

# Wheel-Axle Mechanism Option for Ground Metering of Herbicides in Animal Drawn Sprayers

**Michael C. Amony**

Institute for Agricultural Research (IAR),  
Department of Agricultural Engineering,  
Ahmadu Bello University, Samaru, Zaria, Nigeria

**Abdullahi El-Okene**

Institute for Agricultural Research (IAR),  
Department of Agricultural Engineering,  
Ahmadu Bello University, Samaru, Zaria, Nigeria

**M. L. Suleiman**

Institute for Agricultural Research (IAR),  
Department of Agricultural Engineering,  
Ahmadu Bello University, Samaru, Zaria, Nigeria

**Ibrahim O. Abdulmalik**

Hydraulic Equipment Development Institute, National Agency  
for Science and Engineering Infrastructure (NASENI), Federal  
Ministry of Science and Technology, Kano, Nigeria  
Email: mikeamonye@gmail.com

**Abstract** – The aim in applying herbicide or any pesticide for that matter is to effectively distribute the appropriate amount on the target. This is to ensure that the desired result is achieved while minimizing non target area contamination. Too much pesticide can cause unacceptable crop damage or leave excessive residues in the crop or soil. It also increases the spraying cost by using more pesticide. To apply a pesticide effectively the application equipment must be well maintained (to avoid delays caused by breakdowns) and accurately calibrated. The purpose of the sprayer is to accurately meter and distribute pesticides. Pesticides are packaged in concentrated form to facilitate handling. In order to uniformly distribute the active ingredient of the pesticide over the area sprayed, it must be diluted with a suitable carrier (in most cases, water). The diluted pesticide must then be uniformly distributed in a manner that gives optimum coverage with minimal drift potential. (Murdoch 1986).

Animal drawn sprayers must necessarily meter herbicide or any pesticide in synchrony with the motion of the animals. Anything to the contrary shall result in excess deposition of pesticide at bends when the animals would temporarily slow down to execute the bend and also when they are compelled to stop for rest or as occasion may warrant. This project introduces a novel mechanism- *The Wheel Axle Mechanism*, to ensure that pesticides are metered accordingly and accurately.

**Keywords** – Pesticide, Sprayer, Metering, Wheel Axle.

## I. INTRODUCTION

Crop yield and quality depend heavily on the effective application of pesticides. In some cases, chemical costs can exceed one-third of the total cost of crop production. Additionally, the cost of some active ingredients has risen from 30 to 60% over the last five years. All these factors emphasize that proper chemical application can save money. (Grissoet al 1989).

Application of herbicides early in the life of the crop is often best performed before the emergence of the crop and weeds. The time during which soil-applied herbicides normally remain phytotoxic depends mainly on the quantity applied. Excessive applications may harm both the treated and following crops, while reduced applications may have little or no effect on target weeds. According to Garnett (1981), herbicide sprayers suitable for small-scale farmers should: (1): Be cheap but durable

(2): Require as little water as possible (3): Be small but light and robust (4): Be ground metered (5): Require no batteries (6): Have an adjustable swath width (7): Produce minimal drift (8): Be simple, but profitable to use and (9): Be acceptable to both the farmer and the labour available in the community. (Fowler 2000). The list is suggestive of the parameters to meet. It may not be possible to meet all parameters in a single machine but design is a compromise among options.

The work of any sprayer is the disintegration of liquids into droplets and this is achieved by mechanical means that forces the liquid through an atomizer or nozzle. The functions of the atomizers are to accelerate and disintegrate the liquid into droplets, to meter the liquid and to disperse the resulting droplets in the preferred pattern. Where possible the atomizer should produce a narrow and predictable variation in droplet size so that the biological optimum droplet size can be produced. (Combella 1978). Sprayers are classified into six main groups according to the type of energy used for droplet atomization at the nozzle, namely; (a): Hydraulic energy sprayers (b): Gaseous energy sprayers (c): Centrifugal energy sprayers (d): Thermal energy sprayers (e): Kinetic energy sprayers and (f): Electrical energy sprayers. (Kaul and Suleiman 1990). They are also classified in terms of volume discharge. In high volume spray, the liquid is sprayed until surface saturation occurs and excess liquid runs off. The volume per hectare (V/ha) will vary with size of the plant and its leaf area. However, the range would normally be from 500 to 3000litre per hectare (l/ha). Medium volume spray is when the liquid is sprayed over the surface of the target until some coalescence of droplets occurs. Spraying is stopped before run-off occurs. The normal volume range would vary from 100 to 500l/ha. Low volume is when the liquid is sprayed over the surface of the target and remains as discreet droplets. There is little or no coalescence of droplets. Volumes from 5l/ha up to 50l/ha would be the normal range. Ultra-low volume is when the liquid is dispersed over the plant surface as small discreet droplets. Volumes of less than 5l/ha are regarded as ultra-low volumes. (Combella 1978).

Most sprayer types are adapted to producing specific types of sprays. For instance hydraulic energy sprayers normally produce high and medium sprays while centrifugal energy nozzle are known for low volume

sprays even as they can be adapted for ultra-low volume sprays. But the underlining factor in spraying is that a certain quantity is the required specification or dosage for desired effect. The desired result cannot be achieved if more or less than the dosage is applied. This underscores the importance of metering. In spraying, pesticide must be metered and dispersed in correct and calculated quantities.

Over application of pesticides causes increases in production costs, potential crop damage, pollution and possible residue carryover. Under application of pesticides can be just as costly because the chemical may not effectively control the target pest. This might require an additional application, which means more fuel and labor due to extra trips across the field. Probably the most difficult area to assess is the potential reduction of yield because of under application of chemicals. (Grisso et al 1989). Tractor boom sprayers can be automated to meter and discharge accurate quantities per time, with tractor speed kept at constant speed. Metering in Knapsack sprayers are regulated by the pumping strokes per unit time synchronized with walking speed. In battery powered hand-held Controlled Droplet Applicators (CDAs), metering is assured from disc speed and walking speed. Correct metering in Animal drawn sprayers require that a synchrony be established between the speed of the work animals and the rate of pumping. On the other hand an Animal drawn Sprayer shall be ground metered for efficient operation. This project solves the problem by using the axle mechanization and tire motion as they are pulled to pump pesticide to hydraulic nozzles on onto the centres of centrifugal discs for CDA operations.

## II. LITERATURE REVIEW

Recent studies and development in pesticides application technology revealed that different droplet sizes and distribution (droplet spectra) are required for different pest situation. The use of high volume (>600L/ha) for field-crops for spraying has certain limitations, including: non-compatibility of hydraulic nozzle sprayers in areas where water is scarce; narrow swath, and the need for a lot of mixing of chemicals during spraying to avoid chemical settlement beneath tank; large droplets produced (about 500micron vmd) may sometimes become unstable resulting in possible run off, causing chemical and environmental pollution and in major changes in population of non-target organisms such as earthworms. In order to overcome the above limitations, a Ground-metered shrouded disc herbicide applicator (GMSD) was developed by Chouldhury, et al (1981). This is a CDA spinning disc manually operated herbicide sprayer based on very low volume (VLV) spraying system. Essentially it consists of a spray head, which is a spinning disc shrouded at an angle of 180°, mounted on a stand such that its position above the ground is adjustable. The spinning disc is driven by a 12V electric motor governed to rotate the disc at 1800-2000rpm. The tank is connected to the spray head by delivery tubes passing through a peristaltic pump operated by the ground wheel. As the operator pulls the machine behind him, a roller presses the flexible spray

delivery tube against the fixed pump wheel and liquid is forced through the tube to the spinning disc which atomizes it into droplets. The rate of pumping of spray liquid to the centre of the disc is directly proportional to the walking speed of the operator. (Shani et al 2006)

Experience in the development of the hand-pushed peristaltic-pump-based herbicide applicator for weed control in maize on small-scale farms in Swaziland indicated that an animal-drawn version might be readily acceptable. Development of the Summer Grain Sub-Centre Cedara (SGSC) Animal-powered herbicide applicator (Figure 1) was therefore begun. The unit is based on a single steel or galvanized iron wheel fitted with anti-skid lugs. A tank of diluted herbicide is carried in a cradle suspended from the traction shafts between the animal and the wheel. The tank is a common 25-litre plastic container, preferably semi-transparent so that it can be graduated and the level of liquid inside can be seen.

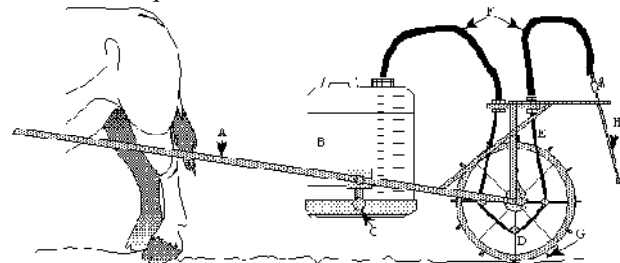


Fig.1. Prototype of the SGSC animal-powered herbicide applicator, showing the shafts (A), tank (B), cradle (C), rollers (D), peristaltic tubing (E), lightweight transmission hose (F), auto-skid wheel lugs (G) and a single nozzle assembly (H) (Fowler 2000).

On the spokes of the wheel are bolts carrying pipe rollers held at 90° to the direction of travel of the unit. Around these rollers runs a length of peristaltic tubing, under tension and clamped to a stay above the wheel. Lightweight hose connects the herbicide tank to one end of the peristaltic tubing, and the other end of the peristaltic tubing to a spraying unit (either a single nozzle or a boom assembly). The pumping action is achieved by the opening and closing of the tensioned peristaltic tubing. As a roller comes into contact with the tube it squeezes it closed and pushes any liquid in front of it through the system. As the tubing opens after the passing of the roller it creates a suction which draws more liquid into the pump, which in turn is forced through the system by the next roller. For every revolution of the wheel the same quantity of herbicide mixture is drawn through the pump. Provided the nozzle or nozzles are matched to this output, the area sprayed with a unit volume of herbicide will be fairly constant over a reasonable range of operating speeds. (Fowler 2000).

Also a Ground Metered Shrouded Disc CDA sprayer was developed by Abdulfatah, 1997. However, it was observed to have the following problems: low capacity in terms of swath produced per passes of the sprayer, over dosing due to incorrect rubber used for the peristaltic pump, low discharge efficiency of the peristaltic pump, poor machine maneuverability and operators comfort, poor re-circulation of spray due to the low pressure at the tank

and non-uniform spray on undulating field. (Shani et al 2006).



Plate 1: Prototype sprayer by Shani et al (2006), being tested on the field

Further attempt to develop an animal drawn Ground Metered Shrouded Disc Applicator was fostered by Shani et al (2006) at the *Institute for Agriculture Research (IAR), Samaru, Zaria*. It was intended to be an improvement to the work of Abdulfatah, 1997. The prototype sprayer was fabricated and tested as shown in Plate 1. Evaluation showed that the set back to the development and proliferation of the equipment is the difficulty in sourcing suitable peristaltic tube for the construction of the pump. It is therefore very necessary to devise an alternative and more reliable mechanism for ground metering. This work has evolved the axle mechanism as a good option to solve the problem of ground metering in pesticide application.

### III. METHODOLOGY

Preliminary Studies of existing ground-metering agricultural spraying technologies were undertaken. The idea of an Animal Drawn Ground Metered Shrouded Disc Sprayer (GMSD) where the motion of a differential flange as the axle is actuated via the tire revolution on the ground, is tapped and utilized to drive a hydraulic gear pump was conceived and adopted.

The pump supplies pesticide to four centrifugal spinning discs that are shrouded at half the circumference. The design was carried out and the requisite drawings were produced in line with engineering practice. The equipment was constructed employing a Land Rover axle and was tested on the farm.

#### 3.1: Equipment Description

It is conceived that to achieve ground-metering of pesticide, the rear axle of any commonly used and serviceable vehicle can be employed. Plate 2 shows such an axle. When tires are bolted to the two wheel hubs and the assembly pulled by work animal, the pinion flange rotates as long as the axle is pulled. The motion of the flange is used to drive a gear pump which pumps chemical to the nozzles. Ground-metering is achieved since whenever the assembly is in motion, the pesticide is pumped to the atomizers and when the pulling animals stop, pumping stops automatically. The framework in angular sections of medium carbon steel material carries

the tank, pump and other appurtenances. The weight of the framework, that of the pesticide tank (with pesticide) and the weight of other appurtenances are sized to match the draft capability of the animals. The wheels are made of rubber tyres to reduce slip and engender smoother revolution of the wheels for even spraying. Figure 2 and 3 are the schematic drawings of the project and axle mechanism motion transmission respectively

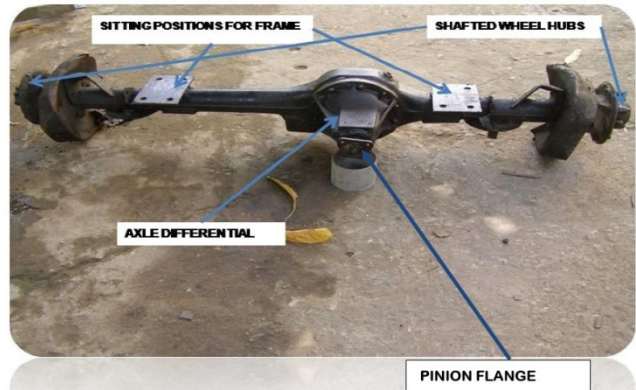


Plate 2: Axle Showing Wheel Hubs and Flange

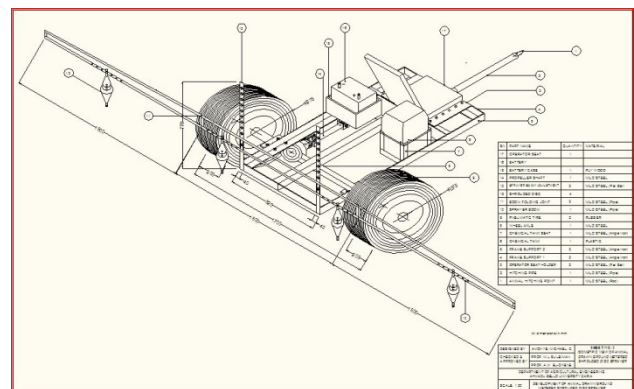


Fig.2. Schematic Drawing of Machine

#### 3.2: Equipment Design

##### 3.2.1: Axle Transmission Parameters (Fig. 3)

The axle characteristic is such that when the wheel shaft rotates once, the axle flange turns 3.6 times. The work of Goe and Mcdowell 1980 on work "Animal Traction: Guidelines" gave value of average speed as 0.7m/s (Goe and Mcdowell 1980). The measured tire diameter is 30 inches (762mm). Hence the Revolution per minute (N) of the tires can be calculated thus:

$$V = wR \quad \text{----- (4.10)}$$

Where  $V$  = animal speed.  
 $w$  = angular velocity of tire.  
 $R$  = Tire radius; but

$$w = \frac{2 \times \pi \times N}{60}$$

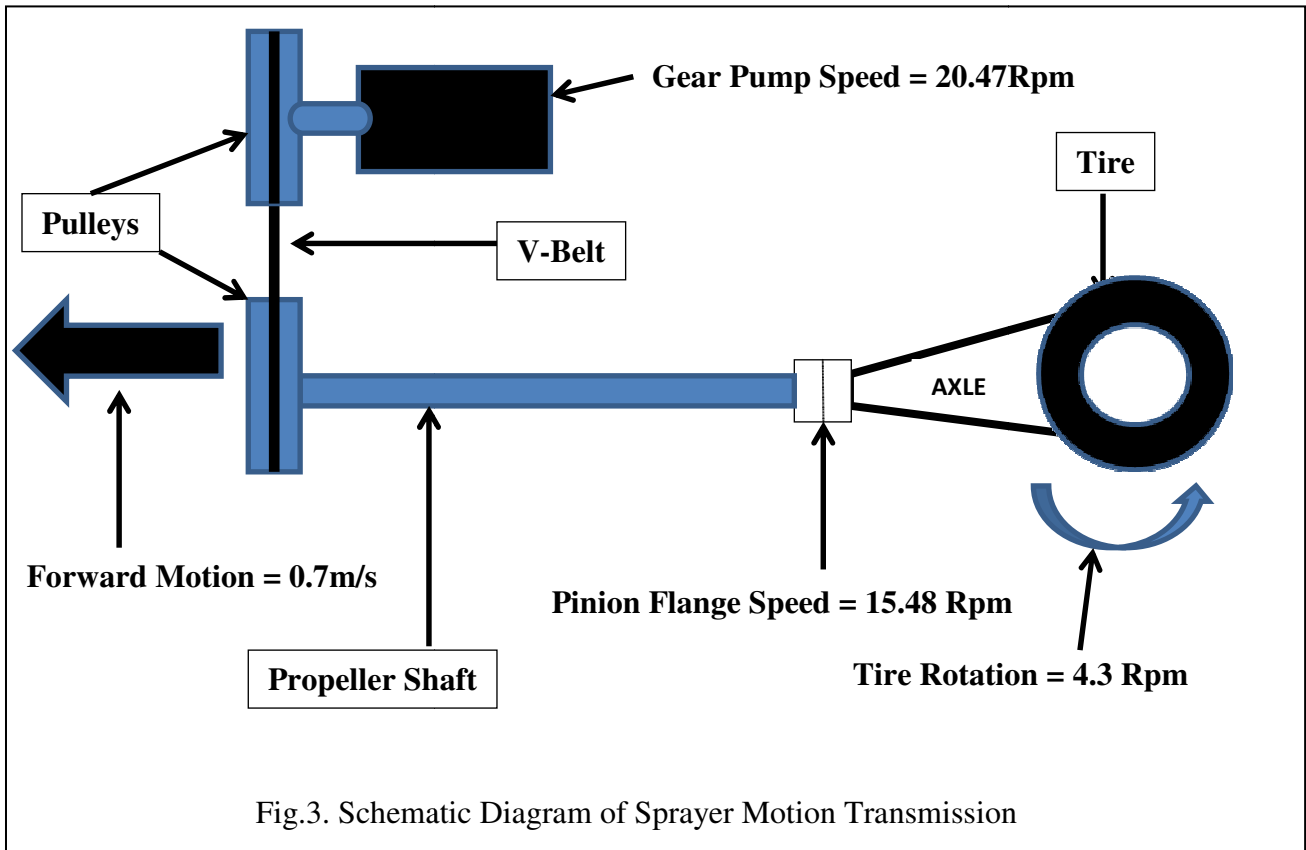
$$\text{Hence } V = \frac{2 \times \pi \times N \times R}{60} \quad \text{----- (4.11)}$$

$$\text{Thus } N = \frac{60 \times V}{2 \times \pi \times R}$$

Substituting values of  $V$  and  $R$  above;  
 $N = 4.3$  revolutions per min (Rpm).

Hence revolution per minute of the axle flange =  $4.3 \times 3.6$   
= 15.48Rpm  
Intermediate shaft pulley diameter = 205mm

Gear pump pulley = 155mm  
Hence pump speed =  $205/155 \times 15.48$  Rpm  
= 20.47Rpm



#### IV. RESULTS AND DISCUSSION

The machine was constructed at the Institute for Agricultural Research (IAR) workshop at the Department of Agricultural Engineering, Ahmadu Bello University, Samaru-Zaria. It was tested on a farm field at the department. The pump was operating from the motion transmitted through the tires. The herbicides were deposited on the four centrifugal spinning discs actuated by 12 volt battery. Plate 3 shows the machine during test-run.

#### V. CONCLUSION

An Animal Drawn Ground Metered Shrouded Disc Sprayer is thus designed and developed at the Institute for Agricultural Research (IAR) workshop, Department of Agricultural Engineering, Ahmadu Bello University, Zaria. It was tested on a farm and the ground metering through an axle mechanism was found to be very operationally efficient. The problem of tubing and consistent replacement of tubes in the peristaltic sprayer is now over, as the axle mechanism is mechanically stronger and more long lasting. However there is need for further work to incorporate more sordid atomizers to avoid nozzle dangling when the work animals move through undulating surfaces. Effort should also be made to address the

channeling of the unspent chemical occasioned by the shrouding of the disc.



Plate 3: Animal Drawn Ground Metered Shrouded Disc Sprayer in Operation

#### REFERENCES

- [1] J. H.Combellack, "The Value of Controlled Droplet Application (CDA) as a Spot Spray Technique for the Control of Noxious Weeds in Victoria," A publication of Keith Timbulla Research Institute, 1978, pp. 15.

- [2] M. Fowler Richard, "Animal Drawn Herbicide Applications for use in Small Scale Farmers Weed Control Systems" Starkey P and Simialenga T (eds) 2000, pp. 124.
- [3] M. R. Goe and R. E. McDowell, "Animal Traction: Guidelines for Utilization," Cornell International Agriculture Mimeograph 81, 1980, pp 5-40.
- [4] R. Grisso, C. Elbert, E. C. Dickey, and L. D. Schulze, "The Cost of Misapplication of Herbicides," American Society of Agricultural Engineers 0883-8542, paper 282; 1989, pp.344.
- [5] R. N. Kaul and M. L. Suleiman, "Introduction to Crop Protection Machinery," ABUCONS (NIGERIA) Publication Series No. 1, 1990, pp. 8.
- [6] C. L. Murdoch, "Spray Systems for Turfgrasses: Calibrating Sprayers and Mixing Pesticides," Research Extension Series 066; 630 US ISSN 0271-9916, 1986, pp. 3.
- [7] B. B. Shani, M. L. Suleiman, and U. S. Mohammed, "Performance Evaluation of an Improved Animal Drawn Ground Metered Shrouded Disc (GMSD) Sprayer," Journal of Agricultural Engineering and Technology (JAET), Volume 14, 2006, page 4-11.

## AUTHOR'S PROFILE



### **Engr. Mike Amony, MNSE;**

hails from Obosi in Anambra State of Nigeria and holds a Bachelor of Engineering Degree from the University of Benin, Benin City, Nigeria. He is a postgraduate student of Farm Power & Machinery at the Department of Agricultural Engineering, Ahmadu Bello University, Zaria, Nigeria. He is the

Head of Department, Manufacturing Services at Hydraulic Equipment Development Institute, Federal Ministry of Science & Technology, Kano.



### **Prof. M. L. Suleiman**

is a professor of Agric. Power & Machinery Engineering at the Ahmadu Bello University, Zaria, Nigeria. He holds a Bachelor of Engineering Degree (B. Eng.) in Agricultural Engineering from Ahmadu Bello University Zaria, in 1977; MSc in Agric. Machinery Engineering from Cranfield University;

UK, England in 1983 and PhD in Agric. Power & Machinery Engineering from Ahmadu Bello University in 1994. He is a Crop Protection Specialist and the first supervisor of the project.



### **Abdullahi El-Okene**

Born in Okene, Nigeria on Thursday 6th, June 1957, and has a Bachelor's degree in Engineering from Ahmadu Bello University, Nigeria in 1979, M.Sc in 1984 and PhD in 1995. He is currently Professor of Agricultural Engineering and heads the Agricultural Mechanization Research Programme. He is the

second supervisor of the project.



### **Engr. Dr. Ibrahim O. Abdulmalik**

hails from Okene, Kogi State, Nigeria. He holds PGD and Master's Degree in Mechanical/Production Engineering from NnamdiAzikiwe University, Awka in 2004 and 2005 respectively; and PhD in Manufacturing Strategy from London South Bank University, UK, England in 2010. He is presently the

Acting Director of Hydraulic Equipment Development Institute, Federal Ministry of Science & Technology, Kano, Nigeria, a research institute mandated to develop hydraulic and pneumatic devices and equipment.