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RESEARCH PAPER

Influence of different methods and levels of irrigation on vegetative growth and yield of oil palm (*Elaeis guineensis* Jacq.)

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Abstract : A field experiment with two methods and three levels of irrigation using crop factor was carried out on eighteen years old oil palm plantation at ICAR-Indian Institute of Oil Palm Research, Pedavegi to find out their influence on vegetative growth and yield of fresh fruit bunches during the year 2016-2017. The data obtained have indicated non-significant differences for most of the parameters evaluated. However, application of irrigation water through drip method at crop factor 0.8 recorded highest number of leaves produced (25.83), highest number of female inflorescences (7.16), lowest number of male inflorescences (5.12) which contributed to increased production of number of fresh fruit bunches (7.16), total weight of FFBs (148.44 kg/palm/year) thereby FFB yield (21.23 t/ha). Further, the same treatment combination has increased percentage of fruits to the bunch (64.79%).

Key Words : Crop factor, Female inflorescence, Fresh fruit bunches, Male inflorescence, Oil palm

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INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is considered as high edible oil yielding tropical perennial plant recommended to grow under hot and humid tropical climatic conditions. Optimal temperatures ranging between 80-90^{o} F is considered as the best temperature for healthy growth and development of oil palm. Ferwerda (1977) reported that an average daily temperature which is below 75^{o}F is highly favourable for the cultivation of oil palm. Zhu *et al.* (2008) reported that plants receiving direct sunlight of 5-7 hours per day have been found very much beneficial for optimal growth and development. Areas receiving high rainfall (ranging from 2000-3000 mm) with well distribution over a larger part of the year like in Malaysia and Indonesia are considered as the traditional areas to grow oil palm without supplemental irrigation, whereas, in countries like Nigeria, Republic of Benin and *Cote d' Ivorie* which have marked dry season require supplemental irrigation otherwise, it is difficult to obtain good growth and development of fresh fruit bunches. In India, where the monsoon season is limited to a shorter period of 3-4 months duration only need supplemental irrigation for proper growth and development of fresh fruit bunches in oil palm. Therefore, it is considered that supply of

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supplemental irrigation water during dry spells under tropical humid climatic conditions is the prerequisite for successful cultivation of oil palm. Irrigation trials conducted in the non-traditional areas/countries have shown some positive response in terms of growth and yield of oil palm. The availability of moisture in the soils of oil palm plantation plays an important role for proper vegetative growth (Henson and Harun, 2005) and also functions as a signal for female sex representation (Jones, 1997). In areas of water shortage, it was observed that a large number of male flowers were produced coupled with slow growth rate and led to poor yield of fresh fruit bunches. The basic information relating to water stress responses in oil palm is a hot topic which should be investigated further for water deficit tolerance screening. Water deficit is a major abiotic stress, which is widely distributed worldwide over 1.2 billion hectares, especially in the rain-fed areas (Chaves and Oliveira, 2004; Kijne, 2006 and Passioura, 2007). The water deficit environment is reported as a key factor that limits plant growth and development prior to loss of productivity especially of crop species (Reddy *et al.*, 2004; Blum, 2005 and Neumann, 2008). In India, the period during October to May is generally rainless and crops are subjected to water stress which is usually terminated with either onset of monsoon in June or by giving supplemental irrigation as and when required. Keeping all these things in view, the present investigation was aimed at assessing the vegetative growth and yield performance of oil palm with different methods and levels of irrigation using crop factors.

MATERIAL AND METHODS

The present investigation was carried out on the existing eighteen years old oil palm plantation at ICAR-Indian Institute of Oil Palm Research, Pedavegi, Andhra Pradesh and was laid out in split-plot design with four replications consisting of main plot treatments with two methods of irrigation systems and three sub-plot treatment levels with different crop factors based on the rate of evapo-transpiration. The crop factor was developed using the following formula (Rao *et al.*, 2016).

Potential evapo - transpiration (PE) = Pan evaporation × Crop factor

Water use of crop 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 evapo-transpiration. While evaporation is easily measured, transpiration is not. Therefore, it is much simpler to relate the crop evapo-transpiration to daily evaporation via a crop factor. A crop factor is related to the per cent 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 (Rao *et al.*, 2016).

Evaporation from open pan: 6.70 mm (for example).

Crop factor: 0.7

Potential evapotranspiration (PE) = Pan evaporation × Crop factor

PE = 6.07 × 0.7 = 4.69 mm/day

46,900 lit/day/ha as 1mm of rainfall is equal to 1Lm^{-2}

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

Water holding capacity at not less than 70 per cent 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 mm × 70% = 3.283 mm/day or 32,830 lit/ha/day or 220 lit/palm/day

The two methods of irrigation systems adopted were micro-jet and drip, while the three irrigation levels used were based on crop factors (CF) *viz.*, 0.6, 0.7 and 0.8. The treatments were: T_1: Micro-jet method of irrigation at crop factor 0.6; T_2: Micro-jet method of irrigation at crop factor 0.7; T_3: Micro-jet method of irrigation at crop factor 0.8; T_4: Drip method of irrigation at crop factor 0.6; T_5: Drip method of irrigation at crop factor 0.7; T_6: Drip method of irrigation at crop factor 0.8. All the vegetative growth and yield parameters were recorded as per the time schedule framed. The height of the palm was recorded in meters and expressed as per palm per year by marking yellow colour at a height of 0.5 meters on the trunk of the palm from the ground level. From the yellow colour mark the height was measured with the help of a measuring tape upto the 33rd leaf base using poly vinyl chloride (PVC) pipe and finally added 0.5 m to get the total height of the palm. Height recorded during beginning of the experiment was noted down as h_1 and at the end of the experiment as h_2. The difference between h_1 and h_2 is considered as height of the palm recorded in meters. Number of leaves produced per palm were recorded and expressed as per palm per year. To record the number of leaves produced on the palm the first opened leaf was marked with red colour at the beginning of the experiment and the last opened leaf during the next recording was marked with yellow colour, thus the number of leaves between the two markings indicated the number of leaves produced during that particular period. Girth of the palm was measured by giving yellow colour mark at a height of 0.5 meters on the trunk of the palm from ground level and the girth was measured on the mark with the help of measuring tape and recorded in meters. The number of male and female inflorescences produced between the 9^{th} to 17^{th} leaves was recorded at quarterly interval and the sum up of all the quarters in a year are expressed as number of male and female inflorescences produced per palm per year. The number of fresh fruit bunches (FFBs) per palm was recorded in every harvest and sum up of all the harvests in that particular year are expressed as number of fresh fruit bunches per palm per year. Total fresh fruit bunch weight of the palm was recorded per palm in each harvest and total of all harvests of the palm is expressed as kilograms per palm per year. Average yield of fresh fruit bunches per palm in each treatment was multiplied with number of palms per hectare and expressed in tonnes. The percentage of fruits to the bunch was calculated by removing the individual fruits from the bunch and arrived by using the following formula:

$$\text{Percentage of fruits to the bunch} = \frac{\text{Weight of the fruits in a bunch}}{\text{Total weight of the bunch}} \times 100$$

The data thus, arrived were subjected to statistical analysis as per the basic procedure outlined by Panse and Sukhatme (1985).

Results and Discussion

The data pertaining to height of the palm was found non-significant with different methods and levels of irrigation using crop factors (Table 1). But interaction effect between methods and levels of irrigation on height of the palm was found significant. Micro-jet method of irrigation using crop factor 0.8 recorded significantly highest height of the palm (0.283 m) and was found at par with the drip method of irrigation using crop factor 0.7 (0.280 m). Water is considered as the most potential of the crop inputs in increasing the vegetative growth and development of oil palm. Larsen (1981) has opined that unavailability of water reduces the productivity of any crop by hampering the crop growth and development due to alterations in the physiological and biochemical mechanisms thereby pre-disposal of the crop to attack of insect pests and diseases that ultimately reduce the quantity and quality of economically important products.

Table 1: Effect of methods of irrigation and levels of irrigation using crop factors on growth and yield of oil palm

Treatments	Height of palm (m)	Girth of palm (m)	Number of leaves per palm	Number of male inflorescences	Number of female inflorescences
Methods of irrigation					
M_1 (Micro-jet method of irrigation)	0.272	0.04	25.59	6.16	7.08
M_2 (Drip method of irrigation)	0.271	0.03	25.71	5.87	7.29
LSD $_{0.05}$	NS	NS	NS	NS	NS
Levels of irrigation using crop factor					
(L_1) Crop factor 0.6	0.268	0.05	25.66	7.93	5.49
(L_2) Crop factor 0.7	0.273	0.02	25.64	7.87	7.03
(L_3) Crop factor 0.8	0.274	0.03	25.65	5.75	6.80
LSD $_{0.05}$	NS	NS	NS	0.464	1.100
Interaction of M x L					
M_1L_1	0.268	0.03	25.64	7.75	5.77
M_1L_2	0.265	0.03	25.65	5.75	7.09
M_1L_3	0.283	0.05	25.48	5.00	6.43
M_2L_1	0.268	0.01	25.68	7.50	5.22
M_2L_2	0.280	0.02	25.63	5.00	6.97
M_2L_3	0.265	0.07	25.83	5.12	7.16
LSD $_{0.05}$	0.22	0.03	NS	NS	NS

NS= Non-significant

Methods of irrigation and levels of irrigation individually might have not shown any significant influence on palm height, but the interaction effect of these two was found significant in increasing the plant height. The reason might be due to improved microclimate around the plant with micro-jet method of irrigation with higher level of irrigation *i.e.,* using crop factor 0.8, whereas, application of irrigation water through drip method of irrigation at moderate level of irrigation using crop factor 0.7 might have reduced evaporation losses as the water is directly delivered to the root zone of the palm. This might have influenced the higher root activity, thereby recorded increased growth in height of the palm. Rao (2009) while working with different nutrient and irrigation levels through basin method of irrigation has reported an increase in palm height of oil palm by application of increased quantity of nutrients and highest quantity of water and was found similar to the observation recorded in the present result.

The data furnished in Table 1 pertaining to girth of palm was found non-significant with different methods and levels of irrigation water applied. However, the interaction effect between different methods and levels of irrigation was found significant. Application of irrigation water through drip method of irrigation using crop factor 0.8 recorded significantly highest girth of palm (0.07 m), whereas, application of irrigation water through drip method of irrigation using crop factor 0.6 recorded significantly lowest girth of palm (0.01 m). Sun *et al.* (2011) reported that under environmental stress conditions the plants would change their biomass allocation among the constituent organs thereby growth rate would gradually become slow with an increase in the duration of stress period. In the present investigation, the quantity of irrigation water applied to all the palms in a particular level of irrigation was the same except the method of application of water. However, oil palm irrigated through drip method of irrigation at higher level of irrigation with crop factor 0.8 recorded a significant increase in girth of palm which might be due to increased water use efficiency. Rao (2009) and Gajbhiye *et al.* (2011) in oil palm, Basavaraju *et al.* (2011) in coconut reported an increase in the girth of palm by application of more water to the palms in their earlier studies.

The data pertaining to number of leaves produced per palm per year (Table 1) showed non-significant differences with different methods, levels as well as their interaction effects between these two. Number of leaves produced per palm per year ranged between 25.48 to 25.83 irrespective of the method and level of irrigation. In any plant, development of foliage is considered to be the critical aspect of plant with response to water stress. Hsiao *et al.* (1985) reported that attributes of leaf growth are very sensitive to water stress. In contrary to the opinion of Hsiao *et al.* (1985), production of number of leaves per palm per year was found less sensitive to the methods of irrigation as well as levels of irrigation using crop factors adopted in the present experiment.

The data pertaining to number of male and female inflorescences produced per palm per year (Table 1) was found non-significant with different methods of irrigation. However, significant differences were observed in the number of male and female inflorescences produced per palm per year with different levels of irrigation. Among the levels of irrigation, application of irrigation water at crop factors 0.7 and 0.8 have recorded significantly highest number of female at the same time recorded significantly lowest number of male inflorescences (7.03 and 5.75, respectively) per palm per year. Interaction effect between methods and levels of irrigation was found non-significant in the production of number of male and female inflorescences. Application of irrigation water showed profound influence on the production of male and female inflorescences with different levels of irrigation. Occurrence of male and female inflorescences is a result of the process of differentiation which is known to occur 27 to 35 months before anthesis and is concurrent with the process of leaf production (Hartley, 1988). Leaves and stem have a concurrence with reproductive growth by accumulation of nutrients and photo-assimilates. A small reduction in these two attributes due to shortage of irrigation water supply showed an amplification of inhibitory effect on the number of female inflorescences produced per palm per year which ultimately showed the effect on the number of fresh fruit bunches produced per palm per year. The tendency of male flower production is generally higher with a decrease in the availability of water particularly during the periods of differentiation of vegetative primordia to floral primordia which led to temporal dioecism *i.e.,* production of male inflorescences to reduce the energy cost on the reproduction. Application of higher quantity of irrigation water recorded production of decreased number of male inflorescences and at the same time recorded increased number of female inflorescences. Gawankar *et al.* (2003); Gajbhiye *et al.* (2011) and

Sanjeevraddi *et al*. (2014) reported increased number of female inflorescences in oil palm with increased quantity of irrigation water in oil palm.

The data pertaining to production of number of fresh fruit bunches per palm per year (Table 2) recorded non-significant differences between the methods of irrigation. However, application of different levels of irrigation water recorded significant differences in number of fresh fruit bunches per palm per year. Significantly highest number of fresh fruit bunches per palm per year (7.03) was observed by application of irrigation water at crop factor 0.7 and was found at par with crop factor 0.8, whereas, significantly lowest number of fresh fruit bunches per palm per year (5.49) was recorded by application of irrigation water at crop factor 0.6. Interaction effect between methods of irrigation and levels of irrigation using crop factors was found non-significant. Production of male and female inflorescences in oil palm has been considered due to the process of differentiation of vegetative primordia to floral primordia which is known to occur between 27 to 35 months before anthesis and was found concurrent with the process of leaf production (Hartley, 1988). Among the reproductive attributes, production of female inflorescences appeared to be highly sensitive to water stress showing a reduction. The number of fresh fruit bunches per palm per year depends mainly on the number of productive female inflorescences produced in oil palm. In the present study, it is clear that quantity of irrigation water applied to palm at a particular level is the same through different methods of irrigation. Hence, it may be concluded that method of irrigation has no significant impact on the vegetative growth of the plant as well as on the development of reproductive parts mainly formation of female inflorescences which ultimately influenced number of fresh fruit bunches formed on the palm. However, application of irrigation water at crop factor 0.7 recorded significantly highest number of female inflorescences per palm per year (7.03) thereby recorded significantly highest number of fresh fruit bunches (7.03) per palm per year. Gawankar *et al.* (2003); Rao (2009); Gajbhiye *et al*. (2011) and Sanjeevraddi *et al.* (2014) reported increased number of fresh fruit bunches per palm per year which is in accordance with the present result.

Data concerned with total weight of fresh fruit, bunches per palm per year were found non-significant (Table 2) with different methods of irrigation, levels of irrigation and their interaction effects. The data with regard to total weight of fresh fruit bunches per palm per year ranged between 115.47 kg to 148.44 kg

Table 2: Effect of methods of irrigation and levels of irrigation using crop factors on growth and yield of oil palm

Treatments	Number of fresh fruit bunches per palm	Weight of fresh fruit bunches (kg/palm/year)	Yield of fresh fruit bunch (t/ha)	Per cent of fruits to bunch
Methods of irrigation				
M_1 (Micro-jet method of irrigation)	6.43	141.00	19.84	61.71
M_2 (Drip method of irrigation)	6.45	127.05	18.17	59.82
LSD $_{0.05}$	NS	NS	NS	NS
Levels of irrigation using crop factor				
(L_1) Crop factor 0.6	5.49	126.22	17.57	61.15
(L_2) Crop factor 0.7	7.03	138.72	19.83	61.32
(L_3) Crop factor 0.8	6.80	137.15	19.61	59.83
LSD $_{0.05}$	1.010	NS	1.944	NS
Interaction of M x L				
M_1L_1	5.77	136.96	18.62	54.87
M_1L_2	7.09	137.22	19.55	59.42
M_1L_3	6.43	139.69	19.68	60.94
M_2L_1	5.22	115.47	16.51	61.37
M_2L_2	6.97	129.00	18.44	63.32
M_2L_3	7.16	148.44	21.23	64.79
LSD $_{0.05}$	NS	NS	NS	NS

NS= Non-significant

irrespective of the method and level of irrigation. In the absence of assured rainfall, supplemental irrigation is considered to be the most potential factor of the crop inputs in increasing the growth and development of oil palm. Larsen (1981) has opined that unavailability of sufficient moisture to the plant during its growth and development lead to alterations in the physiological and biochemical mechanisms thereby pre-disposing the plants to insect pests and diseases which may ultimately reduce the quantity and quality of economically important products. Assured supply of irrigation water through drip method of irrigation using crop factor 0.8 increased the number of leaves produced per palm per year (Table 1) which ultimately led to increase in the photosynthetic rate, thus increased production of photo-assimilates led to an increase in the total weight of the fresh fruit bunches by irrigation through drip method at crop factor 0.8. Rao (2009) reported an increase in the total weight of fresh fruit bunch in oil palm by increased application of nutrients and water.

The data pertaining to yield of fresh fruit bunches per palm per year (Table 2) recorded non-significant differences between the methods of irrigation. However, application of different levels of irrigation water at different crop factors recorded significant differences in the yield of fresh fruit bunches per palm per year. Among the levels of irrigation, significantly highest annual yield of fresh fruit bunches (19.83 t/ha) was observed by application of irrigation water using crop factor 0.7 and was found at par by application of irrigation water at crop factor 0.8. Significantly lowest annual yield of fresh fruit bunches per palm per year was registered by application of irrigation water at crop factor 0.6 (17.57 t/ha). Interaction effect between methods of irrigation and levels of irrigation using crop factors on the annual yield of fresh fruit bunches was found non-significant. Number of fresh fruit bunch production in oil palm generally depends upon the number of productive female inflorescences produced. A small reduction in the number of leaves produced due to shortage of water showed an amplification of inhibitory effect on the number of female inflorescences produced thereby a reduction observed in the number of fresh fruit bunches per palm per year which ultimately led to reduction in the annual yield of fresh fruit bunches. A small shortage in the application of irrigation water to palms showed a reduction in the number of female inflorescences produced (Table 1) thus, the number of fresh fruit bunches produced was influenced which led to a reduction in the annual yield of fresh fruit bunches per palm per year. Gawankar *et al.* (2003) and Rao (2009) reported increased yield of fresh fruit bunches by application of increased quantity of water and nutrients in oil palm.

The data pertaining to percentage of fruits to the bunch (Table 2) recorded non-significant differences between methods of irrigation, levels of irrigation and their interaction effect. Percentage of fruits to the bunch ranged between 54.87 per cent to 64.79 per cent irrespective of the method and level of irrigation. Percentage of fruits to the bunch generally depends on several factors which include number of female inflorescences produced, availability of nutrients and sufficient irrigation water supply including optimum range of weather parameters existing in the close vicinity of the crop during development of fresh fruit bunches. Proper development of stem and leaves showed a concurrence with reproductive growth. All these factors coupled together lead to proper filling and development of fresh fruit bunches which may increase the percentage of fruits to the bunch. In the present investigation, it has been observed very clearly that plants applied with proper nourishment and assured supply of irrigation water irrespective of method of irrigation recorded higher percentage of fruits to the bunch. Sanjeevraddi *et al.* (2014) reported increased per cent fruits to the bunch in oil palm.

On perusal of the results obtained in the present investigation, it clearly indicated that morphological growth and yield attributes are interrelated which were influenced by several physiological and biochemical changes based on the level of irrigation water applied which ultimately influenced the final output of palm in terms of yield. Increased level of irrigation water supply at crop factor 0.8 through drip method of irrigation system increased the availability of higher rate of moisture content and thus increased rate of water use efficiency by releasing the irrigation water at the effective root zone thereby avoiding the evaporation losses which ultimately contributed to an increase in the membrane stability index thereby favoured opening of stomata which led to gaseous exchange between leaves and the external atmosphere thus led to accumulation of photo-assimilates in the palm which favoured the growth, development and formation of more fresh fruit bunches in terms of yield.

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