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A COMPARATIVE STUDY ON ZERO TILLAGE WITH BULLDOZING AS LAND PREPARATIONS ON OIL PALM GROWTH, AND NUTRIENT STATUS AFTER 5 YEARS OF PLANTING.

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ABSTRACT

A comparative study on zero tillage and bulldozing, as land preparations for oil palm seedling transplanted into the field was conducted at Ayip Eku Oil Palm Estate between 1993 and 1997. The experimental site was a five-year fallow land in which *Panicum maximum* (Guinea grass) and *Centresoma pubescence* were dominant fallow species. Sprouted oil palm nuts were obtained from the Nigerian Institute for Oil Palm Research (NIFOR) and established in a single stage nursery and used for the experiment. Number of leaves per palm, palm height and leaf area (LA) determined after 12 months of field planting, were significantly higher in the zero tillage plots than the bulldozed plots. Zero tillage exerted a more significant ($P < 0.05$) effect on growth parameters through increased plant height, leaf number per palm, and Leaf Area and nutrient status of the soil than bulldozing. On the average, the number of leaf blades per palm and palm height increases were 25.0% and 34.7% respectively, higher in the zero tillage plots compared with bulldozed soil. Seasonal trend showed that zero tillage had the highest N content of 32.29g/kg within the 0 – 20cm depth compared with the bulldozed plots. Cropping for 5 years under both tillage systems resulted in a decrease in soil pH by approximately one unit in the surface horizon. Zero tillage system maintained a significantly ($P< 0.05$) higher level of exchangeable Ca and Mg in the surface depth, 0 - 20cm layer that by implication has the highest organic matter content. Equally, both tillage systems had more than adequate amount of available P and exchangeable K up to 80cm depth. These findings are discussed in light of tillage systems and soil nutrient status in oil palm management.

KEY WORDS: Zero tillage, bulldozing, crop growth and nutrient status after 5 years

INTRODUCTION

The oil palm (*Elaeis guineansis Jacq*) is monocious and cross pollinated, and individual palms are usually very heterozygous. It strives in a wide range of soils in Nigeria, but the most important soils for oil palm are the acid sands derived from the coastal plain and basement complex soil in South Eastern and Western Nigeria, (Omoti et al. 1986). Yields are limited and very often drop drastically due to nutrient deficiency caused by previous cropping, nature of land preparation, cultivars planted, weather effect such as prolonged drought resulting in low water table, inadequate moisture resulting to low movement of inorganic solutes and heavy rains that cause flood, erosion, leaching and associated increase in soil acidity, Omoti, et al (1986).

The basement complex soil of Ayip Eku Oil Palm Estate near Oban hills has basement rocks consisting mainly of gneisses, migritites, schists, quartzites and marbles but have emplaced within them smaller bodies of granite or syenite and intrusions of more basic amphibolites and olivinrich dykes (Murchoch, 1976). The chief features of these basement complex soils include a sandy surface horizon underlaid by a weakly developed clayey, mottled, and occasionally concretionary sub-soil, (FAO 1966).

Bulldozing as a means of land preparation has widely been adopted in the establishment of farmlands and tree crop plantations in the tropics especially when a large-scale plantation development is involved. Juo and Lal (1978 reported that crop response to tillage systems depends upon soil characteristics, climatic conditions and the nature of crops to be grown, and that nutrient depletion in the conventionally tilted soil was mainly due to accelerated soil erosion, with grain yield being consistently higher from zero tillage than bulldozed at the same rate of N-treatment.

Some people seem to support the zero-tillage method, which is assumed to be cost effective and reduces nutrient losses. (Lal, 1976a; Philip and Young, 1973). Much research into a comparative effect of zero tillage with bulldozing in the plantation agriculture had not been done. The objective of this study is to evaluate the influence of zero tillage and bulldozing methods of land preparations, on growth parameters, and nutrients status of polybag-seedlings transplanted into the field.

MATERIALS AND METHODS

The experiment was conducted at Ayip Eku Oil Palm Estate, near Calabar, Cross River State, Nigeria oil palm seedlings which had been planted as germinated seeds from Nigerian Institute for Oil Palm Research (NIFOR) and managed in a single stage nursery at Ayip Eku Oil Palm Estate, as outlined by Aya (1976; 1978) were transplanted into the field at 10 months age, and used for this study. the Estate is located between 5^0 06' and 5^0 08 latitude and $8^0$29'E longitudes.

The experimental site was previously cropped with cassava followed by a four-year fallow in which *Panicum maximum* (Guinea grass) and *Centrosoma pubescens* were dominant fallow species. Land was cleared manually with matchet, axe and chainsaw. Tree stumps were carefully dug out, carried away outside the plot and burnt for the zero tillage plots. The bulldozed plot was mechanically bulldozed to a 30cm depth, and all stumps removed by land. This study was carried out for 5 years, 1993 – 1997.

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Table 1: Average rainfall values (mm) for 1993 – 2000

Months	1993	1994	1984	1996	1997	1998	1999	2000	Rainfall (mm)
	Rainfall (mm)		Rainfall (mm)		Rainfall (mm)		Rainfall (mm)		
January	15.6	16.0	8.1	9.0	24.8	25.0	21.6	22.7	9.6
February	40.8	39.9	28.6	27.2	26.2	27.1	20.4	21.4	19.2
March	41.2	40.6	35.4	36.4	48.1	49.2	31.2	32.0	24.1
April	52.1	53.0	29.2	28.7	40.7	39.5	52.7	51.6	48.5
May	81.4	80.6	92.5	93.0	67.2	68.0	127.5	126.3	97.2
June	121.7	122.4	124.1	124.3	158.9	157.8	121.6	122.4	134.8
July	97.6	98.1	98.7	97.8	162.5	163.0	101.2	102.0	98.2
August	65.2	64.9	78.5	79.0	107.6	107.5	92.4	93.1	85.6
September	82.5	83.0	91.2	92.1	92.5	93.2	91.0	92.3	71.4
October	49.3	48.5	52.7	53.1	87.4	88.1	41.5	42.4	16.9
November	31.0	32.1	29.4	28.9	42.5	43.2	9.1	9.0	10.4
December	10.4	10.2	11.2	11.3	15.2	15.4	4.8	4.6	5.1
Mean	57.4	57.4	56.6	56.7	72.8	73.1	59.6	60.0	51.8

Source: Meteorological Station, Ayip Eku Oil Palm Estate, Akamkpa, Cross River State, Nigeria.

Analytical data for a representative soil profile under natural vegetation in the vicinity of the experimental site prior to land clearing are shown in Table 2. The soil is derived from basement complex rocks consisting mainly of banded gneisses and micaceous schist. It is classified as oxic Paleustalf (USDA) or Ferrick Luvisol (FAO, 1966).

Soil samples of 20cm intervals, up to 80cm depth, were collected for individual plots in March 1993 for analysis. Ten separate soil samples from each depth were composited for each of the four replicate plots from tillage treatments. After air-drying soil samples were ground gently and passed through a 2 -mm sieve.

Soil samples were analyzed for organic carbon (by dichromate oxidation). Total N (by Kjeldahl digestion) Bray – 1 P and for I N ammonium –acetate extracted Ca, Mg and K. Effective cation exchange capacity (ECEC) was obtained by summation of NH_4 OAC – exchangeable bases plus KCl exchangeable acidity. Soil pH was by the use of PH meter. (Pye modal 291). Potassium – chloride acidity (H^+ and Al^{3+}) was determined by titration with 0.05 N NaOH. Procedures for the above analysis are given in Black's Method of soil analysis.

At 3 and 5 years of the experiment, soil samples were again analysed to determine the values of exchangeable cations. A randomised complete blocks (RCB) design was used with four replications, and 22 palms per plot, at a spacing of 8.8m triangular. Polybag seedlings were carefully carried to the field for planting. The method adopted for field planting was as follows: A planting hole deep and wide to just accommodate the entire polythene bag in which the seedling was growing was dug at each planting site in the field just prior to the planting exercise. The bag was then stripped off from the soil ball encompassing the seedling roots, taking care to avoid injury to the latter and disturbance to the soil ball. The intact ball of earth was then lowered into the prepared hole adjusting its depth where necessary by partial filling or further excavation until the top of the soil ball was flushed with the surrounding soil surface. The seedlings were finally consolidated in position by gently firming the soil around the palm base with the foot while maintaining the palm in an upright position. A uniform spacing of 8.8cm triangular was adopted for this study. The following fertilizers and rates were applied per palm in each of the years. N as urea at 0.57kg, p as super phosphate at 0.68kg, k as muriate of potash at 0.75kg and mg as magnesium sulphate at 2.27kg.

To safeguard the palms against animals attack in the field, each palm was protected by a cylindrical collar of wire netting mesh of 2.5cm, height 50.0cm and radius of 15.0cm. The following recommended fertilizer rates (Omoti, et. al, 1986) were carried out.

Table 1: Fertilizer Recommended Years of Planting

Fertilizer applied	1	2	3	4	5
	Rates kg/Palm /year				
N as urea	0.23	0.46	0.57	0.57	0.00
P as Superphosphate	0.23	0.46	0.68	0.68	0.00
K as Muriate of Potash	0.46	0.53	0.75	0.5	0.00
Mg as Magnesium Sulphate	1.02	2.05	2.27	.27	0.00

Table 2: Properties of a representative profile at the experimental site prior to treatment

Property	Soil Depth (cm) 0-20 A	20 –40 B1	40– 60 Bt1	60 –80 Bt2
N g/kg	33.2	29.0	26.3	21.5
Silt	4.0	4.0	3.8	3.4
Clay (%)	27.0	42.3	57.1	52.0
Sand (%)	54.1	46.0	40.3	31.4
Texture	Scl	Scl	Sc	Sc
PH (H_2O)	6.6	6.1	5.9	6.0
Organic Carbon (%)	1.05	0.95	0.86	0.62
Exchangeable cations cmol(+) kg-1				
N g/kg	33.2	29.0	26.3	21.5
Ca	3.20	3.12	2.88	2.58
Mg	0.81	0.69	0.72	0.59
K	0.45	0.23	0.21	0.20
Na	0.06	0.05	0.04	0.05
(Al^+)	0.16	0.16	0.16	0.16
Effective CEC cmol(+) kg-1	6.33	3.71	4.39	4.26
Bray –1P (mg/g) -	5.00	3.60	2.64	1.85

Surface application of fertilizer was carried out two times each year of the experiment. No fertilizer application was carried out during the 5th year of the experiment in which the final soil analysis was done. At 12 months of the experiments, ten palms were randomly selected from every plot for the study of growth parameters namely: number of leaves per palm, palm height; and Leaf Area (LA). The total number of leaves produced during the study was counted and the sum was divided by the total number of palms used to obtain the average number of leaves per palm on marked palms. As earlier produced and developed leaves on these marked palms were not counted. From the marked palms, measurement was made in-situ from palm base to the leaf blade tip to obtain palm heights (cm). Five leaves were marked for LA determination from the ten randomly selected palms. Leaf area was measured using a leaf area meter L1 – COR Model. Total number of palms that survived were counted and calculated to obtain the percentage.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) and means compared with Fisher's Least Significant Difference (LSD) at 5% level.

Growth Parameters

At 12 months of the experiment, leaf number, Leaf area and plant height were significantly ($P < 0.05$) higher in the zero tillage plot than in the bulldozed plots. The average leaf number at 12 months of the study was 15.0, LA 126.4cm^2, and plant height 105cm for zero bulldozed plots. There was, on the average a 25% (12.0 – 15.0) unit increase in the number of leaf blades per palm in the zero tillage plots compared with the bulldozed soil; and a 50.1% (84.2 – 126.4) unit increase in leaf area in the zero tillage plots compared with the bulldozed soil. Highest plant height 105.1cm was obtained from zero tillage plots giving about 34.7% (78.0 – 105.1) unit increase compared with the bulldozed soil. About 99.7% of palms transplanted into the field survived from zero tillage plots compared with 90.4% obtained from bulldozed plots.

Table 4, shows the influence of zero tillage and bulldozing of land on the soil nutrient status after 3 years of transplanting oil palm into the field. Seasonal trend showed that N, Ca and Mg contents of the bulldozed soil were reduced by more than two-fold of zero tillage soil due to nutrient losses by erosion. The chemical characteristics of the soil before transplanting contained on the average, N 33.2g/kg Ca, 2.764cmol(+) kg^{-1} Mg, 1.268cmol(+) kg^{-1} K, 0.278cmol(+) kg^{-1} Na 0.304cmol (+) kg^{-1} P 2.868mg/kg.

At 3 years field planting on the average the N, Mg, K and Na contents in the soil were reduced to more than half in the zero tillage plots and approximately four fold reduction in the bulldozed plots (table 4). The Ca and P content of the zero tillage plots after 3 years were more than double that of the bulldozed plots.

Soil nitrogen and organic matter after 5 years

One of the most pronounced effects of zero tillage system is probably the maintenance of a higher level of soil organic matter in the surface soil compared with the bulldozed soil. The seasonal trend in terms of N content was favoured by zero tillage, with highest N of 12.40g/kg within the depth of 0-20 in the first year compared with bulldozed soil. At depth of 60-80cm, the N content 3.58g/kg from zero tillage in the 4th year was two-fold that of the bulldozed soil. There was a

Table 3: Average growth parameters on zero tillage compared with bulldozing after 12 months of field planting

Parameters	Zero tillage	Bulldozed	LSD P = 0.05
Leaf number/palm	15.0	12.0	1.5
Leaf area (LA) cm^2	126.4	84.2	12.4
Height cm	105.1	78.0	10.8
% Survival	99.7	90.4	8.5

significant downward reduction of N from 0 – 20cm depth to 60 – 80cm depth, and a progressive decrease from the 1st year to the 5th year. Equally, organic C, 30g/kg obtained from soil depth of 60 – 80cm in the zero tillage plots was significantly higher than the 24g/kg obtained from 0-20cm depth in the bulldozed soil.

Zero tillage treatment led to stratification of soil pH throughout the 0 – 80cm profile. Continuous cultivation for 5 years under both tillage systems resulted in a decrease soil pH by approximately one unit in the surface horizon, up to a depth of about 60cm. (Table 6), compared with the average initial surface soil pH of 6.6 at the beginning of the study. On the average, the pH values obtained from zero tillage plots were significantly ($P < 0.05$) higher than those from bulldozed soil.

Calcium and Magnesium

The zero tillage treatment maintained a significantly ($P<0.05$) higher level of exchangeable Ca in the surface depth 0-20cm layer (Table 7) and this coincides with the high organic matter content given in Table 2.

Continuous cropping with oil palm for 5 years under both tillage systems also resulted in a decrease in soil exchangeable Ca. There seem to be a slight downwards movement of Ca in the bulldozed soil between 0 – 40cm of depth.

Tillage treatments showed significant ($P<0.05$) effect on the amount and distribution of exchangeable Mg in the profile after 5 years of cropping with oil palm. There was a significantly higher level of exchangeable Mg in the surface 0 – 20 cm layer than the bulldozed soil. It is however a well known fact that cation exchange sites on the soil organic matter preferentially retain Ca and Mg and even K than values of Mg obtained from 40 – 80cm layer in the zero tillage plots, (Table 7), indicating the availability of Mg throughout the profile layers (0-80cm) in the zero tillage plots.

Potassium and Phosphorus

Zero tillage resulted in accumulation of available P and exchangeable K in the surface 0-20cm layer of the profile. Under Bulldozed soil, however, there was a downward movement of both P and K (Tables 8 and 9) compared with data in Table 1. It has been observed in the present study that

Table 4: Effect of zero tillage and bulldozing on the soil nutrient status after 3 years of field planting.

Nutrient	Initial characteristics	Zero tillage (Years)			Bulldozed (Years)			LSD P < 0.05
		1	2	3	1	2	3	
N (g/kg)	33.200	22.400	8.000	3.200	2.600	1.200	0.400	1.300
Ca cmol (+) kg^{-1}	2.764	1.370	0.812	0.330	0.860	0.300	0.14	0.040
Mg cmol (+) kg^{-1}	1.268	0.196	0.069	0.029	0.122	0.040	0.02	0.020
K cmol (+) kg^{-1}	0.278	0.050	0.035	0.020	0.040	0.008	0.004	0.002
Na cmol (+) kg^{-1}	0.304	0.056	0.016	0.014	0.044	0.008	0.006	0.004
P mg/kg	1,868	1.400	0.640	0.501	0.810	0.251	0.162	0.030

Table 5: Effect of tillage systems on distribution of organic carbon and nitrogen in the soil profile after 5 years.

Depth (cm)	TOTAL Ng/kg											ORGANIC C g/kg											C/N Ratio	
	Zero Tillage					Bulldozed soil					LSD (P<0.05)	Zero Tillage					Bulldozed					LSD (P<0.05)	Zero Tillage	Bulldozed Soil
	Y1	Y2	Y3	Y4	Y5	Y1	Y2	Y3	Y4	Y5		Y1	Y2	Y3	Y4	Y5	Y1	Y2	Y3	Y4	Y5			
0-20	12.40	9.10	6.22	4.31	0.17	10.25	8.51	5.20	3.01	0.12	1.02	35	25	20	15	10	24	20	16	14	10	2.5	12	9
20-40	11.89	8.84	5.68	4.49	0.15	8.28	6.20	5.09	2.82	0.10	0.85	35	25	20	13	10	24	20	16	12	9	2.4	11	10
40-60	9.25	8.35	6.12	2.86	0.15	6.22	5.81	4.70	1.38	0.08	0.72	35	25	20	11	10	23	22	15	10	9	2.4	9	9
60-80	8.11	7.30	5.46	3.58	0.14	5.30	4.51	3.40	1.20	0.04	0.68	30	21	20	10	7	22	20	15	8	7	1.0	8	7

L. S. D (0.05) between treatment means

Table 6: Effect of tillage system on soil PH measure in H_2O at 1.1 soil to water ratio after 5 years

Depth (cm)	Zero tillage	Bulldozed soil	LSD (P < 0.05)
0-20	5.6	5.0	0.5
20- 40	5.3	4.8	0.4
40-60	5.4	4.9	0.5
60 – 80	5.6	5.0	0.4
LSD (0.05) between treatment means.			

Table 7:Distribution of exchangeable Ca and Mg in the Soil profile after 5 years.

Depth	Ca cmol(+) kg-1			Mg cmol(+) kg-1		
	Zero tillage	Bull Dozed soil	LSD (P< 0.05)	Zero tillage	Bull dozed soil	LSD (P < 0.05)
0 – 20	5.8	4.6	1.2	1.3	0.9	0.3
20 – 40	4.1	3.4	0.7	1.1	0.8	0.2
40 – 60	2.4	3.2	0.5	1.2	0.8	0.2
60 – 80	1.7	3.2	1.2	0.9	0.7	0.2

LSD (0.05) Between treatment means

Table 8: Effect of tillage on available P mg/kg (Bray -1P) distribution in the soil profile after 5 years.

Depth	Zero tillage	Bulldozed soil	LSD (P < 0.05)
0 – 20	2.441	1.041	1.2
20 – 40	2.402	1.101	1.3
40-60	1.847	1.117	0.7
60-80	1.238	1.012	0.2
LSD (0.05) between treatment means			

Table 9:Effect of tillage system on exchangeable K (cmol(+)kg-1) distribution in the soil profile after 5 years

Depth	Zero tillage	Bulldozed soil	LSD (P < 0.05)
0 – 20	0.42	0.32	0.09
20 – 40	0.36	0.28	0.08
40 - 60	0.38	0.32	0.06
60 - 80	0.29	0.21	0.07
LSD (0.05) between treatment means			

both zero tillage plots and bulldozed soil contained more than adequate amount of available P and exchangeable K up to 80cm depth. Zero tillage values of P in the 0-40cm depth was more than double, the values obtained from the bulldozed plots after 5 years of cropping (Table 8). This seem to lead to slight stratification of exchangeable K levels in the 0 – 80cm profile.

DISCUSSION

The findings suggest that better result could be achieved with zero-tillage than with bulldozing. This is because nutrient losses are minimized, and oil palm seedling will therefore utilize applied fertilizer more efficiently for growth and development than in the bulldozed plots. Again the period of high temperature with low rainfall during the season, favoured good crop performance, in the zero – tillage and this might have contributed to greater enhancement of palm growth parameters, and significant higher palm height than the bulldozed plots. Lal (1975) reported high soil temperature as one of the factors that retard crop growth in the tropical soils. Although the data was not presented, the zero-tillage soil provided a partial cover as evidenced in the humus deposits on the top soil. This helped to reduce the top soil temperature and conserved soil moisture on the 0 – 5 cm layer during dry period is in agreement with the reports of Lal, (1975), and Ubi, (2004).

The growth differences of oil palms in the zero tillage plots compared with the bulldozed plots may be attributed to variation in soil nutrient status, a few years after planting because nutrient demand was higher by the plant and could account for the greater yield difference recorded in this study. In a comparative study, Ataga (1980) reported on nutrient demand by 12 months old palm seedlings and suggested that fertilizer application is imperative as the level of exchangeable and reserve K cannot sustain high yields of oil palm for more than a few years after planting.

This investigation shows that the loss of top soil by bulldozing cannot be compensated for by fertilization even after 5 years. Bulldozing removes valuable top soil. The effect is long lasting because top soil is the richest part of the soil. It was observed in this study that the bulldozed plot are of rough surface and slopes giving opportunity for erosion, soil exhaustion and leaching and could account for the low nutrient status of these plots and may lead to low yield consequently. These findings are in consonance with the findings of Olivine (1986).

The significant differences in organic C and total N levels in the surface 0-80cm layers between the two tillage systems and surface runoff in the bulldozed soil are in consonance with the earlier reports, (Lal 1976a; 1976b; Philip and Young, 1973). The fast rate of decomposition of fresh plant residue and immobilization of soil organic matter by soil microflora may also contribute to a lower level of C and N.

Equally, the fast rate of N mineralization in the bulldozed soil compared with zero tillage plots, would enhance leaching loss of NO_3 – N, and is in consonance with the findings of Riley et al (1975). The relatively low C/N ratio indicates that soil organic matter was well humified and favoured N mineralization by making N available after decomposition. The moderately large amount of total N accumulated in the surface layers of zero tillage suggests that mineralization could contribute an important portion of available N to plants during the growing season. This can be illustrated by the higher growth parameters under zero tillage than under bulldozed soil.

Zero tillage treatment led to stratification of soil pH throughout the 0-80cm profile. After 5 years of cropping under both tillage systems, the soil PH was decreased by approximately one unit in the surface horizons, up to a depth of 60cm, compared with the average initial soil PH of 6.6 at the time of clearing. It is believed that the extreme PH values, the hydrogen or hydroxyl ions can have some direct detrimental effects on plant growth, especially when the concentration of inorganic ions in the soil solution is low.

There appeared to be a slight downward movement of Ca and Mg in the bulldozed soil between 20 – 40cm of depth. This could be due to effect of loss of surface soil by erosion and could account for the reduction in Ca and Mg and could affect the effective Cation Exchange Capacity of the soil.

The considerable downward movement of P together with a high availability of P in both treatments reported in this study suggests that lower rates and frequent applications should be adopted. The relatively lower available P levels in the surface horizons of the bulldozed soil may be attributed to soil erosion menace, leaching and increased P fixation, Hassan and Leitch (2000), Jenkins and Ali (2000). Soil pH determined the particular ion specie present such as P. Under acidic conditions the $P_2PO_4^-$ ion dominates. As pH is raised HPO_4^{2-} and finally PO_4^{-3} are found. The influence of PH on plant nutrient is obvious. High levels of fertilizer will help increase soil PH. The Kaolinitic Alfisols in West Africa such as the Palenstaff at this experimental site, retain little phosphorus in the course – textured surface horizon, but P sorption capacity increases with depth due to increasing clay and sequioxide contents (Juo and Fox 1977).

The greater mobility of K in the soil profile is expected, particularly in the bulldozed soil, in view of the predominance of Kaolinite throughout the profile.

In the present study, the zero tillage plots contained adequate amounts of available P up to the 80cm depth, while moderately high levels of available K or exchangeable K occurred throughout the 60cm profile. But as the PH decreases along with years of cropping it would reach a stage that the soil would be deficient in the exchangeable bases. A higher level of fertilizer is suggested. However one may not expect any excessive concentration of roots growth close to the soil surface but in this case, root concentration near the soil surface in the zero tillage plots may be necessarily harmful and is an indication of a more favourable soil temperature and moisture regimes that could adequately support oil palm growth.

CONCLUSION

From the findings in this study, zero tillage system has added advantage of preventing soil erosion menace, improving soil structure and compactment, soil temperature and moisture regimes and building up of soil organic matter and nutrient status, through reduced erosion, leaching tendencies and surface run offs. Zero tillage system apart from helping to improve crop growth and development, it also helps in soil fertility maintenance especially in a monocropping system like oil palm plantation.

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