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EFFECT OF SELECTED HOE TYPES AND FORWARD SPEED ON THE PERFORMANCE OF A DEVELOPED MECHANICAL ROW CROP WEEDER

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Abstract

A mechanical row crop weeder was developed to overcome the tedious manual weeding operation experienced in a row crop farming system and its performance evaluated. The machine is made up of a frame, handle, hoeing disk, pneumatic wheel, belt/pulley and power unit. Three different weeding tool types (U-blade, L-blade and Hoe-blade) were developed and used at three different walking speeds of 0.2, 0.4, and 0.6 m/s in three replications. The experimental plots were 27 which measured 800cm by 26cm each. Parameters such as weeding efficiency, weeding index, Field efficiency, effective field capacity and theoretical field capacity were measured using standard known formulae. This weeding machine has a swath-width of cut of 26cm which corresponds to an average furrow width of farm cropping system. Results from field performance showed that both theoretical and effective field capacities increased with increase in the walking speed of the operator while field efficiency decrease with increase in the walking speed. The mean field efficiencies obtained were 93.58 %, 91.91 % and 85.64 % at the walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively. ANOVA revealed that the working speed and tool type have significant effect on the weeding index and weeding efficiency of the machine at $p<0.05$. The results showed that weeding index decreased with increasing walking speeds with all the tool types investigated, the walking speed of 0.2 m/s had the highest weeding index of 0.937 with the L-blade tool type. The least weeding index of 0.580 was obtained at the walking speed of 0.6 m/s with the hoe-blade tool type. The highest weeding efficiency of 93.7 % was obtained for 0.2 m/s walking speed and L-blade tool type. This device will contribute greatly to weeding status of row crop farms for small scale farmers

Keywords

Hoe, speed, performance, row, crop and weeder

1. Introduction

Weed is essentially any plant growing in the wrong place at the wrong time and doing more harm than good [1]. Among the activities involved in crop production such as land preparation, weeding, fertilizer application and harvesting, weeding is the most labour-intensive operation [1]. Weeding accounts for about 25% of the total labour requirement (900-1200 man-hours/hectare) during a cultivation season [2].

The use of sort handle hoe is effective and it is the most widely used manual weed control method in Nigeria. It is reported that manual weeding is labour-intensive, accounting for about 80% of the total labour required for producing food in Nigeria [3]. [4] observed that a farmer using only hand hoe for weeding would find it difficult to escape poverty, since this level of technology tends to perpetuate human drudgery, risk and mystery. [5] concluded that the use of herbicides has possible effect on desert encroachment and other adverse impact, while [6] asserted that the need for non-chemical weed control techniques has steadily increased in the last fifteen years, as a consequence of the environmental pollution originated by the intensive application of pesticides in agriculture. The use of herbicides in killing weeds has been the usual practice of some farmers but the recent upsurge in environmental awareness of the public and interest in organic food production and some health related problems with the use of herbicides not to be a better alternative.

The most common methods of weed control are mechanical, chemical, biological and cultural methods. Out of these four methods, mechanical weeding either by hand tools or weeders are most effective in both dry land and wet land [7]. Various types of cutting blades are used for manually operated weeders. V-shaped sweep is preferred where weeders are continuously pushed and tool geometry of these cutting blades is based on soil-tool-plant interaction [8]. Mechanical weed control don't only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity. Manual weeding can give a clean weeding but it is a slow process [9].

As the time period available for weeding is limited, improved mechanical weeders are to be used to complete the weeding operation in due time at less cost. At present, there are different designs of hoes and weeders available in Nigeria. All these designs are region specific to meet the requirements of soil type, crop grown, cropping pattern and availability of local resources.

The use of herbicides in killing weeds has been the usual practice of some farmers but the recent upsurge in environmental awareness of the public and interest in organic food production and some health related problems with the use of herbicides not to be a better alternative. [10] reported that mechanical weed control allows farmers to reduce or even eliminate herbicide use. He gave a comparison of mechanical weeding versus herbicides use and concluded that mechanical weeding reduces cost of weed control, aerates the soil, reduces pollution, breaks soil crust and contributes to a better environment. Thus, there is a need for the design and development of a mechanical weeder for intensive and commercial farming system in Nigeria.

The objective of the project is to design and construct a mechanical weeder, evaluate three deferent weeding blades and the performance of the machine.

2. Materials and Methods

Description of the Machine

Figures 1 and 2 are the isometric and orthographic drawings of the row crop weeder. The principal components of the machine are the frame, handle, hoeing disk, power and transmission unit. The weeder is powered by a two stroke petrol engine. The belt and pulley mechanism actuate and power is transmitted to the shaft which rotates the weeding implement through the bearing that is mounted on a frame. A slight push by the operator moves the machine in the direction for which weeding is required.

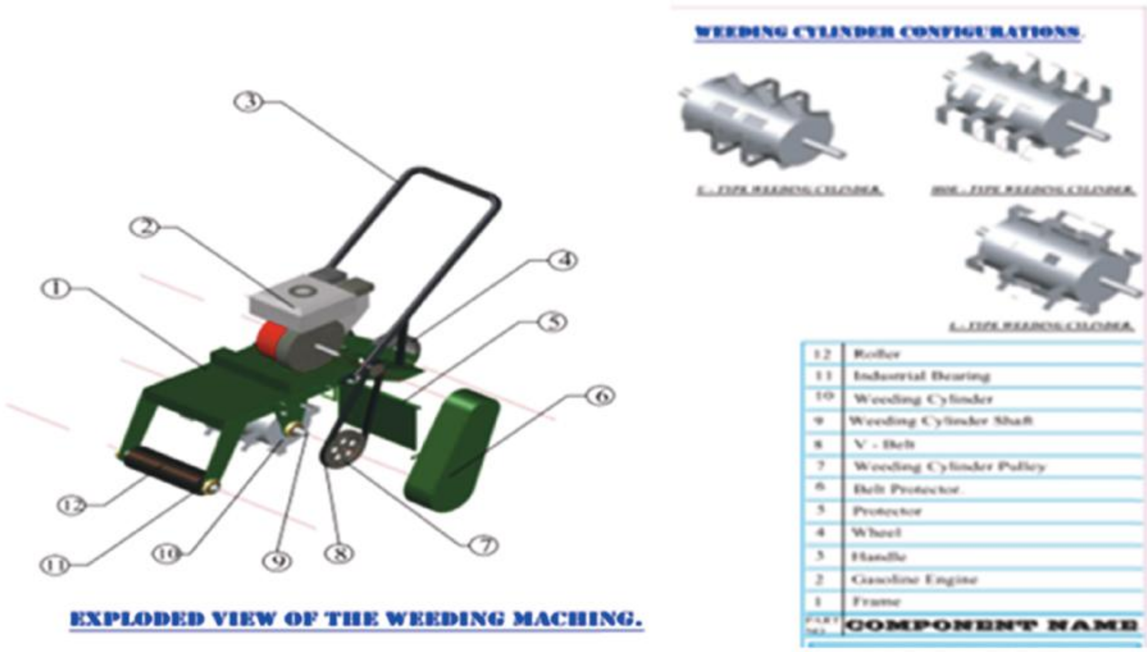

Figure 1. Isometric Drawing of the Row Crop Weeder

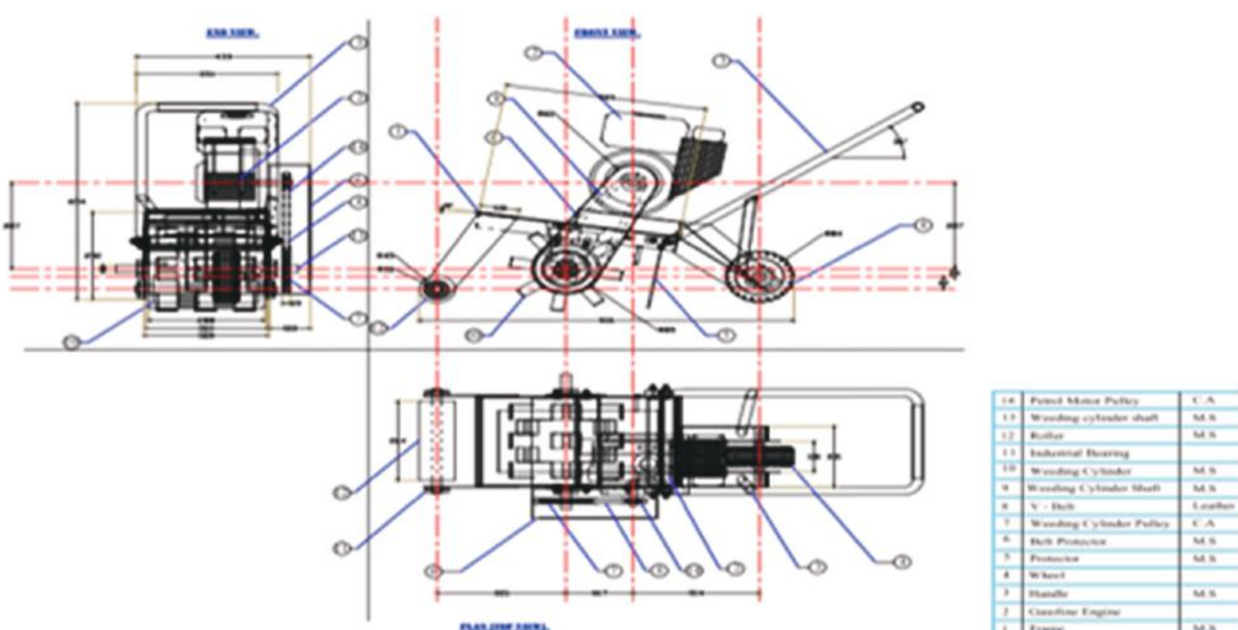

Figure 2. Orthographic drawing of the row crop weeder

Machine Performance Evaluation

Effective Field Capacity

Effective field capacity is the amount of area that a weeding tool can cover per unit time. It was determined using Equation 1.

$$E_{fc} = T_w + T_t + T_r \quad (1)$$

Where:
E_{fc}= Effective field capacity (ha/hr),
T_w = Time taken for weeding (hr),
T_t = Time taken for turning (hr),
T_r = Time taken for resting (hr).

Theoretical Field Capacity

This is the rate of field coverage, if the machine works all the time at recommended speed and utilizes its entire width of operation. The theoretical filed capacity was determined using 0.2, 0.4 and 0.6 m/s respectively by applying Equation 2 below.

$$T_{fc} = T_w \quad (2)$$

Where:
T_{fc} = Effective field capacity (ha/hr),
T_w = Actual time taken for weeding (hr).

Field Efficiency

Field efficiency is the ratio of the effective field capacity to the theoretical field capacity which was calculated using Equation 3

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoritical field capacity}} \times 100\ \% \quad (3)$$

Weeding Index

Weeding index is a ratio between the number of weeds removed by a weeder and the number present in a unit area and is expressed as a percentage and was calculated using Equation 4.

$$\text{IW} = \frac{W_1}{W_1+W_2} = \frac{W_1}{W_1+(W_T-W_1)} \quad (4)$$

Where,
IW = weeding index,
W_1 = weight of weeds removed (g),
W_2 = weight of survived weeds (g),
W_T = Total weight of weeds (g)

Weeding Efficiency

Weeding Efficiency was calculated using Equation 5.
Where,

$$E_w = \frac{W_1}{W_1+W_2} \times 100\% = \frac{W_1}{W_1+(W_T-W_1)} \times 100\% \quad (5)$$

E_w = weeding efficiency (%),
W_1 = weight of weeds removed (g),
W_2 = weight of survived weeds (g) and
W_T = Total weight of weeds (g)

Experimental Plot Design

The experimental plot is located beside the collapsed mini dam at theUniversity of Agriculture, Makurdi road (Figure 1). The experimental plot was measured out using a measuring tape. Its dimensions were 8 m long and 7 m wide. The experiment was laid out in a Completely Randomized Design (CRD).

Figure 3. The Experimental Field

The experimental design for the statistical analysis follows a two-treatment effect (walking speed and tool type) in a split-plot factorial design with Completely Randomized Design (CRD) involving a two-way classification with three observations (replications) per experimental unit. The experimental unit comprises two factors; three walking speeds (0.2, 0.4 and 0.6 m/s) in each of the three tool types(U-type cutting blade, L-type cutting blade and Hoe type cutting blade) giving nine treatment combinations and twenty-seven observations for the experiment as walking speed versus tool type. The walking speed in the combination forms the levels of factor 'A' while the tool type forms the levels of factor 'B'. All data collected were subjected to analysis of variance (ANOVA) to test for significant effects at 95 % confidence limit using the procedure recommended [11]. When significant difference was observed, treatment means were separated using the F-LSD.

3. Results and Discussion

The raw and mean results of the weight of weeded and total weight of weeds, weeding index, weeding efficiency and time of weeding are presented in Table 1, 2, 3 and 4 respectively.

Table 1. Raw and Mean values of the Weight of Weeded and Total weight of Weed for the Various Hoe-Types at Different Walking Speeds

Tool Type	Rep	Working Speed (m/s)					
		0.2		0.4		0.6	
		Weight removed, kg	Total weight, kg	Weight removed, kg	Total weight, kg	Weight removed, kg	Total weight, kg
	1	0.39	0.45	0.25	0.37	0.32	0.50
U-blade	2	0.51	0.56	0.38	0.54	0.35	0.60
	3	0.34	0.40	0.28	0.42	0.36	0.57
	Mean	0.41	0.47	0.30	0.44	0.34	0.56
	1	0.44	0.48	0.38	0.46	0.37	0.49
L-blade	2	0.47	0.50	0.29	0.38	0.39	0.53
	3	0.42	0.44	0.37	0.45	0.30	0.40
	Mean	0.44	0.47	0.35	0.43	0.35	0.47
	1	0.38	0.51	0.30	0.48	0.22	0.42
Hoe blade	2	0.41	0.54	0.36	0.52	0.30	0.44
	3	0.42	0.53	0.35	0.55	0.23	0.43
	Mean	0.40	0.53	0.34	0.52	0.25	0.43

Table 2. Raw and Mean Values of the Weeding Index of the Selected Hoe Types at the Different Walking Speeds

Tool Type	Replications	Working Speed (m/s)		
		0.2 Kg	0.4 Kg	0.6 Kg
	1	0.867	0.676	0.640
U – Blade	2	0.911	0.704	0.583
	3	0.850	0.667	0.632
	Mean	0.876	0.682	0.618
	1	0.917	0.826	0.755
L – Blade	2	0.940	0.763	0.736
	3	0.955	0.822	0.750
	Mean	0.937	0.804	0.747
	1	0.745	0.625	0.524
Hoe Blade	2	0.759	0.692	0.682
	3	0.792	0.636	0.535
	Mean	0.765	0.651	0.580

Table 3. Raw and Mean Values of the Weeding efficiency of the Selected Hoe Types at Different Walking Speeds

Tool Type	Replications	Working Speed (m/s)		
		0.2	0.4	0.6
	1	86.7	67.6	64.0
U – Blade	2	91.1	70.4	58.3
	3	85.0	66.7	63.2
	Mean	87.6	68.2	61.8
	1	91.7	82.6	75.5
L – Blade	2	94.0	76.3	73.6
	3	95.5	82.2	75.0
	Mean	93.7	80.4	74.7
	1	74.5	62.5	52.4
Hoe Blade	2	75.9	69.2	68.2
	3	79.2	63.6	53.5
	Mean	76.5	65.1	58.0

Table 4. Time of Weeding

Speed (m/s)	weeding (s)	Turn (s)	Total (s)
0.2	40	3	43
0.4	20	2	22
0.6	13	2	15
Mean	24.33	2.33	26.67

Table 5. Mechanical Row Crop WeederPerformance Evaluation

Speed (m/s)	Effective field capacity (ha/hr)	Theoretical field capacity (ha/hr)	Field efficiency (%)
0.2	0.0175	0.0187	93.58
0.4	0.0341	0.0371	91.91
0.6	0.0495	0.0578	85.64
Mean	0.0337	0.0379	90.38

Table 6. ANOVA Result on Weeding Index

Sources of Variation	Df	SS	MS	Observed F	Required F (5%)
Working Speed (S)	2	0.2108	0.1054	70.27*	3.55
Tool Type (T)	2	0.1236	0.0618	41.20*	3.55
Interaction (S×T)	4	0.1236	0.0309	20.60*	2.93
Error	18	0.0273	0.0015		
Total	26	0.3685			

* Represent significant difference

Table 7. ANOVA Result on Weeding Efficiency

Sources of Variation	Df	SS	MS	Observed F	Required F (5%)
Working Speed (S)	2	2107.89	1053.945	69.34*	3.55
Tool Type (T)	2	1235.79	617.895	40.65*	3.55
Interaction (S×T)	4	1235.79	308.948	20.33*	2.93
Error	18	273.58	15.199		
Total	26	3685.27			

* Represent significant difference

4. Discussion

To carry out the evaluation, the performance of the constructed weeder was conducted on the experimental field to investigate the effect of walking speeds and blade types on performance of the weeding tool.The weeder was tested on a flat wet ground surface with average weeds density. Three different weeding tool types (U-blade, L-blade and Hoe-blade) were used with three different walking speeds of 0.2, 0.4, and 0.6 m/s. Each of the experiments was repeated thrice at 800cm length run at constant weeding width of 26 cm giving an area of 20,800 cm2 (2.08 m2).

A time study was carried out to obtain the capacity performance of the weeder during the weeding operation. The observations were obtained for each operations and the average for the speed, turning, machine failure, management stop and the operation time as well as the total field time were obtained for each weeding operation. During the time study, the 8 m length plot was cover in 40 seconds, 20 seconds and 13 seconds at different walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively.

Soil Properties

The soil properties investigated include soil texture, soil particle size distribution, moisture content, bulk density, soil porosity and soil strength. The result of soil texture shows that the soil of the experimental plot is predominantly sandy. The mean percentage sand is 87.8% compared to silt and clay which are 4.3 % and 7.8 % respectively. The mean particle size distribution was 16.6 % and 83.4 % for silt/clay and sand respectively. The sandy nature of the experimental plot therefore, is ideal for tillage and weeding operations. Soils that are predominantly sand are classified as coarse texture soils according to [12] co-operate documents. According to [3], the predominant soil type in Makurdi is sandstones. On soil texture, [12] reported that soils that have high sand contents are easy to cultivate, plant and harvest which are termed to be light whereas soils that are difficult to cultivate, plant and harvest have high clay content and are called heavy soils.

The percentages of soil moisture content obtained immediately before planning at five randomly selected places at a depth of 5 cm ranged from 10.6 % to 11.8 % with a mean of 11.34 %. The soil moisture content greatly affects weeding operations. Dry soils are difficult for most weeding tool penetration and increased draft. If the soil becomes extremely dry, it is extremely difficult for the soil cutting tool to penetrate. Soil moisture content has considerable influence on the soil shear strength and the resistance of the soil to sliding at an interface and scouring ability of weeding blades.

The result of bulk density on the experimental plot before weeding operations has mean result of 1.445 kg/m3. This indicates that the bulk density of 1.455 kg/m3 observed in the soil makes weeding easy. It was also observed that porosity ranged from 31.14 % to 49.10 % with the mean value of 40.82 %.

The minimum value of the soil strength was 64.27 N/m2 and the maximum value was 64.27 N/m2, with the mean value of 65.72 N/m2. This shows that the soil shear strength for penetration and weeding will be easy.

Capacity Performance of the Weeder

A time study was carried out to obtain the capacitive performance of the harvesting operation. The observations were obtained for each operation and their average for the speed, turning, machine failure, management stop and the operation times as well as the total field time were obtained for each weeding operation.

From Table 5, it was observed that both the theoretical and effective field capacities increased with increase in the walking speed of the operator. It was also observed that the field efficiency has negative association with the walking speed of the operator. The field efficiency decreases with increase in the walking speed. It was observed that the average effective field capacities were 0.0175 ha/hr, 0.0341 ha/hr and 0.0495 ha/hr at the walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively while the average theoretical field capacities were found to be 0.0187 ha/hr, 0.0371 ha/hr and 0.0578 ha/hr at the walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively and the field efficiencies obtain were 93.58 %, 91.91 % and 85.64 % at the walking speeds of 0.2 m/s, 0.4 m/s and 0.6 m/s respectively.

Effect of walking speed and tool type on the weeding index

From the ANOVA result (Table 6), there is a significant effect of the walking speed,] and tool type on the weeding index of the weeding machine. It was observed that the weeding index decreased with increasing walking speeds with all the tool types investigated. The walking speed of 0.2 m/s had the highest weeding index of 0.937with the L-blade tool type. The least weeding index of 0.580 was obtained at the walking speed of 0.6 m/s with the hoe-blade tool type.

Effect of walking speed and tool type on the weeding efficiency

From the ANOVA result (Table 7), there was a significant effect of the walking speed and tool type on the weeding efficiency of the machine. It was observed that the weeding efficiency decreased with increasing walking speeds with all the tool types investigated. The best weeding efficiency of 93.7 % was obtained for 0.2 m/s walking speed and L-blade tool type. The lowest weeding efficiency of 58.0 % was obtained for the condition of 0.6 m/s and hoe-blade tool type.

5. Conclusion

The presented research can be concluded as follows:

- That a mechanical row crop weeding machine was designed, fabricated and evaluated successfully. The L-type blade gave the best performance among the three blade types used.
- The highest weeding efficiency of 93.7% was obtained at a walking speed of 0.2m/s. with the L-type blade.
- The theoretical and effective field capacities increased with increase in the walking speed of the operator while the field efficiency decreased with increase in the walking speed.
- ANOVA result revealed there was a significant effect on the walking speed and tool type on the weeding index and efficiency of the developed weeding machine.

References

[1] Parish, S.: 1990. A Review of Non-chemical Weed Control Techniques. Biological Agriculture and Horticulture, Vol. 7. No. 2. pp. 117-137.
http://dx.doi.org/10.1080/01448765.1990.9754540

[2] Yadav, R., Pund, S.: 2007. Development and Ergonomic Evaluation of Manual Weeder. Agricultural Engineering International: the C1GRE journal. Manuscript, PM 07 022, Vol. 9. pp. 1-9.

[3] Odigboh, E. U.: 1997. Confronting the Challenges of Agricultural Mechanization in Nigeria. Nigerian Society of Agricultural Engineers (NSAE)'s Annual Conference NSAE Conference Proceedings, pp. 7-16.

[4] Nganilwa, Z. M., Makungu, P. J., Mpanduji, S. M.: 2003. Development and Assessment of an Engine Powered hand held weeder in Tanzania. International Conference on Industrial Design Engineering, UDSM, Dare Salam.

[5] Busari, L. D.: 1996. Influence of Row- spacing on weed control in Soya bean in the Southern Guinea Savanna of Nigeria. Nigerian Journal of Weed Science, Vol. 19. pp. 17-23.

[6] Gite, L. P., Yadav, B. G.: 1990. Optimum handle height for a push pull type manually operated dryland weeder. Ergonomics, Vol. 33. No. 12. pp. 1487-1494.
http://dx.doi.org/10.1080/00140139008925348

[7] Bernacki, H., Haman, J., Kanafajoki, G.: 1972. Agricultural Machines- Theory and Construction, Vol. 1. National Science Foundation, Washington D.C.

[8] Biswas, H. S.: 1990. Soil tool interaction for mechanical control of weeds in black soils. Unpublished Ph.D. dissertation, Indian Institute of Technology, Kharagpur.

[9] Duval, J.: 2014. Mechanical Weed Control in Cereals. Ecological Agriculture Projects (EAP), Publication-72. McGill University (Macdonald Campus).
Link: https://eap.mcgill.ca/publications/EAP72.htm

[10] FAO.: 2012. The State of Food and Agriculture of the United Nations, Rome, 2012, ISBN 978-92-5-107317-9

[11] Isikwue, M. O., Onyilo, A. F.: 2010. Influence of land use on the hydraulic response of a loamy sand tropical soil , Journal of Emerging Trends in Engineering and Applied Sciences, Vol. 1. No. 2. pp. 145-150.

[12] Kaul, R. N., Egbo, C. O.: 1985. Introduction to agricultural mechanisation. Macmillan, London. Link: Macmillan intermediate agriculture series