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Research Article

Maximizing the oil palm production in coastal area of Sindh, Pakistan: A perfect blend of synthetic fertilizers and organic manure for post-nursery stage of oil palm

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Abstract

The coastline of Pakistan spans over 1046 km and presents a promising opportunity for domestic production of oil palm, thus reducing the reliance on imported edible oils. However, oil palm requires a significant amount of nutrients during its 3 to 4 years maturation period. To address this, a study was conducted in which synthetic fertilizers (NPK) and farmyard manure were strategically integrated and applied to oil palm during the post-nursery stage based on FGVR principles (Felda Global Venture, Malaysia recommendation). Treatments included T_1 (Control), T_2= FGVR (143 g plant^{-1} NPK i.e. 10g [1st month], 14g [2nd month], 21g [3rd, 4th and 5th months = 63g]; 28g [6th and 7th months = 58g]); T_3=NPK 75%<FGVR, T_4=NPK 50%<FGVR, T_5=NPK 25%>FGVR, T_6=NPK 50%>FGVR, T_7=FYM 2 kg + NPK 25%<FGVR and T_8=FYM 2 kg + NPK 50%<FGVR. The study's findings indicated that the application of FYM 2 kg + NPK 25%<FGVR (T7) had the most significant impact on oil palm growth, leading to increases in seedling height, number of leaves per seedling, bole diameter, number of fronds per seedling, frond length, as well as nutrient concentrations and uptakes in the leaves. Moreover, T7 also enhanced physiological characteristics, such as leaf chlorophyll content, leaf area, LAI, and TDM. In terms of varieties, Yangambi PB 14 demonstrated its superiority over the 3-way cross variety in all aspects evaluated. Not only did T7 improve various physiological characteristics of oil palm, such as leaf chlorophyll content, leaf area, LAI, and TDM, but the variety Yangambi PB 14 also demonstrated superiority over the 3-way cross variety across all measured traits. When T7 was combined with Yangambi PB 14, it resulted in the maximum enhancement of all the studied traits during the post-nursery stage of oil palm growth. Based on these findings, it is recommended that FYM 2 kg + NPK 25%<FGV recommendations be used to fertilize oil palm seedlings during the post-nursery stage for optimal results.

Keywords: Integration; NPK; Oil palm; Organic manure and Post-nursery

Introduction

Oil palm (*Elaeis guineensis* Jacq.) is a member of the Arecaceae family and is believed to have originated in West and Central Africa. It is known for its higher oil output compared to other oil-producing plants grown in tropical or temperate environments. Due to its high oil content, ease of processing, and widespread cultivation, oil palm has become popular throughout Asia. Oil palm requires a temperature of at least 15°C for germination and thrives in tropical rainforests that receive between 1780 to 2280 mm of annual precipitation and temperatures ranging from 24 to 30°C **[1-3]**. Pakistan imported 2.754 million tons of edible oil worth US$ 3.681 billion in 2022, while domestic production of edible oil was estimated at 0.460 million tons. The total availability of edible oil during this period was estimated at 3.214 million tons **[4-7]**. In 2022, oilseed crops were cultivated on 5.809 million hectares of land in Pakistan, yielding 2.723 million tons of oilseeds and 0.460 million tons of edible oil, which is insufficient to meet the estimated domestic demand of 3.214 million tons. This means that only 14.31 percent of the total edible oil consumption in Pakistan is locally produced, while the rest is imported **[8]**.

Palm oil production may offer economic benefits to farmers **[9]**. As palm oil and palm kernel oil have a wide range of applications beyond the food industry. In food production, these oils are used in the creation of various frying oils, fats, and spreads, such as margarine. The processing of these oils typically involves fractionation, refining, and hydrogenation **[10]** Planting crops through a nursery is often preferred for the financial advantages it offers, including oil palm. The seeding process involves one or two steps, with two-part nurseries, which include both a pre-nursery and a main nursery, being considered more desirable than one-part nurseries **[11, 12]**. In tropical agricultural communities, inorganic fertilizers are frequently employed to increase oil palm yields. This is due to the fact that they are able to boost crop performance in addition to the chemical attributes of the soil structure **[13]**. In spite of these obstacles, it has been suggested that oil palm farming should make use of organic manures because it has been demonstrated that these fertilizers increase production **[14]**. Farmers working on a small scale and earning a low income may have difficulty gaining access to inorganic fertilizers because of their excessively high cost. Additionally, because the applications of organic fertilizer and inorganic nutrients are complementary, the use of fortified fertilizer is strongly advised **[15]**.

[16] fertilized oil palms with common organic components and compost, which has the advantage of preserving the soil's physical structure and allowing roots to develop. **[17]** recommended that FYM integration with NPK are advantageous in a variety of ways, including providing media for the life of beneficial bacteria for soil fertility, decreasing porosity in sandy soils, and assisting aeration in clay soils. Manure, in addition to being a great soil enhancer, is also a rich source of macro- and micronutrients **[18]**. Samuel *et al.* **[19]** used FYM, urea, and NPK for the growth of oil palm seedlings prior to planting them in nursery beds. The best growth of oil palm seedlings was achieved using the combination of 0.02 g urea and 40 g FYM, which was the same as 0.04 grams N, P and K fertilizers and 50 grams of FYM. The oil palm plantation was fertilized with Ferti-plus and NPK and in result, plant N absorption was improved **[20]**.

Keeping in mind the above facts, this study was carried out to optimize the integrated application of synthetic NPK and organic manure for post-nursery stage production of oil palm.

Materials and Methods

Experimental details

The current study was carried out in the greenhouse of the Dalda Agriculture Research Station (DARS) in Mirpur Sakro, district Thatta (Latitude N 24o39’58.24385” Longitude: E 67 o34’1.01598”). Soil samples

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were analyzed for their physical and chemical properties at the Soil Chemistry laboratory of the Department of Soil Science prior to the experiment. The soil was found to be sandy loam in texture, with a neutral to non-alkaline pH of 7.5, non-saline with a conductivity of less than 0.94 dS m-1, and low in organic matter content (0.78%). 20 kg of agricultural plough layer soil was filled into polythene bags with a size of 18.5×14.5 inches. Two FGV Malaysian oil palm varieties (3way Cross and Yangambi PB14) were grown in these bags with different rates of NPK fertilizer and farmyard manure (FYM). Healthy seedlings that were pre-nursery grown for four months were transplanted into each bag. The details of the experiment are presented in (Table 1). To maintain optimum moisture levels, approximately 1600 ml of canal irrigation water was applied regularly or as needed. The polythene bags were manually weeded to prevent weeds from acting as hosts to pests and competing with the seedlings for nutrients. The seedlings were kept in the nursery for eight months and the experiment was terminated seven months after planting.

Table 1. Treatment details

Months	Treatments	Fertilizers	Doses (g seedling^{-1})
1st	T1 (Control)	0	0
	T2 (Rec. by Felda Global Venture, Malaysia)	NPK	10
	T3 (75% <of Recommended)	NPK	2.5
	T4 (50%< of Recommended)	NPK	5
	T5 (25> Recommended)	NPK	12.5
	T6 (50%> Recommended)	NPK	15
	T7 (FYM 10%+<25% of recommended)	FYM+NPK	7.5
	T8 (FYM 10%+50% < than recommended)	FYM+NPK	5
2nd	T1 (Control)		
	T2 (Recommended by FGV))	NPK	14
	T3 (75% <of Recommended)	NPK	3.5
	T4 (50%< of Recommended)	NPK	7
	T5 (25> Recommended)	NPK	17.5
	T6 (50%> Recommended)	NPK	21
	T7 (FYM 10%+<25% of recommended)	NPK+FYM	10.5
	T8 (FYM 10%+50% < than recommended)	NPK+FYM	7
3rd	T1 (Control)		
	T2 (Recommended by FGV)	NPK	21
	T3 (75% <of Recommended)	NPK	7
	T4 (50%< of Recommended)	NPK	10.5
	T5 (25> Recommended)	NPK	28
	T6 (50%> recommended)	NPK	31.5
	T7 (FYM 10%+<25% of recommended)	FYM+NPK	14
	T8 (FYM 10%+50% < than recommended)	NPK	10.5
4th	T1 (Control)		
	T2 (Recommended by FGV))	NPK	21
	T3 (75% <of Recommended)	NPK	7
	T4 (50%< of Recommended)	NPK	10.5
	T5 (25> Recommended)	NPK	28

	T6 (50%> Recommended)	NPK	31.5
	T7 (FYM 10%+<25% of recommended)	NPK	14
	T8 (FYM 10%+50% < than recommended)	NPK	10.5
5th	T1 (Control)		
	T2 (Recommended by FGV))	NPK	21
	T3 (75% <of Recommended)	NPK	7
	T4 (50%< of Recommended)	NPK	10.5
	T5 (25> Recommended)	NPK	28
	T6 (50%> Recommended)	NPK	31.5
	T7 (FYM 10%+<25% of recommended)	NPK	14
	T8 (FYM 10%+50% < than recommended)	NPK	10.5
6th	T1 (Control)		
	T2 (Recommended by FGV))	NPK	28
	T3 (75% <of Recommended)	NPK	7
	T4 (50%< of Recommended)	NPK	14
	T5 (25> Recommended)	NPK	35
	T6 (50%> Recommended)	NPK	42
	T7 (FYM 10%+<25% of recommended)	NPK	21
	T8 (FYM 10%+50% < than recommended)	NPK	14
7th	T1 (Control)		
	T2 (Recommended by FGV))	NPK	28
	T3 (75% <of Recommended)	NPK	7
	T4 (50%< of Recommended)	NPK	14
	T5 (25> Recommended)	NPK	35
	T6 (50%> Recommended)	NPK	42
	T7 (FYM 10%+<25% of recommended)	NPK	21
	T8 (FYM 10%+50% < recommended)	NPK	14

Treatment details

The study was carried out using 48 pots arranged in a completely randomized design with three replicates in a factorial arrangement. Factor A of the treatment consisted of two oil palm varieties (3-way Cross and Yangambi PB14), while Factor B consisted of eight different doses of NPK fertilizer and farmyard manure.

During the seven months following planting (Table 2), the vegetative growth of the seedlings was monitored, with measurements taken of plant height, girth size, number and length of palm fronds, and total leaf area. At the end of the study, leaf samples were collected for analysis of nutrient content, specifically nitrogen, phosphorus, and potassium (NPK). The biomass of the upper and lower shoots was separated and dried in an oven at 70ºC until a constant weight was achieved to determine biomass allocation. Additionally, the amount of nutrients taken up by each growth medium was calculated using a specific equation.

DMY × NUT.CONC/100.

Table 2. Weather data of the experimental site during the planting period

Months	Relative Humidity (%)	Temperature (°C)		Rainfall (mm)
		Minimum	Maximum	
June	54.18	28.65	41.99	0.12
July	61.77	28.67	38.76	3.71
August	74.33	26.08	35.70	3.88
September	73.44	26.36	35.98	0.97
October	57.88	22.44	35.45	0.33
November	45.24	18.22	31.05	0.17
December	35.75	11.75	26.83	0.05

Soil and plant analysis

The physical and chemical characteristics of the soil utilized in this study were examined, including pH and EC **[21]**, organic matter **[22]**, total N **[23]** as well as available P and extractable K **[24]**. In addition, the uptake and concentration of plant nutrients for N **[25]** and K **[26]** were evaluated.

Physiological traits

The leaf area of the seedlings in each treatment was measured using the length and breadth method multiplied by a factor of 0.75. Meanwhile, the leaf area index was calculated using the formula LAI = Leaf area / ground area. The total dry matter was obtained by oven-drying the samples at 80°C and then weighing them. The chlorophyll (SPAD) values were also recorded throughout the experiment.

Statistical analysis

The collected data were analyzed statistically using ANOVA to test the significance of the treatment effect ($P<0.05$). To compare the treatment means, the Least Significant Difference (LSD) test was used.

Results

Plant height

The height of seedlings in response to the integrated use of NPK and FYM, considering FGV (Felda Global Venture, Malaysia) recommendations as standard, for oil palm was measured and the data are shown in (Table 3). The height of oil palm seedlings at post-nursery stage was significantly influenced by NPK+FYM integration and varieties ($P<0.05$); while the relative interactive effect was non-significant ($P>0.05$). The treatment consisted of FYM (2 kg plant^{-1}) + NPK 25%<FGV recommendation maximized the oil palm plant height (92.15 cm), followed by T_5 (NPK 25%>FGV recommendation) and T_2 (NPK @ FGV recommendation) giving average plant height of 85.10 and 80.10 cm, respectively; while the least plant height (65.90 cm) was found in control. Oil palm variety Yangambi PB 14 reflected better plant height (78.71 cm) than the companion variety 3way cross (74.80 cm). The interactive effect indicates that T_7 × variety Yangambi PB 14 interaction maximized the plant height (94.30 cm); while the lowest plant height (64.20 cm) was noted in the interaction of T_1 × variety 3way cross.

Trunk girth (cm)

The trunk girth of oil palm seedlings at post-nursery stage varied significantly due to the effect of treatments based on NPK+FYM integration and varieties ($P<0.05$); while their interactive effect was insignificant ($P>0.05$). Trunk girth of oil palm was highest (26.55 cm) in plantation supplied with 2 kg FYM + NPK 25%<FGV recommendation, followed by the average trunk girth of 24.45 and 21.80 cm recorded in treatments comprised of NPK 25%>FGV recommendation and NPK @ FGV recommendation, respectively. The minimum trunk girth, however, was determined in control seedlings supplied neither with FYM and nor NPK fertilization (14.45 cm). In case of oil palm varieties, Yangambi PB 14 was found with greater trunk girth (21.14 cm) than variety 3way cross (19.96 cm). Treatment interaction revealed that T_7 × variety Yangambi PB 14 interaction produced seedlings with maximum trunk girth (27.50 cm); while the seedlings with least trunk girth (14.20 cm) was found in the interaction of T_1 (control) × variety 3way cross (Table 3).

Number of leaves seedling^{-1}

The number of leaves seedling^{-1} was significantly affected by different treatments based on NPK+FYM integration and varieties ($P<0.05$); while their interactive effect on the number of leaves seedling^{-1} was insignificant ($P>0.05$). The leaves on oil palm seedlings were greater in number (13.67 seedling^{-1}) in treatments where 2 kg FYM + NPK 25%<FGV recommendation was provided, followed by 11.83 and 11.33 average leaves number of oil palm seedlings when fertilized with NPK 25%>FGV recommendation and NPK @ FGV recommendation, respectively. However, the least count of leaves on oil palm seedlings (6.50) was recorded in control where neither NPK nor FYM was applied. In varieties, Yangambi PB 14 was recorded with more leaves (10.83 seedling^{-1}) as compared to its companion variety 3way cross (9.38 seedling^{-1}). Interaction study indicated that T_7 × variety Yangambi PB 14 interaction resulted in highest leaves number (14.33 seedling^{-1}); while the lowest leaves number (6.00 seedling^{-1}) was recorded in the interaction of T_1 (control) × variety 3way cross (Table 3). The integration of FYM and NPK showed positively greater impact to improve leaves number seedling^{-1} in oil palm, regardless of varieties; while 50% decrease in NPK caused decreased foliage; while 50% increase in NPK over FGV recommendation showed excessiveness symptoms and suppressed seedling growth.

Number of fronds seedling^{-1}

Fronds number seedling^{-1} of oil palm was significantly affected by different treatments based on NPK+FYM integration and varieties ($P<0.05$); while the interactive effect of varieties × nutrient management on this parameter was insignificant ($P>0.05$). The fronds on oil palm seedlings were greater in number (12.17) in case of plantation fertilized with 2 kg FYM + NPK 25%<FGV recommendation was provided, followed by 10.50 and 9.00 average fronds number on oil palm seedlings when fertilized with NPK 25%>FGV recommendation and NPK @ FGV recommendation, respectively. However, the least number of fronds on oil palm (3.5 seedlings^{-1}) was counted in T_1 (control) where the oil palm seedlings were raised with applied nutrients. The varietal effect showed that variety Yangambi PB 14 was found to have more fronds (8.83 seedling^{-1}) as compared to other variety 3way cross (7.25 seedling^{-1}). Interaction study showed that T_7 × variety Yangambi PB 14 interaction caused the highest fronds number (13.33 seedling^{-1}); while the least fronds number (3.0 seedling^{-1}) was counted in the interaction of T_1 (control) × variety 3way cross (Table 3).

Fronds length (cm)

The fronds length of oil palm seedlings at post-nursery stage differed significantly due to the effect of treatments based on NPK+FYM integration and varieties ($P<0.05$); while NPK+FYM treatments × varieties interaction showed insignificant effect ($P>0.05$) on the trait being described. Fronds length was maximum (63.10 cm) when seedlings were fertilized with 2 kg FYM + NPK 25%<FGV recommendation (T_7); while the average fronds length of decreased to 58.80 and 54.40 cm when seedlings were fertilized with NPK 25%>FGV recommendation (T_5) and NPK @ FGV recommendation (T_2), respectively. The least fronds length (42.50 cm), however, was measured in control (T_1) where the seedlings were kept untreated of any nutrients. Among varieties, Yangambi PB 14 was found with greater fronds length (59.19 cm) than variety 3way cross (54.03 cm). The interactive effect of T_7 × variety Yangambi PB 14 resulted in seedlings with longest fronds (64.70 cm); while the seedlings with least fronds length (41.0 cm) were found in the interactive effect of T_1 (control) × variety 3way cross (Table 4). This integration of NPK and FYM showed greater positive influence on fronds length in both the tested oil palm varieties.

Tablet 3. Plant height, trunk girth, number of leaves (seedling^{-1}) and number of fronds of oil palm as influenced by NPK+FYM integration

Treatments	Plant height (cm)	Trunk girth (cm)	No. of leaves seedling^{-1}	No. of fronds seedling^{-1}
T_1=Control	65.90^g	14.45^f	6.50^e	3.50^e
T_2=NPK @ FGV Malaysia recommendation	80.10^c	21.80^c	11.33^{bc}	9.00^{bc}
T_3=NPK 75%<FGV recommendation	68.55^f	17.85^e	7.50^e	6.00^d
T_4=NPK 50%<FGV recommendation	71.30^e	18.85^{de}	9.50^d	7.33^{cd}
T_5=NPK 25%>FGV recommendation	85.10^b	24.45^b	11.83^b	10.50^b
T_6=NPK 50%>FGV recommendation	75.05^d	20.35^{cd}	10.00^{cd}	7.67^{cd}
T_7=FYM 2 kg+NPK 25%<FGV recommendation	92.15^a	26.55^a	13.67^a	12.17^a
T_8=FYM 2 kg+NPK 50%<FGV recommendation	75.90^d	20.10^{cd}	10.50^{bcd}	8.17^c
LSD 0.05	1.8412	1.7592	1.8106	
Varieties				
V1=3way Cross	74.80^b	19.96^b	9.38^b	7.25^b
V2= Yangambi PB 14	78.71^a	21.14^a	10.83^a	8.83^a
LSD 0.05	0.5770	0.5524	0.5685	0.5493
Significance				
Treatments	**	**	**	**
Varieties	**	**	**	**
T × V	NS	NS	NS	NS

** = Significant at P=0.05 NS= non-Significant ^{abc} Means followed by common letter are similar at 5% probability level.

Chlorophyll content (SPAD)

The chlorophyll content of oil palm seedlings at post-nursery stage was significantly affected by NPK and FYM based treatments and varieties (P<0.05); while the relative interactive effect on chlorophyll content was non-significant (P>0.05). The integrated use of FYM (2 kg plant^{-1}) and NPK 25%<FGV recommendation (T_7) produced the seedlings with highest chlorophyll content (64.5), followed by T_5 (NPK 25%>FV recommendation) and T_2 (NPK @ FGV recommendation) producing seedlings with 61.0 and 58.0 chlorophyll content, respectively; while the chlorophyll content was lowest (42.0) in T_1 (control). In varieties, Yangambi PB 14 reflected greater chlorophyll content (53.88) as compared to variety 3way cross (51.5). The interactive effect indicates that T_7 × variety Yangambi PB 14 interaction produced seedlings with highest chlorophyll content (65.0); while the lowest chlorophyll content (41.0) was determined in the interaction of T_1 × variety 3way cross (Table 4).

Leaf area (cm)

The effect of fertilizer treatments and crop varieties on leaf area was significant ($P<0.05$); while the interactive effect of fertilizer treatments × varieties on leaf area was negligible ($P>0.05$). The results showed that leaf area of oil palm seedlings was considerably higher in treatments T_7=2 kg FYM + NPK 25%<FGV recommendation (112.54 cm^2), T_5=NPK 25%>FGV recommendation (109.89 cm^2) and T_2=NPK @ FGV recommendation (107.91 cm^2). The leaf area was considerably decreased to 105.16 cm^2 in the oil palm seedlings fertilized with T_6 (NPK 50%>FGV recommendation), 105.19 cm^2 in T_8 (2 kg FYM + NPK 50%<FGV recommendation) and 102.69 cm^2 in T_4 (NPK 50%<FGV recommendation). There was a decline in the leaf area (100.93 and 87.89 cm^2) in seedlings fertilized with treatments T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively (Table 4). The varietal effect showed that the leaf area was considerably higher (104.68 cm^2) in variety Yangambi PB 14 as compared to variety 3way cross (103.5 cm^2). The treatment interaction suggested that T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety Yangambi PB 14 resulted in maximum leaf area (113.6 cm^2); while the lowest leaf area (86.85 cm^2) was measured in the interaction of T_1 (control) × variety 3way cross.

Leaf area index

Leaf area index was significantly influenced by nutrient integration, crop varieties as well as interactive effect of fertilizer treatments × varieties ($P<0.05$). It can be seen from the data that leaf area index of oil palm seedlings was markedly higher in treatments T_7=2 kg FYM + NPK 25%<FGV recommendation (0.547), T_5=NPK 25%>FGV recommendation (0.534) and T_2=NPK @ FGV recommendation (0.527). The leaf area index was decreased to 0.5125 in the oil palm seedlings fertilized with T_8 (2 kg FYM + NPK 50%<FGV recommendation), 0.510 in T_6 (NPK 50%>FGV recommendation), and 0.500 in T_4 (NPK 50%<FGV recommendation). There was a decline in the leaf area index (0.494 and 0.487) in seedlings fertilized with treatments T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively (Table 4). In varieties, the leaf area index was higher (0.516) in variety Yangambi PB 14 as compared to variety 3way cross (0.513). The treatment interaction suggested that T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety Yangambi PB 14 resulted in maximum leaf area index (0.548); while the lowest leaf area index (0.487) was measured in the interaction of T_1 (control) × variety 3way cross.

Total dry matter (TDM)

The effect of nutrient management and crop varieties on total dry matter was significant ($P<0.05$); while the interactive effect of fertilizer treatments × varieties on TDM was insignificant ($P>0.05$). The maximum TDM of oil palm seedlings was recorded in T_7=2 kg FYM + NPK 25%<FGV recommendation (105.4 g), T_5=NPK 25%>FGV recommendation (100.6 g) and T_2=NPK @ FGV recommendation (97.0 g). The TDM was decreased relatively to 94.0, 93.3 and 88.5 g in the oil palm seedlings fertilized with T_8 (2 kg FYM + NPK 50%<FGV recommendation), T_6 (NPK 50%>FGV recommendation) and T_4 (NPK 50%<FGV recommendation), respectively. However, the TDM declined further to 85.5 and 81.8 g in seedlings fertilized with treatments T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively. In varieties, the TDM was higher (95.237 g) in variety Yangambi PB 14 as compared to variety 3way cross (91.287 g). The interaction analysis revealed that TDM was maximum in T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety Yangambi PB 14 interaction (108 g); and the least TDM (80.4 g) was determined in the interaction of T_1 (control) × variety 3way cross (Table 4).

Table 4. Fronds length, chlorophyll content, leaf area and leaf area index, total dry matter of oil palm varieties as influenced by different fertilizer treatments

Treatments	Fronds length (cm)	Chlorophyll content (SPAD)	Leaf area (cm^2)	Leaf area Index	Total dry matter (g)
Nutrient Management					
T_1=Control	42.50^e	42.0^e	87.89^f	0.4875^h	81.80^e
T_2=NPK @ FGV Malaysia recommendation	54.40^c	58.0^b	107.91^c	0.5270^c	97.00^{bc}
T_3=NPK 75%<FGV recommendation	45.10^e	45.0^{de}	100.93^e	0.4940^g	85.50^{de}
T_4=NPK 50%<FGV recommendation	48.50^d	48.5^{cd}	102.69^e	0.5005^f	88.500^d
T_5=NPK 25%>FGV recommendation	58.80^b	61.0^{ab}	109.89^b	0.5345^b	100.60^b
T_6=NPK 50%>FGV recommendation	51.70^c	51.5^c	105.16^d	0.5100^e	93.30^c
T_7=FYM 2 kg+NPK 25%<FGV recommendation	63.10^a	64.5^a	113.07^a	0.5470^a	105.40^a
T_8=FYM 2 kg+NPK 50%<FGV recommendation	52.75^c	51.0^c	105.19^d	0.5125^d	94.00^c
LSD 0.05	0.9430	1.4577	0.5767	5.774	1.1630
Varieties					
V1=3way Cross	50.19^b	51.50^b	103.50^b	0.5126^b	91.287^b
V2= Yangambi PB 14	54.03^a	53.88^a	104.68^a	0.5156^a	95.237^a
LSD 0.05	0.5770	0.7289	0.2883	2.887	0.5815
Significance					
Treatments	**	**	**	**	**
Varieties	**	**	**	**	**
T × V	NS	NS	NS	**	NS

** = Significant at P=0.05 NS= non-Significant [abc] Means followed by common letter are similar at 5% probability level

Residual soil pH as influenced by different fertilizer treatments

The soil pH of oil palm seedlings at post-nursery stage was significantly affected by treatments and by interaction of treatments × varieties (P<0.05); while varietal effect on soil pH was non-significant (P>0.05). The treatment based of FYM (2 kg plant^{-1}) and NPK 50%<FGV recommendation (T_8) and FYM (2 kg plant^{-1}) and NPK 25%<FGV recommendation (T_7) caused reduction in soil pH up to 7.55 and 7.6, respectively; while the treatment based on NPK 50%>FGV recommendation (T_6) caused increase in soil pH (7.9). However, in all other treatments and control, the average pH remained similar (7.7). The pH was almost similar (7.69 and 7.7) for soil used to develop seedlings of varieties Yangambi PB 14 and 3way cross, respectively (Table 5). The treatments' interaction exhibits that T_7 × variety Yangambi PB 14 and T_8 × variety 3way cross resulted in equally least soil pH of 7.5; while interactions comprised of T_6 (NPK 50%> than FGV recommendation) × varieties Yangambi PB 14 and 3way cross caused relative increase in soil pH (7.9).

Residual soil EC as influenced by different fertilizer treatments

The soil EC was significantly influenced by treatments and interaction of treatments × varieties (P<0.05); while varietal effect on soil EC was insignificant ($P>0.05$). Treatments comprised of 2 kg FYM plant^{-1} + NPK 50%<FGV recommendation (T_8) and 2 kg FYM plant^{-1} + NPK 25%<FGV recommendation (T_7) resulted in a significant ($P<0.05$) reduction in soil EC equally upto 0.69 dS m^{-1}, respectively. The treatments based on NPK 50%<FGV recommendation (T_3) and control (T_1) resulted in increased soil EC equally upto 0.96 dS m^{-1}. However, increase in soil EC (0.93, 0.86, 0.83 and 0.77 dS m^{-1}) was determined in treatments comprised of NPK at FGV recommended rate (T_2), NPK 25%> FGV recommended rate (T_5), NPK 50%<FGV recommendation (T_4) and NPK 50%>FGV recommendation (T_6), respectively (Table 5). The EC of the media used for growing varieties Yangambi PB 14 and 3way cross was almost similar (0.831 and 0.834 dS m^{-1}), respectively. The treatments' interaction indicated that EC was highest in the interaction of T_1(control) × variety 3way cross (0.98 dS m^{-1}); while it was least (0.66 dS m^{-1}) in the interaction of T_8 (2 kg FYM plant^{-1} + NPK 50%<FGV recommendation).

Residual soil OM as influenced by different fertilizer treatments

The soil OM was significantly influenced by treatments and oil palm varieties ($P<0.05$); while interactive effect of treatments × varieties on soil OM was insignificant ($P>0.05$). The soil OM was relatively higher (0.89%) in treatments comprised of 2 kg FYM plant^{-1} + NPK 25%<FGV recommendation (T_7), followed by treatments comprised of NPK 50%>FGV recommendation (T_6), NPK 25%>FGV recommendation (T_5) and 2 kg FYM plant^{-1} + NPK 50%<FGV recommendation (T_8) where the average OM content in soil media was 0.79, 0.76 and 0.75 percent, respectively. The soil in treatment based on NPK @ FGV recommended rate (T_2) contained 0.73 percent OM content; while soil OM reduced to 0.64 and 0.52 percent in treatments comprised of NPK 50%<FGV recommendation (T_4) and NPK 75%<FGV recommendation (T_3), respectively (Table 5). However, the least soil OM content was determined in control (T_1). In varietal response to soil OM content suggested that the soil used for growing oil palm variety 3way cross contained higher OM (0.71%) than the soil used to grow variety Yangambi PB 14 (0.67%). The treatments' interaction revealed that soil organic matter was considerably higher (0.92%) in the interaction of T_7 (2 kg FYM plant^{-1} + FYM 25%< FGV recommendation) × variety 3way cross; while the soil OM was least (0.46%) in the interaction of T_1 (control) × variety 3way cross.

Residual soil N as influenced by different fertilizer treatments

The treatments and oil palm varieties had significant impact on soil N ($P<0.05$); while interactive effect of treatments × varieties on soil N was statistically non-significant ($P>0.05$). The soil N was relatively greater (0.56%) in treatments based on 2 kg FYM plant^{-1} + NPK 25%<FGV recommendation (T_7), followed by treatments NPK 50%>FGV recommendation (T_6), NPK 25%>FGV recommendation (T_5) and 2 kg FYM plant^{-1} + NPK 50%<FGV recommendation (T_8) where the average soil N was 0.05, 0.0475 and 0.0468 percent, respectively. The soil N in treatment based on NPK @ FGV recommended rate (T_2) contained 0.0458 percent; while soil N reduced to 0.0407 and 0.033 percent in treatments comprised of NPK 50%<FGV recommendation (T_4) and NPK 75%<FGV recommendation (T_3), respectively. However, the least soil N content was determined in control (T_1). Varietal impact on soil N content indicates that the soil used for growing oil palm variety 3way cross contained higher N (0.0447%) than the soil used to grow variety Yangambi PB 14 (0.0423%). The interaction study showed that soil N was relatively higher

(0.058%) in the interaction of T_7 (2 kg FYM plant^{-1} + FYM 25%< FGV recommendation) × variety 3way cross; and it was least (0.0277%) in the interaction of T_1 (control) × variety Yangambi PB 14 (Table 5).

Residual soil P as influenced by different fertilizer treatments

The P of soil media indicated that significant variation ($P<0.05$) associated with fertilizer treatments and crop varieties; while interactive effect of fertilizer treatments × varieties on soil P was statistically insignificant ($P>0.05$). The value for this soil property was greater (6.30 and 6.15%) in treatments T_6 (NPK 50%>FGV recommendation) and T_7 (2 kg FYM + NPK 25%<FGV recommendation), respectively; while there was relative decrease in P (5.50 and 5.0%) in soil used for treatments T_5 (NPK 25%>FGV recommendation) and T_8 (2 kg FYM + NPK 50%<FGV recommendation), respectively. The soil P further decreased to 4.78, 3.55 and 3.10 percent in soil media samples used for treatments T_2 (NPK @ FGV recommended rate), T_4 (NPK 50%<FGV recommendation) and T_3 (NPK 75%<FGV recommendation), respectively. The P content was least control soil (T_1) where neither the FYM and nor the NPK were used. Among varieties, the soil media used for growing variety 3way cross contained higher P (4.74%) than the soil used for variety Yangambi PB 14 (4.50%). This indicates that variety 3way cross was less efficient to take soil P as compared to its companion variety. Moreover, the interaction of T_6 (NPK 50%> FGV recommendation) × variety 3way cross caused highest soil P content; and it was least (2.50%) in the interaction of T_1 (control) × variety Yangambi PB 14 (Table 5).

Residual soil K as influenced by different fertilizer treatments

There was highly significant effect of fertilizer treatments and crop varieties ($P<0.05$); while interactive effect of fertilizer treatments × varieties on soil K was non-significant ($P>0.05$) statistically. The soil K was greater (178.5 and 178.0%) in treatments T_7 (2 kg FYM + NPK 25%<FGV recommendation) and T_6 (NPK 50%>FGV recommendation), respectively; while there was relative decrease in soil K (162.17, 154.5 and 149.67%) in soil used for treatments T_5 (NPK 25%>FGV recommendation), T_2 (NPK @ FGV recommended rate) and T_8 (2 kg FYM + NPK 50%<FGV recommendation), respectively. There was a decline in soil K (82.67, 74.65 and 65.66%) in treatments comprised of T_4 (NPK 50%<FGV recommendation), T_3 (NPK 75%<FGV recommendation) and T_1 (control), respectively. In varieties, the soil media used for growing variety 3way cross contained higher K content (131.92%) as compared to the soil used for variety Yangambi PB 14 (129.54%). Furthermore, the interaction of T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety 3way cross caused highest soil K content (181.0 %); and it was least (65.0 %) in the interaction of T_1 (control) × variety Yangambi PB 14 (Table 5).

Leaf N of oil palm varieties as influenced by different fertilizer treatments

There was highly significant effect of fertilizer treatments and crop varieties ($P<0.05$) on leaf N content; while interactive effect of fertilizer treatments × varieties on leaf N content was insignificant ($P>0.05$). The leaf N was higher (2.55 and 2.25%) in treatments T_7 (2 kg FYM + NPK 25%<FGV recommendation) and T_5 (NPK 25%>FGV recommendation), respectively; while there was relative decrease in leaf N (2.20, 2.05 and 1.95%) in oil palm seedlings in treatments T_8 (2 kg FYM + NPK 50%<FGV recommendation), T_6 (NPK 50%>FGV recommendation) and T_2 (NPK @ FGV recommendation), respectively. A considerable reduction in leaf N of oil palm seedlings (1.60, 145 and 0.85 %) was determined in treatments T_4 (NPK 50%<FGV recommendation), T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively. In case of varieties, the leaf N of variety Yangambi PB 14 was markedly greater (1.98%) as compared to its companion variety 3way cross (1.756 %). However, the treatment interaction suggested that interactive effect of T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety Yangambi PB 14 resulted in highest leaf N content (2.7 %); and it was least (0.80 %) in the interaction of T_1 (control) × variety 3way cross (Table 6).

Table 5. Residual soil pH, soil EC, soil organic matter, soil nitrogen, soil phosphorous and soil potassium of oil palm varieties as influenced by different fertilizer treatments

Treatments	**Soil physicochemical properties**					
	pH	**EC ($dS\ m^{-1}$)**	**OM (%)**	**N (%)**	**P ($mg\ kg^{-1}$)**	**K ($mg\ kg^{-1}$)**
T_1=Control	7.7^{b}	0.96^{a}	0.45^{f}	0.0283^{h}	2.55^{f}	65.66^{g}
T_2=NPK @ FGV Malaysia recommendation	7.7^{b}	0.93^{b}	0.73^{c}	0.0458^{c}	4.78^{c}	154.50^{c}
T_3=NPK 75%<FGV recommendation	7.7^{b}	0.96^{a}	0.52^{e}	0.033^{e}	3.10^{e}	74.65^{f}
T_4=NPK 50%<FGV recommendation	7.7^{b}	0.83^{c}	0.64^{d}	0.0407^{d}	3.55^{d}	82.67^{e}
T_5=NPK 25%>FGV recommendation	7.7^{b}	0.86^{c}	0.76^{bc}	0.0475^{bc}	5.50^{b}	162.17^{b}
T_6=NPK 50%>FGV recommendation	7.9^{b}	0.77^{d}	0.79^{b}	0.0500^{b}	6.30^{a}	178.00^{a}
T_7=FYM 2 kg+NPK 25%<FGV recommendation	7.6^{b}	0.69^{e}	0.89^{a}	0.056^{a}	6.150^{a}	178.50^{a}
T_8=FYM 2 kg+NPK 50%<FGV recommendation	7.55^{b}	0.69^{e}	0.75^{c}	0.0468^{c}	5.00^{c}	149.67^{d}
LSD 0.05	0.187	0.033	0.052	0.0294	0.307	3.976
Varieties						
V1=3way Cross	7.69	0.831	0.71^{a}	0.0447^{a}	4.74^{a}	131.92^{a}
V2= Yangambi PB 14	7.7	0.834	0.67^{b}	0.0423^{b}	4.50^{b}	129.54^{b}
LSD 0.05	--	--	0.013	0.0092	0.096	1.2485
Significance						
Treatments	**	**	**	**	**	**
Varieties	NS	NS	**	**	**	**
T × V	**	**	NS	NS	NS	NS

** = Significant at P=0.05 NS= non-Significant [abc] Means followed by common letter are similar at 5% probability level

Leaf P of oil palm varieties as influenced by different fertilizer treatments

High significant effect of nutrient management was exhibited by crop varieties as well as the interactive effect of fertilizer treatments × varieties on leaf P content (P<0.05). The leaf P in oil palm seedlings was higher (0.13, 0.97 and 0.090%) in treatments T_7 (2 kg FYM + NPK 25%<FGV recommendation), T_5 (NPK 25%>FGV recommendation) and T_2 (NPK @ FGV recommendation), respectively; while there was significant reduction in leaf P (0.084, 0.082 and 0.070%) in oil palm seedlings in treatments T_6 (NPK 50%>FGV recommendation), T_8 (2 kg FYM + NPK 50%<FGV recommendation) and T_4 (NPK 50%<FGV recommendation), respectively. The leaf P of oil palm seedlings was further declined (0.064 and 0.054 %) in treatments

T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively (Table 6). In varieties, the leaf P content of variety Yangambi PB 14 was greater (0.086%) as compared to its companion variety 3way cross (0.082 %). The treatment interaction indicated that interactive effect of T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety Yangambi PB 14 resulted in highest leaf P content (1.4 %); and it was least (0.54 %) in the interaction of T_1 (control) × both the tested varieties equally.

Leaf K of oil palm varieties as influenced by different fertilizer treatments

The leaf K was significantly affected by nutrient management, crop varieties as well as interaction of fertilizer treatments × varieties on leaf K content (P<0.05). The leaf K was markedly higher (1.5, 1.25 and 0.985%) in treatments T_7 (2 kg FYM + NPK 25%<FGV recommendation), T_5 (NPK 25%>FGV recommendation) and T_2 (NPK @ FGV recommendation), respectively; whereas, there was considerable decrease in leaf K (0.93, 0.91 and 0.85%) in oil palm seedlings treated with T_6 (NPK 50%>FGV recommendation), T_8 (2 kg FYM+NPK 50%<FGV recommendation) and T_4 (NPK 50%<FGV recommendation), respectively. The leaf K of oil palm seedlings was even decreased to 0.71 and 0.65 % in treatments T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively. The varietal effect showed that the leaf K content of variety Yangambi PB 14 was significantly higher (1.0%) as compared to variety 3way cross (0.95%). The interaction study revealed that interactive effect of T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety Yangambi PB 14 caused highest leaf K content (1.6 %); and the leaf was lowest (0.65 %) in the interaction of T_1 (control) × varieties Yangambi PB 14 and 3way cross equally (Table 6).

N-uptake of oil palm varieties as influenced by different fertilizer treatments

The analysis of variance demonstrated highly significant effect of nutrient management and crop varieties on N uptake of oil palm seedlings (P<0.05); while the interactive effect of fertilizer treatments × varieties on nitrogen uptake was insignificant (P>0.05). N-uptake was markedly higher (2.83, 2.70 and 2.07 g) in treatments T_5 (NPK 25%>FGV recommendation), T_7 (2 kg FYM + NPK 25%<FGV recommendation) and T_8 (2 kg FYM + NPK 50%<FGV recommendation), respectively. The N-uptake in oil palm seedlings decreased to 1.90, 1.88 and 1.41 kg in seedlings treated with T_6 (NPK 50%>FGV recommendation) and T_2 (NPK @ FGV recommendation), respectively. Markedly lower N-uptake in oil pam seedlings (1.25 and 0.70 g) was determined in treatments T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively. In varieties, the N-uptake was markedly higher (1.915 g) in variety Yangambi PB 14 as compared to variety 3way cross (1.63 g). The treatment interaction of T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety Yangambi PB 14 resulted in highest N-uptake by the oil palm seedlings (2.93 g); and the lowest N-uptake (0.65 g) was determined in the interaction of T_1 (control) × variety 3way cross equally (Table 7).

P-uptake of oil palm varieties as influenced by different fertilizer treatments

The indicated highly significant effect of nutrient management, crop varieties and interaction of fertilizer treatments × varieties on P uptake of oil palm seedlings (P<0.05). P-uptake was higher (0.1367, 0.0967 and 0.0868 g) in treatments T_7 (2 kg FYM + NPK 25%<FGV recommendation), T_5 (NPK 25%>FGV recommendation) and T_2 (NPK @ FGV recommendation), respectively. The P-uptake in oil palm seedlings followed a decreasing trend (0.0778, 0.0772 and 0.0635 g) in seedlings fertilized with T_6 (NPK 50%>FGV recommendation), T_8 (2 kg FYM + NPK 50%<FGV recommendation) and T_4 (NPK 50%<FGV recommendation), respectively. Markedly lower P-uptake in oil palm seedlings (0.0547 and 0.0442 g) was determined when fertilized with T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively. So far, the varietal effect is concerned; the P-uptake was higher (0.0829 g) in variety Yangambi PB 14 than the companion variety 3way cross (0.0764 g). The interaction study suggested that T_7 (2 kg FYM + NPK 25%< FGV recommendation) × variety Yangambi PB 14 resulted in highest P-uptake by the oil palm seedlings (0.15 g); and the lowest P-uptake (0.0433 g) was determined in the interaction of T_1 (control) × variety 3way cross (Table 7).

Table 6. Leaf N, P and K content (%) of oil palm varieties as influenced by different fertilizer treatments

Treatments	Leaf N	Leaf P	Leaf K
	------------ (%) ------------		
T_1=Control	0.85[e]	0.054[f]	0.65[e]
T_2=NPK @ FGV Malaysia recommendation	1.95[c]	0.090[c]	0.985[c]
T_3=NPK 75%<FGV recommendation	1.45[d]	0.064[e]	0.71[e]
T_4=NPK 50%<FGV recommendation	1.60[d]	0.070[e]	0.85[d]
T_5=NPK 25%>FGV recommendation	2.25[b]	0.097[b]	1.25[b]
T_6=NPK 50%>FGV recommendation	2.05[bc]	0.084[cd]	0.93[cd]
T_7=FYM 2 kg+NPK 25%<FGV recommendation	2.55[a]	0.130[a]	1.50[a]
T_8=FYM 2 kg+NPK 50%<FGV recommendation	2.20[bc]	0.082[d]	0.91[cd]
LSD 0.05	0.2844	0.00214	0.0949
Varieties			
V1=3way Cross	1.75[b]	0.082[b]	0.95[b]
V2= Yangambi PB 14	1.98[a]	0.086[a]	1.00[a]
LSD 0.05	0.0893	0.00218	0.1536
Significance			
Treatments	**	**	**
Varieties	**	**	**
T × V	NS	**	NS

** = Significant at P=0.05 NS= non-Significant [abc] Means followed by common letter are similar at 5% probability level

K-uptake of oil palm varieties as influenced by different fertilizer treatments

The results showed highly significant effect of fertilizer treatments, crop varieties as well as fertilizer treatments × varieties interaction on K uptake of oil palm seedlings ($P<0.05$). K-uptake was markedly greater (1.5167, 1.2667 and 0.9533 g) in treatments T_7 (2 kg FYM + NPK 25 % <FGV recommendation), T_5 (NPK 25%>FGV recommendation) and T_2 (NPK @ FGV recommendation), respectively. The K-uptake in seedlings was found as 0.865, 0.8483 and 0.75 g in the seedlings supplied with T_6 (NPK 50%>FGV recommendation), T_8 (2 kg FYM + NPK 50% <FGV recommendation) and T_4 (NPK 50%<FGV recommendation), respectively.

Relatively decreased K-uptake in seedlings (0.6083 and 0.5317 g) was found in treatments T_3 (NPK 75% of FGV recommendation) and T_1 (Control), respectively. Among varieties, the seedlings of variety Yangambi PB 14 contained greater K-uptake (0.9546 g) as compared to variety 3way cross (0.8804 g). In case of treatment interactions, the seedlings in T_7 (2 kg FYM + NPK 25 % < FGV recommendation) × variety Yangambi PB 14 contained highest K-uptake (1.6333 g); and the least K-uptake (0.5233 kg) was determined in the interaction of T_1 (control) × variety 3way cross (Table 7).

Tablet 7. Nutrients-uptake of oil palm varieties as influenced by different fertilizer treatments

Treatments	N-uptake	P-uptake	K-uptake
	------------- (g plant^{-1}) -------------		
T_1=Control	0.70^e	0.0442^f	0.5317^f
T_2=NPK @ FGV Malaysia recommendation	1.88^c	0.0868^c	0.9533^c
T_3=NPK 75%<FGV recommendation	1.25^d	0.0542^e	0.6083^f
T_4=NPK 50%<FGV recommendation	1.41^d	0.0635^e	0.7500^e
T_5=NPK 25%>FGV recommendation	2.83^b	0.0967^b	1.2667^b
T_6=NPK 50%>FGV recommendation	1.90^c	0.0778^{cd}	0.865^d
T_7=FYM 2 kg+NPK 25%<FGV recommendation	2.70^a	0.1367^a	1.5167^a
T_8=FYM 2 kg+NPK 50%<FGV recommendation	2.07^f	0.0772^d	0.8483^d
LSD 0.05	0.2639	0.0096	0.0830
Varieties			
V1=3way Cross	1.63^b	0.0764^b	0.8804^b
V2= Yangambi PB 14	1.915^a	0.0829^a	0.9546^a
LSD 0.05	0.0829	0.0030	0.1344
Significance			
Treatments	**	**	**
Varieties	**	**	**
T × V	NS	**	**

** = Significant at P=0.05 NS= non-Significant [abc] Means followed by common letter are similar at 5% probability level

Discussion

A seven-month analysis was conducted to assess the impact of various nutrient management practices on oil palm growth in the post-nursery stage. The optimal response was observed in seedlings treated with 2 kg of FYM and 25% NPK, based on Felda Global Venture's recommendation for soil and coastal climates in Sindh, Pakistan (Fig. 1). FGV has developed NPK and FYM recommendations for oil palm, with a monthly application of 10g in the first month, 14g in the second month, 21g from months 3-5, and 28g from months 6-7 per seedling. The Yangambi PB 14 variety performed better than the 3way cross variety in all studied traits. The integrated application of FYM and NPK was found to be highly effective in improving seedling growth, with the addition of more NPK not surpassing the effectiveness of the integrated application. The combination of FYM and NPK also improved foliage in oil palm seedlings, irrespective of the variety. However, a 50%

decrease in NPK caused a reduction in foliage, while a 50% increase in NPK over FGVR led to excessiveness symptoms and suppressed seedling growth.

The post-nursery stage analysis of oil palm was conducted over a period of seven months, evaluating various nutrient management practices. Results showed that the application of FYM 2 kg+NPK 25%<FGVR was the most effective in improving frond number seedling-1, frond length, and chlorophyll content of oil palm seedlings compared to FGV's recommended NPK and FYM application for oil palm. The physicochemical properties of the soil were significantly altered by the integration of FYM+NPK, resulting in reduced EC, improved organic matter, N, P, K, leaf N, P, K, and plant N, P, K uptake. The optimal integration of FYM+NPK also improved leaf area, LAI, NAR, and TDM of oil palm. However, decreasing the NPK rate below 25% of FGV recommendation did not provide any additional benefit when FYM was applied at the recommended rate. Combining organic and inorganic fertilizers creates an optimal growth medium for oil palm development. The use of manure as an organic component is advantageous in preserving soil physical structure and promoting root development. FYM integration with NPK is beneficial in various ways, including enhancing the soil's fertility, reducing porosity in sandy soils, and improving aeration in clay soils. **[27]** Fertilized oil palms with common organic components and compost to promote plant growth, while **[28]** recommended integrating FYM with NPK for similar benefits.

Manure is a valuable soil amendment due to its high content of macro- and micronutrients **[29]** Cow dung is a common type of manure used in agriculture and has been shown to be effective in maintaining soil organic matter **[30]**. Cow dung contains a wide range of minerals, including 3% nitrogen, 2% phosphoric acid and 1% potassium **[31]**. Combining FYM and NPK has been suggested as a sustainable approach to improving soil fertility and oil palm production **[32]**. Using organic fertilizers may also increase plant height and leaf number **[33]**. **[34]** Found that the optimal combination of FYM, urea, and NPK for oil palm seedling growth was 0.02 grams of urea and 40 grams of FYM, which was equivalent to 0.04 grams of NPK fertilizers and 50 grams of FYM. In a recent study, fertilizing an oil palm plantation with Ferti plus and NPK improved plant N uptake **[35]**.

The results of this study, along with similar studies conducted in various parts of the world, indicate that the soil and climate of the coastline of Pakistan, particularly in the coastal belt of Sindh province, are highly favorable for large-scale cultivation of oil palm. In addition to the 1.5 million acres of land along the coastline, areas such as Hyderabad, Tando Muhammad Khan, Matiari, Tando Allahyar, Mirpurkhas, and even up to Sanghar districts have suitable climatic conditions for oil palm cultivation. However, the development of farming communities and the establishment of proper markets for oil palm cultivation require serious efforts from the government. Proper planning and implementation of strategies could help reduce the high import bill for edible oil and provide economic stability to poverty-stricken areas such as Thatta, Sujawal, Badin, and surrounding districts, where more than 70 percent of the population lives below the poverty line.

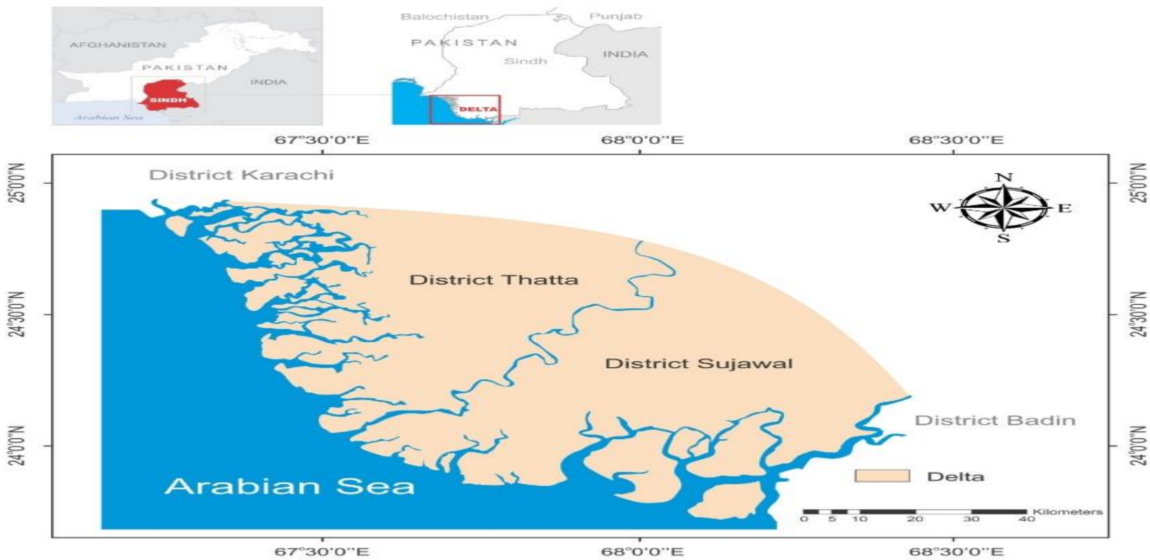

Figure 1. Map of the coastal area of Sindh, Pakistan

Conclusions
The optimal fertilizer treatment for achieving higher agronomic and physiological performance, as well as improved leaf nutrient contents and uptake, at the post-nursery stage of oil palm was FYM @ 2 kg + NPK 25%<FGVR per seedling. NPK 25%>FGVR ranked second in performance, while a 50% increase or decrease in NPK over FGVR did not have a significant effect on oil palm growth. This treatment resulted in improved number of fronds per seedling, frond length, chlorophyll content, leaf area, leaf area index, and dry mass of oil palm seedlings. The physicochemical properties of the soil after harvest of the seedlings showed significant changes, with the integrated use of FYM and NPK (FYM @ 2 kg + NPK 25%<FGVR) resulting in reduced EC, improved organic matter, residual soil N, P, K, leaf N, P, K contents, and uptake. In a previous experiment comparing the response of both varieties (3way cross and Yangambi PB 14) to the integrated use of macronutrients (NPK) and FYM, Yangambi PB 14 showed superiority over the 3way cross in all studied traits.

Authors' contributions
Conducted experiment and wrote first draft of manuscript: NS Memon, Supervised the experiment and helped in technical writing: AW Gandahi, Technical guidance throughout my research: AW Gandahi, Corrected this manuscript: MS Sarki & QA Panwar, Formatted this manuscript and helped statistical analysis: MS Sarki & QA Panwar, Helped in data collection: MS Sarki & QA Panwar.

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