



RESPONSE OF NODULATION AND DRY MATTER YIELD OF SOYBEAN (*Glycine max* (L.) merr.) TO TILLAGE IN SANDY LOAM SOILS

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ABSTRACT

A field experiment was conducted at the Teaching and Research farm of Adamawa State College of Education Hong during the rainy season of the year 2021 to determine the effects of tillage on nodulation and dry matter yield of soybean (*Glycine max* (L.) Merr.) The experiment consisted of six treatments namely Conventional Tillage (CT), Ridge Tillage (Rg-T), Mulch Tillage (MT), Minimum Tillage with Residues (M + R), Reduced Tillage (RT) And No - Tillage (NT) laid in a Randomized Complete Block Design (RCBD) in three replications with each plot measuring 12 m² and a discard of 1m² between plots, and total area of 216 m². Data on plant dry matter weight and number of nodules were collected and analyzed using analysis of variance (ANOVA) using (SAS) program and differences observed were separated using LSD. Results obtained revealed that there were significant differences ($p < 0.05$) in dry matter and nodule number/ha with the mulched treatments giving the highest dry matter yield of 3213.1 kg/ha and nodule numbers of 4222.0 kg/ha at harvest. The least dry matter weight was obtained from the No-Tillage treatment with 172.5 kg/ha and a nodule weight of 1672.0 kg/ha. Thus, dry matter weight in the Mulch Tillage treatment were 63.7% higher than the Conventional Tillage while the nodule number was 61.6% greater in the Mulch Tillage than in the Conventional Tillage treatments. Therefore, the plants raised on the Mulch Tillage treatments gave the best result among the treatments and may be the most appropriate for optimum growth and yield of soybean. Adoption of Mulch Tillage as a complement to or instead of the conventional tillage currently used by soybean farmers in the study area, has the potential to significantly increase soybean output.

Key Words: Biomass, Dry, Fertility, Nodulation and Soil.

INTRODUCTION

Tillage is the mechanical manipulation of soil aimed at improving conditions affecting crop production, thereby playing an important role in crop growth and soil improvement. Tillage enhances rapid, extensive root growth and improves water infiltration. Thus adopting the appropriate tillage method is vital to optimum crop productivity. Soybean is an important grain, oil and biofuel crop and the largest source of plant protein worldwide. World leading producers of soybean are USA (32 %), Brazil (28 %), Argentina (21 %), China (7 %) and India (4 %) with a sown area of 130 million hectares yielding 130 million tons about 68 % of global production in 2018 – 2019 (Adamic and Leskovsek, 2021). 45 % of this output is from the South American countries of Argentina, Brazil and Paraguay (Pérez-Pizá *et al.*, 2020). Soybean yield depends on the physical properties and water storage capacity of the soil, and also the physiological parameters and root development of the plant (da Silva *et al.*, 2022). Therefore, the provision of a soil environment whereby the roots obtain moisture and plant nutrients at critical stages of the plants' growth is essential in determining crop growth, nodulation and yield; the various tillage practices accomplish these in different ways.



Conservation tillage for instance enhances nodulation and nitrogen fixation through increased soil moisture retention and increased soil temperature and soil microbial biomass, however soil compaction under Conservation Tillage may decrease nodulation and pH (Shahram *et al.*, 2019; Adamic and Leskovsek, 2021) as infiltration and water availability to the plant is reduced and the soil is vulnerable to erosion because of poor infiltration. Minimum Tillage on the other hand enhances soil microbial activities, nodulation and nitrogen uptake compared with No-Tillage; while No-Tillage systems decreases dehydrogenase activity, root nodulation and nitrogen uptake compared with the Conventional Tillage (Solar Farhangi Abriz *et al.*, 2021), but the No-Tillage had resulted into a 7.8 % higher grain yield than the Conventional Tillage in the long term (da Silva *et al.*, 2022). These suggest that Soybean growth, nodulation and yield are dependent among other factors on the tillage practice(s). Soybean, being a relatively new crop in the agro-ecological zone where the current study was conducted, farmers in the area generally engage in the Conventional Tillage practices of ploughing and in some cases harrowing and the Zero tillage – where herbicides are applied to destroy weeds prior to planting. The influence of these tillage practices on growth and yield of soybean as well as on certain parameters governing yield such as nodulation has been poorly described in this area. Thus, very little information on the most suitable tillage practices for optimum yield of soybean supported by research evidence exists. Therefore, there is a need to research into and identify the most appropriate and effective types of tillage for soybean optimum growth and yield in the area. This study was conducted to determine the most appropriate tillage method for optimum vegetative growth, and nodulation of soybean in Hong Local Government Area of Adamawa State, Nigeria.

MATERIALS AND METHODS

The Study Area

The experiment was conducted on the Teaching and Research Farm of the Adamawa State College of Education Hong located on Latitudes 10° 23' and 10° 28' N and Longitudes 12° 48' and 13° 00' E at an elevation of 304 – 400 meters above sea level along the Yola-Maiduguri highway in Adamawa State of Nigeria (Adebayo and Tukur, 1999; Latur, 2002) during the 2021 rainy season. The Area is characterized by a distinct dry season occurring from November to March and a rainy season from April to October with rainfall amounts ranging from 700 – 1200 mm annually and a mean annual rainfall of 1000 mm with a greater part falling between July and September (Adebayo and Tukur, 1999) (Figure 1).

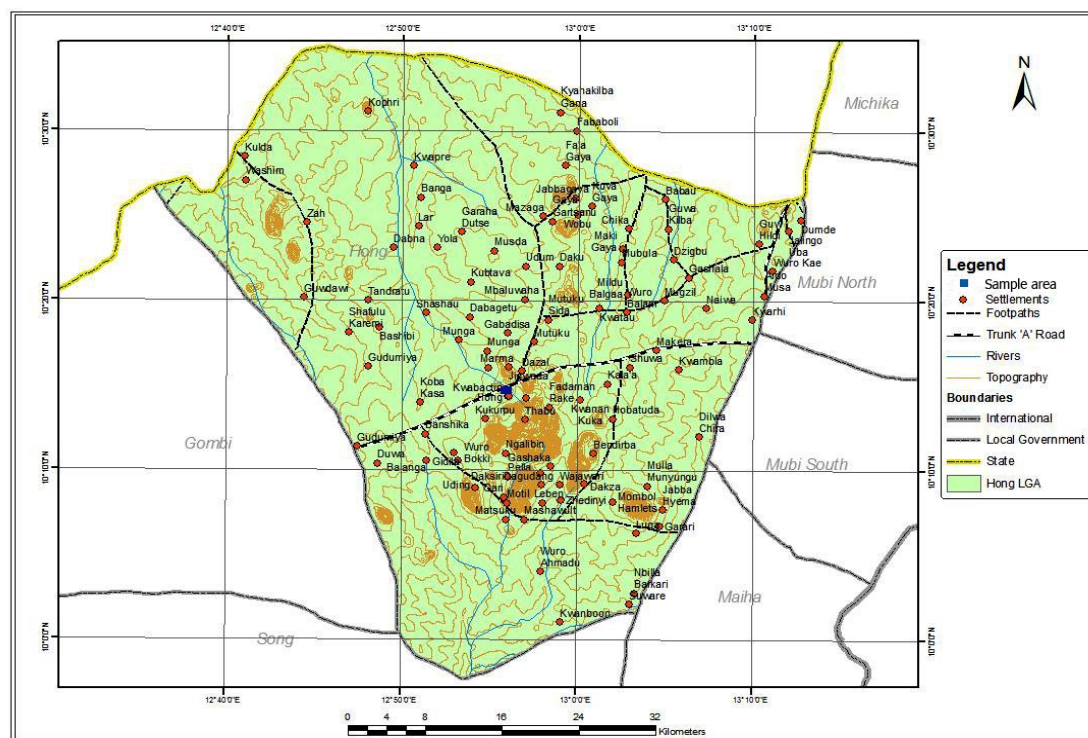


Figure 1: The Map of Hong Local Government Area showing the area of study

Treatments and Experimental Design

The experiment consists of six treatments as follows: Conventional Tillage (CT), Ridge Tillage (Rg-T), Mulch Tillage (MT), Minimum tillage with Residues (M+ R), Reduced Tillage (RT) and No - Tillage (NT) arranged in a Randomized Complete Blocks Design (RCBD) in three replicates. The experimental plots were 4m x 3m each giving an area of 12 m²/plot and the total experimental area of 216 m². Distances of 1m were maintained as alleys between each treatment and a 50 cm dyke maintained to separate subplots between the replications.

Tillage operations and planting

The experimental site was cleared using cutlass and hoes, all grasses, shrubs and crop residues were burnt completely before the rains. The field was ploughed with a disc mounted on a tractor and all plots incorporated with stubbles. No form of tillage except for the disc plough was done on the Conventional Tillage (CT) treatment plots that served as the Control. On the Mulch Tillage (MT) plots, additional straw was deposited, to cover the entire surface, leaving only gaps naturally created by the straw arrangement. Ridges were constructed on the Ridged Tillage (Rg+T) plots, along the lengths of the plots, raised to about 30 cm high. The Minimum Tillage with Residues (M + R) treatments involved manually turning the soil with a hoe to a depth that allows the stubble to be completely buried under the soil. A similar operation to that of the Minimum Tillage with Residues (M + R) was conducted to produce the Reduced Tillage (RT) treatment, but no residues added. On the No-Tillage (NT) plots Glyphosate herbicides were used at the rate of 2.5 L per hectare to clear all grasses. Plots were laid out and planting distance of 40 cm x 15 cm and depth of 3 cm were maintained throughout.

Weeding and fertilizer application

Weeding was done at two weeks after planting (2WAP) and four weeks after planting (4WAP) manually using hand and hoe. Weeds on the plots was constantly checked and reduced to a minimum. Phosphorus fertilizer (Single Super Phosphate SSP) and Potassic fertilizer (Muriate of Potash MOP) were applied to all plots at the rates of 60 kg/ha and 20 kg/ha respectively. The first rate of application was one – third of recommended dose of application at 4WAP and the remaining two-thirds of the recommended dose at second application at 8WAP. Both applications were as side dressing placed 15 – 17 cm away from the stand to avoid plant burning.

Measurements

The parameters measured were taken 2WAP and 4WAP while Number of Nodules (kg/ha) was taken at 50 days after planting (DAP).

Number of Nodules (kg/ha)

Uprooted plants were washed and the nodules counted then converted to per hectare basis at 50 days after planting.

Dry Matter Weight (kg/ha)

The dry matter weight (kg/ha) were obtained at 2 WAP and at 4 WAP.

The dry matter weight for each treatment was calculated using the formula:

$$\text{Dry matter weight (DMW)} = \text{Stover weight} \times \frac{100}{\text{Plot Size}}$$

$$\text{Plot size} = 12 \text{ m}^2$$

$$\text{DMW} = \text{Stover weight} \times \frac{100}{12} \text{ kg/ha}$$

Analytical Techniques

The data collected were subjected to analysis of variance (ANOVA) using computer software statistic version 12. The differences between the means were separated using least significant difference at 5% level of significance.

SOIL PROPERTIES

Soil Physical Properties

The soil texture was determined using the Bouyocus Hydrometer method while the gravimetric soil moisture content, particle density and bulk density were determined as described by Jaiswal (2003).

Soil chemical properties

The soil chemical and physical properties are shown on Table 1. The soil pH was measured in a 1:2 soil to water ratio using a glass electrode (H19017 microprocessor) pH meter () and the EC was measured using Jenway 4320 EC meter. The organic carbon content of the soil was determined by wet oxidation while the percentage organic matter was obtained by multiplying the organic carbon content by 1.724. Total nitrogen was determined by the macro kjeldahl digestion, distillation and titration. The available P were determined using Bray 1 method as described by Bray and Kurtz (1945) and updated by Jaiswal (2003). Exchangeable bases were extracted with one normal (1N) ammonium acetate. Potassium and Sodium were determined using flame photometer, while Calcium and Magnesium was determined by titration with 0.01N EDTA (ethylene di-amine tetra-acetic acid) as described by Jaiswal (2003). The soil was extracted with unbuffered 1.0M KCl, and the sum of Al and H was titrated with 0.1M NaOH in the presence of phenolphthalein indicator to a permanent pink color (Jaiswal, 2003). The ECEC was determined by (summation method) summing up the exchangeable bases and exchangeable acidity (IITA, 1984). The

percentage base saturation was calculated by dividing the exchangeable bases by the effective cation exchange capacity and expressing the result as a percentage as described by Jaiswal (2003). Sodium adsorption ratio (SAR) were determined by estimation of sodium adsorption ratio (SAR) (Njoroge, 1990). Exchangeable Sodium percentage (ESP) was estimated from SAR by substituting the value of SAR of extract from saturated paste (Richard 1954).

Table 1: Physical and chemical properties of soils in the Study Area

Soil Properties (Particle size g/kg)	Characteristic
Sand	83.40
Silt	10.00
Clay	06.00
Texture	LS
Bulk density (g/cm ³)	1.65
Particle density (g/cm ³)	2.67
Water holding Capacity	37.60
pH (1:2)	6.43
Organic Carbon OC	0.83
Organic Matter OM	1.43
Calcium Ca	2.90
Magnesium Mg	1.10
Potassium K	0.59
Sodium Na	0.30
Available P	0.59
Total N	0.08
TEB	4.89
TEA	2.20
EC (ds/m)	0.13
ECEC	7.00
PBS	68.97
SAR	0.16
ESP	4.23

(Soil analysis, 2023)

RESULTS AND DISCUSSION

Physical and Chemical Properties of Soils

The physical and chemical properties of the soil in the area is presented in Table 1. The physical characteristics of the soil showed that sand had the highest fractional value followed by silt, while clay recorded the lowest value giving the textural classification of loamy sand. The bulk density, particle density and water holding capacity were 1.65 g/cm³, 2.66 g/cm³ and 37.60 % respectively. The soil pH was 6.43 making it slightly acidic, while organic carbon and organic matter were 0.83g/kg and 1.4g/kg respectively. The exchangeable cations and acidity indicate that the soil was low in fertility. This low fertility may be attributable to the high sand quantity, low

bulk and particle density, low organic matter content among others which is typical of tropical soils in accordance with (Umeugokwe *et al.*, 2021).

Table 2. Dry matter weight (Kg/ha) at two weeks after planting and four weeks after planting and the number of nodules per hectare

Treatments	Dry matter weight Kg/ha 2WAP	Dry matter weight Kg/ha 4WAP	Number of nodules per hectare
Conventional Tillage (CT)	1622.5 ^c	2536.1 ^{bc}	2234 ^{bc}
Ridge Tillage (Rg + T)	2611.1 ^b	2813.9 ^a	3351 ^b
Mulch Tillage (MT)	3138.9 ^a	3213.1 ^a	4222.0 ^a
Minimum Tillage with Residues (M + R)	2286.1 ^b	2361.1 ^c	2333.0 ^{bc}
Reduced Tillage (RT)	1840.6	2430.2 ^{bc}	2211.0 ^c
No-Tillage (NT)	1400.0 ^d	172.50 ^d	1672.0 ^d
SE \pm (0.05)	173.5	459.2	3000.1
LSD	546.9	1447.0	945.6

LSD= Least Significant Different, SE=Standard Error of Means, and WAP= Weeks After Planting.

DRY MATTER WEIGHT

The effect of treatments on dry matter weight at 2 WAP and 4 WAP is presented in Table 2. At 2 WAP the effect of tillage on dry matter weight was significantly different for all treatments at p (0.05) except for the M + R (Mulch + Residues) and Rg + T (Ridged Tillage) treatments where no significant differences were recorded between treatments. The highest mean dry matter weight at 2WAP was 3138.9 Kg/ha produced from the MT (Mulch Tillage) plots whereas the lowest was 1400.0 kg/ha recorded on NT (No Tillage) treatments. The Rg + T (Ridged Tillage) and M+R (Minimum Tillage + Residues) treatments produced 2611.1kg/ha and 2286.1kg/ha dry matter weights respectively. In the Rg + T (Ridged Tillage), MT (Mulch Tillage), M + R (Minimum Tillage + Residues) treatments dry matter weight increased by 60.9 %, 93.5 %, 40.9 % respectively and decreased by 13.7 % in the RT (Reduced Tillage) when comparison with the CT (Conventional Tillage) control treatment. Furthermore, at 4WAP dry matter weight was significantly different in all treatments except between the CT (Conventional Tillage) and Rg + T (Ridged Tillage) and also between the Rg + T (Ridged Tillage) and MT (Mulch Tillage) treatments at p (0.05). The highest dry matter weight at 4WAP was recorded on the (Mulch Tillage) MT at 3213 kg/ha whereas the lowest value was on the NT (No-Tillage) with 172.5 kg/ha. The CT (Conventional Tillage) and RT (Reduced Tillage) yielded 2536.1 kg/ha and 2430.2 kg/ha respectively of dry matter. Thus, dry matter weight increased by 10.9 % and 26.7 % in the Rg + T (Ridged Tillage) and MT (Mulch Tillage) treatments respectively, while in the NT (No-Tillage) dry matter weight decreased by 93.2 % compared with the CT (Conventional Tillage) control treatment. Therefore, the dry matter weight at both 2 WAP and 4 WAP were highest in the Mulch Tillage (MT) and lowest in the No-Tillage (NT) of all the treatments in the current study; with the responses from the No-Tillage (NT) treatments being lower than in the Conventional Tillage (CT) control treatments. Dry matter weight increased as the number of weeks increased in all treatments. Increased vegetative growth leading to increased dry matter weight over time suggests that vegetative growth of soybeans benefited from all treatments, however the (NT) No-Tillage practice seems not to be favorable

while the Mulch Tillage (MT) provided the most beneficial conditions for soybean dry matter output under the current study. Increased vegetative growth under Mulch Tillage is consistent with reports by Wahyuni *et al.* (2022), which showed increased leaf number and plant height of soybean under Rice straw mulch compared with un-mulched treatments. Similarly, results of this study agree with Akhtar *et al.* (2019), where wheat mulch led to increased soil moisture retention causing higher photosynthesis, leaf area index, SPAD-values thereby producing higher biomass and seed yield of soybean over the un-mulched. Thus, regardless of the type of mulch material used, mulch application has significant positive impact on vegetative growth and subsequent dry matter production of soybean in accordance with the result of this study.

NUMBER OF NODULES PER HECTARE

The effects of tillage methods on number of nodules is shown on Table 1. There were significant differences in number of nodules between all treatments except between the CT (Conventional Tillage) control treatment and the M + R (Mulch + Residues) and Reduced Tillage (RT) treatments where no significant differences occurred. The Mulch Tillage (MT) produced the highest nodule number of 4222.0 per hectare whilst the No-Tillage (NT) gave the lowest number of nodules at 1672.0 per hectare. Number of nodules per hectare increased by 50 % in the Ridged Tillage (Rg + T) and by 89 % in the Mulch Tillage (MT) compared with the Conventional Tillage (CT) control, but decreased by 25 % in the No Tillage (NT) treatment. Therefore, the Mulch Tillage (MT) treatment induced the highest nodule numbers compared with the Conventional Tillage (CT), Ridge Tillage (Rg + T), and Mulch with Residues (M + R), Reduced Tillage (RT) and the No Tillage (NT) treatments. This corresponds with other findings (Virk *et al.*, 2019; Buczek and Jańczak-Pieniążek, 2022; Wang *et al.*, 2023) where there was higher soybean nodule weight, and consequent nitrogen fixation under mulched compared with the un-mulched treatments, with greater effects on these parameters recorded in the upper layer of the mulched than the un-mulched soils. In addition, the higher yield by the Conventional tillage (CT) control over the No Tillage (NT) treatment was perhaps due to decreased dehydrogenase activity, root nodulation and nitrogen uptake in the No Tillage (NT) compared with the conventional tillage (Farhangi-Abriiz *et al.*, 2021, Adamič and Leskovšek, 2021). Hence, the tillage practice that is best for production of high nodule numbers in soybean under the conditions of this study is the Mulch Tillage (MT).

CONCLUSION AND RECOMMENDATIONS

The findings of this study revealed that the type of tillage operations employed in soybean cultivation influences nodulation. The Mulch tillage (MT) produces the highest number of nodules and weight of dry matter compared to the Conventional Tillage (CT) control that is the most common practice among farmers in the area of study. Whereas the Ridge Tillage (Rg + T), Mulch with Residues (M + R), Reduced Tillage (RT) treatments were better at giving higher nodule numbers than the Conventional Tillage (CT) control, the No-Tillage (NT) practice appeared not to be as good in giving higher dry matter weight and nodule numbers as even the Conventional Tillage (CT) control.

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