will be 215-265 liters per palm per day. The demand could be met during summer by using four drippers of 16 LPH or two microjet of 30 LPH per palm and operating a motor for 4.5 hours. Similarly, if PET is 1.4-2.1 mm, it is required to provide water at the rate of 100-150 liters per palm per day. Under such circumstances, four drippers of 16 LPH or two microjet of 30 LPH per palm could be used and motor can be operated for 2.5 hours.

If the PET is 2.2 to 2.4 during winter, it is required to provide water at the rate of 160-170 liters per palm per day. At this stage use of four drippers

of 16 LPH or two microjets of 30 LPH per palm and motor can be operated for three hours to meet the demand. If the PET is 5.0 mm during severe summer, water requirement may raise to 350 liters per palm per day. Under such situations, usage of four drippers of 16 LPH or two microjets of 30 LPH per palm along with operation of motor for six hours could meet the demand.

10. Quality of irrigation water

Quality of irrigation water has a significant influence on soil properties as well as growth and yield of palm. Water with pH between 6.0 and 7.0 is generally considered to be desirable for irrigation. Special management practices are to be considered to improve growth and yield of oil palm if the pH goes beyond the extremes mentioned above. Similarly, continued use of irrigation water with electrical conductivity (EC) exceeding 1.0 dS m^{-1} or total dissolved salts (TDS) greater than 1000 ppm is not advisable. Periodic leaching of salts from the root zone with irrigation water exceeding potential evapotranspiration (PET) of oil palm is effective in reducing soil salinity.

11. Results of irrigation trials

Irrigation trials conducted in different countries indicated that:

- Yield responses to irrigation increased with increased level of water deficits.
- The increase in yield is due to increase in bunch number with little or no effect on bunch weight.
- Increase in bunch number is due to change in sex ratio and reduced abortion.
- Effect of irrigation could be seen after several months (as many as 28 months) of irrigation treatment.

12. Drought Sensibility Index

Maillard et al. (1974) measured a drought sensibility index (SI), which was a numerical assessment of the drought effects recorded in a population or progeny with a formula: $SI = (10M + 5S_1 + 3S_2 + 2S_3) / N$, Where N is total

number of palms, M is number of dead palms, S is palms showing an accumulation of unopened spears, S is palms with four to six leaves broken or collapsed and S is palms with all the leaves withered.

The drought sensibility indices of oil palm hybrids grown under Indian conditions are given in the table below.

Drought sensibility indices of oil palm hybrids

Source	Total Palms	Spear	Total broken	Dried leaves	Yellow leaves	Palms (broken Leaves)	SI
Malaysia	27	12	52	30	36	14	10.6
Palode	32	15	23	6	47	16	5.2
Deli X Ghana	34	20	49	10	36	19	8.2
Deli X Nigeria	34	18	35	0	36	19	6.0

13. Soil moisture conservation methods

In oil palm plantations, soil moisture can be conserved by mulching with leaves cut while harvesting fresh fruit bunches, male inflorescences and empty fruit bunches providing windbreaks, application of anti-transpirants/ growth regulating chemicals and by removal of young inflorescences. In hilly terrains, mulching, formation of half moon terraces, bench terraces, contour bunding and planting on the contour line, use of drip irrigation system and construction of water storage tank for irrigation could be followed for soil and water management.



Mulching with harvested oil palm leaves



Mulching with empty fruit bunches

14. Rain water harvesting system in hilly terrains

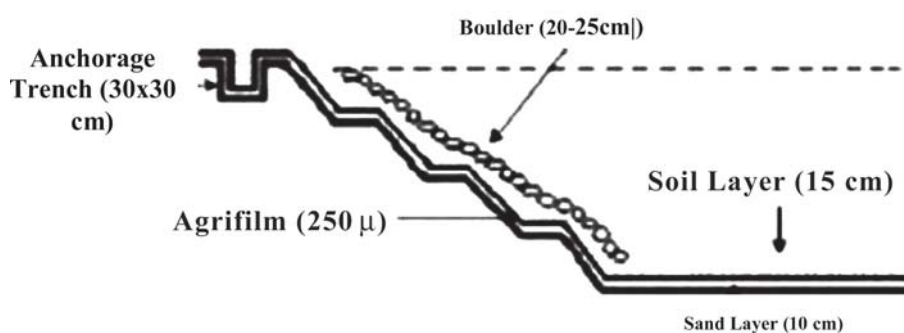
To design a water-harvesting tank for irrigation purposes, the irrigation requirements of oil palm in the region is to be calculated first. Knowledge of factors such as effective rainfall, evapo-transpiration, soil type, application efficiency and leaching requirements, if any, is essential for calculating the irrigation requirements of oil palm. Subsequently, the total seasonal water requirement for the entire area to be irrigated can be found. Water needed for other purposes, such as fishery, may also to be taken into consideration while designing the tank. Direct evaporation from the water surface in the tank has also to be taken care of and corresponding adjustments can be made in the size of the tank.

Normally three types of ponds, viz. embankment type, excavated (dugout) and dugout-cum-embankment type are constructed for collection of excess run-off. Embankment type and dugout-cum-embankment type of ponds are feasible in hilly and undulating topography. Embankment type of ponds are made by constructing a small length of dam across a water course, whereas dugout-cum-embankment type of ponds are made by excavating a site surrounded by hillocks from two or three sides and making the embankment from the excavated soil on the remaining sides. In flat areas, where these two types of ponds are not feasible, dugout ponds are constructed. Three steps are to be followed while designing of a water-harvesting pond. These are hydrologic design, hydraulic design and structural design.

According to a study at the ICAR Research Complex for NEH Region, Barapani, Meghalaya, India, seepage losses could be as high as about 55 litres/sq.m/day. Owing to the high rate of seepage loss and evaporation, harvested water will be lost within 1-2 months after recession of rain. Therefore, lining of the pond with non-permeable film is essential for retention of harvested water in the pond for the entire dry season, i.e. from November to March in the North-East region. LDPE (low density polyethylene) plastic sheets, popularly known as Agrifilm, are found to be a low-cost and durable lining material.

Lining of the pond with agrifilm

After the pond is dug according to the design, the pond bed and sides are made weed and stonefree. Steps at 50 cm vertical intervals are made on the sides of the pond to hold the agrifilm at place. On top of the sides, a continuous trench of 50 x 50 cm is dug for the purpose of anchoring the agrifilm, to prevent it from sliding down. After the sides and bed are dressed properly, 10 cm thick layer of sieved sand is spread uniformly on the bed and sides to provide a cushion to the agrifilm. Then the agrifilm (preferably 250 μ m LDPE) is laid properly on the pond. For joining the film to suit the



Schematic diagram of agrifilm lining of a water-harvesting pond

size and shape of the pond, bitumen of 85/25 and 80/100 grade in the ratio 2 : 1 is used. Soil cover of 30 cm is provided over the agrifilm. Stone pitching is done on the sides only, to safeguard the sides of the pond against erosion and any other external forces. With this type of structure seepage loss from agrifilm-lined ponds could be reduced from 55 to 2.9 litres/sq.m/day, i.e. by 94.7% (Manoj and Satapathy, 2008).

To prevent seepage and percolation losses, the dug-out tanks can also be lined using UV-resistant polyethylene films such as Silpaulin (200 GSM or more) or nylon (500 GSM). These sheets are made up of water proof, UV-stabilized, heat-sealed, multi-layered and cross-laminated plastic materials and hence ensure high tensile strength, long life and high resistance to external pressure. Generally trapezoidal-shaped storage tanks are constructed by excavating soil and dumping the removed soil along the four sides of the tank. After this, plastic sheets are made into the shape of the pond according to the final dimensions of the constructed pond by a

process called thermal welding. Then the pond-shaped plastic sheet is inserted into the pond and the sides are stabilized by burying it into the soil or shoulder bunds, or by riveting through the metal rings provided along the sides of the pond-shaped plastic sheet. The shoulder bunds can be further stabilized with rubble pitching and vegetative fencing. Soil cover or rubble pitching over the plastic lining is generally not needed in case of tanks lined with UV-stabilized sheets. It is found that silpaulin or nylon-lined ponds are more stable and have a longer and useful life. It can be made in any size and is also suitable for multiple uses of harvested water.

Terrace farming: Terraces are cut across mountain slopes for farming operations. This system of cropping is beneficial for retaining fertility of soil; preventing landslides and checking soil erosion. Secondly, it is helpful in retaining the soil moisture and also for conserving water.



Terrace farming

Bamboo-drip irrigation system: The terraced fields are irrigated by a network of water channels of bamboos that reach to every field. Sometimes, holes are made in the bamboo-pipes that facilitate the flow of water in drips.



Bamboo-drip irrigation system

15. Conclusions

Under the Indian context, agronomic techniques for achieving better water reserves at plantation level (through irrigation and erosion control), ensuring more effective distribution of available water to oil palm (by reducing competition with weeds, bare soil cropping, anti-transpirants, cropping with other palms) and reducing water consumption by palms during dry seasons through ablation of bunches and mulching are effective, but becomes limited due to technical or economic reasons. Use of drought tolerant planting materials will be another option for overcoming Moisture stress in the long run.

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