

EFFECT OF TILLAGE METHODS AND MULCHING RATES ON SOIL TEMPERATURE AND ROOT LENGTH OF OKRA (*Abelmoschus esculentus* L. Moench) IN MAKURDI, BENUE STATE OF NIGERIA.

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ABSTRACT

This study was carried out during the 2015 and 2016 cropping seasons at the Teaching and Research Farm of the University of Agriculture, Makurdi to determine the effect of tillage and mulching on soil temperature and root length of okra in the study area. Three (3) tillage methods including Flat, Open and Tied ridges, with five (5) mulching rates at 0, 2, 4, 6 and 8 t/ha, making a total of fifteen treatments combinations were laid out in a Randomized Complete Block Design (RCBD) and replicated three (3) times. Total area of the field was 702 m². Weekly data was taken on soil temperature using simple mercury-in-glass thermometers at 3pm on designated days and data on length of root was taken on the last day of harvest, at 16 weeks after planting. Results revealed that Tied ridging had the lowest soil temperatures (25.00 °C), followed by Flat tillage (25.17 °C) and least by open ridging (25.50 °C). Among the mulch rates, 4 – 8 t/ha regardless of tillage method significantly produced higher moderating effect on both soil temperature and root length of okra. The longest root was obtained at 8 t/ha, but was not significantly different from that at 6 t/ha at 5% level of probability, however was significantly higher than 4 and 2 t/ha. It was recommended that Application of 6 t/ha mulch with Tied ridging tillage method which was most suitable for optimum soil temperature regime and enhanced root length of okra was recommended for inceptisol in the study area.

Keywords: Tillage, Mulching, Soil temperature, Root length, Okra

INTRODUCTION

In Nigeria, Okra is usually boiled in water and results in slimy soups and sauces which are relished. The fruits serve as thickeners (Schippers, 2000), while the leaves, buds and flowers are also edible. The dried seeds are nutritious materials that can be used to prepare vegetable curds or roasted and ground to be used as a coffee additive or substitute (Farinde *et al.*, 2001). Rehn and Espig (1991) reported that Okra contains about 20% edible oil and protein. Fanen (2012) reported that the mucilage preparations from the immature pods are used medicinally in the treatment of Ulcer and relief of haemorrhage. Tihamiyu *et al.* (2012) were of the view that the immature stems contain crude fibre which could be used in paper industries and for making ropes. Markose and Peter (1990) explained that the Okra mucilage is usually

used in glazing certain papers and also useful in confectionary industries among other uses.

Tillage effects on annual variations in soil temperature are small and planting on ridges, furrows, mounds, flat beds and orientation of rows significantly affect the soil temperature. And that ridges and mounds have a higher maximum temperature than the flat seedbed (Lal, 1975). It can be deduced that different tillage systems have varying effects on the yield of different crops through the interactions of various soil factors. Tillage affects soil temperature, soil structure, nutrient availability, water accumulation/retention and root development. These factors influence crop performance.

According to Lal (1975), mulching drastically reduces loss of water through evaporation from the soil, minimizes losses due to lodging, enhances efficient fertilizer use

and higher biological activity, maintains soil structure, increases soil moisture storage and availability, regulates soil temperature, controls soil erosion by reducing runoff and increasing infiltration, suppresses weeds, upon decomposition increases soil organic matter, ensures steady yield returns over a long time and encourages higher transpiration, which ultimately leads to higher yield. Adding that transpiration has a direct relationship with yield.

Lal (1975) confirmed that surface mulching with crop residue at the rate of 4 – 6 t/ha decreases soil temperature and maintains favourable soil structure through enhanced biological activity. Further, he stated that mulching is an important factor in maintaining the fertility status and cation exchange capacity of tropical soils through increased organic matter content. He continued that, a mulched plot with crop residue is equivalent to a two-layered profile of which the upper layer has a lower contact coefficient. He observed that in tropical climates, mulch keeps the soil temperature more uniform and decreases the amplitude of temperature wave; that during the initial stages of growth, temperature differences of 8°C at 5 cm depth were observed while maximum temperature for un-mulched maize was 42°C at 5 cm depth at IITA Ibadan.

Again, Lal, (1975) hinted that diurnal fluctuations in the soil temperature of cleared land can be between 20-30°C; soil temperature above 36°C can adversely affect emergence vigor and yield of crops such as maize, soya beans and yam; on the average, there is 10% decrease in fresh and dry shoot weight per degree increase in root zone temperature above 30°C; shoot and root concentration of nitrogen, phosphorus and potassium decreases with increased temperature; and that maximum temperature on mulched plots occurs one or two hours after that of un-mulched plots. He further observed that there was an eight-fold increase in yield by mulching even on flat cultivation for the early planting as compared to total failure for the un-mulched heaps and ridges.

Arising from the foregoing, it has become expedient to explore the most common tillage methods and introduce ties in

the ridges with varying quantities of mulching. By so doing, we will be able to see the ability of these variables to moderate soil temperature and bring it to a “comfort zone” suitable for the thriving of roots throughout the growing season. This will indirectly increase the availability of moisture to crops and eventually lead to increased crop yield per unit area of land put into okra production. The objective of this work therefore was to evaluate the effect of tillage practices and mulching on soil temperature and root length of okra.

MATERIALS AND METHODS

Field experiments were carried out during the 2015 and 2016 cropping seasons at the Teaching and Research Farm of the University of Agriculture, Makurdi within the Southern Guinea Savanna agro-ecological zone of Nigeria, located between latitude 7°41' to 7° 42' N and longitude 8° 37' to 8° 38' E at an elevation of 97m above mean sea level with a slope of about 3%. According to Abagyeh (2016), the soils of the UAM Teaching and Research Farm are predominantly Inceptisols with maximum depth of 50cm with horizon description as follows: Horizon AP (0-21cm depth) having dusty red (2.5 YR-3/2); sandy loam, weak medium to coarse crumbs, slightly sticky, slightly plastic when wet, very friable when moist, hard when dry with many fine to coarse roots, few Iron (Fe) and Manganese (Mn) concretions, few gravel and gradual smooth boundary. Further, the soil is classified as Typicustropepts (USDA) (Fagbemi and Akamigbo, 1986).

The experimental site experiences a hot tropical climate with distinct wet and dry season. The wet season starts from April and lasts till October while the dry season begins from November and ends March. The rainy season is associated with the southwest trade maritime wind, which blows across the area from the Atlantic Ocean whereas the dry season is ushered in by the North-east wind (harmattan) which is dry, cold and dusty (Agbede *et al.*, 2011).

Experimental treatments and Design

The experiment consisted of Tillage (3 methods): Flat Cultivation (FC), Open Ridge

(OR) and Tied Ridge (TR), and mulch (5 rates): 0, 2, 4, 6 and 8 t/ha, giving FC0, FC2, FC4, FC6, FC8, OR0, OR2, OR4, OR6, OR8, TR0, TR2, TR4, TR6 and TR8. These were laid out in a 3x5 factorial arrangement in

Randomized Complete Block Design (RCBD) with three replications, giving a total of 45 plots. Each plot measured 3m x 3m, giving an area of 9m²/ plot, but for the 45 plots, the area involved was 702m² (0.0702 ha).



Plate 1: A Section of the Experimental Field Layout at UAM Teaching and Research Farm Showing Okra Plants growing on Mulched Tied Ridges

Test Crop

Improved variety of Okra, NHAe₄₇₋₄ seeds were obtained from NIHORT, Ibadan and used as test crop. It was planted at the recommended intra and inter-row spacing of 50 and 75cm respectively as shown in Figure 1.

Data Collection

Soil temperature

Simple mercury thermometers were used to measure soil temperature. They were inserted into the soil at 5 cm in each of the treatments for one hour, between 2-3 O'clock in the afternoon on designated days to measure

what was taken as the highest soil temperature for that day.

Crop data

Data was collected on root length at harvest. This was done by using a meter rule to measure the length of the longest root from its point of attachment to the stem to the tip of its most active growing point.

Data Analysis

All data were subjected to Analysis of variance (ANOVA) using Gen Stat Release version 14 (Payne *et al.*, 2011), after which significant means were separated using

Fisher's Least Significant Difference (F-LSD) at 5 % level of probability.

RESULTS AND DISCUSSION

The rainfall for the two years went into at least the second week of October, thus ensuring the availability of moisture for maturing and good yield of okra. The lowest temperature (26.95°C) for 2015 was recorded

in the month of July while that for 2016 was 27.00°C obtained in the month of September. The highest were in October with 28.10°C and 27.95°C in the respective years. Both extremes of temperature for the two years were higher than the long-term averages for the corresponding months (Table 1). These environmental conditions were conducive for profitable rain fed okra production.

Table 1: Meteorological Data for Makurdi

Year/month	Temperature (°C)		
	2015	2016	*
January	28.85	26.20	26.01
February	30.00	29.95	29.80
March	30.00	30.85	29.90
April	30.45	29.65	30.12
May	29.70	28.75	27.70
June	28.15	27.70	25.83
July**	26.95	27.05	26.18
August**	27.20	27.05	24.63
September**	27.10	27.00	26.10
October**	28.10	28.20	25.97
November	27.05	28.25	27.27
December	25.04	26.40	25.10
Total	-	-	-
Total for July to October	-	-	-

* = Long term average of 6 years, spanning from 2009 to 2014, computed for this research.

** = Cropping period.

Source: Nigerian Meteorological Agency, Nigerian Air Force Base, Makurdi

The main effect of tillage practices on soil temperature at 5 cm depth (Table 2) shows that in 2015, a low rainfall year, among the tillage methods, FC had the lowest temperature of 27.90 °C and highest temperature of 32.97 °C was recorded by OR. In 2016, the lowest temperature of 26.30°C was recorded by TR and highest was from OR with 33.03 °C. Lal (1975) stated that tillage effects on annual variations in soil temperature are small. That planting on ridges, furrows, mounds, flat seedbed and orientation of rows significantly affects soil temperature. Stating further that ridges and mounds have higher maximum temperature than the flat seedbed.

He reported that shoot and root concentration of N, P and K increases and decrease with temperature. Maintaining that diurnal fluctuations in soil temperature of cleared land can be between 20-30 °C. He cautioned that soil temperature above 36 °C could adversely affect emergence vigor and yield of crops such as maize. And concluded that on the average, there is a 10% decrease in fresh and dry shoot weight per degree increase in root zone temperature above 30 °C. Osunbitan *et al.* (2005) confirmed that variation in bulk density over the growing season of a crop is due to tillage impact, natural compaction, the fluctuation of soil water content through the season and the influence of roots, ants,

termites and earthworms as well as farm traffic.

Table 2: Effect of Tillage Practices on Soil Temperature (°C) in Makurdi at 5 cm depth

Tillage	2015					2016				
	3WAP	6WAP	9WAP	12WAP	15WAP	3WAP	6WAP	9WAP	12WAP	15WAP
FC	32.20	27.90	27.97	28.07	32.70	29.90	32.83	26.53	28.10	29.37
OR	32.63	28.63	28.77	28.80	32.97	27.00	33.03	26.57	29.43	30.47
TR	31.57	28.30	27.60	27.87	31.20	26.67	32.57	26.30	27.70	29.87
F-LSD _(0.05)	0.500	0.400	0.290	0.530	0.760	0.690	0.700	0.670	0.780	0.180
F-Pr.	< 0.001	0.003	< 0.001	0.003	< 0.001	0.606	0.405	0.690	< 0.001	0.007

WAP = Weeks After Planting, F-LSD = Fisher's Least Significant Difference, FC = Flat Cultivation, OR = Open Ridges, TR = Tied Ridging, F-Pr = Probability

The main effect of mulching on soil temperature (Table 3) shows that it was significant across all the weeks in both the 2015 and 2016 seasons, decreasing with increasing tonnage of mulch. This means that temperature tended to decrease as the rate of mulch increased. The highest temperature for the year 2015 was 34.72°C at 0 t/ha at 15WAP while the lowest was 27.28°C at 8 t/ha at 6 WAP. The highest soil temperature difference of 4.89°C was between the 8 and 0 t/ha treatments in 2015, with the difference decreasing with increasing mulch rate. The lowest difference was 1.50°C between 2 t/ha and 0 t/ha, though it was statistically significant at 5% level of probability. In the 2016 season, a high rainfall year, the highest

temperature was 33.56°C at 0 t/ha at 15WAP, a difference of 1.16°C less than that of 2015 while the lowest soil temperature was 25.22°C at 9WAP, a difference of 2.06°C less than that of the 2015 season. Like in 2015, the soil temperature differences between the mulch treatment and the control (0 t/ha) were significantly different across all the weeks of the study. The difference between the highest and lowest soil temperature at 15WAP, the driest week was 6.45°C. This was higher than that of 2015, however it correlates well with the higher atmospheric temperature in the month of October (15WAP) 2016 as opposed to the lower atmospheric temperature in 2015 for the same month.

Table 3: Effect of Mulching on Soil Temperature (°C) in Makurdi at 5 cm depth

Mulching (t/ha)	2015					2016				
	3WAP	6WAP	9WAP	12WAP	15WAP	3WAP	6WAP	9WAP	12WAP	15WAP
0	33.61	29.72	29.00	29.39	34.72	27.94	33.89	28.61	31.50	33.56
2	32.94	28.67	28.89	28.44	33.22	27.17	33.33	27.28	29.44	32.06
4	31.89	28.28	27.89	28.11	33.22	26.78	32.83	26.67	28.00	29.44
6	31.11	27.44	27.44	27.89	31.44	26.17	32.00	25.22	26.28	27.33
	31.11	27.28	27.33	27.39	29.83	26.22	32.00	25.22	26.28	27.11
F-LSD _(0.05)	0.640	0.520	0.380	0.690	0.980	0.900	0.910	0.890	1.010	0.230
F-Pr	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

WAP = Weeks After Planting, F-LSD = Fisher's Least Significant Difference, F-Pr = Probability

The above observations are in agreement with the work of Lal (1975) who demonstrated that surface mulching with crop residue at the rate of 4-6 t/ha decreased soil temperature and maintained a favourable structure through

enhanced biological activity. He explained further that mulching drastically reduces the loss of water through evaporation from the soil and regulates soil temperature, enhancing greater transpiration, which ultimately leads to

higher yields. This underscores the point that transpiration has a direct relationship with yield.

Lal (1975) concluded that a mulched plot with dry crop residue is equivalent of a two-layered profile, of which the upper layer has a lower contact coefficient. That in the tropics, mulch keeps the soil temperature more uniform and decrease the amplitude of temperature wave. And that at IITA Ibadan, at the initial stages of growth, temperature differences of 8°C at 5cm depth were observed, with maximum temperature for un-mulched maize on ridges reached at 42°C. He ended by stating that maximum temperature on mulched plots occurs one or two hours after that of the un-mulched plots.

The effect of decreased soil temperature on early crop establishment as influenced by mulching was obvious in the heavily mulched plots. In the field the 4-8 t/ha mulched plots had taller plants with more leaves and branches, higher leaf areas, bigger stems and ultimately higher yield, whether pod number and weight or dry matter yield (Data not shown).

The interaction effect of tillage practices and mulching on soil temperature at 5 cm depth (Table 4) shows that in 2015, it was significant at 9WAP while in 2016; the interaction was not significant across all the weeks. OR0 with 29.17°C and 34.33 °C recorded the highest temperatures for the 2015 and 2016 seasons respectively, while the lowest temperatures were obtained from TR6 and TR8 (26.83°C) in 2015 and FC8 (26.00 °C) in 2016. Temperature in both seasons tended to decrease with increasing mulch level. In 2015, a low rainfall year, the effect was more pronounced while in 2016, a high and evenly distributed rainfall year, the perpetual soil wetness all year round made it very difficult for any meaningful variations to be picked up by the soil thermometers used. This is in agreement with Lal (1975) that in humid tropical climate, mulch keeps the soil temperature more uniform and decrease the amplitude of temperature wave. This result suggests that combining mulching with tillage may not necessarily lead to increased or better soil condition especially in an excessively wet year.

Table 4: Effect of Tillage Practices and Mulching (t/ha) on Soil Temperature (°C) in Makurdi at 5 cm depth

Treatment	2015					2016				
	3WAP	6WAP	9WAP	12WAP	15WAP	3WAP	6WAP	9WAP	12WAP	15WAP
FC0	33.83	29.33	29.00	29.50	35.50	28.50	34.33	28.00	31.67	33.21
FC2	33.33	28.00	28.00	28.50	34.00	28.00	33.83	27.67	28.83	32.00
FC4	32.33	27.83	27.83	27.67	32.50	26.67	32.67	26.50	27.67	29.17
FC6	31.00	27.33	27.33	27.50	31.50	25.83	31.83	25.33	26.33	26.33
FC8	30.50	27.00	27.17	27.17	30.00	25.50	31.50	25.17	26.00	26.00
OR0	33.83	30.17	29.17	30.17	36.00	27.83	33.67	27.50	32.82	34.33
OR2	33.17	29.00	30.17	28.83	33.67	26.67	33.33	26.83	30.67	32.83
OR4	32.00	28.50	28.33	28.67	33.00	26.67	32.83	26.83	28.83	29.67
OR6	32.00	27.83	28.17	28.50	32.00	26.50	32.67	26.17	27.83	27.87
OR8	32.17	27.67	28.00	27.83	30.17	27.33	32.67	25.50	27.00	27.67
TR0	33.17	29.67	28.30	28.50	32.67	27.50	33.67	27.33	30.00	33.00
TR2	32.33	29.00	28.00	28.00	32.00	26.83	32.83	27.33	28.83	31.33
TR4	31.33	28.50	27.00	28.00	31.17	27.00	33.00	26.67	27.50	29.50
TR6	30.33	27.17	26.83	27.67	30.83	26.17	31.50	25.17	26.33	27.83
TR8	30.67	27.17	26.83	27.17	29.33	25.83	31.83	25.00	25.83	27.67
F-LSD _(0.05)	1.110	0.900	0.660	1.190	1.710	1.550	0.700	1.530	1.740	0.400
F-Pr	0.254	0.786	0.812	0.812	0.512	0.195	0.652	0.840	0.855	0.305

FC0 = Flat + 0t/ha mulch, FC2 = Flat + 2t/ha mulch, FC4 = Flat + 4t/ha mulch, FC6 = Flat + 6t/ha mulch, FC8 = Flat + 8t/ha mulch, OR0 = Open ridge + 0t/ha mulch, OR2 = Open ridge + 2t/ha mulch, OR4 = Open ridge + 4t/ha mulch, OR6 = open Ridge + 6t/ha mulch, OR8 = Open ridge + 8t/ha mulch, TR0 = Tied Ridge + 0t/ha mulch, TR2 = Tied Ridge + 2t/ha mulch, TR4 = Tied Ridge + 4t/ha mulch, TR6 = Tied Ridge + 6t/ha mulch, TR8 = Tied Ridge + 8t/ha mulch. WAP = Weeks After Planting, F-LSD = Fisher's Least Significant Difference, F-Pr = Probability

The result of the main effect of tillage practices on okra root length determined on the 17th day of October each of the two years of the study, which was the day of final harvest and removal of the plant from the ground (Table 5) indicates that in both the

2015 and 2016 seasons, TR had plants with the longest roots, followed by FC and least by the OR. The differences between TR and FC were not statistically different at 5% level of probability.

Table 5: Effect of Tillage Practices and Mulching rates (t/ha) on Root Length (cm) of Okra at 15 WAP in Makurdi

Treatment	2015	2016
Tillage		
FC	42.94	32.36
OR	41.23	30.47
TR	45.04	32.87
F-LSD (0.05)	0.180	0.760
Mulching		
0	40.04	30.86
2	41.26	31.31
4	43.66	33.09
6	44.71	32.62
8	45.69	32.61
F-LSD (0.05)	0.240	0.980
F-Pr.	<0.001	0.002

WAP = Weeks After Planting, F-LSD = Fisher's Least Significant Difference, FC = Flat Cultivation, OR = Open Ridges, TR = Tied Ridging, F-Pr = Probability.

The result of the main effect of mulching on okra root length (Table 6) indicated that in 2015, the longest roots were obtained at 8 t/ha, followed by 6, 4 and 2 t/ha in decreasing order, with the mulch rates being statistically significantly different from the control (0 t/ha) at 5% level of probability. In 2016, this trend changed, with 4 t/ha having the longest root length, followed by 6, 8, 2 and 0 t/ha in a decreasing manner. There was no significant difference between 6 and 8 t/ha. This trend was sustained in the interaction effect of tillage and mulching on root length (Table 7). The roots of plants can be likened to their mouths through which water, nutrients and air are interchanged with the rhizosphere or soil root environment. The length of roots will determine their ability to access their needs,

which may not be very close to the immediate soil environment where the plant may be anchored into the soil. Sometimes nutrients could be held in the soil at great depths (horizons) until roots that may have grown and reached those depths can reach them. To an extent, the length and how disperse the roots of a plant are, the easier will it be able to access sufficient nutrients and water to meet up its requirements for those materials. With a maximum profile depth of about 50 cm, the longest roots were from TR8 (46.80 cm), TR6 (46.30 cm) FC8 (45.87 cm), TR4 (45.17 cm) and OR8 (44.40 cm), in decreasing order. With the roots going down more than 80% of the profile depth, it means that they had ample opportunity to maximize their search for their needs, hence their impressive performance.

Table 6: Interaction Effect of Tillage Practices and Mulching (t/ha) on Okra Root Length (cm) in Makurdi

Treatment	2015	2016
FC0	40.10	31.50
FC2	41.70	31.70
FC4	42.93	33.50
FC6	44.10	33.07
FC8	45.87	33.03
OR0	37.03	29.53
OR2	38.13	29.90
OR4	42.87	30.33
OR6	43.73	31.27
OR8	44.40	31.30
TR0	43.00	31.53
TR2	43.93	32.33
TR4	45.17	33.53
TR6	46.30	33.51
TR8	46.80	33.43
F-LSD _(0.05)	0.410	1.690
F-Pr	<0.001	0.995

FC0 = Flat + 0t/ha mulch, FC2 = Flat + 2t/ha mulch, FC4 = Flat + 4t/ha mulch, FC6 = Flat + 6t/ha mulch, FC8 = Flat + 8t/ha mulch, OR0 = Open ridge + 0t/ha mulch, OR2 = Open ridge + 2t/ha mulch, OR4 = Open ridge + 4t/ha mulch, OR6 = open Ridge + 6t/ha mulch, OR8 = Open ridge + 8t/ha mulch, TR0 = Tied Ridge + 0t/ha mulch, TR2 = Tied Ridge + 2t/ha mulch, TR4 = Tied Ridge + 4t/ha mulch, TR6 = Tied Ridge + 6t/ha mulch, TR8 = Tied Ridge + 8t/ha mulch. WAP = Weeks After Planting, F-LSD = Fisher's Least Significant Difference, F-Pr = Probability

CONCLUSION

Tied ridging (TR) produced okra plants with significantly higher root lengths and also had a higher moderating effect on soil temperature in a low rainfall year, but in a high rainfall year, Flat bed (FB) was superior to tied ridging and the least by open ridging. Also, in a high rainfall year, open ridges had the highest moderating effect on soil temperature. Even in the absence of mulch, tied ridging demonstrated superiority as a viable alternative to farmer's practice of planting okra on open ridges or flat cultivation, especially under low soil moisture conditions.

RECOMMENDATIONS

Based on the findings of this study, it is hereby recommended that tied ridging with 6 t/ha mulch be adopted for okra production, since it produced plants with the highest root length and also had the highest moderating effect on soil temperature.

REFERENCES

- Abagye, S. O. I. (2015). Characterization and Irrigation Suitability Ratings of Soils of Mid-Benue Valley using Okra (*Abelmoschus esculentus* L. Moench) as a test crop. Unpublished Ph.D thesis. Department of Soil Science, College of Agronomy, University of Agriculture, Makurdi – Nigeria. 178pp.
- Agbede, O. O., O. J. Jayeoba, L. T. Ogunremi, A. Ali, S. Amhakhain, S. A. Rahman, S. M. Amana, I. M. Ogara and E. Ndor (2011). Inventory of Farmer's Physical Environments, Farming Practices and Constraints in Southern Guinea Savanna of Nigeria (desktop study). RFA-CARGS Programme. Agricultural Research Council of Nigeria. P70-71.
- Fagbami, A. and Akamigbo, F. O. R. (1986). Soils of Benue State – their Capabilities. Proceedings of the 14th Annual Conference of the Soil Science

- Society of Nigeria held in Makurdi between 4th – 7th Nov. p. 49 – 52.
- Fanen, F. T. (2012). The Effect of Population Density, Planting Dates and Cropping Systems on Yield of Egusi Melon-Okra Mixture. Unpublished M.Sc. Thesis, Department of Crop Production College of Agronomy, University of Agriculture, Makurdi – Nigeria.
- Farinde, A. J., Owarafe, O. K. and Ogungbemu, O. I. (2001). An overview of production, processing, marketing and utilization of okra in Egbedove Local Government of Osun State, Nigeria. Agricultural Engineering International. *The CIGRE Journal* Vol. IX.
- Lal, R. (1975). Role of mulching Techniques in Tropical soil and water management. IITA Ibadan. *Technical Bulletin* No. 1.
- Markose, B. L. and Peter, K. V. (1990). Review of Research on vegetable and Tuber crops. Kerala Agricultural University Press, Kerala, India.
- Osunbitan, J. A., D. J. Oyedele and Adekalu, K. O. (2005). Tillage effects on bulk density, hydraulic conductivity and strength of a loamy sand soil in southwestern Nigeria. *Soil and Tillage Research*, 82 (1): 57-64.
- Payne, R. W., Harding, S. A., Murray, D. A., Soutar, D. M., Baird, D. B., Glaser, A. I., Welham, S. J., Gilmour, A. R., Thompson, R. and Webster, R. (2011). The Guide to GenStat Release 14, Part 2: Statistics. VSN International, Hemel Hempstead, UK.
- Rehn, S. and Espig, G. (1991). The cultivated plants of the tropics and subtropics, CTAD 6992, Germany. p 552.
- Schippers, R. R. (2000). African Indigenous vegetables: An overview of cultivated spices. National Resources Institute (NRI), University of Greenwich, London, United Kingdom. 224pp.
- Tiamiyu, R. A., Ahmed, H. G. and Muhammed, A. S. (2012). Effects of Sources of Organic Manure on Growth and yield of Okra (*Abelmoschus esculentus* L. Moench) in Sokoto, Nigeria. *Nigerian Journal of Basic and Applied Science*, 20(3) 212 – 216.
- Wuese, S. T. (2013). The Effect of Selected Tillage practices on Soil Loss in the Southern Guinea Savanna Agroecological Zone of Nigeria. Unpublished M.Sc. thesis,

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