DEVELOPMENT AND PERFORMANCE EVALUATION OF A PORTABLE MOTORIZED SEED AND FERTILIZER BROADCASTER

BY

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Abstract

In an attempt to ease one of the production constraints i.e. broadcasting of our peasant farmers, a portable motorized spinning disc type broadcaster was designed, constructed and evaluated to ameliorate the broadcast seeding and fertilizer application. The machine was constructed with a net weight of 7.5 kg and gross weight of 23.5kg. The diameter of the driven pulley was 135mm and the power required by the machine was 770.28Watts. The length of belt required was 708mm. The diameter and the torsion rigidity of the shaft were 10mm and 0.75^0, respectively. The total volume hopper was determined to be 13,479cm^3 while the mean flow rate of the four materials was 65.5g/sec. Performance test was done using four materials namely rice, soya bean, urea fertilizer and beniseed. The test results gave the spreading width as 2.3 m for rice, 2.8 m for soya bean, 2.6 m for urea fertilizer and 2.5 m for beniseed. One person can successfully broadcast any material in a field of one hectare within one hour. The average efficiency of the broadcaster was 58.7% while the average broadcasting throughput capacity was 143.9 kg/hr. All mean values of variables from analysis of variance (ANOVA) showed significant difference at 5% level of probability. It is recommended among other things that there should be a special design of 1kW light and compact D.C motor for the machine and /or redesigning of the agitators in such a way that they may not have a direct load bearing from the material in the hopper.

Keywords: Development, performance, evaluation, portable, motorized, broadcaster

Introduction

Seed and fertilizer placement operation is done either on a straight row, hip or sown at a depth or scattered on the surface of the soil otherwise termed broadcasting (Yohanna, 2007). Broadcasting operation, either seed or fertilizer has been an old method carried out by peasant farmers especially with small seeds and later manure and fertilizer. Because the depth to which seeds should be sown is proportional to its size, small seeds such as beniseed and rice can be broadcasted as they can easily fall between soil particles and be covered on already prepared land while bigger or larger seeds such as soya beans must be covered with a harrowing operation after the broadcast operation (Onwualu *et al.*, 2006).

Today, there are many types and models of seed and fertilizer placement equipment in the market that meets varying requirements of the farmers. Whether the farmer's requirement is drilling, hill dropping, parallel row or broadcast placement, there is an equal model designed to achieve these purposes. All the farmer needs is to select the type and model that meets his requirement and available fund (Ojha and Michael, 2003)

Broadcasting is done either by hand or mechanical means. The former method is the one widely used by peasant farmers due to their subsistence levels, of farming. However, with the growing demand of these industrial crops, majority of the peasant farmers in the middle belt region of Nigeria where most of these crops are grown are increasing their hectarages making hand broadcast tedious, hence unreliable (Yohanna, 2007)

The broadcast operation is usually done after the land has been prepared. The seed is usually carried in an open container, calabash or even polythene bags and scattered with the throw of hand. Uniformity of broadcast is usually not achieved especially when the operation is carried out after land preparation. This non-uniformity results in the seed germinating in cluster or over crowded thereby affecting yield. Likewise non-uniformity of fertilizer broadcast affect yield as some plants will get the nutrients more than others or scrotching of plants where they are hipped (Yohanna 2004; 2007).

Also when the farmer is desirous of optimum yield, thinning and/or supplying are done for plants such as soybeans and rice respectively. These exercises are of course laborious and time consuming resulting into loss and hence increase in production cost (Kepner *et al*., 1980, Kwaya, 2000). Mechanical broadcasting on the other hand is done by a variety of machines. The most common among them is the spinning disc type broadcaster. It is also known as centrifugal type broadcaster. This broadcaster has been in use for the purpose of broadcasting both seed and fertilizer in some advanced counties such as Britain and the United States of America for a century (Smith, 1965, Kepner et al., 1980., Suresh and Sanjay, 2004). It is often used for broadcasting granular fertilizer such as superphosphate and small seeds such as clover or alfafa (Aji, 1977; Culpin, 1978).

The spinning disc is usually of circular type with radial vanes mounted perpendicular to the disc surface. The disc is mounted to a vertical shaft and rotates horizontally with the driven shaft. Seed or fertilizer falling on the rotating disc from the hopper is accelerated radially outward by the centrifugal force generated by the rotating disc (Inns and Reece, 1962; Paterson and Reece, 1962). At the edge of the spinning disc, the seed or fertilizer are projected out and spread on the soil surface. The advantage of the spinning disc type broadcaster is its ease of operation and simplicity of manufacture and maintenance. It is also easily used on irregular fields and those having surface obstructions (Garba, 1998; 2002)

The objectives of this work included:

i) The designing of the machine, constructing one using locally available materials and

ii) To carry out the performance test of the machine.

Materials and methods

Design considerations

The design of this portable motorized seed and fertilizer broadcaster was based on the following considerations:

i) The availability of materials locally to reduce the cost of production

ii) The hopper is wide opened type to allow easy loading of seed/fertilizer – do you incorporate a metering device to ensure uniform distribution?

iii) The seed/fertilizer outlet was inclined at an angle 20^0 for effective discharge

iv) It was desired that there should be minimum or no loss of seed/ fertilizer during the operation, therefore the pulley was carefully designed to meet the required speed 350rpm of the discharging unit

Description of the seed/fertilizer broadcaster

A good description starts with the identification of the component parts or units in the machine. The machine was designed with a simple frame structure that made it look very compact with over all height standing at 450 mm and width 380 mm. The main components of the machine are hopper, hopper bottom, and aperture adjusting plate, spinning disc, drive shaft, bearings, electric motor, belt and pulleys, supporting frame, battery and dynamo. The main drive shaft is held in place by the two ball roller bearings fixed to the upper and lower stationary plate of the frame and is extended upward into the hopper to hold the two agitators. The volumetric capacity of the hopper was calculated to be 13,479.38 cm^3 while the mass of material the hopper can hold on an average was calculated to be 11.2 kg.

The spinning disc, which is made of aluminum sheet and riveted to a steel flange, is also keyed immediately on top of the upper stationary plate and directly below the hopper to receive materials to be broadcasted. The hopper is mounted on the frame work directly above the spinning disc. The fixed hopper bottom and the aperture adjusting discs (opening and closing) are directly mounted to the hopper bottom to receive and discharge materials accordingly.

At the protruded side of the frame structure is mounted the D.C motor to provide rotational drive of the spinning disc and agitators via pulleys and belt drive. A 12V-motorcycle battery is provided to induce power to the motor while a regulator is also provided to regulate the speed of the motor to suit the type of material to be broadcasted (Fig 1 appendix 2). A dynamo was provided for continuous recharging of the battery while in operation. It is mounted to one of the frame vertical supports and receives drive from the drive belt.

Operating principles

With the discharge aperture closed, materials to be broadcasted were poured into the hopper. The machine was lifted up against the chest and carried on the shoulder by the use of the two belts straps. Operation commenced by first switching ‘on’ the motor. As the disc rotates, materials were let loose on the rotating disc by opening of the discharge aperture through the feed regulating handle. Forward movement was carried out steadily with approximately constant pace to achieve uniformity of spread and rate of applications.

In operation, the spinning disc rotating was achieved when the switch was switched 'on' power from the battery was directed to the electric motor through the regulator. The regulator allows for speed variation. Through the multiplier effect of the field winding, the high current developed by the field windings induced rotation of the armature. The rotating action of the armature shaft is then transferred to the spinning disc shaft via the belt. When the machine was loaded with material and switched on, there was a 2 seconds hick-up before the spinning disc began to rotate. This showed the resistance the motor has to overcome to be able to push the agitators through the material.

Design analysis

Pulley size: The machine was powered by a D.C motor having a speed of 4500 rpm. The drive pulley was chosen to be 0.03 m diameter so as to reduce the drive speed considerably from 500 to 3500 rpm. The driven pulley was calculated thus:

$N_1D_1=N_2D_2$ ---------------- (1)

Where, N_1 - speed of motor (4500 rpm)

N_2- speed of spinning disc (1000 rpm maximum chosen)

D_1 – diameter of drive pulley (0.03m chosen)

D_2 – diameter of driven pulley = $\frac{N_1 D_1}{N_1}$ = 0.135 m (or 135 mm)

Powered required by the machine.

The power required by the machine is a function of the total load both the axial and radial and the speed of the rotating belt.

Hence P = Ft V -----------------(2)

Where, P = power required, watts.

Ft = total load (forces) to be overcome by belt power, Newton

= $[(m_s + m_d+ m_p) g + (F_b + T_b)]$ N ----------(3)

V = speed of the machine, m/s =πDN/60= 7.07.(Hall et al., 1980). Where D-diameter of pulley=0.135m and N-Speed of pulley=1000rpm.

m_s = mass of spinning shaft, kg = $\rho\pi r^2 l$ =0.14.(Hall et al., 1980). Where ρ – density of steel=7860kg/m, r-radius of shaft= 0.005m and l-length of shaft= 0.22m.

m_d = mass of spinning disc, kg = $\rho[(\pi D^2 t_1/4)+Avt_2/4]$ =0.2 (Sharpe, 1989). Where ρ– density of pulley material=2698kg/m^3, D-diameter of disc=0.25m, t_1=thickness of disc=0.0015m, Av-area of vane= 0.035x0.01= 0.0035m^2, t_2 - thickness of vane= 0.0015m.

m_p = mass of pulley, kg = 1.35 (calculated)

g= acceleration due to gravity, m/s^2 = 9.81

F_b = force to over come friction by belt, N = f d N =2.12 N. (Hall et al., 1980).Where f- coefficient of friction between belt and pulley = 0.3 for rubber belt on steel, d- diameter of pulley= 0.135m and N- speed of pulley= 1000rpm

T_b = belt tension, N = T_1+T_2=72N+21.25N = 93.25N. (Oberg *et al.*,1992; Hall *et al*., 1980). Where T_1= belt width x thickness x shear stress= 0.01x0.06x1.2x10^6 =72N

Substituting into equation 2, the required power P, of the machine is P = 770.28 Watts.

Length of belt required

The total length was calculated from Sharma and Aggarwal (1998), Akintunde and Tunde- Akintunde (2001) thus:

$$L =2c + 1.57 (D2 – D_1) + \frac{(D_2 – D_1)^2}{4C} \text{ m} \quad \text{-------- (4)}$$

Where,

C – Centre diameter between pulleys (0.218m) – (calculated)

D_2 – diameter of larger pulley (0.135m) – calculated

D_1 – diameter of smaller pulley (0.03m) – calculated

Substituting in equation 4, the total length of belt required will be

L = 0.708m (or 708mm)

Shaft diameter determination

From Ryder (1969), Hall et al (1980), Akintunde and Tunde-Akintunde (2001), shaft diameter can be calculated thus.

$$d^3 = \frac{16}{\pi s_s} \sqrt{(k_b x m_b)^2 + (k_t + m_t)^2} \quad \text{--- (5)}$$

Where s_s – allowable stress = 40 MPa (for shaft with key ways)

k_b – combine shock and fatigue factor applied to bending moment = 1.0

k_t – combine shock and fatigue factor applied to torsional moment = 1.5

m_b – maximum bending moment = =3.68Nm (calculated)

m_t – torsion moment =(T_1-T_2)R =(72N-21.25N)0.0675m=3.43 Nm. Where T_1-belt tension on tight side, T_2 – belt tension on slight side and R-thickness of belt.T2 is obtained from:

$$\frac{T_1-mv^2}{T_2-mv^2} = б^{(f\alpha\sin\theta/2)} \quad \text{------------------5a}$$

Where m-mass of 1m of belt=0.42 kg (selected belt) Oberg *et al*., (1992). V-belt velocity=7.07m/s calculated. F-cofficient of friction-belt pulley=0.3. α-angle of wrap on small pulley=1800-2sin^{-1}=(DI-

D2)/2C Sharma and Aggarwal, (1998). Centre distance, C=0.218 m (calculated) from equation 5a, α=2.66rad. and

$$\frac{51.01}{T_2-20.99} = 13.23. \quad \text{Hence, } T_2 = \frac{13.23}{51.01} + 20.99 = 21.25\text{N}$$

Substituting into equation 5, shaft diameter d, will be:

d = 0.0099m (or 10 mm).

Torsion rigidity of shaft

Hall et al (1980) gave an empirical equation for the calculation of torsional rigidity of shafts as:

$$\Theta = \frac{584\, m_t l}{G d^4} \quad \text{---------------- (6)}$$

Where, Θ – angle of twist, deg

L- Length of shaft = 22 cm (0.22 m) (chosen)

m_t – torsional moment = 3.43nm (calculated)

G – torsional modulus of elasticity = 80 $\times 10^9$ N/ m^2

d – shaft diameter = 0.01m (calculated)

Substituting values into equation (6), $\Theta = 0.75^0$

The radial deflection is within limit permissible (i.e. 0.3 - 3 deg/m) (Sharma and Aggarwal, 1998)

Hopper design

The hopper shape is cylindrical with a conical bottom half to allow for greater flow of materials. The continuous load carrying capacity for an average weight male of 60kg is 20 kg (Hiraga, 1988). In designing for the 20 kg gross weight, an allowance was made for the net weight of the machine. Bosoi *et al.* (1988) stated that the standard practice width of hoppers is between 250-300 mm.

Hence neck width of hopper chosen =250mm

overall height taken =30cm

cylindrical part = 20cm (high)

conical second half = 10cm

volume v, = $\pi r^2 h$ ------------ (7)

where r_1 - radius of hopper = 12.5cm

h_1- height of hopper =20cm

Therefore v, = 9817.5cm^3

For conical second half, the diameter of the base was 18cm

Hence $v_2 = \frac{1}{3}\pi h_v (R^2+Rr+r^2)$ -----------(8)

where hv – vertical height = 10cm

R - upper radius = 12.5cm

r – lower radius = 9cm

Substituting values in to equation 8:

Therefore V_2 = 3661.88cm^3

Total volume of hopper = $V_1 + V_2$ =13,479.38cm^3

The total mass of material the hopper can hold is given by.

m=ρv (9)

where v- volume = 13, 479.38cm^3

ρ - density =0.83 g/cm^3 (average for rice, soybeans, beniseed, urea fertilizer from Sharma and Aggarwal, 1998).

Therefore, m = 11, 187.89g (or 11.2kg).

Discharge aperture

Mohsenin (1970) stated the equation for finding minimum dimension as;

$$B = \frac{p}{W_2} \sin 2\alpha \text{ (Mohsenin, 1970) ----------- (10)}$$

where, B- aperture minimum diameter, mm

p – base pressure, kg/m^2

w- bulk density of material, kg/m^3

α – arching angle of slot opening (Krut_Z et al., 1984) with horizontal (assumed 30^0)

Minimum average dimension of aperture taken = 6cm (calculated).Equation 2.7

Application rate

4

The flow of granular materials through an orifice as given by Mohsennin, (1970) is calculated as:

$$Q = 35w \sqrt{g}\,(B-1.4d)^{2.5} \text{..........(11)}$$

where Q - flow rate, g/s

w – bulk density, g/cm^2

g- gravitational acceleration, cm/s^2

B – aperture diameter, cm.

d- average diameter of the particles, cm.

Using w and d parameters for the four materials used for this design work and substituting into equation (11), the flow rates are shown on Tables 1& 2.

Performance test of the machine

After the construction and complete assembly, the machine was weighed and tested to ascertained certain parameters

I. Free and efficient rotations of component parts unload and loaded with materials.

II. Field capacity for various materials

Procedure used in carrying out the tests.

Test 1. The battery was fully charged and properly connected. The hopper was cleaned making sure it was free from any material or obstruction cither to the agitators or spinning disc. The machine was then switched on for the motor to run all component parts.

Test 11. The test 1 above was then replicated with the materials (rice, soya beans, beniseed and urea fertilizer) loaded into the hopper in order to test the power of the motor pushing the agitators through the materials.

Test 111: Field capacity for the four (4) materials - rice, soya beans, urea fertilizer and beniseed were evaluated through the following methodology. All the materials were local varieties purchased from the local market.

1.Two measures each of the materials were purchased, properly cleaned and weighed using a weighing balance with the following figures obtained. Rice -2.2 kg, soyabeans-2.8kg, beniseed -2.3 kg and urea fertilizer -2.3kg. The researcher did not buy more quantity of the materials to meet the 11.2 kg capacity of the hopper because of lacked of funds.

2. A length of 40 metres was marked out from a field for the purpose of the test.
3. The person carrying the machine for the test was asked to lift and carry the machine on his shoulders as he will normally do during field operation. The spreading height was measured from the surface of the ground to the level of the spinning disc and 1 meter was obtained.
4. The materials (seeds) were then emptied into the hopper ready to commence test.
5. The machine was switched on with a constant pace, the operator began his movement about five metres before the marked line. As he approached the line, the discharge aperture was opened through the means of an operating lever.
Note that all tests were carried out with the aperture operating lever opened. The operator went through the 40m marked and shut the operating lever as he crossed the last marked line.
6. Time taken to go through the 40m was noted by means of a timing stop watch.
7. The width of spread was measured with a measuring 100 m-tape.
8. The quantity used in spreading through the 40m-length was calculated.
9. The application rate was calculated.
For each material, the above tests were replicated three times and the averages taken. The results of the tests are as summarized in Tables 1& 2.

η_b

b. Broadcasting throughput capacity (BTC), kg/hr : This is the rate of the quantity broadcasted (in kilogrammes) to the time taken (in hours) to complete the activity (adapted from Akintunde and Tunde-Akintunde,2001 ; Agbetoye and Oyodele, 2005; Babalola and Ndirika, 2006).

$$BTC = \frac{q_b}{t} \quad \text{---------------} \quad (2)$$

Where
q_b- Quantity of seed/fertilizer broadcasted, kg.
q_t –Total quantity of materials (seeds and fertilizers) used, kg.
t – Time taken to complete activity, hrs.

Results and Discussion on the results of analysis of variance for the variable accessed.

The results revealed that beniseed had the highest mean

Results of Analysis of Variance (ANOVA) for the variableaccessed

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Results of Analysis of Variance (ANOVA) for the variable accessed

The first and second tests were carried out for the sole purpose of testing the harmonious and efficient working of all component parts of the machine. The first test was done with an empty hopper without materials. With this first test, all component parts rotate smoothly without any hindrance. However, when the machine was loaded with 2.2kg of rice and switched on, there was a 2 second hick-up before the spinning disc began to rotate. This showed the resistance the motor had to overcome to be able to push the agitators through reduction in speed from 500 rpm to 350 rpm. A mechanical tachometer was used to measure the speed of the mean drive shaft before and when the machine was under operation. The results of field replicated tests carried out for different agricultural materials are as given in Table 2 while those of the mean field parameters obtained are summarized in Table 1.

⓪⑥⑤ ☙⑩ ⑩⓿☙⓿☙ ☙❺ ×⑤❸❶☙③ ❶ ☙⓿ ☙③ ⦘📋📋📋📋🖶🗋🗐

Conclusion and recommendations

From the results obtained, it is concluded that:

i. The overall performance of the machine was satisfactory by producing a uniform speed as compared to manual spreading except for the D.C motor where the designed capacity could not be obtained.

ii. The machine had a throughput capacity of 143.9 kg/hr and a broadcasting efficiency of 58.7%

iii. All broadcasting operations could be achieved within the range of one hour per hectare and this time can further be reduced with the right capacity motor. This could also be further improved on the width of spread when the right speed of rotation is attained.

iv. A swath width of 2.3m – 2.8m was attained for the various materials used for the performance tests.

v. The machine can therefore be used to substitute the manual broadcasting method, since more seed/fertilizer can be applied more uniformly and effectively.

vi. From the analysis of variance (ANOVA), all the mean results of the variable accessed were having significant difference at 5% probability.

For further improvement, it is recommended that there should be a special design of 1kW light and compact D.C motor for the machine and/or redesigning of the agitators in such a way that they may not have a direct load bearing from the material in the hopper.

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Appendix 1

Table 1. Mean Field performance parameters of the seed and fertilizer broadcaster.

s/n	material	bulkdensity ($g//m^3$)	matreial particle size (cm)	flow rate (g/s)	minimum aperture opening (cm)	quantity purchased (kg)	quantity used (kg)	width of spread (m)	time taken secs (mins)	area covered in 40m-length (m^2)	time covered lha (mins)	Application rate (kg/ha)	throughput capacity kg/hr	broadcasting efficiency (%)
1.	Rice	0.88	0.32	68	5	2.2	1.1	2.3	36(0.01)	92	65	120	110	50
2.	Soyabean	0.75	0.66	51	6	2.8	1.4	2.8	34(0.009)	112	51	125	155.6	50
3.	Beniseed	1.25	0.043	106	3	2.3	1.15	2.6	35(0.01)	100	56	95	115	50
4.	urea fertilizer	0.44	0.066	37	10	2.3	1.95	2.5	35(0.01)	104	56	111	195	84.78
	Total	3.32	10.29	262	24	9.6	5.6	9.9	140(0.039)	408	228	451	234.78	575.6
	mean	0.83	0.257	65.5	6	2.4	1.4	2.48	35(0.01)	102	57	112.75	58.70	143.9

s/n	material	Material	Bulkdensity g/cm^3	Particle size	Flowrate	min_apertureopening	Quantitypurchased kg	Quantity used	Widthofspread (m)	Timetaken(secs)
1	Rice	1	0.88	0.32	68	5	2.2	1.1	2.3	36
		1	0.89	0.32	69	4	2.2	1.2	2.3	34
		1	0.799	0.31	67	6	2.3	1.1	2.4	37
2	soyabeans	2	0.75	0.66	51	6	2.8	1.4	2.8	34
		2	0.76	0.67	52	6	2.7	1.4	2.7	34
		2	0.743	0.64	50	5	2.9	1.5	2.8	35
3	beniseed	3	1.25	0.043	106	3	2.3	1.15	2.6	35
		3	1.23	0.044	108	4	2.3	1.14	2.7	36
		3	1.27	0.042	105	2	2.4	1.16	2.6	35.4
4	Ureafertilizer	4	0.44	0.066	37	10	2.3	1.95	2.5	35
		4	0.45	0.067	36	9	2.4	1.94	2.6	35
		4	0.43	0.065	38	11	2.3	1.92	2.5	36

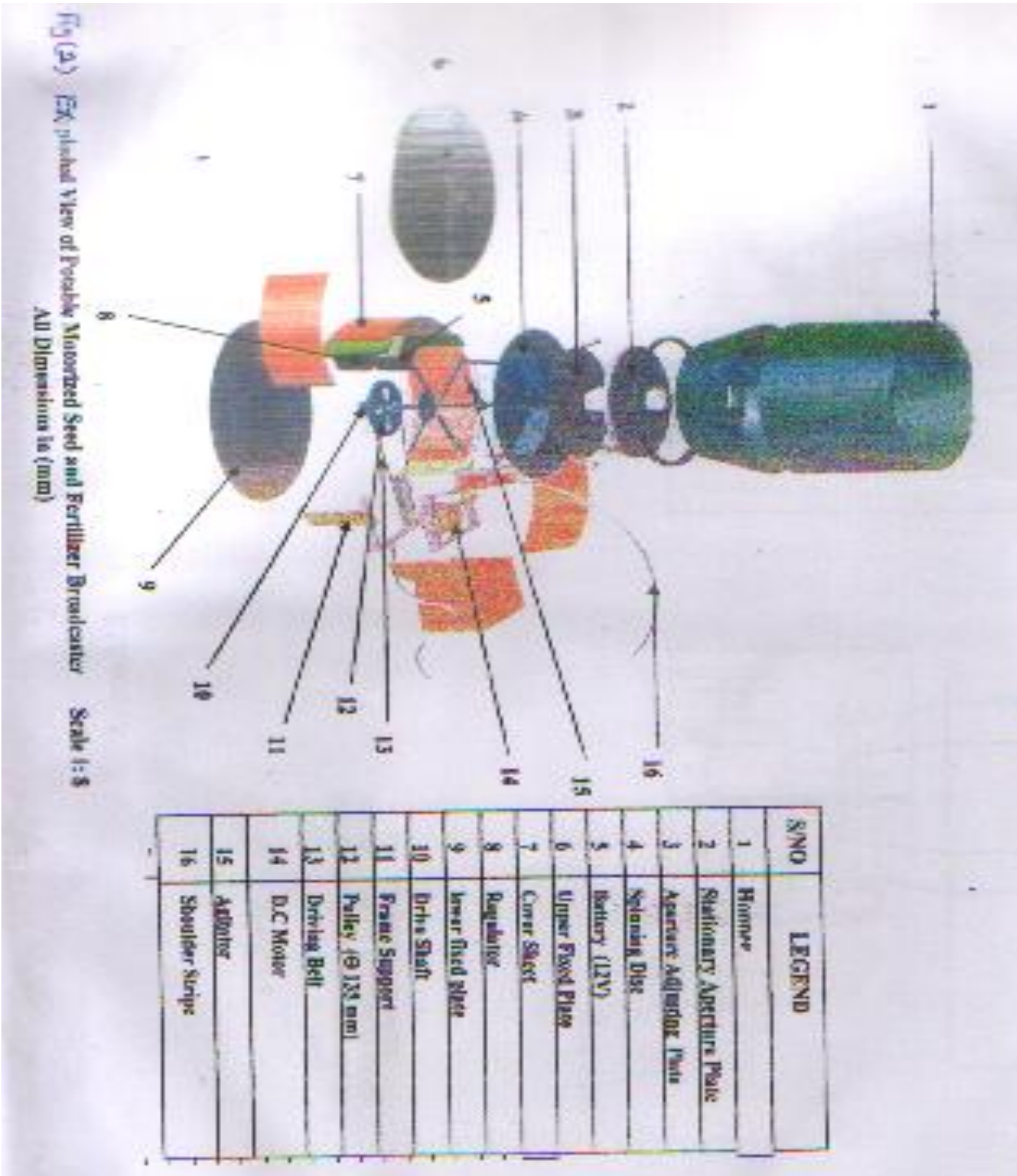
Table 2.continued

s/n	material	Material		areacovered40m_length	timecovered 1ha	Application rate	throughputcapacity	broadcostingefficiency
1	rice	1	0.01	92	65	120	110	50
		1	0.02	93	64	120	111	50.2
		1	0.01	91	65	121	110	51.1
2	Soyabeans	2	0.009	112	51	125	155.6	50
		2	0.0098	113	52	125	155.8	49
		2	0.0092	111	53	126	155.5	51
3	beniseed	3	0.01	100	56	95	115	50
		3	0.011	101	56	95	116	51
		3	0.012	100	54	96	117	52
4	Ureafertilizer	4	0.01	104	56	111	195	84.78
		4	0.012	103	57	110	196	84.79
		4	0.011	102	56	112	197	84.76

<u>Appendix 2</u>
Fig1.isometric

<u>Appendix 3</u>

Fig.2 Exploded view



Appendix 4

Fig. 3 Sectional view