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Development and testing of tractor operated variable depth fertilizer applicator on application of granular urea in wheat crop planted on beds

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Abstract
High fertilizer rate and labor requirement are common problems in traditional application of fertilizer. Fertilizer applicator was tested and evaluated for wheat crop (Triticumaestivum) planted on bed cultivation system. Study included suitable measurement techniques for recording various field parameters. Physical properties of granular urea fertilizer have been studied such as size and shape, sphericity, moisture content 18.7%, bulk density 0.76 g/m^3 and hundred particles weight 0.8 gm. The 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. Operating parameters such as operational speed 3.7 km/h, wheel slippage 4.69%, average field capacity 0.65 ha/h, field efficiency 80.10% and plant damage 4.33% were found respectively. Crop and Straw yield were found for three fertilizer application methods broadcast5.72 t/ha, 5.38 t/ha,foliar application6.1 t/ha and 15.82 t/haand tractor operated fertilizer applicator15.89 t/ha, 16.5 t/ha. The tractor operated variable depth fertilizer applicator resulted 3% and 6.5% increase in yield as compared to broadcast and foliar application. Because in this method ammonia did not evaporate to the atmosphere due to placing of fertilizer at a depth of 100 mm below the soil surface. The saving of fertilizer by placing it in the soil by tractor operated fertilizer applicator was 33.33 and 16.6 kg/ha as compared to broadcast and foliar methods, which leads to saving of Rs 341 and Rs 611/ha respectively.

Keywords: Wheat crop, tractor operated, fertilizer applicator, broadcast and foliar application

Introduction
Tractor operated variable depth fertilizer applicator for application of granular urea at the root zone of wheat plants. Was introduced in the country for its useful to meet the growing needs of the farmers with high level of production and productivity and increase the use efficiency of urea. Top dressing of Nitrogen to the wheat crops results emission of nitrogen gas to the atmosphere and placement is not in the proper root zone thus to reduce the loss of nitrogen in to atmosphere and increased the utilization efficiency, research work is needed for the placement of nitrogen in to the root zone of plants to avoid the nitrogen emission to the atmosphere and increase the use efficiency of nitrogen. 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) [9] as compare to spreading of nitrogenous fertilizer in the field, that loss about 30% N to the atmosphere.
India is second largest producer of wheat in the world, averaging an annual production of 65,856 MT. On average, India consumes 65,283 MT of wheat, ranking second largest consumer of wheat in the world. On average, India imports 990 MT of wheat, and for various reasons, exports an average of 767 MT of wheat. The ending stocks in India average 9,900 MT, giving India the third largest ending stocks in the world. The major winter wheat growing areas in India are located in the northern regions of the country. The state of Uttar Pradesh produces the most wheat in India, accounting for 35 percent of India’s total wheat production. Following on Punjab producing 22 percent of the nation’s total wheat production.

The sowing of winter wheat begins from October and runs through the end of December, with harvest following in March and May.

The world today uses around 83 MT of N, which is about a 100 fold increase over the last 100 years. About 60% of global N fertilizer is used for producing the world's three major cereals: rice, wheat, and maize. While India uses many types of fertilizers, urea accounts for most of the consumption of N and DAP for most of that of P_2O_5. Urea accounts for 82 percent of the total consumption of straight N fertilizers.

Rowse and Stone 1980.Studied the reduction and application of the N content to the soil. Only 40 to 50% of N fertilizers, 20 to 30% of P and K fertilizers were effectively used by crops while the remaining become volatilized, leached to groundwater, or get fixed within the soil as per the properties of their contents. Contrary to this loss, the basal application of fertilizers using planters and seed-drills have been found to be effective, but application of fertilizers even by these methods does not distribute fertilizers evenly as per the needs of roots and therefore, more research works are needed to be done on these aspects.

Wuest and Cassman 1992.Found recovery of N applied at planting ranged from 30 to 55%, while recovery of N applied at anthesis ranged from 55 to 80% in irrigated wheat. The amount of fertilizer N applied at anthesis had the greatest influence on post-anthesis N uptake, which ranged from 17 to 77 kg N/ ha. This showed that late N application can be efficiently taken up by plants. Grain protein levels may increase with late-season N applications. Fertilizer N use efficiency varied considerably depending upon the native soil N supply, previous N uptake, developmental stage of the plant when supplemental N was applied, and yield potential. Optimizing fertilizer N use, achieving acceptable grain yield, and maintaining adequate grain protein required knowledge of expected N uptake efficiency and utilization within the plant in relation to the rate and timing of N applied.

Yang *et al*. 2001 [17]. Studied variable rates application of nitrogenous (N) and phosphorus (P) fertilizer for grain sorghum. The results showed that VRT increased yield, reduce yield variability, and raised economic returns. VRT was effective in reducing the input of N fertilizer; however, the causes and effects were complex. The fertilization method did not influence crop responses to P fertilizer. However, VRF resulted in better P fertilizer management because it applied 12 to 41% less fertilizer and reduced soil-test P variability compared with the conventional injection fertilization method. Koch (2004) assessed the economic feasibility of variable rate nitrogen application and found that variable-rate N application utilizing site-specific management zones were more economically feasible than conventional and uniform N application.

Blackshaw *et al*. 2004 [2]. He found investigated the effect of nitrogen fertilization application in simulating wheat (*Triticum aestivum*) yield loss caused by wild oat (*Avenafatua*) interference. Fertilizer application could affect the biomass of wild oat in spring wheat. Although the little information to assess the effect of fertilizer application on wheat yield loss due to wild oat interference. The knowledge of the effect of N fertilization on weed population dynamics might be use full for recommending the most convenient method and stage of the crop cycle for fertilizer application to both increase the crop yield and reduce the growth rates of weed populations.

Nitrogen (N) loss from winter wheat plants has been identified but has not been simultaneously evaluated for several genotypes grown under different N fertility. Two field experiments were initiated in 1993 and 1994 at the Agronomy Research Station in Desai, R.M. and C.R. Bhatia, 1978to estimate plant N loss from several cultivars as a function of N applied and to characterize N use efficiency (NUE). A total of five cultivars were evaluated at preplant N rates ranging from 30 to 180 kg ha. Nitrogen loss was estimated as the difference between total forage N accumulated at anthesis and the total (grain + straw) N at harvest. Forage, grain, straw yield, N uptake, and N loss increased with increasing N applied at both Stillwater and Perkins. Significant differences were observed among varieties for yield, N uptake, N loss and components of NUE in forage, grain, straw and grain + straw. Estimates of N loss over this two year period ranged from 4.0 to 27.9 kg ha (7.7 to 59.4% of total forage N at anthesis). Most N losses occurred between anthesis and 14 days post-anthesis. Avoiding excess N application would reduce N loss and increase NUE in winter wheat varieties. Varieties with high harvest index (grain yield/total biomass) and low forage yield had low plant N loss.

The application of fertilizers is usually accomplished by methods such as manual spreading, broadcasting, placement or mixing in upper soil layer of 20-50 mm only. Broadcasting of fertilizers, especially P and K, produces fixation problems due to more soil contact, whereas volatilization of N results in reduction of applied N content to the soil. Only 40 to 50% of N fertilizers, 20 to 30% of P and K fertilizers are effectively used by crops while the remaining become volatilized, leached to groundwater, or get fixed within the soil as per the properties of their contents (Olsen *et al*., 1971). Contrary to this loss, the basal application of fertilizers using planters and seed-drills have been found to be effective, but application of fertilizers even by these methods does not distribute fertilizers evenly as per the needs of roots. Fertilizer application technology use to place the fertilizer under the soil near root zone of plants has the potential to increase crop yields and soil and water quality relative to broad casting. Application of fertilizer inside the soil surface increases the utilization efficiency of fertilizer and reduces the emission of N to the atmosphere. The various types of equipment and technology available for fertilizer application are also discussed.

Materials and Methods

The fertilizer applicator machine together with testing and performance evaluation of application of fertilizer (Urea) on bed planted wheat crop. It also includes suitable measurement techniques for recording various parameters related to performance evaluation of machine under the laboratory and field condition. The properties of fertilizer (granular urea) used in the experiment were determined for efficient metering the application rate of fertilizer. Machine was calibrated in the laboratory for different rates of fertilizer application and determination of coefficient of variation. The field tests of machine were conducted on the wheat crop planted on beds and its performance parameters were recorded. For efficient metering of fertilizer by the machine, the physical properties such as shape, size, sphericity, and weight of granular urea were determined in the laboratory

The machine parameter of the frame and row to row spacing between tines were considered according to wheat crop and fertilizer application between rows. For the 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. Machine componentare main frame, fertilizer box, fertilizer metering system, shank furrow openers and ground drive wheel.

Table 1: Fertilizer applicator machine component and materials

S. No.	Machine parts	Materials
1.	Frame	Mild steel
2.	Hitching system	MS flat
3.	Fertilizer box	Angle iron, MS sheet
4.	Fertilizer adjustment lever	Mild steel
5.	Fertilizer metering system	Die casted aluminum (BIS: 6816 part 1973)
6.	Fertilizer metering drive mechanism	Mild steel, Chain, Gear
7.	Fertilizer tube	Transparent plastic pipe
8.	Furrow opener	Mild steel, MS pipe, MS plate, MS sheet
9.	Ground wheel	Mild steel, MS flats, MS rod

Table 2: Machine Specification are given below.

S. No.	Particulars	Dimension
1.	All dimension of Machine LxWxH, mm	1850x 1645x 1258
2.	Weight of Machine, kg	126
3.	Capacity,ha/h	0.65
4.	Speed, km/h	3.7
5.	Power requirement (tractor), hp	35
6.	Depth of application of fertilizer, mm	100-150
7.	Row spacing of crop, mm	225

Laboratory and field testing

Machine was calibrated for application of grannular urea at 60.2 kg/ha and 130 kg/ha to provide 30 and 60 kg N/ha in wheat crop. The following steps were followed for calibration of fertilizer applicator.

Machine Calibration

a. Diameter of the ground drive wheel was measured to calculate circumference of wheel.
b. Area covered in one revolution of the drive wheel was calculated.
c. The calibration was done for 20 revolution of the drive wheel; therefore, the area delivered in 20 revolution of the wheel was calculated from the area covered by 20 revolution of drive wheel.
d. The rate control adjustment for the fertilizer was set for maximum dropping.
e. The fertilizer dropped in polythene bags attached with each furrow opener was weighed separately and total weight of fertilizer was calculated.

Fig 1: Calibration of fertilizer applicator in the laboratory

Coefficient of uniformity

The uniformity is proper distribution pattern of fertilizer particles from the outlet in longitudinal direction of travel of machine. It was calculated by using equation (1)

$$Cu = 100\,(1 - \Sigma X/ m\, n) \quad \text{…. (1)}$$

Where

Cu = Coefficient of uniformity in percent,
m = mean value of all observations g,
n = total number of observations,
X = numerical deviation of individual observation from the mean application rate g,

Soil and Machine parameter

Table 3: Type and character of soil are reported.

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)

Moisture content

For measurement of soil moisture, core sample of wet soils were taken in three different locations of test plots selected randomly. Samples were weighed in a physical balance and weight of each wet soil sample was recorded. Samples were placed in a hot air oven maintained at 105^0 C for at least 8 hours. At the end of 8 hours, samples were cooledin desiccators and weighed in a physical balance. Soil moisture (% dry weight basis)was calculated using the formula given below.

$$\text{Soil moisture content} = \frac{\text{Weight of wet soil sample} - \text{Weight of oven dry soil sample}}{\text{Weight of oven dry soil sample}} \times 100 \ldots (2)$$

Where

Mw= Moisture content on dry weight basis%
Wm= Soil weight of moisture sample, g,
Ws= Soil weight of oven dry sample, g.

Bulk density

For measuring of bulk density of soil. Core samples of soil were obtained from three locations selected randomly in the test plot. The diameter and length of cylindrical soil sample was measured. The core samples were kept in a hot air oven maintained at 105^{0}c for at least 8 hours. At the end of 8 hour, the samples were taken out from the oven and cooledin desiccators. Cuter samples wereand weigh in a physical balance and the bulk density was calculated by using equation [7].

$$\text{Bulk density of soil} = \frac{M}{V} \quad \text{….. (3)}$$

Where

M= oven dry mass contained in core sample, g
V= volume of cylinder core sampler, cm^3

Cone index
Cone index is an indication of soil hardness and is expressed as force per square centimeter required for a cone to penetrate into soil. Cone index is the same soil varies with cone apex angle and area of cone bottom. An apex angle and area or diameter of cone used should be given in the report. The cone index of soil was recorded by using a dial type cone penetrometer have apex angle $30^0$and dia 50 mm.

Field testing of machine
The machine was evaluated for placement of granular urea at depth of 100 & 150 mm in wheat crop. During the test following parameter were recorded.

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

$$\text{Speed(km/h)} = \frac{3.6\times\text{distance travelled (m)}}{\text{Time (s)}} \quad \text{..... (4)}$$

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

$$\text{Hp} = \frac{\text{Draft(kg)}\times\text{Speed(m/min)}}{4500} \quad \text{..... (5)}$$

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 revolution. The distance traveled by the tractor is 10 revolution of tractor rear wheel was measured and wheel slip was calculated as follows [6].

$$\text{wheel slippage \%} = \frac{\text{N1}-\text{N2}}{\text{N1}}\times 100 \quad \text{..... (6)}$$

Where
N1= No. of revolution of drive wheel for a given distance under load.
N2= No. of revolution of drive wheel for the same distance at no load.

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.

$$\text{Effectivefieldcapacity (S)} = \frac{\text{A}}{\text{T}_\text{P}+\text{T}_\text{l}} \quad \text{..... (7)}$$

Where
S = Effective field capacity, ha/ha
A = Area covered, ha
Tp = Productive time, hr
Tl = Non-productive time, hr.

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{W}\times\text{S}}{10} \quad \text{..... (8)}$$

Where
S = Speed of operation, (km/h)
W = Theoretical width covered, (m)
= no. of furrow opener multiplied by distance between two consecutive furrow opener.

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \quad \text{... (9)}$$

$$E_f = \frac{W_e\times V_e\times T_p}{W_t\times V_t\times (T_p\times T_l)}100$$

Where
E_f = field efficiency, %
W_e = Effective working width
W_t = Theoretical working width
V_e = Effective operation speed
V_t = Theoretical operation speed
T_p = Productive time
T_l = Non-productive time.

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.

Results and Discussion
Physical properties of granular urea a tractor drawn fertilizer applicator was developed and tested in laboratory and field for application of urea on wheat crop sown on beds. The parameters obtained from the laboratory studies have been utilized for the field testing of machine in the field. Physical properties of fertilizer (granular urea) related to fertilizer applicator that have been studied included size and shape of 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. Mean values of shape and sphericity are summarized in Table 4. The bulk density of and of granular urea investigated was 0.76 ± 0.0011 g/m^3 at moisture content of 18.7% granular urea Table 5 and the hundred particles weight of urea was 0.8 ± 0.6 at 18.7% moisture content of urea (Table 6) fertilizer mass (weight) of hundred particles.

Table 4: Axial dimensions (diameter) and sphericity of granular urea

Particulars	Axial dimension (mm)			Sphericity
	A	B	C	
Mean	1.82	1.84	1.85	0.9908
S.E.(mean)	0.202675	0.202082	0.206257	0.0026
95 % confidence limit	1.82 ± 0.4	1.84 ± 0.4	1.85 ± 0.4	0.99 ± 0.004

Table 5: Bulk density of the granular urea.

Particular	Mass (gm)	Density (gm/cm^3)
Mean	382.58	0.76
S.E. mean	0.284839	0.00057
95% confidence limit	382.58 ± 0.56	0.76 ± 0.0011

Table 6: Hundred particles weight of granular urea.

Mean, g	S.E. Mean	95% confidence limit
0.8	0.038944	0.8 ± 0.6

Calibration of fertilizer applicator

The fertilizer applicator was calibrated for application of granular urea at the rate of 60.2 kg/ha and 130.4 kg/ha in the laboratory to provide the 30 and 60 kg N/ha 20 revolutions of ground drive wheel gave .00471 ha area. The fertilizer delivered in each tube of furrow opener was collected and weighed for three replications. Mean discharge rate and coefficients of variation of fertilizer application rate are shown in Table 7. The minimum and maximum quantities of fertilizer discharged from 20 revolution of ground drive wheel were 0.290 and 0.350 kg. The average fertilizer discharge rate ranged from 0.034 to 0.046 kg, in tube 1, 0.042 to 0.050 kg in tube 2, 0.059 to 0.069 kg in tube 3, 0.034 to 0.051 kg in tube 4, 0.081 to 0.085 kg in tube 5, 0.038 to 0.049 kg in tube 6. The mean discharge rate of fertilizer from all the tubes ranged from 0.048to 0.058 kg for 20 revolution of ground drive wheel, It resulted mean fertilizer application rate of 61.57 to 74.30 kg/ha. The Coefficient of variation for calibrated fertilizer application rate ranged from 2.6 to 3.9% among the all fertilizer tubes. It revealed that there was no significance difference for the fertilizer delivery rates among the tubes. Because, coefficient of variation is less than 5% level.

Table 7: Calibration of machine for fertilizer metering device urea (60.2kg/ha)

S. No.	Discharge from the tube for 20 revolution of ground wheel									
	Tube 1	Tube 2	Tube 3	Tube 4	Tube 5	Tube 6	Application rate kg/ha	Mean discharge kg	S.D.	C.V.
1	0.046	0.05	0.069	0.051	0.085	0.049	74.30	0.0583	0.0154	0.026
2	0.038	0.042	0.062	0.036	0.081	0.041	64.33	0.0500	0.0178	0.036
3	0.034	0.043	0.059	0.034	0.082	0.038	61.57	0.0483	0.0189	0.039
Mean	0.0393	0.045	0.0633	0.0403	0.0827	0.0427	66.7333	---	---	---
S.D.	0.0061	0.0044	0.0051	0.0093	0.0021	0.0057	6.6967	---	---	---

Table 8: Calibration of machine for fertilizer metering device urea (130.4 kg/ha)

S. No.	Discharge from the tube for 20 revolution of ground wheel									
	Tube 1	Tube 2	Tube 3	Tube 4	Tube 5	Tube 6	Application rate kg/ha	Mean discharge kg	S.D.	C.V.
1	0.108	0.101	0.114	0.098	0.114	0.098	134.00	0.1057	0.0073	0.0695
2	0.106	0.088	0.104	0.089	0.118	0.091	126.53	0.0993	0.0120	0.1207
3	0.11	0.089	0.119	0.091	0.126	0.094	133.54	0.1048	0.0157	0.1499
Mean	0.1140	0.0967	0.1223	0.0983	0.1243	0.1010	131.55	---	---	---
S.D.	0.0106	0.0142	0.0202	0.0145	0.0057	0.0148	4.3854	---	---	---

Similarly the fertilizer applicator was calibrated for grannular urea application rate of 130 kg/ha in the laboratory by operating 20 revolutions of ground drive wheel. It gave 0.00471 ha area. The fertilizer delivered in each tube of furrow opener was collected and weighed for three replications. Mean discharge rate and coefficients of variation of fertilizer application rate are shown in Table 8. The minimum and maximum quantities of fertilizer discharge from 20 revolution of ground drive wheel were 0.596 and 0.745 kg. The average fertilizer discharge rate ranged from 0.106 to 0.126 kg in tube 1, 0.088 to 0.113 kg in tube 2, 0.0104 to 0.144 kg in tube 3, 0.089 to 0.115 kg in tube 4, 0.118 to 0.129 kg in tube 5, 0.091 to 0.118 kg in tube 6. The mean discharge rate of fertilizer from all the tubes ranged from 0.099 to 0.124 kg for 20 revolution of ground drive wheel, It resulted mean fertilizer application rate of 126.53 to 158.17 kg/ha. The coefficient of variation for calibrated fertilizer application rate ranged from 6.95 to 14.99% among the all fertilizer tubes. It revealed that there the fertilizer discharge rate below the specified limit of 20% CV in the field resulted the uniformity application among the tubes. Because, coefficient of variation is less than 14.99% level.

Field Performance

The developed machine was tested in the field for application of granular urea on wheat crop sown on bed. The size of beds on which wheat crop was sown in 5 rows is given in Table 9. Moisture content, bulk density and cone index of experimental field is shown in Table 10. During 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, respectively. The crop parameters recorded during the testing of machine as plant height nos. of plants and tillers are shown in Table 11.

Table 9: Size of experimental beds used for sowing of wheat crop.

S. No.	Dimension of bed (size)	I	II	III	Mean	S. D.
1	Top width, mm	1200	1250	1230	1226.67	25.16
2	Bottom width, mm	1630	1650	1640	1640	10.00
3	Height, mm	162	201	152	171.67	25.89

Table 10: Moisture content, bulk density and cone index of experimental field at depth 0-100 mm at standing crop.

Depth of soil (0-10 cm)	Moisture content (%)	Bulk density g/cc	Cone index kg/cm^2
T1	25.01	1.15	3.71
T2	26.68	1.43	4.50
T3	24.56	1.21	3.97
T4	29.66	1.52	3.45
Mean	26.47	1.32	3.90
S. D.	2.309	0.175	0.448

Table 11: Crop parameter for wheat Varity HI-1544 sown

S. No.	Particulars	I	II	III	Mean	S. D.
1	Row spacing, mm	224	222	225	223.67	1.53
2	Depth of application, mm	140	149	150	146.33	5.51
3	Width of application, m	1.5	1.5	1.5	1.5	0
4	No. of plant/m^2 at 21 DAS.	80	85	82	82.33	2.52
5	Plant height at the time of fertilizer application, mm	150	155	160	155	5
6	No. of tiller / plant	13	12	14	13	1
7	Per cent plant damage, %	3.5	4.5	5	4.33	0.76

Fertilizer application rate

The machine was evaluated to apply the calibrated quantity of fertilizer i.e. 130.4 Kg/ha. This resulted application of nitrogen at the rate of 60 kg/ha. The mean discharge rate of fertilizer was 100.00 kg/ha is shown in Table 12. It was due to application of fertilizer in four rows only as the two outside furrow openers were closed during the application of fertilizer in 5 rows bed planted wheat crop. During the field testing the average discharge of furrow opener varied from 0.106 to 0.132 kg revolution. The difference in discharge rate during laboratory and field-testing was probably due to variation in tractor speed in field condition. The minimum and maximum discharge of fertilizer were 98.32 kg/ha to 102.97 kg/ha. The coefficient of variation of fertilizer delivery from all tubes varied from 5.23 to 10.30%. That machine applied the fertilizer at uniform rate as the CV was to % with well acceptable limit for field experiment.

Table 12: Discharge rate of fertilizer under field condition at fertilizer application rate 130.4 kg/ha

Test No.	Average discharge kg						Application rate, kg/ha	Mean discharge ratekg	S. D.	C.V.
	T1	T2	T3	T4	T5	T6				
Field testing										
1	0.00	0.113	0.127	0.115	0.118	0.00	100.42	0.1183	0.0061	0.0523
2	0.00	0.107	0.121	0.106	0.131	0.00	98.72	0.1163	0.0119	0.1030
3	0.00	0.113	0.126	0.114	0.132	0.00	102.97	0.1213	0.0086	0.0713
Mean	0.00	0.1110	0.1246	0.1120	0.1266	0.00	100.70	---	---	---
S. D.	0.00	0.0034	0.0032	0.0051	0.0075	0.00	2.1391	---	---	---

Machine 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. During the field testing the operational speed and wheel slippage of machine were 3.7 km/h and 4.69% respectively, show in Table 13.

Table 13: Details of fertilizer (granular urea) application in wheat crop

S. No.	Characters	Particulars			Mean	S. D.
		I	II	III		
1	Speed of operation(km/h)	3.70	3.90	3.50	3.70	0.2
2	Wheel slippage (%)	4.71	4.23	5.14	4.69	0.46
3	Field capacity (ha/h)	0.64	0.67	0.63	0.65	0.02
4	Field efficiency %	78.90	81.22	80.2	80.11	1.16
5	Fuel consumption (lit/h)	3.70	3.50	3.40	3.53	0.15

The field capacity and field efficiency during fertilizer application in wheat crop are given in Table 14. The average field capacity and field efficiency of machine were 0.65 ha/h and 80.10% respectively. Average plant damage was 4.33% in the field during the application of fertilizer at the depth of 150 mm in wheat crop sown on beds.

Crop yield parameters

Yield of wheat crop under different method of application of granular urea is given in Table 14 and the grain yields were 5.72 +/ha, 5.38 +/ha and 6.1 +/ha for fertilizer application through broadcast, foliar application and developed tractor operated fertilizer applicator, respectively. The tractor operated fertilizer applicator resulted 3% and 6.5% increased in yield as compared to broadcast and foliar application. Because ammonia did not evaporated to the atmosphere due to placing of fertilizer at a depth of 150 mm below the soil surface.

The saving of fertilizer placed in the soil by tractor operated fertilizer applicator was 33.33 and 16.6 kg/ha as compared to broadcast and foliar application methods. The fertilizer use efficiency has increased significantly as the 46% N/ha was use by the plant as compared to 61.33 kg/ha and 38.33 kg/ha in broadcast and foliar methods respectively. Nitrogen use efficiency in tractor operated fertilizer applicator was 33.33% and 16.6% higher than broadcast and foliar application methods. This showed that the tractor operated fertilizer applicator placed the granular urea very effectively below the 150 mm from the top soil surface near the root zone of plant that resulted increased biological yield of crop and reduced the quantity of fertilizer application and emission of N to the atmosphere.

Table 14: Wheat yields and Straw yields in different method of granular urea application

S. No.	Method of granular urea application in wheat crop	Quantity of fertilizer, kg/ha	Grain Yield kg/ha			Mean kg/ha	Straw yield kg/ha			Mean kg/ha
			I	II	III		I	II	III	
1	Broadcast (kg)	133.33	5920	5610	5640	5723.33	16330	15380	15750	15820.00
2	Foliar application (kg)	83.33	5260	5670	5200	5376.67	15190	16730	15770	15896.67
3	Fertilizer application (kg)	100.00	6000	5670	6410	6026.67	16920	15640	16940	16500.00

Straw yield of wheat crop under different method of application of granular urea is given in Table 14 and the straw yields were 15820 kg/ha, 15896.67 kg/ha and 16500 kg/ha for fertilizer application through broadcast, foliar application and developed fertilizer applicator, respectively. The tractor operated fertilizer applicator resulted 6.8% and 6% increased in yield in straw as compared to foliar application and broadcast methods. It was due placing of fertilizer at a depth of 150 mm below the soil surface near the root zone of plants that prevented the evaporation of ammonia to the atmosphere and increased the utilization of N efficiently and effectively by the plants.

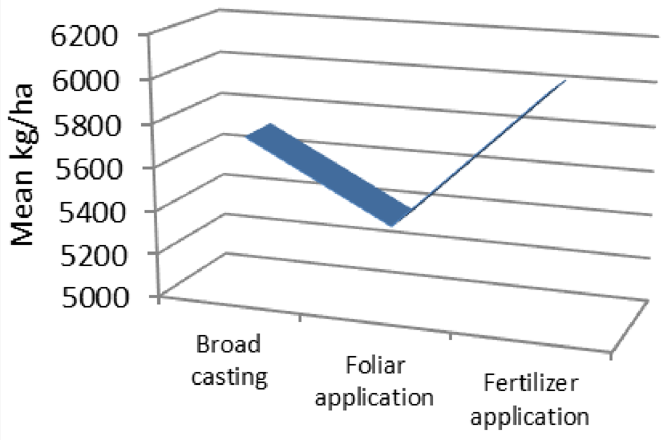

Fig 2: Grain yields in different method of granular urea application

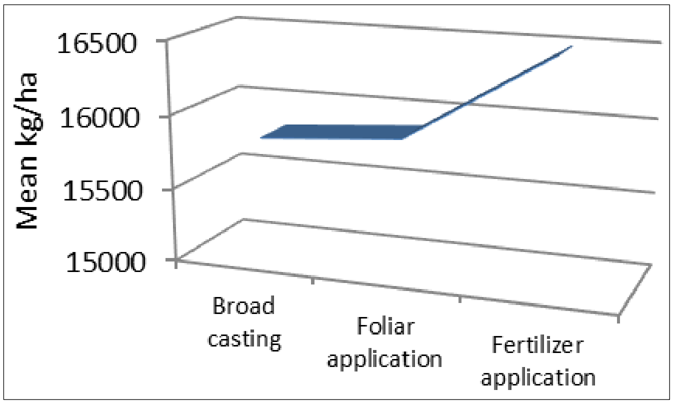

Fig 3: Straw yields in different method of granular urea application

Cost Economics

The cost of application in foliar application of granular urea in top dressing by labours was Rs. 270/ha, Rs. 540/ha and the cost operation for tractor operated fertilizer was applicator of six rows has been estimated as Rs. 650/ha. The savings in granular urea were 8.74 and 2.76 kg/ha by using the tractor operated fertilizer applicator as compared to broadcast and foliar application. This resulted saving of fertilizer of Rs. 721 and Rs. 216/ha as compared to there to method. Thus tractor operated fertilizer applicator resulted saving of Rs 341 and Rs 611/ha. For the application of fertilizer at 150 mm below the soil surface as compared to broadcast and foliar application methods.

Conclusion

The application of granular urea on bed planted 5 rows wheat crop. Properties of granular urea were studied included size and shape (linear dimension), density, sphericity, fertilizer mass (weight) of hundred particles. The fertilizer applicator was calibrated for granular urea application rate of 60.2 kg/ha to 130.4 kg/ha. The developed machine was tested in the field for application of granular urea/nitrogen at the rate of 130 kg/h (60 kg N/ha) on bed planted wheat crop. The developed machine operated with a 35 hp tractor performed very and efficiently for the placement of urea at the depth of 150 mm below the soil surface. It saved the fertilizer, fuel, time and resulted increased in yield, use efficiency of nitrogen, saving in fertilizer by placing near the root zone of wheat plant below the soil. It prevented the loss of nitrogen to atmosphere. The savings in granular urea was 8.74 kg/ha by using the tractor operated fertilizer applicator as compared to broadcasting. The machine has also resulted saving in cost of operation Rs. 341/ha and Rs. 611/ha as compared to broadcast and foliar application methods including cost of fertilizer. The major conclusion of the study is reported below.

1. The physical properties of fertilizer (granular urea) size, shape, sphericity, density and hundred particles weight were observed. The mean values for size shape (sphericity), bulk density and hundred particle weight were 1.85 ± 0.4, 0.99 ± 0.004, 0.76 ± 0.0011, and 0.8 ± 0.6 with 95% confidence limit at moisture content of 18.7%
2. Under laboratory condition during the calibration, the fertilizer applicator gave 66.73 and 131.55 kg/ha of granular urea with CV of, 0.10 and 0.033 respectively. Thus showed that machine uniform fertilizer application rate.
3. The developed tractor operated fertilizer applicator has applied the granular urea at the rate of 100 kg/ha in 4 rows between the 5 rows wheat crop planted on bed. Average depth of application of urea was 150 mm below the soil surface on wheat crop planted on beds. Also machine worked satisfactorily for applying the fertilizer at different depth (50-300mm).
4. The speed of operation and slippage of developed machine in the field were 3.70 km/h and 4.69% during the field operation.
5. The field capacity and field efficiency of machine were 0.65 ha/h and 80.10% during the fertilizer application on 5 rows bed planted wheat crop.
6. The tractor operated fertilizer applicator resulted 3% and 6.5% increased in yield as compared to broadcast and foliar application methods. Increased in yield of crop straw were 6% and 6.8% as compared to foliar application and broadcast methods.
7. The savings in granular urea were 8.74 and 2.76 kg/ha by using the tractor operated fertilizer applicator as compared to broadcast and foliar application. This gave saving of Rs 341 and Rs 611/ha for tractor fertilizer applicator as compared to broadcast and foliar application methods.

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