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Development and Performance Evaluation of Two Row Fertilizer Applicator for Side Dressing In Maize (*Zea Mays* L.)

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ABSTRACT
Maize (*Zea mays* L.) ranks third in total world production after wheat and rice, and it is considered as the *"Queen of Cereals"* with its utilization as food, feed and fodder besides several agro-based industries uses. Conventional method of applying fertilizers in standing maize crop is generally done manually including problems like uneven spreading, more time and human effort, creating health hazards and loss of costly fertilizers. The problems faced by farmers in fertilizer application were taken care and a two-row fertilizer applicator pushed by a single operator for side dressing in maize was developed. The performance of developed fertilizer applicator was evaluated at different independent parameters; forward speeds (0.3,0.4,0.5 m/s), no. of ground wheels (1 & 2 nos.) & varieties of maize (GM-3 & GAYMH-3) in terms of EFC, TFC, FE, HR, CR. During the field evaluation, it was found that the developed fertilizer applicator performed better at 0.4 m/s forward speed with single ground wheel. The different performance parameters obtained in varieties of maize (GM-3 & GAYMH-3) were 0.136 & 0.161 ha/h EFC, 107.22 & 106.44 bpm heart rate, 3.00 & 3.00 comfort rating, respectively. The performance of developed fertilizer applicator was also compared with traditional manual method of side dressing in maize crop. The EFC of developed machine in case of vareiety-1 & 2 were found 57.35 & 54.65 % more, respectively as compared to traditional manual method. Also, fertilizer application was more comfortable than traditional method. The cost of operation (Rs/ha) and labor requirement (man-h/ha) for variety-1 & 2 were found 49.50 & 46.32 % and 57.56 & 54.83 % less for developed fertilizer applicator, respectively as compared to traditional method. The developed machine worked satisfactorily with expected payback period of 264.26 hour on hour basis.

Keywords: *Maize, manual, side dressing, fertilizer applicator, heart rate, comfort rating, cost of operation, payback period.*

I. INTRODUCTION
India is an agriculturally based country, where nearly 70-72% people are dependent on agriculture for their livelihood and country's economy depends on agricultural products. Maize (*Zea mays L.*) ranks third positions in world of total production; so, it is considered as the *"Queen of*

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Cereals". In Indian farming, maize has a special importance on an account of its utilization as food, feed and fodder besides some agro-based industries uses. Immense need for the development of machines for mechanization of different agricultural operations which are being practiced by conventional methods. Application of fertilizer in split doses after crop sowing is one operation, which is being ignored for mechanization. Also, there is need to save the labour requirement in this operation along with more precise application of fertilizer near to crop for obtaining more fertilizer absorption by the plant.

II. MATERIALS AND METHODS

Design of Fertilizer Applicator

To develop the fertilizer applicator, various components of fertilizer applicator were deigned/selected as per the availability. The design considerations and design details are given below:

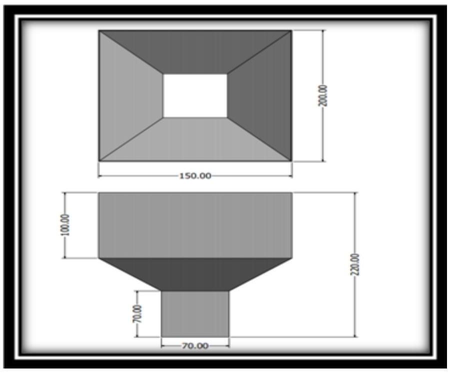
- A two-row manual operated fertilizer applicator for maize crop to be developed.
- Design to be simple and easy to fabricate with minimum maintenance.
- Provision for changing fertilizer application rate according to varieties and crop.
- Application of fertilizer close to soil surface in furrow of 5-10 mm deep to avoid dispersion of urea.
- Machine to be pushed during operation by a single operator with forward of 0.3 to 0.5 m/s.
- Provision of ground wheel to provide power to the metering mechanism.
- Provision for row spacing and furrow depth control adjustment.

Constructional details of developed fertilizer applicator

A designed and developed of the manually operated push type two row fertilizer applicator as shown in Figure. The developed fertilizer applicator consisted of fertilizer hopper, ground wheel, metering mechanism, furrow opener, support wheel, main frame, chain & sprockets, handle and main frame.

Fertilizer Hopper

The fertilizer hopper of 3.5 kg capacity was fabricated as per the designed dimension using 16-gauge G.I. sheet. As shown in given figure detailed designed dimensions and view of the hopper. The shape of hopper was kept rectangular (200 mm x 150 mm) at the top and trapezoidal (70 mm x 70 mm) at the base. The top depth of fertilizer hopper was kept 100 mm while the depth of the lower portion of hopper was kept 70 mm. Thus the total depth of the seed hopper was 220 mm. The sides of hopper were kept vertical in the top most portion of the hopper, while lower portion of the seed hopper was kept sloppy or 35^0.



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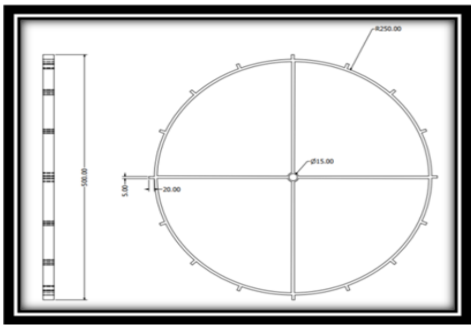
Ground Wheel

The ground wheel was used in the fertilizer applicator for smooth running. The ground wheel was fabricated from M. S. flat (25mm x 5 mm). The diameter of ground wheel was kept 500 mm was suggested by Verma (1986). The wheels were mounted on a M. S. flat having 5 mm thickness, 25 mm diameter and 1570 mm length. The internal diameter of ground wheel hub was 15 mm and 30 mm length were made to carry it to wheel shaft of 15 mm diameter and 400 mm length. Four spokes were provided in between the rim and hub.

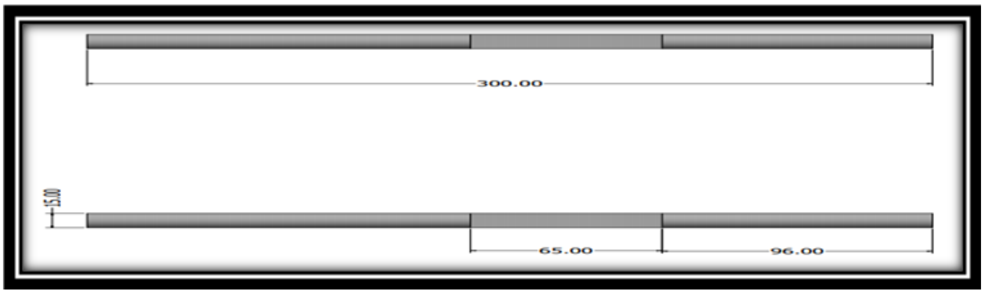


Metering Mechanism

A cell feed mechanism consists of a metering shaft, metering rotor and feed hopper.

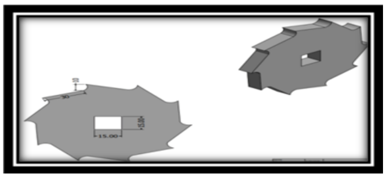
Metering shaft

The Metering shaft was developed by a square rod of 15 mm x 15 mm with 65 mm length into round shaft. The total length of metering shaft was 300 mm (Pandya & Shah, 1962). The detailed dimensions of the metering shaft are shown in Figure.



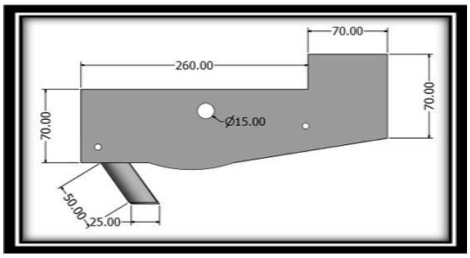
Metering rotor

Fertilizer metering device has a vertical rotor with ten cells on its periphery. It was made up of plastic. The cell has 10 mm depth and 30 mm length along the periphery of cell. The outer edge of the cell was circular in shape along the width of rotor. The detailed dimensions of metering rotor are shown in Figure.



Feed hopper

The feed hopper was fabricated by 16-gauge G.I. sheet. The rectangular box (260 mm x 70 mm) was kept carrying the plastic rotor with metering shaft. The depth of feed hopper was kept 70 mm. A screw was provided for adjusting to control the fertilizer movement towards metering mechanism. The diameter of 25 mm round hollow M. S. pipe of 50 mm length was provided in front of fertilizer metering rotor in the feed hopper for proper delivery of the fertilizer to the fertilizer tube.



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Power Transmission Unit

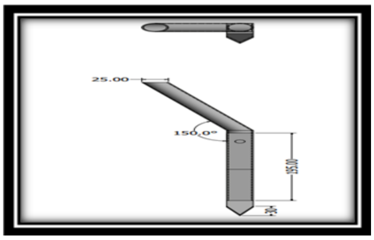
The frame of the ground wheel was fabricated from M. S. angle of size 30mm x 30mm x 2 mm. The length of chain was kept as 925 mm. The ground wheel was fabricated from M. S. flat (25mm x 5 mm). The diameter of ground wheel was kept 500 mm. Four spokes were provided in between rim and hub. The 16 pegs on ground wheel were fabricated from M. S. flat of size 25mm x 5 mm. The length of each peg was kept 20 mm which provided at equal distance on drive wheel. The power is transmitted from the ground wheel shaft to metering shaft in 1:1 ratio.

Chain and Sprockets

The power was transmitted to shafts through chain and sprocket mechanism. Chain was used in the developed fertilizer applicator; it was for ground wheel to metering shaft. Thus, numbers of chain links, centre-to-centre distance between two sprockets and length of chain determined were 74 mm, 385 mm and 925 mm, respectively. (Khurmi and Gupta, 2005) The roller chain is shown in Figure.

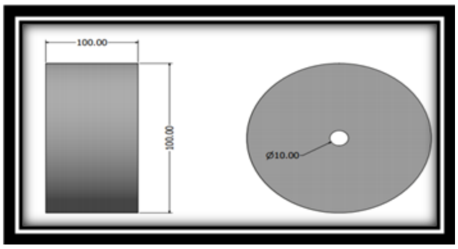
Furrow Opener

A single hoe type furrow opener was selected. The furrow opener consisted of tine and shovel. The tine of furrow opener was made from M. S. flat 25mm x 5 mm. The shovel of furrow opener having 30 mm length was fabricated from M. S. flat of 25mm x 5 mm. At the lower end of the tine, the shovel was welded at a suitable angle with the vertical with connected hollow square and round pipe. The isometric view of furrow opener is shown in Figure.



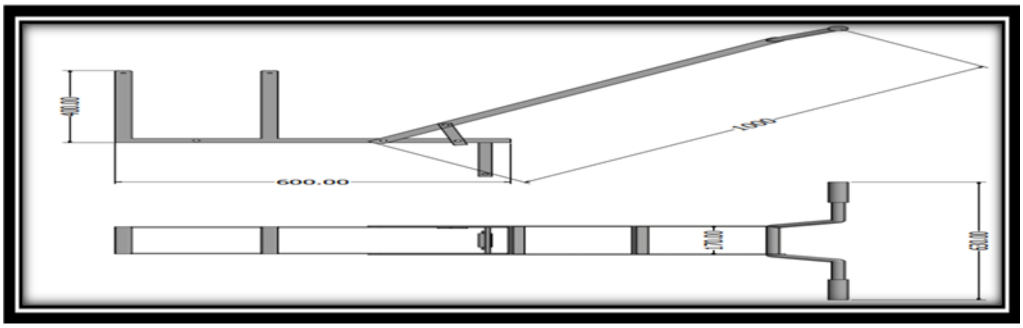
Support Wheel

Support wheels were used in the fertilizer applicator for smooth running and maintain stability during operation. The support wheel was fabricated from 16-gauge G.I. sheet. The diameter of the support wheel was kept 100 mm and 100 mm length shown in Figure.



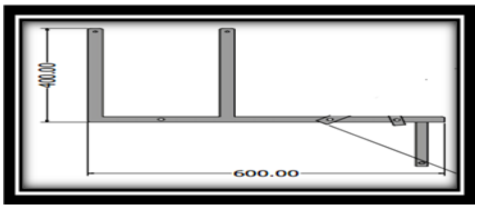
Handle

A handle was provided for pushing the fertilizer applicator by operator. The handle was fabricated from the M. S. flat of 30 mm x 2 mm and S. S. hollow round bar of 25 mm x 2 mm. The length of the handle was 1000 mm. The width of the handle was 170 mm. The handle was designed as per ergonomic design. The handle grip was 30 mm. The nuts and bolts were provided on couple for length adjustment according to operator's height and comfort (Gite and Yadav, 1990).



Main Frame

It should be constructed from M. S. angle of 30mm x 30mm x 2mm with an adjustable length and width of more than 600 x 150 mm with height of 425mm. Another should hold the furrow opener, support wheel and fertilizer box attached with the main frame. A view of main frame is shown in Figure.



Fertilizer Tube

It conveys the urea granules from the hopper through a metering device to the row side. The fertilizer tube was made from transparent and flexible PVC pipe. The inner diameter of the seed tube was 25 mm and length were 1500 mm. It was fitted between the feed cup outlet and the furrow opener. The fertilizer tube carries the fertilizer/urea granules which discharged from metering mechanism to the furrow opener.

The Following Parameters Were Calculated Performance of the Developed Two Row Fertilizer Applicator.

Calibration of fertilizer applicator

Before field experiments, machines were calibrated to drop recommended quantity of urea at different forward speeds. Fertilizer dropping rate was obtained at full hopper capacity and different speed when the machine was stationary. The test was conducted at full capacity of hopper at 0.3, 0.4 and 0.5 m/s speed.

Field Test

Field tests were carried out in the Instructional farm, Kankanpur, College of Agricultural Engineering and Technology, AAU, Godhra, Panchmahal, Gujarat in November-2019 to March-2020. In Gujarat, urea is generally applied in 3 equal split doses/stages (at the time of 4 leaves stage, 8 leaves stage and flowering stage) in maize crop.

Soil moisture content

The moisture content was determined by the hot air oven method. Three samples were taken randomly from the test plots with stage wise. The samples were kept in hot air oven for 24 hours at high temperature of 105°C. The samples were weighed before and after drying. Moisture content (db.) of soil was calculated by using following formula:

$$\text{Moisture content (\%, d. b.)} = \frac{\text{(Wt. of wet soil) - (Wt. of dry soil)}}{\text{(Wt. of dry soil)}} \times 100$$

Soil bulk density

The metallic core sampler was used to take samples from fields having 50 mm diameter and 50 mm length. The samples were weighed, and dry weights of the samples were calculated from the moisture content (d. b.). Bulk density of soil was calculated by using following formula:

$$\text{Bulk density of soil (g/cc)} = \frac{W - (W \times m.c./100)}{V}$$

Where, W = Weight of moist soil collected (g)

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V = Volume of metallic core (cm^3) and
m. c = Moisture content of the soil (%)

Machine parameters

Machine parameters such as width of coverage, effective field efficiency, theoretical field efficiency and field efficiency were measured as below:

Width of coverage

The working width of coverage of the machine was measured at randomly places selected crops as shown in below Plate.

Theoretical field efficiency

The ratio of width coverage by the machine with at rated speed without interruptions and covering 100 % of its rated width is known as theoretical field capacity.

$$\text{TFC (ha/h)} = \frac{\text{Width of coverage(m)} \times \text{Speed (km/h)}}{10}$$

Effective field capacity

The effective field capacity is the actual rate of area covered by machine upon to the time taken. The machine was operated at a different speed at the operation.

$$\text{EFC (ha/h)} = \frac{\text{Area covered (ha)}}{\text{Time taken (h)}}$$

Field efficiency

Field efficiency is used to describe the efficiency of the machine in operation. Field efficiency was calculated by using following formula:

$$\text{FE (\%)} = \frac{\text{EFC (ha/h)}}{\text{TFC (ha/h)}}$$

Ergonomical Parameter

Ergonomical parameters such as heart rate and comfort rating were measured as below:

Heart rate

The heart rate was measured in beats per minute. It was measured by the equipment which directly senses the heartbeat and displays the reading in bpm. Digital heart rate monitor was used to measure heart rate of the subject during the experiment. The chest belt of heart rate monitor used during experiment is as shown in below.

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Comfort Rating
Comfort is the body pain/unrest arising as a result of the working posture and the excessive stress on muscle due to the effort involved in the activity. Body discomfort was measured as overall discomfort rating (ODR). For the assessment of ODR a 7-point scale (0= no discomfort, 1= Vey very light discomfort, 2= Very light discomfort, 3= Light discomfort, 4= Moderate discomfort, 5= Heavy discomfort, 6= Vey heavy discomfort, 7= Extreme discomfort) was used as suggested by Corlett and Bishop (1976).

Comparison based on Economic Feasibility
The comparison based on economical feasibility among developed fertilizer applicators and traditional method of fertilizer application was carried out based on cost of operation and labour requirement. Also, the payback period of developed fertilizer applicator was calculated.

Cost of operation
The cost of operation of developed two row fertilizer applicator was determined on the basis of fixed cost and variable cost of the developed fertilizer applicator. The related parameters such as price of fertilizer applicator, depreciation, salvage value of the applicator, life of applicator, rate of bank interest on investment, operating, repair and maintenance cost, labour cost were assumed or taken as per actual. The straight-line method was used for determining the economical evaluation. The cost of operation of the developed fertilizer applicator was calculated on a per hectare and per hour basis. The operating cost of traditional was calculated on the basis of actual labor hours required for application of fertilizer.

Labour requirement
One labour was sufficient to operate he fertilizer applicator during field operation. The labour required for the operation of developed fertilizer applicator and traditional method per ha area basis was calculated.

Payback period of two row fertilizer applicator
The payback period of developed two rows fertilizer applicator on hour and hectare basis had worked out based on relationship of annual use of working hours, total benefits and total manufacturing cost and net benefits suggested by (Rahman *et al.*,2013). The payback period is expressed by the relation given below:

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Average net benefit}}$$

Where,
Average net benefit (Rs) = (Custom hiring rate, Rs/h-Total operating cost Rs/h)
Custom hiring rate, Rs/h = (Cost of operation of applicator per hour + 25 % Overhead Charge) + 25 % profit over new cost
When the above parameters are expressed in hectare, the payback period can be determined on hectare basis.

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III. RESULTS AND DISCUSSION

Laboratory test

In the laboratory test, physico-chemical properties of urea granules were carried out (Mohsenin., 1980).

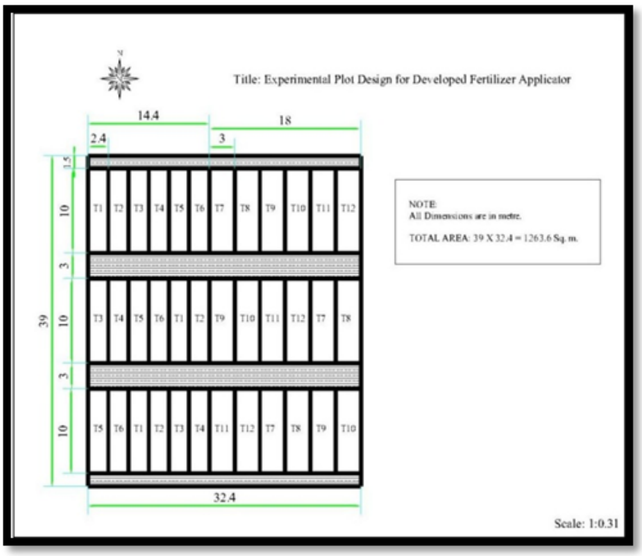
Field test

During the field test plant to plant spacing, row to row spacing, plant height, soil moisture content and soil bulk density were measured and calculated for developed fertilizer applicator.

To conduct the experiments FRBD design was adopted. Total 12 treatments were carried out and data obtained during the experiments. To analyze the data Design Expert Software (Version: 8.0.7.1) was used to correlate the variation of responses with independent variables. The effects of different independent variables on each dependent parameter like theoretical field capacity, effective field capacity, field efficiency, plant height, heart rate, comfort rating, grain yield, fodder, cost of operation and labour requirement are discussed.

Experiments were conducted in the field with two varieties of maize (GM-3 & GAYMH-3) in the total area of 1264 m2 which was divided into 36 test plots with 3 replications including different parameters under study & treatments combination.

1. Statistical design: FRBD
2. No. of treatment combination:
   2 x 3 x 2 = 12
3. No. of replications: 3
4. No. of treatments: 36



IV. CONCLUSION

1. The physico-chemical properties of selected urea granules determined in terms of equivalent diameter, sphericity, thousand grain weight, angle of repose, bulk density and moisture content were 1.73 mm, 0.95, 5.08g, 29^0, 0.71 g/cc and 4.00 %, respectively.
2. The overall dimensions of the developed two row fertilizer applicator were length 1100, width 400 and height 1100mm works satisfactorily at the different forward speed (0.3, 0.4, 0.5 m/s) with the average application rate of 64.54 & 81.38 kg/ha in desired level.
3. In comparison between traditional manual method and developed fertilizer applicator, effective field capacity for variety-1 & 2 were found as 0.136 & 0.161 ha/h, respectively which was approximately 57.35 & 54.65 % higher than traditional manual method (0.058 ha/h for variety-1 & 0.073 ha/h for variety-2). Field efficiency for variety-1 & 2 were observed as 78.90 & 74.69 %, respectively which were approximately 31.55 & 27.70% higher than traditional manual method (54 % for both variety-1 & 2).
4. A comfort rating with developed fertilizer applicator for variety-1 & 2 were observed 50 % more comfortable, respectively as compared to traditional manual method.
5. The cost of operation (Rs/ha) with developed fertilizer applicator for variety-1 & 2 were found 217.64 & 183.85 Rs./ha which, was approximately 49.50 & 46.32 % less, respectively as compared to traditional manual method (431.03 & 342.46 Rs./ha for variety-1 & 2).
6. The labour requirement of developed fertilizer applicator for variety-1 & 2 were 7.27 & 6.22 man-h/ha which was also almost 57.56 & 54.83 % less, respectively as compared to traditional manual method (17.13 & 13.77 man-h/ha for variety-1 & 2).
7. The payback period of developed fertilizer applicator for both varieties found same,

as 264.26 hour on hour basis and 35.94 & 42.54 ha on the hectare basis for both varieties.

FUTURE SCOPE

In the future we can research and develop the project as follows:

1. As of now, it is manually operated, it can be power driven by attaching a small battery or can be made solar operated.
2. The volume capacity of the hopper can be increased so that it covers larger area with minimum refill requirement, without any fail of machine.

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