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Spray Parametric Determination and Testing of anAnimal Drawn Wheel-Axle CDA Boom Sprayer

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Abstract: *Assorted techniques have been developed for warring against pests, but the most important innovation appears to be the use of chemicals which are now available for different pest situations. Many manual and motorized machines have been developed for crop protection. In Nigeria and especially in farming communities of the north, attempts have been geared towards the development of requisite animal drawn machines for on-farm spraying against pests.*
A ground metering Animal Drawn Controlled Droplet Applicator (CDA) Shrouded Disc Sprayer which ground metering is actuated by a wheel axle mechanism was 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. During the course of its development laboratory and workshop tests were carried out to determine the optimum spray height and nozzle spacingfor uniform distribution of herbicide. The values were 30cm, and 1.25m respectively. The pump discharge and boom swath as well as the application rate (l/ha) were also obtained. The equipment was constructed employing the spray components at the determined parameters and was consequently tested on the field.
Key Words: *Pests, farm, spraying, machine, evaluation.*

I. Introduction:

Weeds are the second most significant agricultural problem, second only to soil erosion. The fact is that growers must control weeds or they will suffer crop loss. There are over 30,000 weed species throughout the world and over 4,800 of these cause significant economic losses in production of food, feed, and fiber. **(Howard 2009).** Manual weeding is very laborious requiring to be repeated twice or three times before crop maturity. In large farms even with many labourers there is always the possibility of weed re-emergence before the entire farm is completed. Thus manual weeding is effective only for gardens and very small farms.

Chemical application has been very successful in weed control but must be applied in rationed proportions and spray characteristics. Specialized equipment is thus essential. In fact chemical application is the only fully mechanized farming operation. Developing spraying machines entails determining the nozzle characteristics as well as the pump discharge in order to ensure that desired application rate and coverage are not exceeded. Nozzle characteristics are first inferred from the spray pattern. Spray pattern refers to the regular form of the spray from the showerhead or nozzle, i.e. drenching rain, fine mist, sharp spray and massaging swirl spray patterns. Patternation is the measurement of uniformity and symmetry of the liquid distribution in a spray. Patternator is the instrument used to measure the spray distribution in a spray. Patternation can supply a quantitative measurement for the spray. The quantitative analysis of spray patterns is very important for nozzle design, selection and quality control, because the spray angle, the uniformity and the symmetry of the spray patterns are decisive parameters in practical applications. **(Yang 2000).**

A spray patternator is a device used to empirically determine the distribution (scatter or spread) of fluid from one or more spray nozzles. When one spray nozzle is used, there is a relatively even distribution of fluid on the spray surface. However, if two spray nozzles are used together such that there is an area of overlap, there will be a section of higher fluid concentration. This area of excess fluid is undesired because it results in increased costs and, in some cases, may be harmful to the environment. Therefore, it is desirable to locate an optimal spacing between the nozzles and a certain height from target so that the spray distribution is as uniform as possible and the overlap regions do not result in areas of high concentration, minimizing excess fluid.

A spray patternator consists of a table inclined at about ten degree divided into a number of grooved channels. The width of the channels is dependent upon the desired resolution of the spray distribution. Obviously, smaller channel width will produce higher resolution of the spray distribution. The spray nozzles are supported at regulated heights above the table and turned on. The nozzle location above the table will also affect the distribution of the spray so it is important to test the nozzles at different heights.

When the fluid reaches the table, it will be separated into the different channels and flow down the incline. When the fluid reaches the base of the table, each channel flows into its own graduated cylinder. The conventional spray patternator requires manual data acquisition. The person running the experiment must record the height of the water in each cylinder by reading the measurement in each graduated cylinder. Nozzle patternation was carried out for the Controlled Droplet Applicator (CDA) centrifugal disc nozzles before incorporation in the developed equipment.

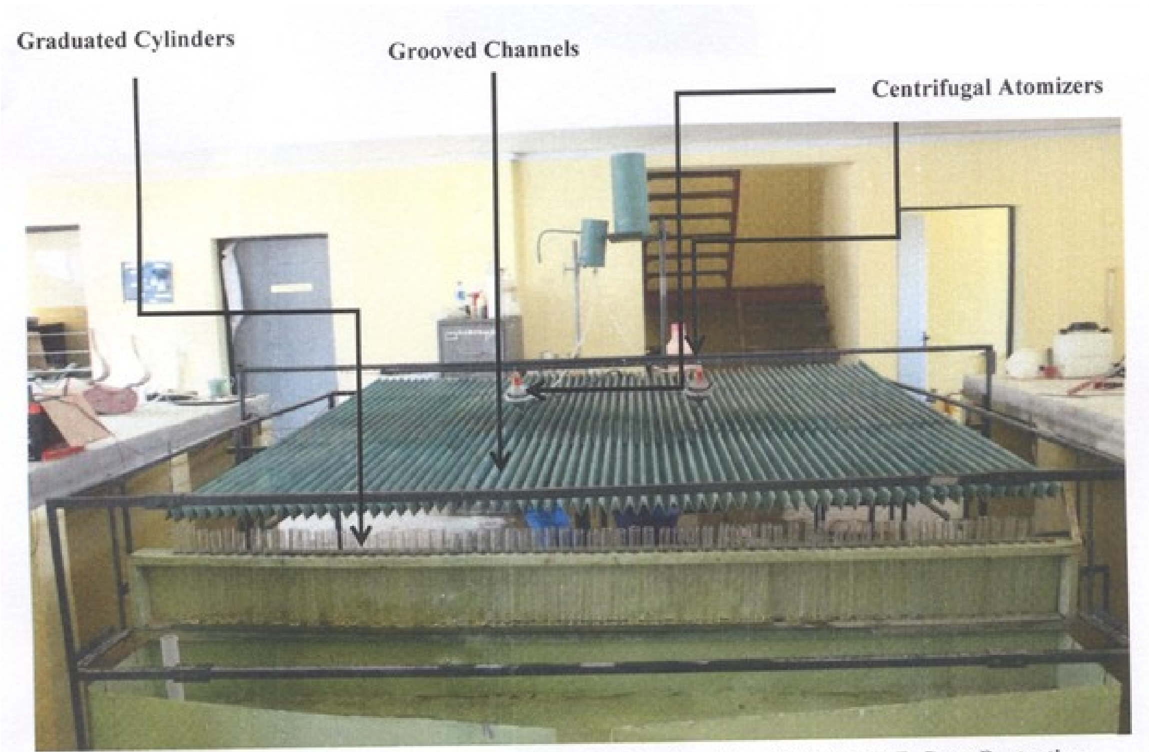

Plate 1: Patternator designed and fabricated by Enaburekhan (1981) at IAR Crop Protection Laboratory, ABU, Zaria

The equipment consists of a boom with four CDA atomizer nozzles, a gear pump, a chemical tank, and chair for an operator; all attached to a framework bolted to a rear axle. The wheels are spaced at 1.5m to pass in-between a specified number of ridges. The boom carrying several CDA atomizers is attached at the rear side of the framework. An attachment for the animal harness is installed at the front of the framework.

To achieve ground-metering of pesticide, the rear axle of a commonly used and serviceable vehicle (Land Rover) was employed. Plate 1 shows the machine. The motion of the axle flange is used to drive a hydraulic 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.

II. Methodology

The spray nozzles were tested on the Patternator and some characteristics were inferred. The patternator was narrow to permit full tests on more than one spinning disc but inference from the test was further confirmed by workshop test-run.

The machine was then constructed and reality tests were carried out to evaluate the conformity with design values. Manual rotation of the tire was used to determine spray parameters of pump discharge rate, nozzle flow rate at various heights as well as the swath.

Plate: 2 Animal Drawn Ground Metered Shrouded Disc Sprayer during test-run

The equipment was then test run on the farm to determine the draft matching, the steering freeness as the work animals turn and also the water/chemical dispensed per hectare.

III. Results

3.1: Laboratory Tests

3.1.1: Experimental Set-Up

The experimental set-up consists of a patternator designed and fabricated by Enaburekhan (1981). It includes the following units: (a): Patternator table and stand (b): Tube rack (c): An adjustable boom to allow (d): Constant head supply (e): Liquid and electric lines. The table is made into 64 V-shaped channels, 4cm apart, 4.5cm deep, with the sides 5cm long at an angle of 45 degrees to the vertical. This patternator table is supported by a stand of dimensions 300cm x 300cm x 100cm.

The tube rack is also supported by this stand fixed 50cm above the ground. It spans along the width of the channeled table, it is designed to hold the collecting tubes in position. A tube is kept directly under each channel on the sloping side of the patternator, so that, spray liquid falling on the patternator, is collected by the tubes.

Tests were carried for heights of 15cm, 30cm, 45cm and 60cm and for disc spacing not exceeding 70cm. Beyond 70cm, liquid flows out of the patternator as a result of the wider swath of the Micron Herbi disc atomizer. Further tests were done in the workshop to confirm theoretical swath. The Coefficient of Variation of Readings of spray volume distribution patterns obtained from Patternator experiments at various boom heights and discs' spacing are summarized in Table 1.

Table 1: Coefficient of Variation for Patterns obtained from Different Boom Height at Various Disc Spacing.

Boom Height (cm)	[*Disc Spacing (cm)] Coefficient of Variation COV (%)		
	[*30]	[*40]	[*70]
15	92	66	70
30	78	62	52.5
45	73	71.9	68.7
60	84	80	79.2

Observation shows there is decrease in Coefficient of Variation with increase in disc spacing. For the 40cm and 70cm disc spacing, the height above Patternator of 30cm is optimum. The best pattern is seen to occur at this height with disc spacing of 70cm. The spray overlap was recorded at 16.6% of single nozzle swath.

3.2: Workshop Tests
3.2.1: Pump Discharge Rate
a. Procedure

One of the tires was fixed ensuring that rotation of one tire turns the axle shaft which in turn rotates the pump pulley. The free tire was manually rotated during one minute. The pump discharge per minute and the number of revolutions were recorded for water and for Glyphosate plus water in two different ratios, in three replications.

b. Results

Table 2: Pump Discharge at various tire-revolutions using Water as test fluid

	Discharge rate (ml/min)	Revolution
1.	760	30
2.	740	27
3.	760	28
Average	753.3	28.3

Table 3: Pump Discharge at various tire-revolutions using Water/ Glyphosate (2:1) as test fluid

	Discharge rate (ml/min)	Revolution
1.	780	30
2.	720	28
3.	710	28
Average	736.6	29

Table 4: Pump Discharge at various tire-revolutions using Water/ Glyphosate (3:1) as test fluid

	Discharge rate (ml/min)	Revolution
1.	740	28
2.	720	30
3.	716	30
Average	725.3	29.3

Result implies that at both the lower and the higher averages for Water/Glyphosate of 29.3Rpm and 0.7253litres/min; and Water/Glyphosate of 29Rpm and 0.7366litres/min, a speed of at least 17Rpm is required for the pump to deliver the needed volume.

3.2.2: Nozzle Flow rate
a. Procedure

One of the tires was fixed ensuring that rotation of one tire turns the axle shaft which in turn rotates the pump pulley. The free tire was continuously rotated for five minutes. Water was used as the test fluid. The discharges from each of the nozzles at different heights were collected in polythene sacks. The discharges were measured and divided by 5 to get the value in (litre/min). The experiment was also conducted for water and for glyphosate plus water.

b. Results for water as Test Fluid

Table 5: Nozzle (red restrictor) Discharge (l/min), at 15cm Height.

Nozzle 1	Nozzle 2	Nozzle 3	Nozzle 4
540	550	520	580
546	534	538	540
518	520	536	510
Av:534.6	537.3	531.3	543.3

Table 6: Nozzle (red restrictor) Discharge (l/min), at 30cm Height.

Nozzle 1	Nozzle 2	Nozzle 3	Nozzle 4
500	520	560	540
526	540	530	510
516	534	510	508
Av: 514	531.3	533.3	519.3

Table 7: Nozzle (red restrictor) Discharge (l/min), at 45cm Height.

Nozzle 1	Nozzle 2	Nozzle 3	Nozzle 4
540	560	520	526
525	526	538	540
540	530	534	546
Av: 536	538.6	530.6	535.3

Table 8: Nozzle (red restrictor) Discharge (l/min), at 60cm Height.

Nozzle 1	Nozzle 2	Nozzle 3	Nozzle 4
530	540	560	510
538	510	540	538
526	536	518	530
Av:531.3	521.3	539.3	526

c. Results for Test Fluid: Glyphosate + Water (Ratio-1:2); Nozzle: Red.

Table 9: Height: 15cm (Discharge l/min)

Nozzle 1	Nozzle 2	Nozzle 3	Nozzle 4
104	103	100	103
103	104	102	103
122	100	103	104
Av:109.6	102.3	101.6	103.3

Table 10: Height: 30cm (Discharge l/min)

Nozzle 1	Nozzle 2	Nozzle 3	Nozzle 4
103	102	100	100
100	103	103	102
102	100	100	100
Av:101.6	101.6	101	100.6

Table 11: Height: 45cm (Discharge l/min)

Nozzle 1	Nozzle 2	Nozzle 3	Nozzle 4
92	100	105	100
100	103	105	104
100	102	100	103
Av:97.6	101.6	103.3	102.3

Table 12: Height: 60cm (Discharge l/min)

Nozzle 1	Nozzle 2	Nozzle 3	Nozzle 4
100	100	100	100
103	106	100	103
102	100	95	102
Av:101.6	102	98.3	101.6

3.2.3: Measurement of Swath Width of Prototype at Various Boom Heights

a. **Procedure:** One of the tires was fixed ensuring that rotation of one tire turns the axle shaft which in turn rotates the pump pulley. The nozzles were started from the battery while the free tire was rotated continuously. The marks on the ground made by the sprayed water were measured at various heights to get the swath widths.

Table 13: Swath at Various boom Heights

Boom Height (cm)	Swath width (cm)
15	547
30	560
45	583
60	595

3.4: Coefficient of Variation Computation

Nodby (1978) suggested that atomizers should be evaluated on the basis of their co-efficient of variation and he introduced the following grading in determining usability of nozzles. From the table if the coefficient of variation obtained is less than 10% the spray distribution is classified particularly good and when it is between 10% and 12% is very good, between 12 and 16 satisfactory and between 16% to 20% and above the spray is termed unusable. **(BabaShani et al 2013).**

The Coefficient of Variation is expressed as the ratio of standard deviation and mean. It is often abbreviated as CV. Coefficient of variation is the measure of variability of the data. When the value of coefficient of variation is higher, it means that the data has high variability and less stability.

Table 14: Suggested grades of Atomizers by Nodby 1978

Co-efficient of variation (%)	Grade
<10	Particularly Good
10-12	Very Good
12-16	Satisfactory
16-20	Unusable
>20	Unusable

When the value of coefficient of variation is lower, it means the data has less variability and high stability. Mathematically, the coefficient of variation is the estimated standard deviation (an absolute Measure).The formula for coefficient of variation is given as:

CV = SD/Mean x 100 ------ (1)(GREEFF 2006)
Where CV= Coefficient of Variation,
SD = Standard Deviation

The Coefficient of Variation of the readings for the test reported by Tables 9 to 12, were computed to find the most suitable height. The calculations are given hereunder in Tables 15 to 18. Calculation shows that at any of the heights, the nozzles are particularly good but the best height is at 30cm above the ground. The boom was set at this height with a swath of 560cm.

Table 15: CV at Height 15cm

No.	X	M	X-M	$(X-M)^2$
1.	109.6	104.2	5.4	29.16
2.	102.3	104.2	-1.9	3.61
3.	101.6	104.2	-2.6	6.76
4.	103.3	104.2	-0.9	0.81
			Total	40.3

Standard deviation = 6.35
Coefficient of Variation = 6.35/104.2 x 100
= 6.

Table 16: CV at Height 30cm

No.	X	M	X-M	$(X-M)^2$
1.	101.6	101.2	0.4	0.16
2.	101.6	101.2	0.4	0.16
3.	101	101.2	-0.2	0.04
4.	100.6	101.2	-0.6	0.36
			Total	0.72

Standard deviation = 0.84
Coefficient of Variation = 0.84/101.2 x 100
= 0.83

Table 17: CV at Height 45cm

No.	X	M	X-M	$(X-M)^2$
1.	97.6	101.2	-3.6	12.96
2.	101.6	101.2	0.4	0.16
3.	103.3	101.2	2.1	4.41
4.	102.3	101.2	1.1	1.21
			Total	18.74

Standard deviation = 4.32
Coefficient of Variation = 4.32/101.2 x 100
= 4.3.

Table 18: CV at Height 60cm

No.	X	M	X-M	$(X-M)^2$
1.	101.6	100.9	0.7	0.49
2.	102	100.9	1.1	1.21
3.	98.3	100.9	-2.6	6.67
4.	101.6	100.9	0.7	0.49
			Total	8.95

Standard deviation = 2.99
Coefficient of Variation = 2.99/100.9 x 100
= 2.96.

IV. Conclusion

Above steps were dutifully followed in the parametric determination of spray component characteristics before final integration into the constructed equipment.

The machine was constructed using the Centrifugal Disc Applicator nozzles that were tested. The boom was installed at the optimum height of 30cm with swath width of 560cm. It was tested on a 50m x 29m farm area at the premises of Institute for Agricultural Research, Ahmadu Bello University Zaria (Plate 2); and the sprayingat the said boom height was found to be very efficient. Water/glyphosate ratio of 3:1 was employed and resulted in Application Rate of 8.62litres of Glyphosate per hectare.

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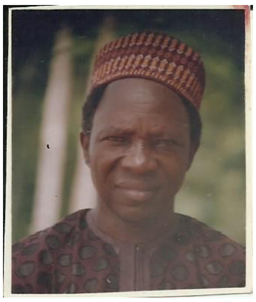

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