WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.7 (1) : 147-149. 2009 *www.world-food.net*

Effect of power tiller operations on physical properties of soil under sawah rice production system in Bida, Nigeria

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Received 28 September 2008, accepted 17 December 2008.

Abstract

The effect of power tiller operations on physical properties of soil under sawah system in Bida, Nigeria,was examined using an Indian model of VST-SHAKTI 130 DI with 10 kW (13 hp) rated power diesel engine of 2400 rpm rated crankshaft speed on different rice fields located at Shaba-Maliki and Ejeti village near Bida on a clayey loamy, sandy soil, under the guinea savannah ecology of Nigeria. Data were collected on soil properties such as soil moisture content, bulk density, porosity, penetrometer resistance/cone index and shear strength. The core technique was used in obtaining samples for bulk density measurement, and soil penetrometer and shear vane readings were determined *in situ*. Soil samples were obtained at various depths of 7 cm intervals, soil laboratory tests were all performed using standard procedures. The results show that the bulk density increased with depth both before and after operation, but the bulk density reduced after the operation. Porosity measured immediately after operation at different depths showed an improvement down the depth and the power tiller operations have improved the soil moisture content, reduced shear strength and penetration resistance respectively. Significant differences exist on these parameters before and after the tillage operations. The use of power tiller has a significant impact on the soil physical conditions for improving the soil conditions for a high yield for rice and not the usual deterioration effect often associated with the use of farm machinery on farm fields.

Key words: Power tiller, tillage operations, physical properties, soil, sawah rice production, Nigeria.

Introduction

Nigeria is a country with a vast territory wherein the farming conditions and management scale vary from place to place. Except few private farms, the management scale under the subsistence system is generally small. It is a well known fact that power tiller industry was originally designed and developed in Japanmainly for rice cultivation. In the early 50's this industry has rapidly grown in Japan and at one time there were as many as 50 manufacturers of power tillers and their peak annual production was reached in the 1960s with more than 300,000/year.

Fasola *et al.* [1] reported that the power tiller is a multipurpose hand tractor designed primarily for rotary tilling and other operations on small farms. While in operations, an operator walks behind to maneuver it. It is also known as a garden tractor, hand tractor, walking tractor or a two-wheel tractor. Two-wheel tractors are sometimes called by other names such as single axle tractor, hand tractor, walking tractor, walk-behind tractor. The two-wheel tractor with different attachments (implements) can accomplish many kinds of farm work like tillage, planting, harvesting and transportation. When a tillage implement is attached to a two-wheel tractor, it is called power-tiller. There are many types of two-wheel tractors such as mini tiller type (1.5- 2.2 kW), traction-type (2.9-4.4 kW), dual type (3.7-5.2 kW), drive type (5.2-10.3 kW) and Thai type (5.9-8.8 kW). The demand, production and concentration of two-wheel tractors have been of particular significance in certain countries of Asia, especially those in which low land rice is a major crop. It has been observed that the power available per unit over most of Africa, for example, is about 0.04 kW/ha, while that in most developed countries, with yields per unit area of between 3 and 5 times greater, is in excess of 0.6 kW/ha [2]. Therefore, it was suggested that in order to achieve reasonable productivity in developing areas such as Africa, a tenfold increase in power to 0.4 kW/ha is necessary. To increase the available power by the introduction of more people or animals was considered unlikely to be feasible since in either case a rise in productivity could be encountered by an increased food demand [3].

The power tiller is the only power-driven tool that is effectively being used for "sawah" activities currently in the country. It is less sophisticated and not too expensive. It can be used for a variety of land preparation activities. Some of these include ploughing, puddling, levelling, and transportation. It can also be used as a power source for stationary machines such as threshers and millers. The small size and low weight of power tillers make them suitable for use in soft ground conditions. It is reinforcing rather than disturbing the soil pan. For ploughing, the power tiller has a mounted plough which easily brakes and inverts/turns the soil after land has been cleared of vegetation and stumps. Ploughing can be done either under semi-moist or flooded conditions, while in puddling/leveling the soil is being pulverized with (indirect puddling) or without initial (direct puddling) ploughing of the field. Puddling is done using the power tiller mounted with a rotavator. Under this operation, ploughed/ unploughed land is further pulverized into a fine-textured medium under flooded condition before transplanting of seedlings is done. The levelling is reinforcing rather than disturbing the soil pan. This is done to reduce the slope/gradient to the barest minimum to ensure uniform distribution of water across the field. The power tiller has an average lifespan of 4-5 years depending on how it is handled. The power tiller has a longer life span if it is used solely for land preparation on paddy fields. Most land preparation activities are conducted only under moist conditions. It can effectively cultivate over 40-50 ha of land per season and can work for about 8 hrs per day. The power tiller can plough 0.5-1.0 ha of land a day and can puddle 1.0-2.0 ha of land over the same period depending on the operators experience and size and shape of the field.

Tillage is usually defined as the mechanical manipulation of the soil aimed at improving soil conditions affecting crop production. Three primary aims are generally attributed to tillage: control of weeds, incorporation of organic matter into the soil and improvement of soil structure [4]. Very little information exists in Nigeria at the moment which can be used to assist in the equipment design, selection and use to effectively meet these aims under different soil and climatic conditions and crops. Yet, crop cultivation constitutes the most important (economic) activity in the country. Differences among soil types are an important factor in crop and water management response to a given tillage treatment. There is need to consider soil responses on each soil type and then tailor tillage practices to meet the specific objectives. In tillage research more attention, therefore, needs to be paid to the specific soil and climate involved. Furthermore, the response of soil to a given tillage treatment at a particular time often depends on the weather during the year. Tillage practices, therefore, need to be tested over a number of years [2].

However, the introduction of two-wheel tractors (power-tillers) in many countries is proving to be a better and more appropriate intermediate technology for the arguments put forward earlier. In the past three to four years, there has been an influx of two-wheel tractors into Nigeria and the demand has particularly been increasing in a place like Niger State where its use for the cultivation of low land rice is increasingly becoming popular. The size of the average family holding in many developing countries is of the order 2 to 5 hectares, with 3 hectares as an appropriate average figure. Such a holding would therefore require a power input of 1.2 kW to provide the level suggested. It is therefore the opinion of many that due to the economic level of majority of farmers in developing countries like Nigeria, in transforming from the presently predominant hand tool technology to a full blown large-scale engine power technology, there has to be an appropriate intermediate technology. The objective of this study was to determine the effect of power tiller operations on physical properties of soil under sawah system in Bida, Nigeria.

Materials and Methods

Description of the equipment: The power-tiller or walking tractor, as it is sometimes called, is a single-axle (two-wheel) tractor. This particular one is of Indian made and the model is VST-SHAKTI 130 DI with 10 kW (13 hp) rated power, diesel engine of 2400 rpm rated crankshaft speed. The engine is single cylinder horizontal, 4 strokes, water cooled and hand-cranking type. The driving wheels are of two types: the pneumatic type for normal traction and the steel or cage wheel for wet puddling.

Field layout and operations: The effect of power tiller on physical properties of soil under sawah rice production system was carried out in different rice fields located at Shaba-Maliki and Ejeti village near Bida on a clayey loamy, sandy soil, under the guinea savannah ecology of Nigeria. Bida is 137 m above sea level and lies on longitude 6°01'E and latitude 9°06'N in Niger State of Nigeria. The 600 mm tine cultivator was attached to the power tiller and it was used for puddling of the field before the transplanting of the rice was done. Fashola *et al.* [6] have a detailed description of the sawah system on farmers' fields. The soil properties monitored included soil moisture content, bulk density, porosity, penetrometer resistance/cone index and shear strength. The core technique was used in obtaining samples for bulk density measurement, and soil penetrometer and shear vane readings were determined *in situ*. Soil samples were obtained at various depths of 7 cm intervals, soil laboratory tests were all performed using standard procedures.

Results and Discussion

The bulk density increased with depth, both before and after operation, but the bulk density reduced after the operation (Table 1). Porosity measured immediately after operation at different depths showed an improvement down the depth. This indicates a positive condition for the flow of water and air through

Table 1. *Soil physical characteristics before and after power tiller operations.

Depth (cm)		Plot	MC (%)	BD (g/cm³)	CI (N/m²)	SS (MPa)	Porosity (%)
0 ≤ 7		I	34.47	1.26	24.12	0.022	52.5
		II	34	1.27	24	0.023	53
	Before	III	34.52	1.25	24.2	0.02	52
	operation	Mean	34.33	1.26	24.10667	0.021667	52.5
		I	39.54	1.36	0	0	48.7
		II	39.34	1.37	0.001	0	48.5
	After	III	38.94	1.35	0.001	0.001	48.8
	operation	Mean	39.27	1.36	0.000667	0.000333	48.67
> 7 ≤ 14		I	19.54	1.65	37.9	0.014	37.7
		II	19.4	1.66	37.8	0.015	38
	Before	III	19.6	1.64	37.7	0.014	37.9
	operation	Mean	19.51	1.65	37.8	0.0143	37.87
		I	29.59	1.53	3.45	0.006	42.3
		II	29.5	1.56	3.44	0.006	42.2
	After	III	29.6	1.55	3.46	0.006	42.1
	operation	Mean	29.56	1.547	3.45	0.006	42.2
> 14 ≤ 21		I	16.92	1.8	93.02	0.06	32.1
		II	16.9	1.9	93	0.065	32
	Before	III	17	1.88	93.01	0.07	32.2
	operation	Mean	16.94	1.86	93.01	0.065	32.1
		I	19.4	1.67	15.16	0.01	37
		II	19.5	1.7	15.2	0.01	36
	After	III	19.6	1.66	15.3	0.01	39
	operation	Mean	19.5	1.67	15.22	0.01	37.33

*MC - Soil moisture content, BD - Bulk density, C.I - Cone index/penetrometer resistance: S.S - Shear strength.

Table 2. T-test statistics comparing soil physical characteristics before and after power tiller operations at 3 soil depths.

Depth (cm)	Period	N	Mean	Std. Deviation	SEM	t	P
0 ≤ 7							
BD (g/cm³)	Before	3	1.2600	1.000E-02	5.774E-03	12.47	0.00
	After	3	1.3600	1.000E-02	5.774E-03		
CI (N/m²)	Before	3	24.1067	0.1007	5.812E-02	414.76	0.00
	After	3	6.667E-04	5.774E-04	3.333E-04		
MC (%)	Before	3	34.3300	0.2869	0.1656	-20.43	0.00
	After	3	39.2733	0.3055	0.1764		
Porosity (%)	Before	3	52.5000	0.5000	0.2887	12.70	0.00
	After	3	48.6667	0.1528	8.819E-02		
SS (MPa)	Before	3	2.167E-02	1.528E-03	8.819E-04	22.62	0.00
	After	3	3.333E-04	5.774E-04	3.333E-04		
> 7 ≤ 14							
BD (g/cm³)	Before	3	1.6500	1.000E-02	5.774E-03	9.80	0.01
	After	3	1.5467	1.528E-02	8.819E-03		
CI (N/m²)	Before	3	37.8000	1.000E-01	5.774E-02	592.0	0.00
	After	3	3.4500	1.000E-02	5.774E-03		
MC (%)	Before	3	19.5133	0.1026	5.925E-02	-149.44	0.00
	After	3	29.5633	5.508E-02	3.180E-02		
Porousity (%)	Before	3	37.8667	0.1528	8.819E-02	-41.11	0.00
	After	3	42.2000	1.000E-01	5.774E-02		
SS (MPa)	Before	3	1.433E-02	5.774E-04	3.333E-04	25.00	0.00
	After	3	6.000E-03	0.0000	0.0000		
> 14 ≤ 21							
BD (g/cm³)	Before	3	1.8600	5.292E-02	3.055E-02	5.58	0.00
	After	3	1.6767	2.082E-02	1.202E-02		
CI (N/m²)	Before	3	93.0100	1.000E-02	5.774E-03	1850.74	0.00
	After	3	15.2200	7.211E-02	4.163E-02		
MC (%)	Before	3	16.9400	5.292E-02	3.055E-02	-39.19	0.00
	After	3	19.5000	0.1000	5.774E-02		
Porosity (%)	Before	3	32.1000	0.1000	5.774E-02	-5.92	0.00
	After	3	37.3333	1.5275	0.8819		
SS (MPa)	Before	3	6.500E-02	5.000E-03	2.887E-03	19.05	0.00
	After	3	1.000E-02	0.0000	0.0000		

*MC - Soil moisture content, BD - Bulk density, C.I - Cone index/penetrometer resistance; S.S - Shear strength.

the soil profile and minimum resistance to root growth and proliferation. The power tiller with the attached tillage tool has improved the soil moisture content and reduced shear strength and penetration resistance respectively.

The readings of the physical soil properties were subjected to statistical analysis using the paired t-test sample cases in order to determine if any significant difference exists in the soil properties before and after the tillage operations. Table 2 shows that significant differences exist for all soil properties for the 3 levels of depth used in this study. Of more importance are the values with inverse differences which include moisture content and porosity. It clearly shows that the more these tillage operations are carried out the less the properties that are inversely indicated. Mohanty *et al.* [4] reported similar findings in their study in India. However, the situation presented by these properties after the tillage operations have been found suitable for the growth and yield of rice in the sawah system hence the high yield recorded on these fields. Also, Tripathi *et al.* [5] noted that the use of power tiller for tillage on rice plots increased bulk density.

Conclucion

The study has shown clearly that the use of power tiller has a significant impact on the soil physical conditions for improving the soil conditions for a high yield for rice and not the usual deterioration effect often associated with the use of farm machinery on farm fields. It is important, however, that an appropriate level of these operations are determined so that it does not lead to adverse soil conditions and probably reduces the cost of production among farmers using the power tiller. The results also serve as input to the design and evaluation of power tillers to be used in Nigeria.

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