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Popular Article

Tractor-operated fertilizer applicator for wheat crop on bed cultivation

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The fertilizer applicator was developed and performance evaluated for wheat crop planted on bed cultivation system. Design and development of tractor operated different depth fertilizer applicator was completed using CAD together with design of frame, fertilizer metering system, tine, furrow opener and ground wheel as power transmission system of machine. Study included suitable measurement techniques for recording various field performance parameters related to evaluation of developed machine. The properties of fertilizer (granular urea) used in the experiment were determined for efficient metering the application rate of fertilizer. The developed machine was calibrated in the laboratory for different rate of fertilizer application and determination of coefficient of variation. The field tests of machine were conducted on the wheat crop planted on bed in 5 rows. Fertilizer is very costly and there precision application is required to sustain the health of soil and increased the use efficiency by crops. For maximum efficiency of applied fertilizer, it is essential to deliver nutrients to the root zone of plants at a rate which is sufficient for maximum uptake while avoiding fixation with clay particles. The attention should, therefore, be given towards addition of fertilizers in subsoil to increase its nutritive status. In situations where deep loosening is required, the incorporation of fertilizer had been found to be beneficial (Godwin and Spoor, 1981) as compare to spreading of nitrogenous fertilizer in the field, that loss about 30% N to the atmosphere.

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Fertilizer uses in India

India's fertilizer consumption is primarily based on urea, with urea accounting for 82% of straight N fertilizers and 22% for other types. Complex fertilizers account for 16% of N consumption, while DAP and other complex fertilizers account for 63% and 27%, respectively (Blackshaw et al., 2004).

Nitrogen loss

Nitrogen (N) loss from winter wheat plants was studied in two field experiments in 1993 and 1994. Five cultivars were evaluated at different N rates. Results showed that N loss increased with increasing N applied, with most losses occurring between anthesis and 14 days post-anthesis. Avoiding excess N application could reduce N loss and increase N use efficiency in winter wheat varieties. Varieties with high harvest index and low forage yield had low plant N loss.

Concept of fertilizer placement

Fertilizer application methods like manual spreading, broadcasting, and mixing are effective but can cause fixation problems and reduce soil content. Only 40-50% of N, 20-30% of P, and K fertilizers are used by crops, while the remaining are volatilized or fixed. Basal application using planters and seed-drills is effective but uneven.

Development of fertilizer applicator

For development of machine the length of the frame and row to row spacing between tines were considered according to wheat crop and fertilizer application between rows. For the design of tine and furrow opener, soil type, soil resistance, working soil moisture and bulk density of black soil were considered as main factors. The sectional strength of these components were selected such as they were able to work at soil depth varying from 50 - 300 mm. Developed machine consisted main frame, fertilizer box, fertilizer metering system, shank furrow openers and ground drive wheel (Patel et al. 2018). Details of different of developed components of machine are described below.

a) Main frame

The fertilizer applicator frame is made of 1700 x 400 x 490 mm mild steel hollow sections with suitable braces and brackets. It features a hitching system with a MS flat hitch frame and a 79 mm rod hitch pin. The frame also includes a bearing block spacer, two bushes, and a shaft for rotation to the ground traction wheel.

b) Three-point hitching system

A three-point linkage was fabricated to hitch the fertilizer applicator machine to the tractor. Hitch unit was made from 50 x 10 mm MS flat conforming to Indian standard specification.

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c) Fertilizer box

A rectangular fertilizer box was created using two MS sheet angle irons, drilled for cultivator tine spacing, and supported by a mild steel stand. A metering device was attached to regulate fertilizer rate delivery.

d) Fertilizer metering system

Indian standard (BIS: 6816 part 1973) for fertilizer metering unit with 8 flutes was used for fertilizer metering suitable for wheat crop and commercial granulated fertilizer commonly being used. These are made of die casted aluminum. The fertilizer rate can be adjusted by controlling the exposed length of flutes, which is in contact with fertilizer.

e) Fertilizer metering drive mechanism

A standard chain and sprocket drive mechanism is used to rotate a fluted roller shaft. A 560 mm diameter mild steel ground wheel with 12 spikes is used. A 19-tooth sprocket and 16-tooth sprocket increase speed, connected to the fertilizer metering shaft.

f) Fertilizer tube

For delivery of fertilizer from fluted roller to furrow opener boot a transparent plastic pipe having internal diameter 25 mm was used as delivery tube. The lengths of the pipe have been taken according to the distance between different fluted rollers and furrow opener.

g) Furrow opener

The machine features a furrow opener for applying fertilizer to crops on beds with varying widths and heights. It includes a shoe, tine, boot, and boot pipe for attachment to the delivery tube. The opener is made of mild steel, with a MS pipe for the boot and a U-shaped MS sheet for the tine.

h) Ground wheel

The fertilizer unit uses two ground drive wheels, one made of mild steel, and two MS flats for soil surface adjustment. The wheel rim has dimensions of 390 mm to 400 mm and 50 mm, with 12 spikes for traction.

i) Power transmission system for ground drive wheel

The ground wheel with the help of spikes gave the rotary motion to the main shaft of fertilizer metering system during the field operation. The power was cut off when the machine was lifted with the help of hydraulic system of tractor in field. Proper chain sprocket arrangements were selected to meter the fertilizer applicator quantity to be applied in the crop Patel et al. 2022.

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Specification of developed machine

The specification of developed machine is given below

a) Over all dimension in mm,

Length: 1850 mm, Width: 1645 mm, Height: 1258 mm.

b) Overall weight without fertilizer in kg: 126 kg.

c) Capacity ha/h: 0.65 at speed of 3.7 km/h.

d) Power requirement hp: 35 hp tractor.

e) Average depth of application of fertilizer: 100-150 mm.

f) Average row spacing of crop: 225 mm.

Physical properties of fertilizer (granular urea)

The important physical properties of fertilizer (granular urea) related to fertilizer applicator that have been studied included size and shape (linear dimension), volume, density, sphericity, fertilizer mass (weight) of hundred particles (Patel et al. 2020).

a. Size and shape

The typical shape i.e. major, intermediate and minor axial dimensions of the granular urea were 1.82 ± 0.4 mm, 1.84 ± 0.4 mm, 1.85 ± 0.4 mm respectively. The sphericity of urea was 0.99 ± 0.004%. The moisture content of urea was 18.7%. It indicated that the urea used in the experiment was almost round in shape.

b. Bulk density

The mass and volume of granular urea were determined to determine the bulk density. The bulk density of and of granular urea investigated was0.76 ± 0.0011 g/m^3at moisture content of 18.7% granular urea.

c. Hundred particles weight of fertilizer

The hundred particles weight of urea was 0.8 ± 0.6 at 18.7% moisture content of urea.

Laboratory/Field testing of developed machine

Machine calibration

The machine was calibrated for applying granular urea at different rates to provide 30 and 60 kg N/ha in wheat crop. The machine had a nominal width of 1.5m and six furrow openers. The fertilizer was delivered in 169.847 revolutions (Fig. 1).

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Fig. 1: Calibration of fertilizer applicator in the laboratory

Machine field testing

The machine was evaluated for placement of granular urea at depth of 100 mm in wheat crop. During the test following parameter were recorded (Fig. 2).

Type and character of soil

The ICAR-CIAE farms have vertisol. The character of the soil is reported below.

S. No.	Particulars	Value
1.	Texture,%	Gravel: 7.12; Sand: Silt: Clay: 14.79: 30.51: 54.70
2.	Porosity,%	41.90
3.	Field capacity at 0.3 bar,%	30.86
4.	Percolation rate of saturated non puddle soil, mm/day	9.80
5.	pH	7.94
6.	Structure	Sub angular blocky
7.	Safe bearing capacity of soil, t/m^2	11
8.	Soil depth	More than one meter
9.	Type of soil	Black (vertisol)

a) Speed of operation

The speed of operation was determined by recording the average time required to cover 50 m length by the following formula.

b) Power requirement

The power requirement was determined from draft and speed of operation using the following formula:

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Fig. 2: Field testing of the fertilizer applicator on the wheat crop (21 days).

c) Wheel slippage

To calculate the wheel, slip the tractor was operated at implement with load and without load condition. A mark on the rear wheel was put to count the number of revolutions. The distance traveled by the tractor is 10 revolution of tractor rear wheel was measured and wheel slip.

d) Field capacity and field efficiency

The effective field capacity, theoretical field capacity and field efficiency were calculated by recording the time consumed for actual work and time lost for other miscellaneous activities such as turning, adjustments under field operating condition. The field capacity was calculated by using the following equations and efficiency.

e) Fuel consumption

The following simple method was used. The fuel tank was filled to full capacity before and after the test operation. Amount of refueling after the test is the fuel consumption for the test. When filling up the tank, careful attention was paid to keep the tank horizontal and not to leave empty space in the tank.

Field performance

The developed machine was tested with a 35 hp tractor for application of fertilizer at the depth of 150 mm on wheat crop sown on beds in 5 rows. The field trials of machine moisture content, bulk density and cone index of experimental field were 26.47%, 1.32 g/cc and 0.79 kg/cm^2 at the depth of 0-100 mm. During the field testing the operational speed and wheel slippage of machine were 3.7 km/h and 4.69 % respectively.

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Crop yield parameters

The study analysed wheat crop yields using various fertilizer methods, with the tractor-operated applicator showing a 3% and 6.5% increase in yields compared to broadcast and foliar applications, as ammonia was not evaporated.

The tractor-operated fertilizer applicator significantly increased fertilizer use efficiency and nitrogen use efficiency, with a 46% N/ha plant utilization compared to broadcast and foliar methods. This method effectively placed granular urea near the root zone, resulting in increased crop biological yield and reduced fertilizer application and nitrogen emissions.

The study analysed wheat crop straw yields using various fertilizer application methods. The tractor-operated fertilizer applicator resulted in 6.8% and 6% increased straw yields, attributed to the application of fertilizer 100 mm below the soil surface, preventing ammonia evaporation and increasing plant utilization of nitrogen.

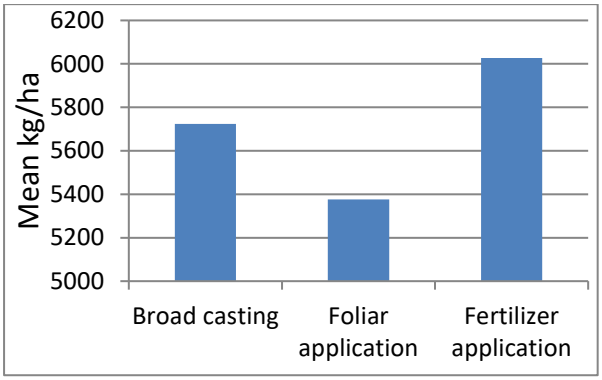

Fig. 3 Grain yields in different method of urea application.

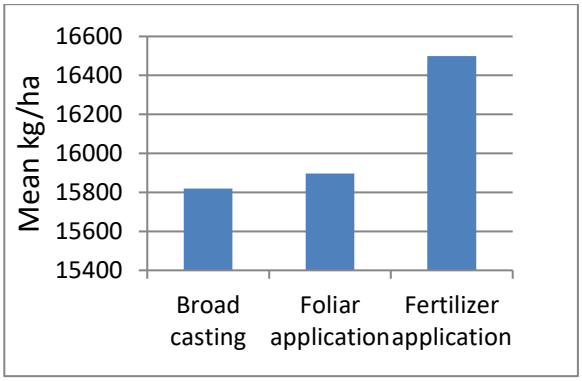

Fig. 4 Straw yields in different method of urea application.

Cost economics

The study found that using a tractor-operated fertilizer applicator resulted in significant savings in granular urea application, fertilizer costs, and time, with savings of Rs. 721 and Rs. 216/ha compared to broadcast and foliar methods, and Rs. 341 and Rs. 611/ha for fertilizer application below the soil surface.

Conclusion

The development and testing of a tractor-operated fertilizer applicator for granular urea application on bed-planted wheat crops revealed significant benefits. The applicator calibrated for application rates ranging from 60.2 kg/ha to 130.4 kg/ha, was tested in the field at 130 kg/h. The machine saved fertilizer, fuel, time, and increased yield, preventing nitrogen loss to the atmosphere. It also reduced operating costs by Rs. 341/ha and Rs. 611/ha.

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