RESEARCH ARTICLE

Effect of fertigation on growth, yield and nutrient use efficiency of oil palm (*Elaeis guineensis* Jacq.)

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ABSTRACT

Oil palm is one of the biggest consumers of mineral fertilizers due to its high growth rate, biomass production and yield and therefore, demands a balanced and adequate supply of nutrients for growth and yield. Fertilizers are usually the largest variable cost in the production. A study has been taken up to standardize the fertilizer dose using drip irrigation to improve nutrient use efficiency in oil palm under sandy clay loam soils of coastal Andhra Pradesh. Six different doses of fertigation were imposed in addition to the RDF through soil application in a 13 years old adult oil palm plantation in RBD with four replications. Fertigation was given at monthly interval from 2011 to 2017 and data on growth and yield parameters were recorded. The three years pooled datafrom 2014-15 to 216-17 recorded highest number of bunches per palm (8.0) and FFB yield (23.9 t/ha) at a fertigation dose of 1200:600:1200g NPK per palm year (T_4). However, it was on par with the treatments T_2 (7.8, 23.1 t/ha), T_3 (7.3, 22.2 t/ha), T_5(7.3, 21.9 t/ha) and T_6 (7.2, 21.9 t/ha). Further, increase in fertilizer dose of NPK did not result to any significant increase in number of bunches and FFB yield in oil palm beyond the dose of T_1 indicates that T_2dose is sufficient to obtain similar yield of FFB compared to higher dose of fertilizers. Higher nutrient use efficiency was also recorded in T_2 than the higher dose of fertigation.

Keywords: Drip irrigation, fertigation, growth, FFB yield, NUE, oil palm

INTRODUCTION

Oil palm is a gross feeder and is one of the biggest consumers of mineral fertilizers due to its high growth rate, biomass production and yield and therefore, demands a balanced and adequate supply of nutrients for growth and yield. Fertilizers are usually the largest variable cost in the production. It is a proven fact that annual allocation of fertilizers at a daily dosage to individual palms, substantial improvement in yields is expected. But the method adopted has to be cost effective and also less labour intensive. Fertigation has been proved to economize water and fertilizer with a corresponding lower expenditure in cost of production and labour towards weeding, fertilization and water application (Mahalakshmi et *al.,* 2001). Fertigation which combines irrigation with fertilizers is well recognized the most effective and convenient means maintaining optimum fertility level and water supply according to the specific requirement of each crop and resulting in higher yields and better quality of fruits (Smith et al*, 1979;* Syvertsen and Smith, 1996). Fertigation is the process of application of water soluble solid or liquid fertilizers through drip irrigation system. It is the process wherein fertilizer is applied through an efficient irrigation system like drip. In fertigation nutrient use efficiency could be as high as 90 per cent compared to 40 – 60 per cent in conventional methods. The amount of fertilizer lost through leaching can be as low as 10 per cent in fertigation, whereas it is 50 per cent in the traditional system Solamalai et alet al (2005). Through fertigation, nutrients are applied directly into the wetted volume of soil immediately below the emitter, where root activity is concentrated. It is commonly accepted that the efficiency of fertilizer use can be improved when it is applied by fertigation to most crops. Therefore, fertilizers in the fertigation system are applied at lower rates compared to broadcast fertilization (Haynes 1985). Patel and Rajput (2005) reported that application through fertigation significantly increased saving of fertilizer nutrients up to 40 per cent without affecting the yield of crops compared to the conventional method of nutrient application. Similarly, Haynes, 1985 reported that fertilizer savings through fertigation can be to the tune of 25 - 50 percent. Ramachandrudu et alet al (2009) reported that 50 per cent of the RDF applied through fertigation is optimum for better growth and vigour of seedlings in oil palm.At the site of the experiment, the period from October to May is generally rainless and crops are subjected to water stress which is usually terminated with either onset of monsoon in June/July month, supplementary irrigation is given as and when required.

Not much work has been done on oil palm to standardize the dose of fertilizer and method of application of fertigation for sustainable production and enhance the nutrient use efficiency. Hence, a study has been taken up to standardize the fertilizer dose using drip irrigation to improve the nutrient use efficiency.

MATERIALS AND METHODS

Afield experiment was laid out during 2011 on an existing 1997-98 oil palm plantation planted at 9m hexagonal method at ICAR-IIOPR, Pedavegi, Andhra Pradesh, India to study the effect of fertigation on oil palm using supplementary irrigation through drip methodin sandy clay loamsoils. The experimental site is located at 16^0 43'N and 81^0 09'S at a mean sea level of 13.41 m. The average rainfall is 1014 mm distributed over 45-65 days.Low rainfall during 2014 and 2015, less number of rainy days coupled with higher temperatures and pan evaporation during summer months from April to June were recorded continuously during 2014-15 and 2015-16 (Table 1).

SOILS OF THE EXPERIMENTAL SITE

Soil samples were collected from the experimental site and analysed for physic-chemical properties. The soil of the experimental site isa sandy clay loam. The soil was neutral in reaction with low in organic carbon and low in available nitrogen, highin available phosphorous and medium in available potassium (Table 2). There is no significant variation in the experimental site among the physic-chemical properties of the soil at the time of laying out the experiment.

Table 2: Physico-chemical characteristics of the experimental filed (Mean)

Properties	Values
pH	7.12
Electrical conductivity (dsm^{-1})	0.022
Organic Carbon (%)	0.44
Available nitrogen (kg ha^{-1})	198
Available phosphorous (kg ha^{-1})	52.3
Available potassium(kg ha^{-1})	284.6
Soil type	Sandy clay loam

Table 1: Monthly meteorological data recorded at ICAR-IIOPR, Pedavegi, West Godavari Dist., Andhra Pradesh during April, 2014 - March, 2017.

Month	2014-15			2015-16			2016-17		
	Mean Max. Temp.(^{0}C)	Rainfall (mm)	Pan Evaporation (mm/day)	Mean Max. Temp.(^{0}C)	Rainfall (mm)	Pan Evaporation (mm/day)	Mean Max. Temp.(^{0}C)	Rainfall (mm)	Pan Evaporation (mm/day)
April	36.18	0.00	4.25	40.00	10.00	4.10	39.2	0.00	4.25
May	38.03	79.15	4.02	40.82	7.80	4.06	40.10	0.00	4.40
June	38.53	9.00	3.51	33.70	155.00	2.60	35.68	94.00	3.47
July	33.68	293.75	2.87	35.76	56.00	3.69	33.58	207.00	3.29
Aug	33.25	129.25	3.36	33.60	178.30	3.15	33.05	173.00	3.37
Sept	33.20	116.50	3.06	32.79	16.00	2.94	33.00	152.00	3.33
October	33.80	56.70	4.93	33.68	0.00	3.00	32.49	148.00	3.48
November	31.84	20.75	2.31	31.70	0.00	2.34	31.51	17.00	2.58
December	39.67	0.00	2.57	30.51	0.00	2.12	33.33	0.00	2.60
January	29.70	0.00	2.49	33.08	0.00	2.45	30.66	0.00	2.61
February	29.69	0.00	2.86	33.34	0.00	2.90	30.94	0.00	3.09
March	34.60	0.00	3.41	39.2	0.00	3.10	33.95	0.00	3.86

The experiment was conducted in a Randomized Block Design with seven treatments and four replications. Each treatment comprising of nine palms planted at 9m hexagonal method accommodating 143 palms per hectare.Treatments comprising of T_1-300:150:300g NPK through fertigation, T_2-600:300:600g NPK through fertigation, T_3-900:450:900g NPK through fertigation, T_4-1200:600:1200g NPK through fertigation, T_5-1200:600:1800g NPK through fertigation, T_6-1200:600:2700g NPK through fertigation, T_7-120:600:1200g NPK (RDF) through soil application (Table 3).

Fertigation treatments were imposed at monthly interval and it has been carried out using injecting pump. All precautions were taken to run the normal water before fertigation to verify the discharge of drippers and also after fertigation to avoid precipitation in drip pipes. For large scale field operations, water soluble solid fertilizer sources are less expensive than liquid formulations and hence, water soluble solid fertilizers viz., urea, DAP(Diammonium Phosphate) and MOP (Potassium Chloride) were utilized for experimentation**.** All cultural practices including weeding, micronutrient application and application of irrigation water were done as per the recommendation of ICAR-Indian Institute of Oil Palm Research. High irrigation water application efficiency associated with negligible deep percolation in drip irrigation systems makes it ideal for fertigation in oil palm.

IRRIGATION WATER REQUIREMENT

The quantity of water applied as irrigation has been given as follows. The method of calculation devised by the institute based on the evaporation rates prevailing at the experimental area has been used to estimate potential-evapotranspiration (PE).

Potential-evapotranspiration (PE) = Pan evaporation × Crop factor

Crop factor 0.7 is considered for an adult oil palm.

Penman's estimate of evaporation and crop factor been used to estimate Potential-evapotranspiration and estimate water requirement for adult oil palm.Water holding capacity of 70% of the field capacity has been taken into consideration to estimate the water requirement per palm per day.

RECORDING OF OBSERVATIONS

Various growth and yield parameters were recorded as per the time schedule framed using standard operating procedures.The height of the palm was recorded in meters at quarterly interval and expressed as per palm per year. The difference in height between two successive years is expressed as height increment in centimeters. Number of leaves produced per palm were recorded on quarterly basis and expressed as per palm per year. The first opened leaf was marked with red color at the beginning of the first quarter and the first opened leaf in the next quarter was marked with yellow color, thus the number of leaves between the two markings indicated the number of leaves produced during that particular quarter.

Number of Fresh Fruit Bunches (FFBs) per palm were recorded in every harvest and expressed on yearly basis as number of fresh fruit bunches per palm per year. Total FFB weight was recorded per palm in each harvest and all harvests of the palms in the treatment 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.

Nutrient use efficiency was calculated for each treatment which is the ratio of FFB yield of oil palm in t ha-1 and total nitrogen(N), phosphorous(P) and potassium fertilizers applied in t ha-1.

Nutrient use efficiency= FFB Yield (t/ha) /Total nutrient as N,P and K

The data thus arrived was subjected to statistical analysis as per the procedure outlined by Panse and

Table 3: Recommended dose of fertilizer for oil palm (RDF)

Age of the palm	N(g/palm)	P_2O_5(g/palm)	K_2O(g/palm)	$MgSO_4$(g/palm)	Boron (Borax)(g/palm)
1st Year	400	200	400	125	25
2nd Year	800	400	800	250	50
3rd Year	1200	600	1200	500	100

Sukhatme (1985). The data on yield components recorded during the last three years *i.e*., 2014-15, 2015-16 and 2016-17 were pooled and analysed. Critical differences (CDs) were worked out at probability pd"0.05 using the ANNOVA wherever the results were significant. The non-significant treatment differences were denoted at NS.

RESULTS AND DISCUSSION

Effect of fertigation on growth of oil palm

Among the growth parameters, number of leaves per palm and height increment did not express any significant difference among the treatments and also no specific trend has been observed with dose of fertigation (Table 4).

Table 4: Height and number leaves per palm as influenced by fertigation

Treatment	Height increment (cm)	No. of leaves/ palm/year
T_1	49	31.9
T_2	45	31.5
T_3	48	31.8
T_4	53	29.9
T_5	44	30.6
T_6	42	29.3
T_7	43	29.4
CD(p=0.05)	NS	NS

Effect on yield characteristics

Effect of different fertigation doses on oil palm during the years 2014-15, 2015-16 and 2016-17 (Table 5&6) revealed that the bunch number per palm and FFB yields were higher in all the treatments during the year 2014-15 and the values were gradually decreased towards 2016-17. This may be attributed to the low rainfall coupled with high temperatures and pan evaporation for a longer period.

The three years pooled data (Table 5&6) in the study with different fertigation doses in oil palm recorded significant difference among the treatmentsfor number of bunches per palm and FFB yield. The bunches were in the range of 6.2 to 8.0 per palm.Except T_1-300-150-300g NPK which recorded the lowest number of bunches per palm (6.2) all other treatments were recorded significantly superior performance over the control T_7-1200-600-1200g NPK through soil application. Narsimha Rao et al, (2011), Sanjeevraddi et al. (2016), also reported similar results in oil palm.Although palms applied with 1200:600:1200g NPK (T_4) through fertigation recorded highest number of bunches per palm (8.0) followed by T2-600:300:600g NPK per palm (7.8), T_3-900:450:900g NKP(7.3), T_5-1200:600:1800g NPK (7.3)and T_6-1200:600:2700g NPK (7.2) per palm, they are not significantly different from each other indicates the lower dose of fertilizer at T_2-600:300:600g NPK is beneficial to obtain higher number of bunches per palm than applying higher doses of fertilizers. Haynes(1985) reported that fertilizer savings through fertigation can be to the tune of 25 - 50 percent in trickle irrigated crops.

Similarly, significant difference was recorded among the treatments for FFB yield per hectare and the yield was in the range of 18.0 to 23.9 t/ha. Highest FFB yield was recorded in T_4(23.9 t/ha) through fertigation, however, it was on par with the treatments T_2(23.1 t/ha), T_3(22.2 t/ha), T_5&T_6 (21.9 t/ha) indicating that the FFB yield increased with increase in number of bunches per palm.While the lowest FFB yield (18.4 t/ha and 18.0 t/ha) were recorded in T7 and T1 treatments respectively, during the same period.

Further, increase in fertilizer dose of NPK did not result in significant increase in number of bunches and FFB yield in oil palm beyond the dose of T_2 indicating that T_2 is sufficient to obtain the equal yield of FFB than higher dose of fertilizers. This may be due to supply of nutrients and water at the active root zone of oil palm which has a shallow root system. Mahalakshmi et al. (2001) also observed that the fertilizer savings through fertigation are presumably because of fertilizer and water are applied to soil where active roots are concentrated in banana.

Nutrient use efficiency

The fertigation at 600:300:600g NPK/ palm/year (T_2) has been found ideal dose to obtain higher FFB yield (23.1 t/ha) which is on par with the higher dose of fertilizers. Nutrient use efficiency has been estimated as 269.2kg FFB/ha kg of nitrogen and potassium and 538.5 kg FFB/ha/kg of phosphorous at T_2 than other treatments (Table 7.)

Table 5: Number of bunchesper palm as influenced by fertigation in oil palm

Treatments	2014-15	2015-16	2016-17	Mean
T_1	7.6	6.0	5.2	6.2
T_2	8.7	8.4	6.1	7.8
T_3	8.7	6.1	7.0	7.3
T_4	8.8	8.0	7.3	8.0
T_5	9.2	6.4	6.4	7.3
T_6	8.0	7.1	6.5	7.2
T_7	7.5	4.8	5.9	6.2
CD(p=0.05)	NS	2.0	1.2	1.3

Table 6: FFB yield as influenced by fertigation in oil palm (t/ha)

Treatments	2014-15	2015-16	2016-17	Mean
T_1	19.4	18.1	15.9	18.0
T_2	25.8	23.8	20.5	23.1
T_3	27.4	18.6	21.6	22.2
T_4	27.7	23.6	21.4	23.9
T_5	26.5	19.1	20.8	21.9
T_6	25.8	21.2	19.9	21.9
T_7	20.3	16.0	17.9	18.4
CD(p=0.05)	NS	5.1	3.6	3.7

Table 7: Nutrient use efficiency as influenced by fertigation

Treatments	N Use efficiency (FFB kg ha^{-1} kg of N)	P Use efficiency (FFB kg ha^{-1} kg of P)	K Use efficiency (FFB kg ha^{-1} kg of K)
T_1	419.6	839.2	419.6
T_2	269.2	538.5	269.2
T_3	172.5	345.0	172.5
T_4	139.3	278.6	139.3
T_5	127.6	255.2	127.6
T_6	127.6	255.2	127.6
T_7	107.2	214.5	107.2

CONCLUSION

Fertigation with NPK 600:300:600g NPK/palm/year at monthly intervals coupled with irrigation based on Potential Evapotransiration (PET) are recommended for higher FFB yield over recommended nutrient application of 1200:600:1200g NPK/palm/yearthrough soil.

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