

DEVELOPMENT OF A RIDGE PROFILE WEEDER

by

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ABSTRACT

The prototype weeder described in this paper consists of a ground-driven rotating horizontal short shaft which is connected by universal joints to two gangs of rotary hoe weeders. With the short shaft nearly at the bottom of a furrow between two ridges, the gangs of weeders lie on the sides of the two ridges. The universal joints make it possible to angle the weeder gangs with respect to the horizontal shaft to make the gangs conform to the profiles of the sides of the ridges facing the common furrow. The operator walks in the furrow and simply pushes the weeder along to weed one side each of two ridges. Thus the weeder can handle any crop planted on ridges, irrespective of the height of the plants. The shares on the gangs of the rotary hoe weeders are independently adjustable to facilitate reaching the surface of any ridge. Field tests show that this weeder is very effective in controlling young weeds where only light earthing up is required.

1. INTRODUCTION

In an Operation Feed the Nation (OFN) sponsored national seminar on crop mechanization held at the Durbar Hotel in Kaduna on 30th and 31st October, 1978 it was determined that weeding accounts for 75-90% of farm labour in Nigeria. As such, weeding constitutes a major bottle-neck limiting agricultural production in the country. Weeding of root crops and other crops planted on ridges poses a special problem because mechanical weeders available from overseas are mostly for crops planted on the flat and are usually too big or too expensive for the small farmer. The Kaduna seminar recommended among other things, that agricultural engineers in the country should be challenged to develop machines suitable for solving the problems of weeding Nigerian farms. The development of the ridge profile weeder described in this paper was undertaken as a contribution towards meeting that challenge

2. DESIGN PRINCIPLES AND THEORY

The ridge profile weeder designed on the principle of the rotary tiller. It may be hand pushed or powered by a small I-C engine. In either case, only a small earthing up, enough to

remove small young weeds, will be done. This is in order to keep draught requirements at a minimum as this design is intended for small/medium size farms. The theory of operation on which the design of the weeder is based is presented as follows.

Fig.1 is the sketch of a rotary hoe with a number of shares denoted as, $A_1, A_2, \dots, A_n, \dots, A_z$. The sketch shows the mechanism of operation and various parameters of the soil slice. The radius of the hoe is R and depth of cut is denoted by a . Let V_m and ω be the forward speed of the implement and the angular velocity of the hoe, respectively. So, as the implement moves forward a distance of $V_m t$, the hoe rotates through an angle of ωt and the shares assume the positions A'_1, A'_n, \dots, A'_z . The coordinates of say A'_1 referred to the x and y axes are given by

$$x = V_m t + R \cos \omega t \quad (1a)$$

$$y = R (1 - \sin \omega t) \quad (1b)$$

2.1 Conditions for cutting off a soil slice:

The equations given in (1) describe the absolute motion of the share to trace the locus of A'_1 over time as

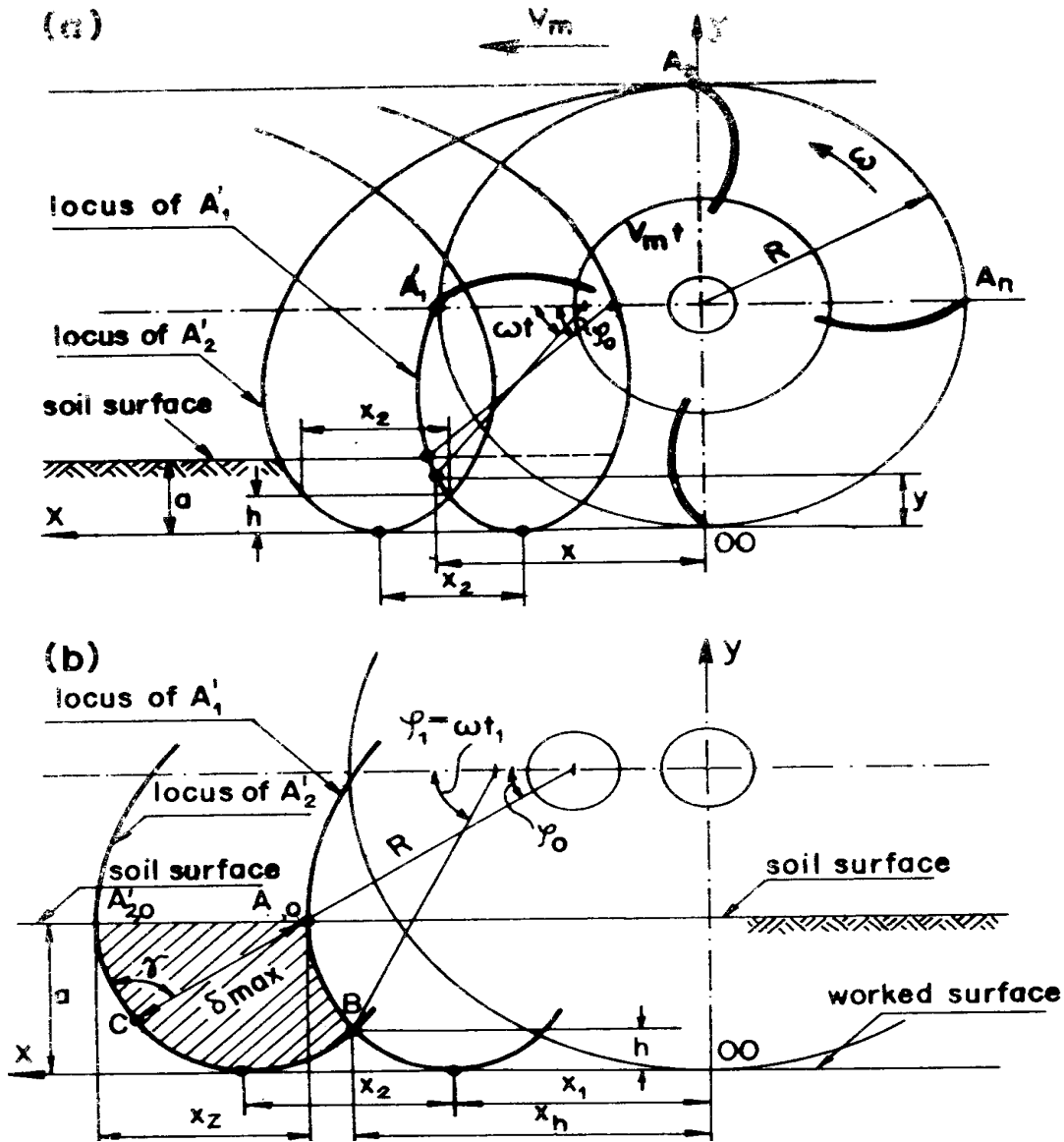


Fig.1 sketch of a rotary hoe weeder
 a - mechanism of operation
 b- Parameters of a soil slice

sketched in fig.1. Let $A'_{1,0}$ denote the position of A_1 as it begins to cut through the soil. Denoting the depth of cut by a , the angle through which A_1 rotates to get to $A'_{1,0}$ is given by ϕ_0 which equals ωt_0 such that from equation, 1b),
 $\sin \phi_0 = 1 - a/R$ (2)

As A_1 starts to penetrate the soil at $A'_{1,0}$ its direction of motion is vertically down. Afterwards, its motion will be opposite to the direction of implement forward travel as it cuts off a soil slice. This means that there is a point of inflexion in the locus traced by A_1

at which the absolute velocities of the share in the x direction is zero and may be given by

$$\frac{dx}{dt} = v_m - R\omega \sin \phi_0 = 0 \quad (3a)$$

and

$$\sin \phi_0 = v_m/R\omega = 1/\lambda \quad (3b)$$

which defines λ as,

$$\lambda = (R\omega) / v_m \quad (3c)$$

From equation (2), λ may be given as

$$\lambda = R/(R-a) = 1/(1-m) \quad (4)$$

where m is the ratio of a/R . The

Expressions in (3) give the necessary condition for cutting off a soil slice. If the relative

magnitudes of the peripheral velocity of the shares, V_m and the implement forward speed, V are such that dx/dt has the same direction as the implement travel after penetrating the soil, then the share withdraws from the soil without cutting off a soil slice. The different possible paths of a share through the soil for various values of λ are illustrated in fig.2 which shows that cutting off a soil slice is possible only when λ is greater than unity. Therefore, for any weeding to occur with a rotary hoe weeder, the ratio R_W/V_m must be greater than unity.

2.2 FORWARD TRAVEL PER SLICE:

Referring again to fig.1, X_z denotes the distance between two consecutive points of contact of two adjacent shares, say A_1 and A_2 , with the soil surface at $A_{1,0}$ and $A_{2,0}$ respectively. X_z is called the 'forward travel per slice' [1] Since the time of one revolution of the rotary hoe is $2\pi/\omega$, the forward

travel per revolution of hoe is given by,

$$z_{rev} = v_m(2\pi)/\omega = (2\pi R)/\lambda \quad (5)$$

Taking the number of shares on the hoe as Z , and since every share cuts off a soil slice per revolution, then the forward travel per slice may be given by,

$$X_z = (2\pi R)/(\lambda Z) \quad (6)$$

Thus, for given values of R and A , the greater the number of shares, Z , the smaller the soil slices. The thickness of the soil slice designated by ∂_{max} fig.1(b) may be computed as,

$$\partial_{max} = A_{1,0} A_{2,0} \cos \phi_0 = x_z \cos \phi_0 \quad (7a)$$

or in terms of m (cf $\sin \phi = 1-a/R = 1-m$), $\partial_{max} = x_z(2m-m^2)^{1/2} \quad (7b)$

From (7), it is clear that, apart from the effect of the number of shares, the

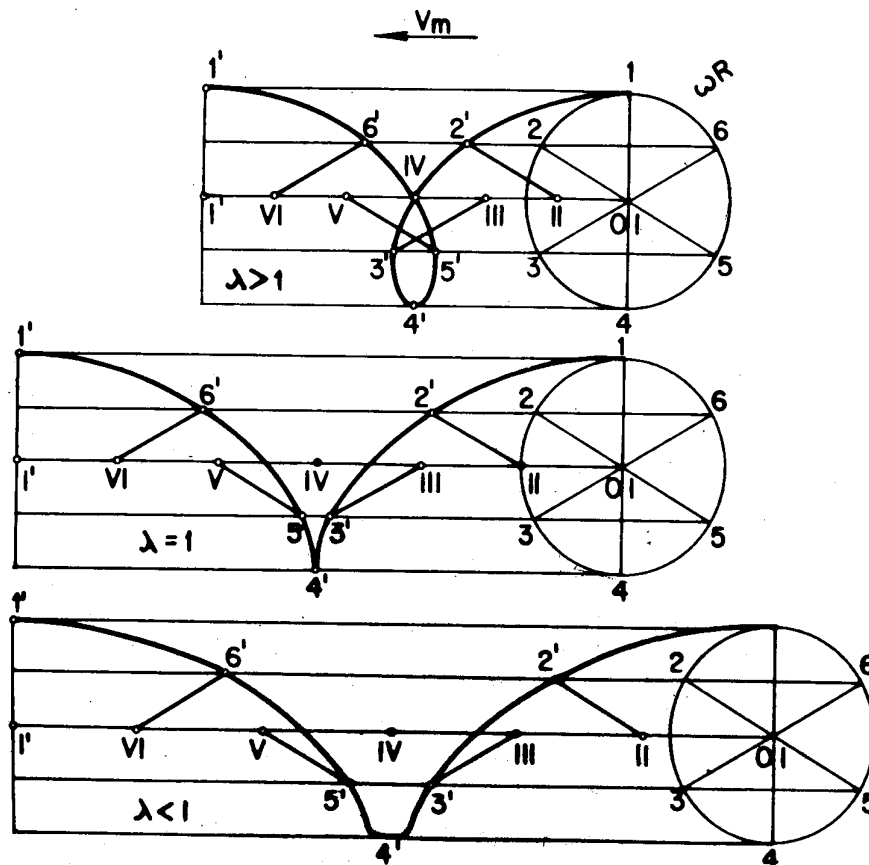


Fig. 2. Locus of share at different values of λ

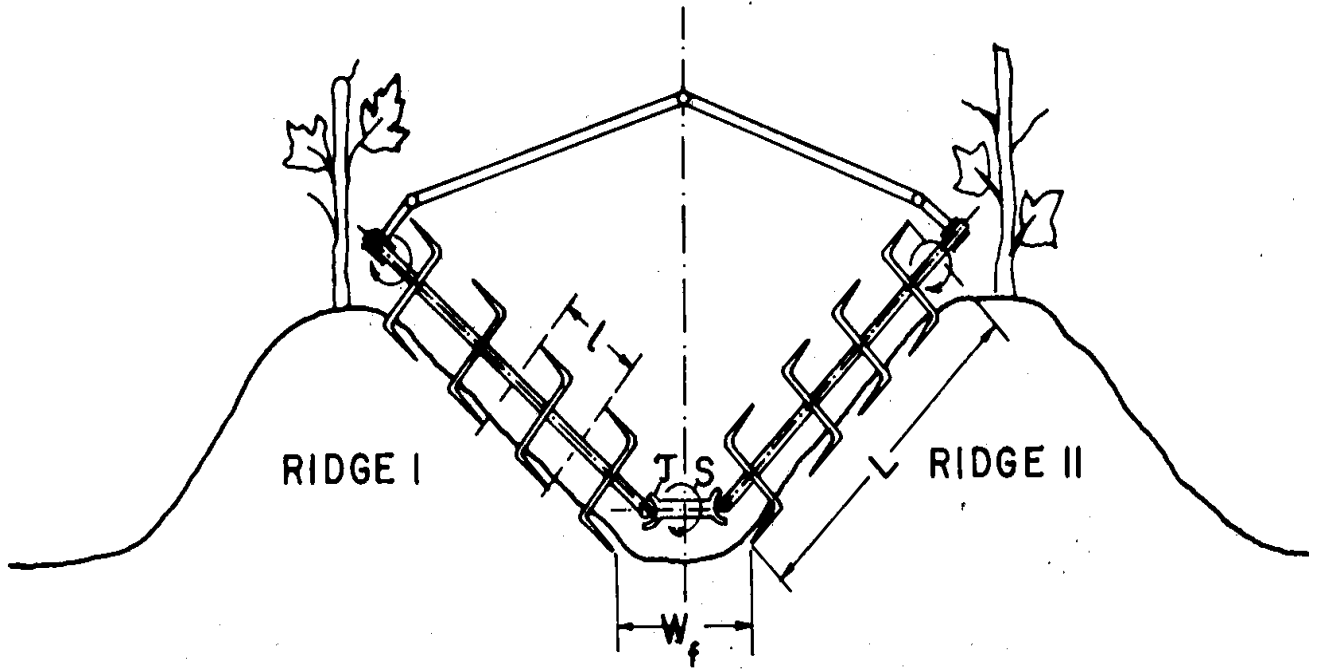


Fig. 3 illustration of ridge profile weeder concept.

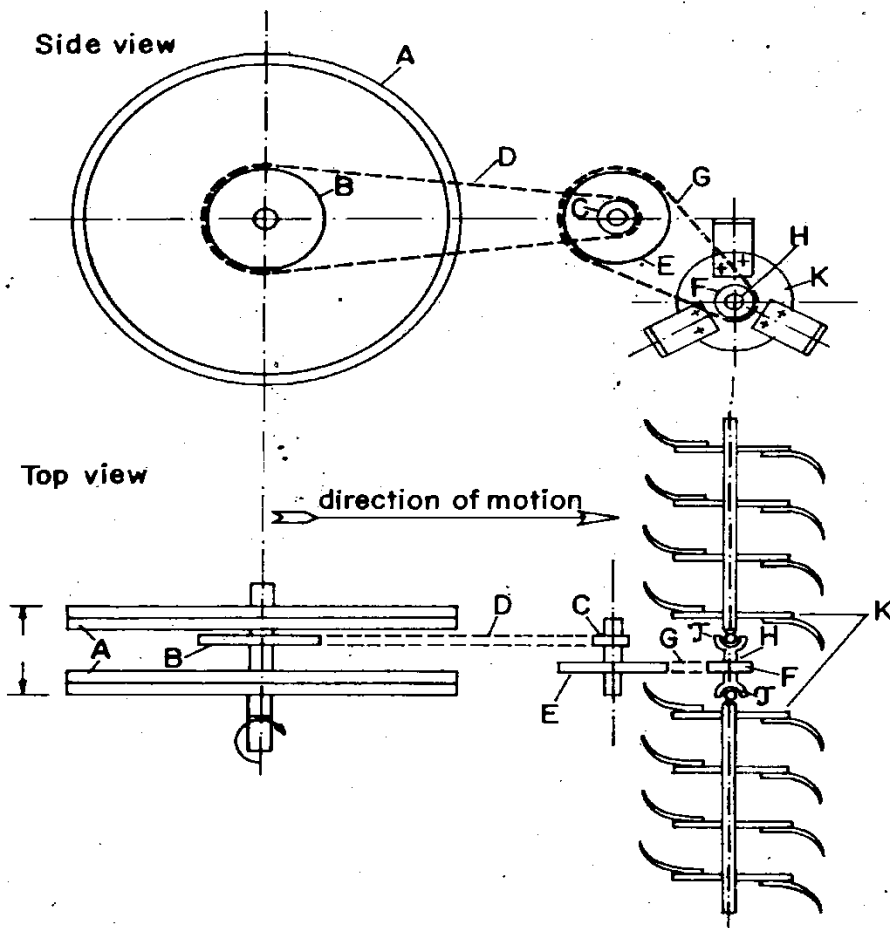


fig. 4. Sketch of weeder drive train.

thickness of the soil slice is decreased by increasing the radius of the share, R and decreasing the depth of cut, a. This means that decreasing m decreases the thickness of the soil slice which, of course, leads to increased, pulverization.

2.3 DETERMINING THE VALUE OF λ

Fig. 1 shows the wave form of the surface worked by a rotary hoe weeder. The value of the amplitude of that wave, denoted by h in fig. 1(b), is influenced by the value of λ. Therefore, it is desirable to be able to choose a value of λ which would keep the ripple at the worked surface to a desired form. To determine λ as a function of λ, the co-ordinates of the wave peak at B may be given as,

$$x_h = v_m t_1 + R \cos \omega t_1 \quad (8a)$$

$$y_h = h = R(1 - \sin \omega t_1) \quad (8b)$$

Replacing t_1 by ϕ/ω [$\omega t_1 = \phi_1$, see fig. (1b)]

$$x_h = (R/\lambda) \phi_1 + R \cos \phi_1 \quad (9a)$$

$$y_h = h = R(1 - \sin \phi_1) \quad (9b)$$

From fig.1(b),

$$x_h = x_1 + x_z/2$$

Since x_1 is the x-co-ordinate of A₁ when it has rotated through ωt equals to $\Pi/2$, x_1 may be computed as,

$$x_1 = v_m (\Pi/2\omega) = (R \Pi) / (2\lambda)$$

So, recalling that x_z equals $(2 \Pi R) / (\lambda z)$, x_h be given as

$$x_h = (\Pi R/\lambda) (1/2 + 1/z) \quad (10)$$

From equations (9a) and (10)

$$\Pi(1/2 + 1/z) = \phi_1 + \lambda \cos \phi_1 \quad (11)$$

From eqn. (9a), $\sin \phi_1 = 1 - h/R$

$$\phi_1 = \sin^{-1}(1 - h/R) \quad (12)$$

$$\text{and } \cos \phi_1 = (1/R) (2Rh - h^2)^{1/2}$$

substituting the values ϕ_1 and $\cos \phi_1$ of (12) into eqn.(11) yields an expression for λ as a function of h as follows,

$$\lambda = [\Pi(1/2 + 1/z) - \sin^{-1}(1 - h/R)] / [(1/R) (2Rh - h^2)^{1/2}] \quad (13)$$

Expression (13) is useful in determining the value of λ which will give a desired value of h and

therefore a desired wave form of the worked surface. For thorough weeding, he should be chosen in relation to a in such a way that no weed escapes the action of the shares.

3. THE DESIGN CONCEPT

The Emcot weeder is commercially available and in limited use in Northern Nigeria for weeding cereal crops planted on ridges. That weeder consists of two gangs of rotary hoes which straddle and weed two sides of one ridge. It is built with enough clearance to avoid injury to young cereal plants. The operator walks in the furrow as he pushes the weeder along on the ridge.

One of the major shortcomings of the Emcot weeder is its unsuitability for weeding tall crops like cassava and staked yam crops. The ridge profile weeder is designed to remedy that defect among others. As illustrated in fig.3, it consists of a rotating horizontal shaft which is connected by two universal joints to two gangs of rotary hoe weeders. With the shaft nearly at the bottom of the furrow between two ridges, the gangs of weeders lie on the sides of the two ridges. The universal joints make it possible to angle the gangs with respect to the horizontal shaft to make the gangs conform to the profiles of the sides of the ridges facing the common furrow. The operator walks in the furrow and simply pushes the weeder along to weed one side each of two ridges. Thus, the weeder can handle any crop planted on ridges irrespective of the height of the plants. The shares on the gangs of the rotary hoe weeders are independently adjustable to facilitate reaching the surface of any ridge.

Since the weeder is to be manually pushed, the arrangement shown in fig.4 is used to ensure that the rpm of the rotary weeder satisfies the condition, $R\omega/V_m > 1$, discussed in section 2.1. In fig.4, A, B, C and D are the weeder wheels, rear and front sprockets and a roller

chain respectively. Another sprocket, E mounted on the shaft, C drives a smaller sprocket, F through a roller chain, G. These socket F is keyed on the horizontal shaft, H which is coupled to the two gangs of rotary hoe weeders, K through two universal joints, J. Let N be the rpm of drive wheel. Denoting the number of teeth on the various sprockets by T_B , T_C , T_E and T_F , the arrangement is such that $T_B > T_C$; $T_E > T_C$ and $T_E > T_F$ let the speeds of the various sprockets be N_B , N_C , N_E and N_F , then, for a given rpm, N of the drive wheels of diameter D, the following relationships hold:

$$\begin{aligned}
 V_m &= \Pi DN &&) \\
 &&&) \\
 N_B &= N &&) \quad (15) \\
 &&&) \\
 N_F &= N(T_B/T_C) (T_E/T_F) &&)
 \end{aligned}$$

From expressions (3c), and (15), the value of λ may be calculated as

$$\lambda = R\omega/V_m = (2R/D) (T_B/T_C) (T_E/T_F) \quad (16)$$

The ratios R/D , T_B/T_C and T_E/T_F are selected to give the desired value of λ as explained in section 5.

4. DESCRIPTION OF THE PROTOTYPE

The prototype weeder was built to the specification outlined in section 3 and on the basis of the theory of section 2. Details of the construction are shown in the photographs of fig. 5. Each wheel of the weeder is made up of two bicycle wheels welded together to a common hub, with the bicycle spokes replaced with 6mm dia. Mild steel rods for greater strength. The frame of the weeder is mounted on the common axle of the wheels and provides attachment positions for all the other parts of the weeder.

The dependence of degree of pulverization on the value of λ was explained in the theory of section 2. So, the value of λ for the prototype is designed to be about 3.0 in order to deep power expenditure for pulverization low while ensuring good weeding. Also, to minimize the power requirement of the weeder, the depth of cut, a,

is designated at a maximum of a 25mm which has been determined to be deep enough to remove the type of young weeds which commonly, grow in fields of root crops planted on ridges especially during the crops growth phase when weed control is agronomically ally most crucial. the peak of the wave of worked surfaces, denoted as h in fig. 1(b), is fixed at about 10mm. Each gang of the rotary hoe weeder has three discs with six knives ($z = 6$) of 200mm radius ($R = 200\text{mm}$) on each disc. From expression (13) of section 2.3 a value of λ is calculated as 2.71.

Using the same notations as in the drive train of fig. 4. The sprocket B, C, E and F, in the prototype have 27, 9, 42 and 21 teeth, respectively. The diameter of the wheels is 0.7m. so from expression (16) the actual value of λ is computed as 3.43 which is practically the same as the value from expression (13). The prototype weeder is provided with a handle for pushing it. The handle is adjustable to any position that suits the operator. The weeder has two small wheels located as shown in fig.5 between the drive wheels and the ganged of rotary hoes. The small wheels serve mainly to take up the weight of the hoes. Otherwise, the operator would have to push down on the handle to hold the hoes up in position. With the small wheels in place, the weeder is stabilized and the operator pushes only to move it along.

5. PROTOTYPE PERFORMANCE

the construction of the prototype weeder was completed only in the past month and is infact still being developed. However, preliminary tests show that this weeder is very effective in controlling young weeds where light earthling up is required. It is designed that, optionally, the weeder can be powered by a small 1-C engine. It is estimated that the weeder may sell at ₦200.00 or ₦500.00 if powered.

REFERENCE

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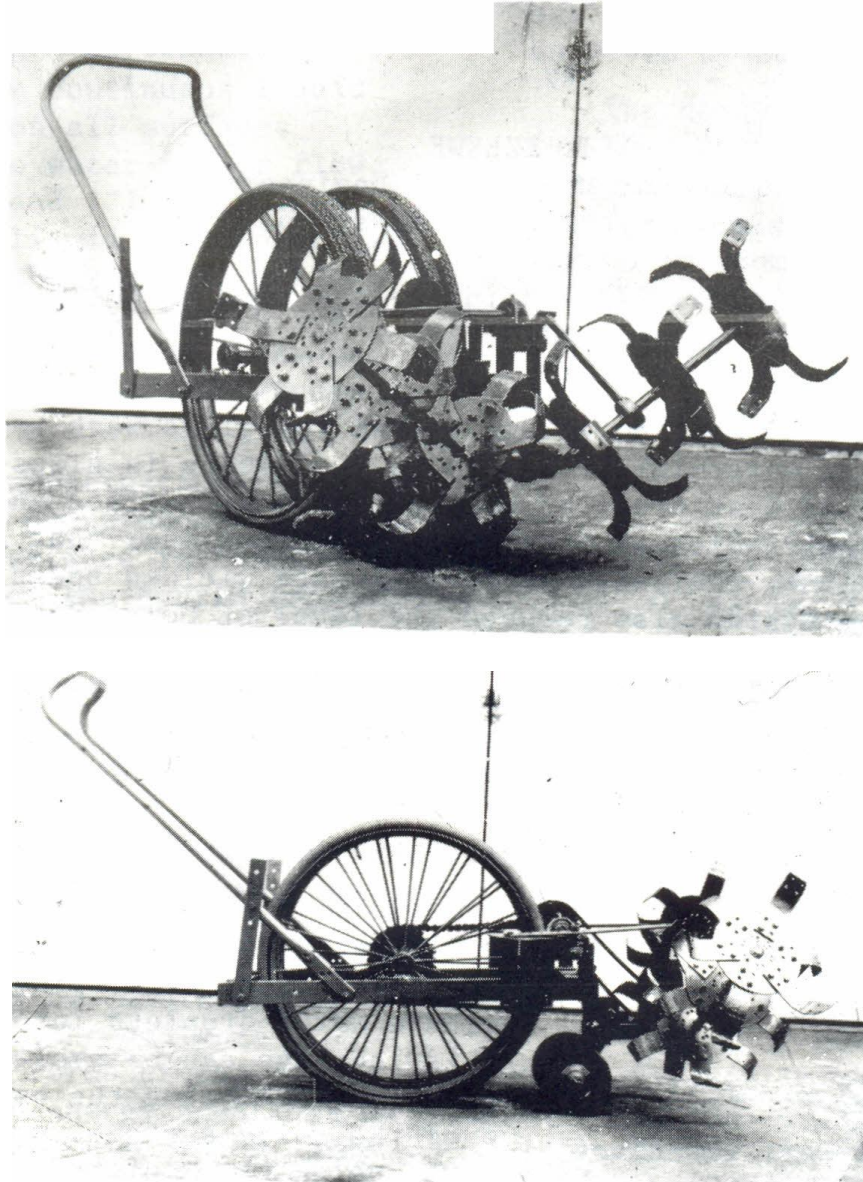


Fig. 5. Photographs of weeder prototype a-front view; b-side view

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