NUTRITIONAL IMBALANCES AND NUTRIENT MANAGEMENT IN OIL PALM

Chapter · February 2022

4 authors:

Sanjib Kumar Behera
ICAR-Indian Institute of Soil Science, Nabibagh, Berasia Road, Bhopal, Madhya Pr…
144 PUBLICATIONS **2,598** CITATIONS

Arvind K. Shukla
Indian Institute of Soil Science
244 PUBLICATIONS **6,373** CITATIONS

Kancherla Suresh
ICAR-Indian Institute of Oil Palm Research
66 PUBLICATIONS **1,813** CITATIONS

Rk Mathur
ICAR-Indian Institute of Oilseeds Research
109 PUBLICATIONS **910** CITATIONS

Natural Resource Management in Horticultural Crops (2022): 161-185
Editors: Subhra Saikat Roy, Poonam Kashyap and Tarun Adak
Today & Tomorrow's Printers and Publishers, New Delhi - 110 002

8

NUTRITIONAL IMBALANCES AND NUTRIENT MANAGEMENT IN OIL PALM

Sanjib Kumar Behera[1], Arvind Kumar Shukla[1], Kancherla Suresh[2] and Ravi Kumar Mathur[2]

[1]ICAR-Indian Institute of Soil Science, Nabibagh, Berasia Road, Bhopal, Madhya Pradesh

[2]ICAR-Indian Institute of Oil Palm Research, Pedavegi, West Godavari, Andhra Pradesh

Corresponding Author's Email: sanjibkumarbehera123@gmail.com

Introduction

Oil palm (*Elaeis guineensis* Jacq.) with a potential to produce 18 t of oil ha^{-1} $year^{-1}$ (Hoffmann *et al.,* 2014) is the most important oil producing crop of the world. Although it covers about 5.5% of the agricultural land under oil producing crops, it meets 32% of the global oil and fat supply (Palmoilresearch 2014). The countries like Malaysia and Indonesia cultivate and produce major share of palm oil in addition to other major producing countries like Nigeria, Papua New Guinea, Colombia, Thailand and Ecuador. In India, oil palm cultivation started as forest plantations and later as small holders' plantations under irrigated conditions. Subsequently, systematized oil palm cultivation started during 1971-84 covering an area of 3,705 hectares, which increased to 0.30 million hectares by the year 2015-16 having a potential area of 19.3 million hectares for oil palm cultivation spread over nineteen states of the country (Rethinam *et al.,* 2012) (Figure 1). At present, oil palm is predominantly grown in Andhra Pradesh, Mizoram, Tamil Nadu, Karnataka, Kerala, Maharashtra, Goa, Odisha, Chhattisgarh, Assam and Arunachal Pradesh states of India. Of which, Andhra Pradesh is having the highest area under oil palm cultivation (Figure 2). Oil palm produces fresh fruit bunches (FFB) from which two types of oil *i.e.,* crude palm oil and palm kernel oil are obtained. These oils are used for domestic and industrial purposes. On average, it produces about 4 to 6 tonnes of crude palm oil and 0.4 to 0.6 tonnes of palm kernel oil per hectare per year during its productive life span from 4 to 30 years. Visualizing its potential, the Government of India has been giving emphasis to expand the area under oil palm cultivation to meet the ever increasing vegetable oil demand of the country and reduce the expenditure on import of vegetable oils.

Fig 1. Potential areas of oil palm cultivation in India

Fig 2. Oil palm plantation in West Godavari district of Andhra Pradesh

Oil palm grows well in almost all types of soils. Best suited soils are well drained, deep loamy, alluvial soils rich in organic matter with an adequate water holding capacity. In India, a great variety of soils ranging from red sandy loam/sandy clay loam (Alfisols), alluvial silty loam (Inceptisols / Entisols), heavy black soils (Vertisols) and acidic red laterite soils (Oxisols) are under use for oil palm cultivation. For example, it is grown in red sandy, red loamy, red loam with clay base, deltaic alluvium soils in Andhra Pradesh. In Karnataka, it is grown in red and brown sandy loams and black clayey soil. River alluvium and red sandy soils, red soils, red loamy and clay loam soils are used for growing oil palm in Tamil Nadu. Laterite soils are used for oil palm cultivation in Kerala. However, alkaline, highly saline, water logged and coastal sandy soils are avoided for oil palm cultivation. Survey of oil palm plantation in states of Andhra Pradesh, Goa, Karnataka, Mizoram, Goa and Tamil Nadu revealed that oil palm is being cultivated in different soil types having Alfisols, Inceptisols, Entisols and Vertisols soil orders with soil pH, electrical conductivity (EC) and organic carbon (OC) content varying from 4.11 to 8.74, 0.01 to 2.54 dSm^{-1} and 0.10 to 48.4 g kg^{-1} respectively (Table 1). The crop requires at least 5 hours of bright sunlight per day. It comes up well between 29-33 ^{0}C of mean maximum and 22-24 ^{0}C mean minimum temperature. A high level of relative humidity viz., more than 80% is favourable for better growth and development of oil palm. Oil palm requires evenly distributed rainfall of 150 mm per month to meet evapo-transpiration demand. Under Indian conditions, several months in a year have little or no rainfall, while few months have abundant rainfall. Therefore, oil palm is promoted as an irrigated crop in India as the rainfall is much less than 2000 mm in most of the cultivated region and rainfall is not evenly distributed having a few dry months.

The high productivity of oil palm has been demonstrated in well managed plantations of India and the highest yield of 53.20 t FFB ha^{-1} $year^{-1}$ has been recorded (Rethinam *et al.,* 2012). On average, oil palm farmers in West Godavari districts of Andhra Pradesh are obtaining FFB yield of 25 to 30 tonnes ha^{-1} $year^{-1}$ with efficient moisture and nutrient management. Many factors contribute to the high productivity of oil palm including improved planting materials and crop management practices. Out of the major practices that are responsible for yield improvement, nutrient management by fertilizer application is the most important contributor accounting for 26 percent of the FFB yield increment in oil palm (Prasad *et al.,* 2012). This was supported by numerous fertilizer response trials conducted in different countries which showed higher FFB yield responses to balanced nutrition. Hence, fertilizers not only have the greatest impact

Table 1. Location-wise soil types, soil properties, age and average FFB yield of oil palm plantations of India

Location	Soil order	Soil pH	Soil EC(dS m^{-1})	Soil OC content (g kg^{-1})	Average annual precipitation (mm)	Age of plantations (year)	FFB yield (t ha^{-1} $year^{-1}$)
West Godavari (Andhra Pradesh)	Alfisols	5.44-8.26	0.05-2.15	0.80-31.2	1094	12-18	7-32
North Goa, South Goa (Goa)	Alfisols	4.25-6.77	0.05-1.06	5.07-48.4	3005	5 - 21	1-22
Mysore, Hassan (Karnataka)	Alfisols Inceptisols	4.91-8.74	0.10-2.54	1.17-28.9	1126	4-18	3-53
Aizwal, Kolasib, Mamit (Mizoram)	Inceptisols Alfisols	4.41-5.41	0.03-0.48	3.12-35.9	1881	5-7	1-16
Surat (Gujarat)	Vertisols	6.38-8.28	0.26-1.16	6.24-16.8	1107	4-5	1-19
Thanjavur (Tamil Nadu)	Inceptisols Vertisols Entisols	4.76-7.97	0.01-0.31	0.10-7.80	940	4-19	4-26

Source: Behera *et al.,* 2016a, 2016b, 2016c, 2017 & 2018b on productivity but also constitute the highest operational cost in well-established oil palm plantations.

Nutrient requirement in oil palm

Oil palm needs a huge amount of nutrients as it produces one of the highest dry matters among the C3 plants. The nutrient requirement of oil palm varies widely, and depends on the soil type, ground cover conditions, target yield, type of planting material, palm spacing, palm age, as well as climate and other environmental factors. It is also associated with the amount of nutrients removed in harvested fruit bunches (Figure 3 and 4), nutrients recycled to the soil through pruned fronds, male inflorescences and leaf wash and nutrients immobilized in the palm biomass. Oil palm removes a higher amount of nutrients compared to other plantation crops (Table 2). It removes about 162, 30, 217, 38 and 36 kg of N, P, K, Mg and Ca ha^{-1} $year^{-1}$ respectively, for 2.5 t of oil ha^{-1} $year^{-1}$. Assuming an oil extraction ratio of 25 per cent, 2.5 t of oil per ha is equivalent to 10 t FFB ha^{-1} $year^{-1}$. But average FFB yield in well managed plantations is much higher. Nutrient content in one tonne of FFB is about 2.94, 0.44, 3.71, 0.77 and 0.81 kg of N, P, K, Mg and Ca, respectively, and 1.51, 2.47, 2.15, 4.76 and 4.93 g of Mn, Fe, B, Cu and Zn, respectively (Ng and Thamboo 1967, Ng 1977). Higher nutrient content in FFB leads to greater nutrient uptake by oil palm fruit bunches especially K. A yield level of 30 t FFB ha^{-1} leads to removal of about 110 kg K ha^{-1}. Out of which, 60 kg K may be recycled back if empty fruit bunches are returned to the field after extraction of oil and kernels. The amount of annual nutrient uptake in trunk tissue is smaller than nutrient uptake in fronds and bunches. However, large amounts of nutrients get accumulated in the trunk over 20-25 years of life span of plantation. These nutrients added to soil of felled trunks are returned to the soil at the time of replanting.

Fig 3. Palm crown with fresh fruit bunches

Fig 4. Fruits in a bunch

Table 2. Nutrient removal by plantation crops vis-à-vis oil palm

Crop	Yield (ha^{-1} $year^{-1}$)	Nutrient removal (kg ha^{-1} $year^{-1}$)				
		N	P	K	Ca	Mg
Oil palm	2.5 t of oil	162	30	217	36	38
Sugarcane	88 t of cane	45	25	121	-	-
Coconut	1.4 t of dry copra	62	17	56	12	6
Banana	45 t of fruit	78	22	224	-	-
Rubber	1.1 t of dry rubber	7	1	4	-	-
Coffee	1 t of made coffee	38	8	50	-	-
Tea	1.3 t of dried leaves	60	5	30	3	6

Source: Mengel and Kirkby (1987)

Nutrient imbalances in oil palm

Nutritional imbalance is one of the major limitations to oil palm productivity in oil palm growing countries including India. It is possible to overcome nutrient imbalances by proper nutrient management. Otherwise, nutrient imbalances like deficiency / disorder could be rectified after proper identification followed by application of that particular nutrient(s) either by soil or foliar application. The nutrient deficiencies and disorders in oil palm, their symptoms and corrective measures recommended for Indian plantations are described below.

Nitrogen deficiency

Nitrogen deficiency occurs commonly due to prolonged water logging leading to poor aeration, inadequate drainage or high water table leading to denitrification. Lateritic soils poor in fertility and acidic in reaction with reduced nitrification lead to low nitrogen availability to plants. Planting in top soil or close to large boulders just lying beneath the soil surface, results in reduced availability of the nutrients. Competition with grasses proliferated in palm basins and inter-row spaces lead to competition between palm roots and roots of grasses. Insufficient N application also caused N deficiency. Inhibition of N mineralization due to the effect of low pH, high salt content and unfavourable soil temperature and water content on soil microbial activity adds to the cause.

In nursery, the most obvious symptom is that the seedlings first become dull and pale green colour. As the deficiency becomes more acute there is a gradual colour change to lemon yellow. Growth is also reduced. In the main field, chlorosis appears first on older fronds, later spreading to younger tissues in older palms (Figure 5). The tissues of the midrib become bright yellow or orange, which contrast with the paler chlorosis of the laminar tissues. The swelling at the pinna base (apocone) also becomes yellow or orange in colour as N deficiency is pronounced. Unlike Mg deficiency, both ranks of pinnae become equally chlorotic and there is no shading effect of the upper rank pinnae on the lower one. In the later stages of acute deficiency, dark coloured discolouration begins to appear normally towards the pinnae, and die – back develops from the pinnae tip and margin. N deficiency symptoms are observed if the available N content of frond 17 is 2.0 – 2.5%. Severe deficiency occurs if it contains N less than 1.5% of dry matter.

To control N deficiency in nursery seedlings, it is recommended to spray 2% urea solution at weekly or fortnightly intervals till deficiency symptom disappears. Cultural practices such as eradication of grasses around the seedlings and improving drainage by making drains helps in preventing occurrence of N deficiency. Application N fertilizer @ 1200g N / adult palm / year (equivalent to 3 kg of urea or 6 kg of ammonium sulphate or 2 kg of urea plus 1.5 kg of DAP/adult palm/year) in 3 - 4 splits is recommended. Addition of organic manures like farm yard manure and neem cake help in overcoming the problem.

Fig 5. Nitrogen deficient Palm

Phosphorus deficiency

Phosphorus deficiency occurs when oil palm is grown in acidic and P deficient soils. In small seedlings, the oldest leaves become dull and assume the olive green colour. The chlorotic condition increases in severity. Under field conditions, P deficient leaves do not show specific symptoms other than reduced frond length. A stunned growth with short dark fronds appears in palms (Figure 6a). Trunks of affected palms are narrow and tapered (Figure 6b). Application of 600g of P_2O_5 / adult palm / year (equivalent to 4 kg of SSP or 1.5 kg of DAP/ adult palm / year) in 3 - 4 splits is recommended to meet the P requirement of oil palm.

Fig 6a. Phosphorous deficient oil palm (small and stunted)

Fig 6b. Phosphorous deficient oil palm trunk

Potassium deficiency

Potassium deficiency occurs when oil palm is grown in soils of with low K status, peat soils and soils with poor moisture retention ability. Heavy application of fertilizers like calcium ammonium nitrate, rock phosphate and kieserite also induce K deficiency. The development of K deficiency symptoms occurs in the older fronds. The most common deficiency symptoms are confluent orange spotting, mid – crown yellowing, orange blotch and premature desiccation. The symptoms of confluent orange spotting begin to appear in older leaves, when the K level of frond #17 falls below 1.0% on dry matter. The other symptoms described above occur when the K level of frond #17 falls to 0.4 – 0.6% of dry matter.

Waterson first used the term 'confluent orange spotting'. Symptoms first appear as pale green rectangular spots bounded by the veins on the pinnae of the older leaves. As the age increases, the outline of the spots becomes irregular and colour changes through olive green to bright orange with coalescence between adjacent spots until a rectangular mass develops in the centre of older spots (Figure 7). When spotting becomes extensive, tissues at the tip and edges of pinnae become pale – greyish brown colour and brittle as they dry out. When more confluent orange spotting occurs, older fronds appear copper or bronze in colour from a distance. In severe cases, fronds may become desiccated but do not collapse. It also retains a semi – erect habit, giving the crown, the shape of an inverted cone. Chapas and Bull first described 'Mid – crown yellowing' –a type of K deficiency in 1956 from Nigeria. The earliest symptom is a rather dull uniform khaki or ochre chlorosis in one of the younger fronds situated in the upper part of the crown. Chlorosis develops from an initial but variable point on the pinnae and spreads until the whole pinna is uniformly affected, with the pinna margin later becoming necrotic. Symptoms described from Benin as 'Decoloration diffuse' also agree with those of mid – crown yellowing. The 'shading effect' characteristic of Mg deficiency is also found in this symptom i.e. where one leaflet is covered by another and the covered portion does not show chlorosis. Orange blotch was first described in Africa as 'Orange spot complex' and later as 'Mbawsi symptom'. Large, elongated and diffused olive green blotches appear on the pinnae of older fronds, located about halfway along the length of pinnae and in pairs on each side of the midrib. With increasing age, the discoloration changes to bright yellow and then orange, with well-defined margins between them and healthy tissues. Ultimately all pinnae become chlorotic, which contain a mass of minute spots. The terminal results of K deficiency symptoms mentioned above viz., confluent orange spotting, mid – crown yellowing and orange blotch end in marginal or terminal die – back of the pinnae. The tissue becomes grey in colour, brittle and desiccated. Finally, fragmentation occurs. To control K deficiency, application of 1200g of K / adult palm / year (equivalent to 2 kg of MoP / adult palm / year) in 3-4 splits followed by leaf analysis is recommended.

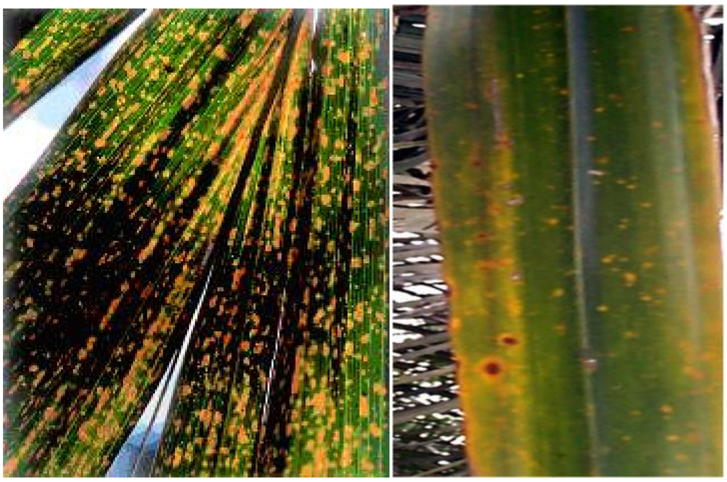

Fig 7. Potassium deficiency symptom in oil palm leaves (Typical confluent orange spotting)

Magnesium deficiency

Heavy application of potash fertilizers causes Mg deficiency. Mg deficiency also appears when palms are grown on soils of granite origin, peat soils and acid – sulphate soils. The symptoms of Mg deficiency are likely to become visible on older leaves when the Mg content falls to about 0.15 - 0.2% of dry matter. Symptoms are also observed when the ratio of K: Mg and N: Mg exceeds about 5 and 10 respectively. Olive green and ochre coloured (Figure 8) areas appear on the pinnae of older leaves and merge gradually with the healthy green tissue. The yellow colour spreads down towards the frond midrib until the whole pinnae are affected, becoming a deep orange colour in later stages. 'Shading effect' is the most apt diagnostic features of Mg deficiency, in which there is an absence of chlorosis in parts of affected pinnae, protected from direct sunlight. As the deficiency becomes more intense, the purplish brown lesions expand rapidly until the entire pinna is affected with distal and marginal tissues being most affected. Application of 500 g magnesium sulphate /adult palm / year or spraying of 2% solution of epsom salts at 3 – 4 intervals for a period of 2 – 3 weeks is recommended to overcome Mg deficiency.

Fig 8. Orange frond or yellowing showing magnesium deficiency in oil palm

Zinc deficiency

It occurs in highly weathered acid and calcareous soils. Heavy application of phosphatic fertilizer also induces Zn deficiency. Appearance of small, narrow white streaks (Figure 9) on lower and mid-crown fronds occurs. It may also produce blotchy leaf symptoms. Two to three applications of zinc sulfate (1 g Zn L^{-1}) as a foliar spray and balanced application of P fertilizer are recommended.

Fig 9. Zinc deficiency symptom

Boron deficiency

Boron deficiency in oil palm occurs due to high rainfall conditions, sandy and peat soils, low and high pH soils, and heavy applications of nitrogen and potash fertilizers. On the basis of leaf analysis data, when the level of boron falls below 10 ppm of dry matter, symptoms of incipient deficiency are observed. The different malformations (Figure 10) such as hook leaf, fish bone leaf, rounded frond tip, blind leaf, leaflet shatter and bristle tip are attributed to B deficiency.

In hook leaf, a terminal hook develops on one or more pinnae, usually towards the tip of the frond. The hook may have a corrugated appearance and tissue distortion affecting both the midrib and lamina. Because of hook fragility, hook leaf symptoms are most frequently seen on younger fronds. The increasing severity of hook leaf symptoms is marked by folding and general distortion of tissues. The 'Fish bone leaf' is considered to be a part of hook leaf - little leaf complex. One or more fronds may be slightly smaller than normal but the pinnae are abnormally stiff, narrow and widely spaced along the rachis, sometimes bearing terminal hooks. An early symptom of possible B deficiency is the rounding of the tip outline of the youngest frond. This results from the shortening of the pinnae towards frond tip. In blind leaf, a pair of pinnae does not terminate the apex of the oil palm frond. Occasionally, one or more laterally situated pinnae at the tip develop in such a plane that the terminal gap is less large. In leaflet shatter, pinnae drop sharply at one particular point. The midrib is normally fractured transversely and the adjoining laminar tissues are rapidly shredded through wind action. This appears as one of the shattered lamina tissues and remnants of midrib protruding from the rachis. Bristle tip is regarded as a transitional symptom between hook leaf and little leaf. There is a replacement of a group of pinnae at the frond apex by a tuft of long, fibrous bristles of varying rigidity. Corrective application of 20g of boron/adult palm/year in the palm basin


Hook leaf


Fish bone leaf


Rounded tip


Blind leaf

Crinkle leaf Turing leaf

Fig 10. Boron deficiency symptoms in oil palm

Copper deficiency

Copper deficiency appears in peat soils (where Cu is complexed by organic compounds) and coarse-textured ferrallitic and farraginous soils poor in copper and calcareous soils. Heavy application N and P fertilizers also induce copper deficiency. Deficiency symptom appears initially as whitish yellow mottling of younger fronds. As the deficiency intensifies, yellow, mottled, interveinal stripes appear and rusty, brown spots develop on the distal end of leaflets. Affected fronds and leaflets are stunted and leaflets dry up. Copper deficient plants exhibit severe stunting in the nursery (Figure 11). Basal application of 50g Cu sulfate to affected palms or application of potash fertilizer eliminates the deficiency.

Fig 11. Copper deficiency in nursery

Iron deficiency

Iron deficiency occurs in soils of very high pH, on or near termite mounds, overlying coral and on poorly drained soils. Heavy application of phosphatic fertilizers results in Fe deficiency. Interveinal chlorosis appears on the youngest fronds but leaf veins remain green (Figure 12). The youngest fronds later turn white but older fronds are yellow. Growth ceases and death may occur after one year in severely Fe deficient palms. It is recommended to provide two to three foliar applications of ferrous sulphate (0.5%) at a weekly intervals to rectify the problem.

Fig 12. Iron deficiency symptoms

Manganese deficiency

Manganese deficiency appears in highly leached tropical soils, deep peat soils, or where large amounts of limestone have been applied to sandy soils. Soil with high exchangeable Mg status also induces magnesium deficiency. During deficiency, discontinuous interveinal chlorotic streaks first appear on younger fronds. These longitudinal streaks eventually become chlorotic with a striped appearance. Newly emerged fronds become progressively smaller and chlorotic, and the palm canopy appears retarded. In severe cases, chlorosis and necrosis affect the newly emerged spear before frond pinnae have expanded. In contrast to Mg deficiency, the symptoms are found on young rather than on older fronds. The symptoms are equally pronounced on upper (sun exposed) and lower (shaded) rank pinnae. Foliar spray of 50 g Mn L^{-1} is sufficient to overcome Mn deficiency.

White stripe (N/K imbalance)

When N: K ratio in the leaves is more than 2: 5, white stripes appear. B deficiency and excessive N application also induce development of white stripe. Narrow bands of chlorotic tissue appear in the pinnae (Figure 13). The white stripes are apparent in young fronds, as the spear opens, extending the entire length of pinnae. In the early stages, the chlorosis produces a stripe delineated from the adjacent green tissue. The stripe may be at any portion between the midrib and the edges of lamina. In severe cases, there is a change in the morphology of the crown, i.e., upright and obconical in shape. Application of 2-3 kg potassium chloride / palm / year and temporary cessation of N fertilizer application is recommended.

Fig 13. White stripe showing N/K imbalance

Nutrient management

Nutrient management in nursery

Oil palm is normally propagated by seedlings which are raised in poly bags for 12 months in a double stage nursery. The growth and productivity of oil palm are mainly dependent on the quality of seedlings. The growth and vigour of oil palm seedlings are mainly decided by nutrient management as it is a heavy feeder and requires a huge amount of nutrients.

The best potting mixture for growing the seedlings should be a medium containing soil, sand and organic manure in 1:1:1 ratio. DAP and neem cake powder @ 100g each should be mixed with the potting mixture before filling the poly bags meant for main nursery. Oil palm factory wastes like palm oil mill effluent (POME) sludge, decanter cake/muck, fruit fibre, nut shells and empty fruit bunches are cost effective and easily available in huge quantity as compared to regular organic manures. POME sludge @10% in a potting mixture can be an optimum dose for raising good quality oil palm seedlings.

During the first few weeks of growth, the seedling is entirely dependent on the supply of stored food material in endosperm. The amount of fertilizers required for the growth of seedlings depends on the composition of potting mixture and variety. When the mixture contains soil, sand and manure in equal proportion, fertilizer dose of 10 g N, 5 g P and 10 g K/ seedling applied in equal splits at an interval of three months is found to be ideal under rainfed conditions. Results of the preliminary study showed that N, P and K @ 30 g, 38 g and 25 g respectively applied at monthly intervals has been found optimum for better growth of seedlings. Manual application of fertilizer is laborious and expensive. Chemical fertilizers like DAP and NPK (17:17:17) complex fertilizers can be applied @ 50 percent of the recommended dose of fertilizers/seedling through drip system of irrigation as they showed promising results with respect to important characters like seedling height, leaf and root production, stem girth and total dry biomass production.

Nutrient management in main field

Nutrient management in oil palm is carried out to supply each palm with adequate nutrients in balanced proportions to ensure efficient nutrient uptake, healthy vegetative growth and optimum economic FFB yields and to minimize negative environmental impacts related to over-fertilization and land degradation. These multi-objectives demands that fertilizer recommendation systems for oil palm entail more than just computation of optimum fertilizer rates. The other major components in the system are fertilizer management, which includes correct timing, placement and methods of fertilizer application and right source of fertilizer, recommendation of optimum growing conditions for oil palm to maximize nutrient uptake, and monitoring of growth, nutrition and yield targets. Therefore, the fertilizer recommendations require a good understanding of general principles governing mineral nutrition of oil palm and methods to maximize fertilizer use efficiency. The dose and the type of fertilizer to be applied in any location should be strictly based on the results of complete fertilizer experiments. As many variables are involved, it is only with the greatest caution that results from trials in one area could be used to assist in formulating a fertilizer programme in another.

Recommended nutrient for oil palm grown under rainfed condition is given in Table 3. It is advised to apply 400-200-400-125 g of N-P_2O_5-K_20-$MgSO_4$ per palm per year during the first year of plantation, 800-400-800-250 g of N-P_2O_5-K_20-$MgSO_4$ per palm per year during the second year of plantation and 1200-600-1200-550 g of N-P_2O_5-K_2O-$MgSO_4$ per palm per year during the third year onwards (Rao *et al.,* 2014). Fertilizer requirements as per the availability of different fertilizers available in the market are given in Table 4. Research on oil palm nutrition conducted at different agro-climatic locations namely Gangavathi (Karnataka), Mulde (Maharashtra), Vijayarai (Andhra Pradesh) and Aduthurai (Tamil Nadu) revealed that the dose of fertilizer varied from place to place. The dose of 1200-600-1200 g of N-P_2O_5-K_2O per palm per year was found to produce FFB yield of 12-15 t FFB ha^{-1} at Tungabhadra command area of Karnataka (Reddy *et al.,* 2009) whereas, application of 800-400-1800-500 g N-P_2O_5-K_2O- $MgSO_4$ per palm per year resulted in the production of 18 to 19 t FFB ha^{-1} under sandy loam soils of Andhra Pradesh (Rao 2009). However, efforts must be made to modify these doses based on soil and leaf analysis. Borax at the rate of 100g/palm/year is recommended in B deficient soils or when the B deficiency symptoms are noticed. If organic nutrient sources like FYM, green manure and neem cake are available, then 50-100 kg of FYM or 100 kg of green manure per palm per year can be applied. Neem cake at the rate of 5 kg/palm/year can also be applied. Whenever organic fertilizers are applied, N applications through chemical fertilizers need to be reduced proportionately.

Table 3. Recommended dose of nutrients for oil palm

Age of the Palm (Years)	Nutrients (g/palm/year)			
	N	P_2O_5	K_2O	$MgSO_4$
1st	400	200	400	125
2nd	800	400	800	250
3^{rd} and above	1200	600	1200	500

Table 4. Fertilizer requirement for oil palm

Fertilizers	Fertilizer requirement (g/palm/year) Age of the palm (years)		
	1st	2nd	3rd and above
Urea	870	1740	2610
Single super phosphate (SSP)	1250	2500	3750
Muriate of potash (MoP)	670	1340	2000
Magnesium sulphate	125	250	500
Urea	700	1400	2100
Diammonium phosphate (DAP)	435	870	1305
Muriate of potash (MoP)	670	1340	2000
Magnesium sulphate	125	250	500
Urea	870	1740	2610
Rock phosphate	1000	2000	3000
Muriate of potash (MoP)	670	1340	2000
Magnesium sulphate	125	250	500
Ammonium sulphate	1942	3884	5825
Single super phosphate (SSP)	1250	2500	3750
Muriate of potash (MoP)	670	1340	2000
Magnesium sulphate	125	250	500
Ammonium sulphate	1942	3884	5825
Rock phosphate	1000	2000	3000
Muriate of potash (MoP)	670	1340	2000
Magnesium sulphate	125	250	500
Ammonium sulphate	1562	3124	4685
Diammonium phosphate (DAP)	435	870	1305
Muriate of potash (MoP)	670	1340	2000
Magnesium sulphate	125	250	500

Choice of fertilizers

In Oil Palm plantations, fertilizers like urea, ammonium sulphate and diammonium phosphate may be used as a source of N as per their availability in the market. However, urea is found to be cheaper. There is a strong interaction between N and P fertilizers as applied N fertilizer will not be efficiently utilized unless adequate P fertilizer is applied. Fertilizers like single super phosphate, rock phosphate and diammonium phosphate can be applied as a source of phosphorus nutrition. Rock phosphate is generally profitable in oil palm as compared to super phosphate. However, under high pH conditions, application of rock phosphate is not recommended. Potassium may be applied as chloride or sulphate according to availability and price. Potassium chloride (Muriate of potash) is found to be cheaper and available in the local market. Magnesium sulphate can be applied as a source of Mg to oil palm.

Frequency of fertilizer application

It is advised to apply fertilizer in four equal splits at three months intervals under irrigated conditions. Irrigation should be given immediately after fertilizer application. Under rainfed conditions, fertilizer application should be made shortly before the onset of the rainy season and not before or during the dry season or in the middle of the rains, and are generally given in two splits.

Basin management

Reddy *et al.,* (2002) observed that most roots of oil palm were in the zone of 10-40 cm in juvenile plantations where the moisture content was less indicating the uptake of water by the roots. In another study, Suresh *et al.,* (2003) indicated that root biomass in adult plantations 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 increase of distance from palm base (Figure 14).

As absorbing roots in adult palms spread up to a maximum distance of 2m from the trunk and to a depth of 40 cm from the surface, for higher water and nutrient use efficiency, irrigation and fertilizer should be applied up to 2 m from the palm trunk. Vertical development of root system largely depends upon the sub soil water table. The Basin area of oil palm almost represents its active root zone. Hence, it must be kept clean and weed free to avoid competition for nutrients and water.

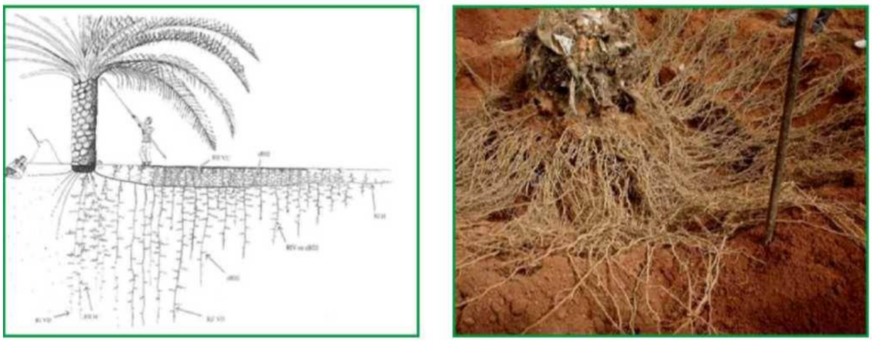

Fig 14. Active root zone of oil palm

Methods of fertilizer application

All the fertilizers should be evenly broadcasted over the clean weeded circles about 1 m away from the palm base and incorporated into the soil with the help of forks (Figure 15). The area of application should be extended as the weeded palm circles become progressively enlarged as the palm gets older. Under normal circumstances, N and K fertilizers should be applied in close sequence followed by Mg, P and B fertilizers. Fertilizers can be mixed in water when drip irrigation method is followed.

Approaches for fertilizer application

The fertilizer requirements of oil palm depend on many interrelated factors that vary from one environment to another. Even in superficially similar agro-ecological environments, the yield responses of oil palm to fertilizers can vary substantially. Thus, the easiest way to determine fertilizer requirements of oil palm is from fertilizer response trials but it is difficult, time consuming and costly to conduct them in different environments, where oil palm is grown. The other alternative is to use some variables that are related to fertilizer requirements of oil palm based on sound principles of soil fertility and mineral nutrition of plants. Optimum fertilizer rates for oil palm could be decided by soil and leaf analysis approaches.

Fig 15. Fertilizer application in oil palm

In soil analysis approach, the soil parameters are assessed to determine nutrient supplying capacity of the soil. The underlying premise is that soil can continuously supply a proportion of nutrients to palms with negligible depletion of soil nutrients. Thus, it makes the assumption that soil nutrients taken up by palms can be replenished by soil weathering processes and biological activities. However, soil nutrient supply varies substantially depending on its fertility status (Table 5) and interpretation of soil test results (Table 6) (Pushparajah and Chew 1979).

Table 5. Soil parameter for oil palm

Soil parameter	Acidic	Neutral	Alkaline
PH	<6.5	6.5 to 7.5	>7.5
EC (dS/m)	<2.0 normal		
	Low	Medium	High
Organic C (%)	0.50	0.50 to 0.75	>0.75
Available P_2O_5 (kg/ha)	<20	20 to 50	>50
Available K_2O (kg/ha)	<150	150 to 300	>300
Exchangeable Ca (meq/100 g)	<1.5	1.5	>1.5
Exchangeable Mg (meq/100 g)	<1.05	1.05	>1.05
Available boron (B) (mg kg^{-1})	<0.5 deficient		

Table 6. Interpretation of soil nutrient status for fertilizer recommendations

Nutrient status	Interpretation
Low	Nutrient deficiency symptoms may occur. Fertilizer response is likely. Increase fertilizer dose by 25%.
Medium	Hidden hunger is likely. May respond to fertilizer. Maintain fertilizer dose.
High	No response to fertilizer. Reduce fertilizer dose by 25%

Leaf analysis is perhaps the most common diagnostic tool to determine the nutritional status of oil palm and estimate the appropriate fertilizer rates. This is because of a significant relationship between leaf nutrient concentration and FFB yield at a site. It is further observed that the highest yield appears to be critically dependent on exact leaf nutrient composition. Each nutrient has a maximum concentration, and when all nutrients reach their highest values, then the maximum yield is attained.

The critical levels of nutrients for oil palm proposed by von Vex Kull and Fair Hurst (1991) are given in Table 7. If the nutrient concentration in leaf sample is found to be deficient, then it is advised to go for fertilizer application for bringing the leaf nutrient concentration to optimum level (Pushparajah and Chew 1979).

Table 7. Nutrient concentration (deficiency, optimum and excess levels) of 17th oil palm frond

Palm Age	Nutrients	Deficiency	Optimum	Excess
Young Palms (< 6 Years)	N (%)	<2.50	2.60-2.90	>3.10
	P (%)	<0.15	0.16-0.19	>0.25
	K (%)	<1.00	1.10-1.30	>1.80
	Mg (%)	<0.20	0.30-0.45	>0.70
	Ca (%)	<0.30	0.50-0.70	>0.6
	S (%)	<0.20	0.25-0.40	>1.00
	Cl (%)	<0.25	0.50-0.70	>1.00
	B (ppm)	<8	15-25	>40
	Cu (ppm)	<3	5-8	>15
	Zn (ppm)	<10	12-18	>80
Old Palms (> 6 Years)	N (%)	<2.30	2.40-2.80	>3.00
	P (%)	<0.14	0.15-0.18	>0.25
	K (%)	<0.75	0.90-1.20	>1.60
	Mg (%)	<0.20	0.25-0.40	>0.70
	Ca (%)	<0.25	0.50-0.75	>1.00
	S (%)	<0.20	0.25-0.35	>0.60
	Cl (%)	<0.25	0.50-0.70	>1.00
	B (ppm)	<8	15-25	>40
	Cu (ppm)	<3	5-8	>15
	Zn (ppm)	<10	12-18	>80

Source: Von Vex Kull and Fair Hurst (1991)

The differences in oil palm leaf nutrient concentrations and their sufficiency ranges pose difficulty in the development of fertilizer recommendations. Because leaf nutrient concentrations are influenced by several factors including leaf age, leaflet rank, leaf number, fruiting cycle, planting material, palm density, fertilizer treatment, rainfall, and soil properties. Therefore, it is recommended to develop fertilizer recommendations based on both soil and leaf analysis results. Optimum nutrient ranges devised for oil palm plantations of different locations of India (Table 8) can be utilised for interpretation of leaf analysis values and development of fertilizer recommendations for oil palm plantations of different areas.

Table 8. Optimum leaf nutrient ranges for oil palm plantations at different locations of India

Nutrient	Goa	Karnataka	Mizoram	Gujarat	Andhra Pradesh	Tamil Nadu
N (%)	1.64-2.79	2.24-2.97	1.91-2.95	2.63-2.85	1.57-2.63	1.61-2.11
P (%)	0.36-0.52	0.08-0.40	0.46-0.65	0.16-0.18	0.08-0.16	0.11-0.12
K (%)	0.37-0.75	0.78-0.91	0.63-1.00	0.56-0.88	0.48-0.88	0.33-0.81
Mg (%)	0.35-0.63	0.25-0.98	0.48-0.88	0.34-0.84	0.25-0.71	0.23-0.73
B (mg/kg)	3.10-13.9	5.71-31.0	9.41-31.0	9.10-32.5	22.6-60.2	30.6-54.8

Source: Behera *et al.,* 2016a, 2016b, 2016c, 2017 & 2018b

From an exhaustive study covering a large number of respondents selected randomly from three major oil palm growing states like Andhra Pradesh, Karnataka and Goa of India, Prasad *et al.,* (2013) reported a wide range in the quantity of fertilizer applied indicating that oil palms were either under-fertilized or over-fertilized. This results in variations of soil properties, nutrient availability in soil and varied leaf nutrient concentrations which has also been recorded by spatial variability studies of soil nutrient availability and leaf nutrient concentrations in oil palm plantations of different areas of India (Behera *et al.,* 2015, 2016d, 2016e & 2018a). Also, the low cost and easy availability of some fertilizers have encouraged farmers to make excessive applications with the belief that high yields would be ensured. However, this management adversely affects productivity, fruit quality and ground water quality. It is therefore pertinent for the farmers to economize on fertilizer adopting a strategy for site-specific and/or area-specific management based on spatial variability of the field to make oil palm production environmentally sustainable and economically viable.

Conclusion

Location specific fertilizer trials conducted so far have revealed that the quantity of fertilizers to be applied varies from place to place and accordingly fertilizer dosage has been recommended. Fertilizer application in oil palm should be strictly based on soil and leaf analysis for effective utilization, while micronutrients should be applied based on the visual symptoms. Nutrient contents of oil palm biomass are considerable and could be effectively recycled to meet its nutritional requirements.

References

Behera S. K., Rao B. N., Suresh, K. and Manoja, K. (2016a). Soil nutrient status and leaf nutrient norms in oil palm (*Elaeis guineensis* Jacq.) plantations grown on southern plateau of India. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* 86(3): 691-697.

Behera S. K., Suresh, K. Rao B. N., Manoja, K. and Manorama, K. (2016b). Soil nutrient status and leaf nutrient norms in oil palm (*Elaeis guineensis* Jacq.) plantations grown on west coastal area of India. *Communications in Soil Science and Plant Analysis.* 47(2): 255-262.

Behera, S. K., Mathur, R. K., Shukla, A. K., Suresh, K. and Prakash, C. (2018a). Spatial variability of soil properties and delineation of soil management zones of oil palm plantations grown in a hot and humid tropical region of southern India. *Catena* 165: 251-259.

Behera, S. K., Rao B. N., Suresh, K., Ramachandrudu, K. and Manorama, K. (2016c). Soil fertility, leaf nutrient concentration and yield limiting nutrients in oil palm (*Elaeis guineensis*) plantations of Surat district of Gujarat. *Indian Journal of Agricultural Sciences.* 86(3): 409-413.

Behera, S. K., Rao, B. N., Suresh, K., Manorama, K., Ramachandrudu, K. and Manoja, K. (2015). Distribution variability of soil properties of oil palm (*Elaeis guineensis* Jacq.) plantations in southern plateau of India. *Indian Journal of Agricultural Sciences* 85(9): 1170-1174.

Behera, S. K., Shukla, A. K., Suresh, K. and Mathur, R. K. (2018b). Evaluation of nutritional status and yield limiting nutrients in oil palm plantations of Cauvery delta zone of Tamil Nadu. *Journal of the Indian Society of Soil Science* 66(1): 89-95.

Behera, S. K., Suresh, K., Ramachandrudu, K., Manorama, K., and Rao, B. N., (2016d). Mapping spatial variability of leaf nutrient status of oil palm (*Elaeis guineensis* Jacq.) plantations in India. *Crop & Pasture Sciences*. 67(1): 109-116.

Behera, S. K., Suresh, K., Rao B. N., Mathur, R. K., Shukla, A. K., Manorama, K., Ramachandrudu, K., Harinarayana, P. and Prakash, C. (2016e). Spatial variability of some soil properties varies in oil palm (*Elaeis guineensis* Jacq.) plantations of west coastal area of India. *Solid Earth* 7: 979-993.

Behera, S. K., Suresh, K., Rao B. N., Ramachandrudu, K., Manorama, K. and Harinarayana, P. (2017). Soil fertility and yield limiting nutrients in oil palm plantations of north-eastern state Mizoram of India. *Journal of Plant Nutrition* 40 (8): 1165-1171.

fertilizer usage. Oléagineux 32, 107e209.

Hoffmann, M. P., Castaneda Vera, A., van Wijk, M. T., Giller, K. E., Oberthur, T., Donough, C., Whitbread, A. (2014). Simulating potential growth and yield of oil palm (*Elaeis guineensis*) with PALMSIM: model description, evaluation and application.

Agricultural Systems 131: 1-10.

Mengel, K., and Kirkby, E. A. (1987). Principles of Plant Nutrition, International Potash Institute, Basel, Switzerland.

Ng, S. K. (1977). Review of oil palm nutrition and manuring e scope for greater economy in

Ng, S. K., and Thamboo, S. (1967). Nutrient contents of oil palms in Malaya. I. Nutrients required for reproduction: Fruit bunches and male inflorescence. *Malaysian Agricultural Journal* 46: 3-45.

Palmoilresearch, (2014). Palm Oil Research: Statistics [WWW Document]. Untangling the great Palm oil debate. http://www.palmoilresearch.org/statistics.html.

Prasad, M. V., Sairam, C.V., Arulraj, S. and Jameema, J. (2012). Estimation of cost of production of oil palm in Andhra Pradesh. In. Abstracts of paper, Plantation Crops Symposium XX, Coimbatore, pp136.

Prasad, M.V., Sarkar, A., Jameema, J. (2013). Performance of oil palm production technologies. *Indian Research Journal of Extension Education* 10(3): 10-15.

Pushparajah, E., Chew, P. S. (1979). Utilization of soil and plant analyses for plantation agriculture. In: The Proceedings of the Malaysian Seminar on the Fertility and Management of Deforested Land, Henry J. T. L. Liau *et al.,* (eds.). Society of Agricultural Scientists, Sabah, Kota Kinabalu, Malaysia, pp. 177-199.

Rao, B. N., Suresh, K., Behera, S. K., Ramachandrudu, K. And Manorama, K. (2014). Nutrient managment in oil palm. Technical Bulletin, DOPR, Pedavegi. pp. 1-24.

Rao, K. K. (2009). Effect of different methods of irrigation and nutrient requirement on yield of oil palm. *International Journal of Oil Palm* 6(1): 31-34.

Reddy, B. G. M., Patil, D. R. Pattara, Arulraj, S. and Shetty, H. (2009). Irrigation and NPK requirement of oil palm for Tungabhadra command area. *International Journal of Oil Palm* 6(1): 35-38.

Reddy, V. M., Suresh, K., Sarma, K. N., Sivasankarakumar, K. M., Bhanusri, A. and Ramakrishna, P. (2002). Root biomass distribution in relation to its moisture pattern under different irrigation methods in oil palm. In: Sreedharan, K., Vinod Kumar, P.K., Jayaram, Basavraj, M. and Chulaki, P. (eds.) Proceedings PLACROSYM_XV. pp. 344-347.

Rethinam, P., Arulraj, S. and Rao, B.N. (2012) Assessment of additional potential areas for oil palm cultivation in India. Report submitted to Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India. Directorate of Oil Palm Research, Pedavegi, Andhra Pradesh, pp. 1-84.

Suresh, K., Reddy, V. M., Sarma, K. N., Bhanusri, A. and Sivasankara Kumar, K. M. (2003). Quantification of root biomass in oil palm grown under basin irrigation. *International Journal of Oil Palm* 2 (3&4): 39-41.

von Uexkull, H. R., Fairhurst, T. H. (1991). Fertilizing for High Yield and Quality. The Oil Palm. IPI, Bern, 79 p.