DEVELOPMENT OF FERTILISER APPLICATOR FOR 4- WHEEL DRIVE RICE TRANSPLANTER

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PROJECT REPORT

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2019

DECLARATION

We hereby declare that this thesis entitled **"DEVELOPMENT OF FERTILISER APPLICATOR FOR 4- WHEEL DRIVE RICE TRANSPLANTER"** is a bonafide record of research work done by us during the course of academic programme in the Kerala Agricultural University and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place: Tavanur

Date:

ANIRUDH M K (2015- 02- 007)

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CERTIFICATE

Certified that this project report entitled **"DEVELOPMENT OF FERTILISER APPLICATOR FOR 4- WHEEL DRIVE RICE TRANSPLANTER"** is a record of project work done jointly by Mr. ANIRUDH M K, Ms. JOSHILA MARY J, Ms. A R SURAJA under my guidance and supervision and that it has not previously formed the basis for any degree, diploma, fellowship or associateship or other similar title of another University or Society.

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Date:

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Dedicated to our Profession

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SYMBOLS AND ABBREVIATIONS

ha	Hectare
%	Percentage
et al	and others
hr ha^{-1}	hours per hectare
N	Nitrogen
P_2O_5	Phosphorus Pentoxide
K_2O	Potassium Oxide
Viz.	namely
kg ha^{-1}	kilogram per hectare
BA	Basal application
AT	At tillering
API	At panicle initiation

HY	High yielding
DAP	Days after planting
DAS	Days after seeding
kg	kilogram
g cm^{-3}	gram per cubic centimeter
rpm	revolution per minute
mm	millimeter
kW	KiloWatt
ps	pound second
max.	Maximum
L	Litre
cm	Cemtimetre
m	Metre
m^2	Square metre

m^3	Cubic metre
$m\ s^{-1}$	metre per second
min	Minute
GI	Galvanised iron
UB	Urea Briquettes
CAE	College of Agricultural Engineering
Anon.	Anonymous
kN	Kilo Newton

Introduction

CHAPTER I

INTRODUCTION

Rice is the most prominent crop of India as it is the staple food for most of the people of the country. This crop is the backbone of livelihood for millions of rural households and plays vital role in the country's food security, so the term "rice is life" is most appropriate in Indian context. India occupies an important position both in area and production of rice. By the adoption of improved production technologies such as high yielding varieties/ hybrids, expansion of irrigation potential, and use of chemical fertilizer, supply of rice in the country has kept pace with the increase in demand.

Total area planted under rice crop in India is 42.20 million ha, which is the largest in the world as against the total area of 148.40 million ha.In 2014-15, the paddy production in Kerala was 5,62,092 tonnes from an area of 1,98,159 ha (Anon., 2017). Palakkad district is the key producer contributing 42.18 per cent of the total rice production. There are three major rice-growing seasons in Kerala. The '*Virippu'* (First crop) season starts in April-May and continues up to September-October, '*Mundakan'* (Second crop) season starts in September-October and extends up to December-January, whereas the '*Puncha'* (Third crop) season starts in December-January and extends up to March-April.

Paddy is grown traditionally by manual transplanting. Manual transplanting is labour intensive, involving drudgery and is one major factor for increased production cost. Manual transplanting takes aout 250- 300 man hours ha^{-1} which is roughly about 25 per cent of the total labour requirement of the crop (Singh et al 1985). Paucity of labourers is an important problem in Kerala. Hence, the less expensive, farmer friendly and labour saving method of mechanical transplanting of paddy is the option, as it ensures timely transplanting and attains optimum plant density that contributes to high productivity.

A rice transplanter is a mechanical device to serve the purpose of planting rice seedlings onto a puddled paddy field. Although rice is grown in areas other than Asia, rice transplanters are used mainly in East, Southeast, and South Asia. This is because rice can also be grown without transplanting. Different types of rice transplanters are being used and the four wheel riding type machine is getting popular as it can ensure speedy operation so as to meet the challenges imposed by climate change.

Production of rice is also input intensive, particularly, the modern varieties of rice, which is dependent on the use of inorganic fertilizers and irrigation. Fertilizers are usually broadcasted in paddy fields prior to transplanting, followed by one or more top dressing in the flood water within the period from transplanting to flowering. The most widely used nitrogen fertilizer is urea, which contains 46 percent N, the highest of all solid fertilizers. Solid fertilizers can be applied by four different methods viz. broadcasting, placement, band placement and pallet application. Broadcasting is done in two ways spreading of fertilizers prior transplanting (basal application) and spreading of fertilizer prior to flowering (top dressing). But such practices are inefficient because only about one third of the fertilizer is used by plants. The remainder is lost through gaseous losses, runoff, and leaching or is immobilized in the soil. Although the application of fertilizers before rice transplanting i.e., basal application in paddy fields exerts a direct effect on growth and yield of rice, it sometimes requires much farm-labour. Thus, there is a good scope for providing basal applicator attachments to the transplanting machine.

Considering above factors, the development of fertilizer applicator attachments for a four wheeled riding type transplanter was contemplated with the following specific objectives:

- To develop a fertilizer applicator for commercially available 4- wheel rice transplanter.
- To standardize the operational parameters of the developed applicator.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

A brief review of work done relevant to various aspects of the present development is reported here.

2.1. FERTILISER PROPERTIES

Rutland et al. (1951) prepared a fertilizer dealer handbook in IFDC and discussed the physical properties of fertilizer. They found that angle of repose of fertilizers was influenced mostly by particle shape, size and surface texture. Angle of repose values for fertilizers normally ranged from about 25° to about 40°. Spherical products, such as prilled urea, usually had lower angle of repose values (<30°). Irregularly shaped products such as granular, angle of repose values will be (>35°).

Hofstee (1992) found out that handling and spreading of fertilizer is affected by the physical properties of the particles and so knowledge of these properties is helpful in understanding fertilser handling and use. Also, it was fund out that the coefficient of friction is influenced to a minor extent by the velocity relative to the friction surface layer and environmental conditions. The coefficient of restitution measurements showed a large effect of the impact surface and smaller effects of particle diameter and fertilizer type. Coarse particles were shown to have a higher aerodynamic resistant coefficient than particles with a smooth surface texture. The breaking force measurements showed that the relationship between strength and particle size depended on the fertilizer type.

Allaire *et al.* (2004) compared the physical properties of compound organic based (COF) and bulk-blended organic-based fertilizers (BOF) with those of mineral fertilizers (MF). Standard and modified methods were used to measure their static properties. Compared with MF, COF had significantly lower bulk, granule, particle densities and higher bulk and granule porosities and angles of repose. The organic matter content significantly influenced most physical properties. Bulk density, granule density and the angle of repose decreased with increasing organic matter content while porosity and tensile strength increased with organic matter content. Bulk density and tensile strength were also significantly related to granule size distribution. The initial water content influenced density, porosity, tensile strength and the angle of repose.

Allaire *et al.* (2004) compared the physical properties of bulk-blended organicbased(BOF) and compound organic-based fertilizers (COF) with those of mineralfertilizers (MF). New and modified methods were used to measure their atmospheric moisture sorption, capillary rise, slaking and dissolution in water over time. Air moisture sorption by fertilizers increased quadratically with time and with relative humidity. At 82% relative humidity major changes in fertilizer behavior occurred. Water sorption from the atmosphere was affected by bulk density as well as by the organic matter (OM), initial moisture and P contents. The water sorption rate over time during capillary rise took the form of an inverse power function and increased as OM content increased. During submersion in water, COF granules dissolved, swelled and slaked to different extents and their diameter decreased quadratically over time. The loss of mass during submersion was affected by OM and nitrogen contents as well as by the initial granule size. Differences between fertilizers were mostly related to the organic matter type and content. Examples of uses and applications of dynamic properties are given for different situations: fast or slow release; dry to wet conditions; and application at the soil surface or incorporation in the soil.

Pare *et al.* (2009) determined the relationships among physico-chemical properties so that the number of measurements required by the industry during manufacturing is reduced. Organo-mineral fertilizers were granulated into 50 mixtures of composts, peat and mineral fertilizers. Fifteen physical properties and 12 chemical properties were measured following standard and modified methods. Bulk density, easy and inexpensive to measure, significantly affected other physical properties (R2>0.74), such as tapped, granule densities, porosities and crushing strength.

Deo (2013) studied that the engineering properties of urea briquettes relevant to design of the mechanical applicator. Physical and engineering properties viz. size, shape, urea briquette weight, bulk density, angle of repose and coefficient of friction of urea briquettes of UB1 (3g) and UB2 (2g) were evaluated in laboratory. Length, breadth and thickness of the urea briquettes UB1 and UB2 were 18.84±0.2.8 mm, 18.39±0.33 mm, 13.76±0.28 mm and16.49±0.18 mm, 16.22±0.19 mm and 11.18±0.17 mm, respectively. Mean diameter was greater for UB1 (16.83±0.22 mm) in comparison to that of UB2 (14.41±0.15 mm). Roundness of UB1 (3g) and UB2 (2g) were 0.82±0.01% and 0.78±0.11%, respectively, while sphericity of these briquettes in the natural rest position were 0.89±0.01 and 0.85±0.01%, respectively. Mean briquette weight was greater for UB1 (2.81±0.11 g) than that of UB2 (1.78±0.07 g). Angle of repose for mild steel surface was 31.64±0.13° and 31.67±0.28° for urea briquettes UB1 and UB2 respectively. The angle of repose of urea was 22˚ to 45˚, which is influenced by size, shape and surface texture.

Antille *et al* (2013) determine the particle size range of two organomineral fertilisers (OMF) that may enable broadcast application with standard fertiliser spreading equipment using conventional tramlines spacing. A theoretical model was developed which predicts the trajectory of individual fertilizer particles off-the-disc. The drag coefficient was estimated for small time steps (10-6 s) in the trajectory of the particle as a function of the Reynolds number. For the range of initial velocities (from 20 to 40 m s-1) and particle densities (from 1250 to 1500 kg m-3) investigated, the model showed that the particle size range for OMF should be between 1.10 and 5.50 mm in diameter. Given the assumptions made in the analysis, this size range is expected to match, approximately, the minimum and maximum landing distances of individual particles of urea (size range: 1.00 to 5.00 mm). It was suggested that OMF should have about 80% of the particles in the range of 2.25 to 4.40 mm in diameter. Due to the characteristics of the materials, spreading OMF with spinning discs applicators may be restricted to tramlines spaced at a maximum of 18 m apart; especially, when some degree of overlapping is required between two adjacent bouts.

2.2 ATTACHMENTS WITH RICE TRANSPLANTER

Takenga (1982) developed a application equipment for granular materials mounted on rice transplanter which helped in applying the granules loaded in the machine to paddy soil at the vicinity of rice seedlings and at a certain depth from soil surface, either as row or dot application. It showed thst, this can save the quantiy of granules to be used, because fewer amount is enough for the row or dot application than for overall application.

Jadhav et al. (1990) developed a simple low cost and high utility device in India to transplant wetland paddy with recommended plant geometry of 15 x 20 cm and to facilitate applying Urea Super Granules (USG) during transplanting at recommended rates without damaging the granules. The device is called the row plant spacing marker-cum-urea super granules dispenser. Feasibility trials showed that: with skilled labour the man-hours/ha required for the device are 230 compared with 268.44 for the local method, giving a labour saving of 38.44 man-hours/ha. When unskilled labour is used, the man-hours/ha required with the device are 510.88 compared with 553.10 for the local method, giving a labour saving of 42.22 man-hours/ha.

Khilael et al. (2004) explained about, to develop a metering mechanism or device that would be well suited to both organic and chemical fertilizer application. The already developed metering devices can meter only large fertilizer granules more than 10 mm in diameter with different shapes, using a low output motor. The rotational speeds and shaft torques of the roller, and the discharge rates were measured in order to evaluate the performance of the improved metering device in comparison with a commercial metering device using four types of organic and chemical fertilizers.

Pappan *et al*. (2012) developed a herbicide applicator attachment for Yanji-Shakthi paddy transplanter for applying pre-emergent herbicides at the time of planting. The herbicide applicator consists of a positive displacement pump. The pump was placed on the main frame of the paddy transplanter which is 80cm in front of the operator‟s position. The pump was directly operated by the paddy transplanter clutch pulley by extending the main driving shaft. A cam was provided at the end of the extended main shaft for converting rotary motion to reciprocating motion. The pump gets drive from the extended shaft which could be engaged by clutch lever.

A tractor drawn combination implement for dry seeding of rice along with application of pre-emergent herbicides was developed at Krishi Vigyan Kendra Palakkad (Anon., 2013). The sprayer system was driven electrically, power being drawn from the battery of the tractor. The system could reduce the cost ofcultivation in dry seeded system.

Mehta et al (2017) explained that a fertilizer applicator suitable for attaching to 13 kW self-propelled riding type power source was developed at CAE, Bapatla. Based on the power availability of power source and angle of repose of different fertilizers, trapezoidal shape hopper was designed with one side having more than 60° slope for easy flow of fertilizer to metering mechanism. For operating the fertilizer applicator, spring augur was selected as fertilizer metering mechanism and concave trough with holes on periphery for fertilizer dropping.

Alam et al. (2017) developed and evaluated a four row pull type manually operated USG applicator at Bangladesh Agricultural University. The width of the applicator was 1.6 m. The lowest values of missing (0.86%), over falling (0.90%) and breaking (0.6%) of USG were found in the speed range of 2.05 to 2.21 km/h in a laboratory experiment. Therefore, the recommended operating speed of the applicator was 2 to 2.2 km/h. The effective field capacity and field efficiency of the applicator at a forward speed of 2.06 km/h were 0.26 ha/h and 78%, respectively. The average spacing between USG in a row was found to be 39.89 cm which was desired. The machine was easy to pull because the maximum draft and drawbar power were only 0.105 kN and 0.06 kW, respectively in puddle field. Moreover, the weight of the whole applicator was only 12 kg which made it easy to carry.

Athul (2017) studied on the developments of attachments for four wheel riding type ttansplanter and an applicator attachment for spraying liquid formulations of bio-fungicides and micronutrients on the mat nursery loaded in the seedling tray of the machine, immediately before transplanting. From the analysis it was found that using these transplanters is economical than manual transplanting whenever the annual operating hour is more than 102 hr.

Development of a deep placement urea briquette applicator attachment for self-propelled rice transplanter was made by Manikyam (2018). He determined that the attachment saved cost of operation by 81.38% and 83.68% compared with manual applicator and manual deep placement method respectively. Also, the urea briquette applicator attachment saved time of operation by 88.49% and 90.06% compared with manual applicator and manual deep placement method respectively.

Materials and Methods

CHAPTER III

MATERIALS AND METHOD

The methodology adopted for fertilizer requirement calculation, determination of fertilizer properties and the concept of design for the fabrication of the fertilizer metering deice attachment for KUBOTA 4- wheel drive rice transplanter for basal application are detailed in this chapter.

3.1. FERTILISER REQUIREMENT

Kerala State has been delineated into thirteen agro climatic zones based on four parameters viz., altitude, rainfall pattern, soil type and topography viz., (1) Onattukara, (2) Coastal Sandy, (3) Southern Midlands, (4) Central Midlands, (5) Northern Midlands, (6) Malappuram Type, (7) Malayorum, (8) Palakkadu plains, (9) Red loam, (10) Chittoor black soil, (11) Kuttanadu, (12) Riverbank alluvium and (13) High ranges.

The fertilizer recommendation for paddy (kg ha^{-1}) for different kinds of land is as follows:

TABLE 3.1 Fertilizer recommendation for paddy, kg ha^{-1}.

Kind of land/ region	**Variety**	**N**	**P_2O_5**	**K_2O**
Uplands (modan)	Upland local varieties	40	20	30
	High yielding short duration varieties	60	30	30
Wetlands (All regions)	High yielding short duration varieties	70	35	35
	High yielding medium duration varieties	90	45	45
	Local varieties	40	20	20
	H4	70	35	35
	Mashuri	50	25	25

Kolelands	Short duration varieties	90	35	35
	Medium duration high yielding varieties	110	45	45
Kattukampal and Ponnani kole lands	Medium duration high yielding varieties	110	45	55
Wetland (Kuttanad)	Medium duration High yielding varieties	90	45	15
Onnattukkara	Dhanya	60	30	30
Koottumundakam	Photo insensitive varieties for first crop	40	20	20
	Photosensitive varieties for second crop	20	10	10

The stages of application of N, P_2O_5 and K_2O is given in table 3.2.

TABLE 3.2 Stages of fertilizer application in paddy.

Kind of land/ region	**Variety**	**Stages of Application**									**Remarks**
		N			**P**			**K**			
		BA **	**AT**	**API**	**BA**	**AT**	**API**	**BA ****	**AT**	**API**	**For direct seeded crop, one week after sowing
Uplands	PTB 28, 29, 30	1/3	1/3	1/3	Full			1/2*		1/2	*Full dose as basal is also recommended
	HYshort duration	1/3	1/3	1/3	Full			1/2*		1/2	*Full dose as basal is also recommended
Wetland, direct seeded	General	1/3*	1/3	1/3	Full			1/2*		1/2	*For wet seeded, the first dose to given 1 week after sowing. For dry seeded, first application to be given after establishment of the seedlings
	Mashuri	1/3	1/3*	1/3 **	Full			1/2		1/2 **	*45 DAS, **85 DAS
Wetland,	HYshort	2/3		1/3*	Full			1/2		1/2	*5-7 days before

Trans-planted	Duration										PI
	HY, medium duration	1/2		1/2*	Full			1/2		1/2	*5-7 days before PI
	Mashuri	1/2	1/4*	1/4*	Full			1/2		1/2 **	*40 DAP, **60 DAP
Onnattu-kara	General	1/2	1/4	1/4	Full			1/2		1/2	In very coarse soils, N & K may be given in five equal splits
Wayanad and hilly region	Long duration trans-planted		1/2	1/2		Full*			1/2	1/2	*Along with first application of N & K
	Direct seeded		1/2*	1/2		Full **			1/2*	1/2	*45 days after seeding, **With first Application of N & K
Pokkali	General	Full			Full *						*Apply entire quantity at the time of dismantling of mounds
Kootum-undakam	First crop	1/2		1/2	Full			1/2		1/2	
	Second crop	Full *			Full *			Full *			*Entire quantity as single dose immediately after the harvest of first crop

BA= Basal application; AT= At tillering; API= At panicle initiation; HY= High yielding; DAP= Days after planting; DAS= Days after seeding.

The commonly used fertilizers in wetlands are urea containing nitrogen (46:0:0), factumphos i.e., ammonium phosphate sulphate consisting of 16% N, 20% P and traces of sulphur (16:20:0) and muriate of potash with 60% K (0:0:60).

$$\text{Amount of fertilizer material (kg)} = \frac{\text{Recommended rate(kg ha}^{-1}\text{) x Area (ha)}}{\text{\% Nutrient in fertilizer material}}$$

3.2. PHYSICAL PROPERTIES OF FERTILISERS

3.2.1. Angle of Repose

Angle of repose or critical angle of repose of a granular material is the steepest angle of descent or dip relative to which a material can be piled without slumping. The particle shape, size and surface texture of the fertilizer influences its angle of repose. Knowledge of the angle of repose is necessary for the design of the hopper.

The procedure for measuring the solid fertilizer static angle of repose involves pouring a sample through a funnel into a level base plate, measuring the diameter and height of the conical pile and calculating the base angle of the cone from these measurements.

3.2.2. Bulk Density

Bulk density represents the mass to volume ratio of a bulk sample. It is the mass per volume of a material tipped into a container and then compacted under clearly specified conditions. It is expressed in grams per cubic centimeter (g cm^{-3}).

The method of determination is by pouring the fertilizer from a specified funnel into a specified measuring cylinder of known volume and weighing the contents of the cylinder.

3.2.3. Particle Size

Particle size is a measure of average granule size normally reported by a single but nominal diameter measurement for an entire fertilizer load or sample. Since particle size varies within fertilizer, particle size distribution indicating the variability in size is normally reported for fertilizers. Particle size and size distribution both have a direct influence on spread width and uniformity. This is an important aspect in determining fertilizer quality.

Particle size is determined with the use of either the uses of sieves or a particle size analyzer. The procedure consists of sieving through a given sieve size. The material is passed through a sieve mesh equal to the maximum particle size prescribed for a given fertilizer. The material is so sieved is retained on a sieve with a mesh equal to the minimum particle size prescribed for that fertilizer.

3.2.4. Crushing Strength

Crushing strength is defined by the International Development Center as the resistance of granules to deform or fracture under pressure. Crushing strength is the minimum pressure needed to crush individual particles.

A method to determine the crushing strength in the field is to apply pressure to individual granules. A simple finger test can be used to evaluate hardness or strength at time of spreading.

- Granule crushed between thumb and forefinger is soft.
- Granule crushed between forefinger and a hard surface is medium hard.
- Granule not crushed between forefinger and hard surface is hard.

Any granule with a less than 3 kg/granule crush strength should not be broadcast with spinner speeds over 700 rpm.

3.3. DESIGN PARAMETERS FOR FERTILISER APPLICATOR

The basic performance parameter for a fertilizer distributor is uniformity of distribution over a wide range of conditions. For drop – type units or band placement, uniformity is determined primarily by the performance of the metering devices. With centrifugal broadcasters or airplane broadcasters, lateral spreading must also be considered.

The metering device should have a positive dispensing action with fertilizers covering a range of drillabilities. Drillability is the ease with which a fertilizer flows.

The drillability of the fertilizer is affected by such factors as the hygroscopicity of the fertilizer, the relative humidity at which it is stored, the size and shape of particles, presence of lumps, the bulk density and the compaction characteristics of the material. It is desirable that the discharge rate be proportional to the forward speed of the implement so that the application rate per hectare will be independent of speed.

The drillability of a fertilizer is inversely proportional to the angle of repose and that fertilizers with angle of repose greater than about 55^0 cannot be metered satisfactorily with most types of equipment.

The discharge rate should be independent of the fertilizer in the hopper and of reasonable inclinations of the distributor. The design should be such that there are no appreciable cyclic variations in discharge rate. The rate should be adjustable in small increments and should have a definite relation to a suitable reference scale provided on the unit. Parts should be accurately made so multiple units will have equal delivery rates.

The metering device should be easy to empty and to disassemble for thorough cleaning. Many fertilizers are corrosive and will tend to “freeze” rotating parts if even small amounts are left in the distributor and become moist or wet. To facilitate emptying, hoppers should be mounted so they can be easily tipped or completely removed, or they should have hinged or removable bottoms. Corrosion – resistant materials should be used where feasible, and particularly for the working parts.

3.4. CONCEPT OF DESIGN

The concepts for the design and development of various components of fertilizer metering unit are discussed in the following sub-sections.

3.4.1. Study of KUBOTA Rice Transplanter

The development of the fertilizer applicator system was done based on the Kubota make 6 – row transplanter (Kubota NSPU – 68C). The technical specifications of the model are given in Table 3.2.

Table 3.3: Technical specifications of Kubota NSPU-68C rice transplanter.

<table>
<tr><td colspan="4">Model</td><td>NSPU- 68C</td></tr>
<tr><td colspan="4">Drive type</td><td>4- wheel drive</td></tr>
<tr><td rowspan="4">Dimensions</td><td colspan="3">Overall length (mm {inch})</td><td>3000 {118.11}</td></tr>
<tr><td colspan="3">Overall width (mm {inch})</td><td>2210 {87.01}</td></tr>
<tr><td colspan="3">Overall height (mm {inch})</td><td>2570 {101.18}</td></tr>
<tr><td colspan="3">Minimum ground clearance (mm {inch})</td><td>430 {16.93}</td></tr>
<tr><td colspan="4">Weight (kg)</td><td>590</td></tr>
<tr><td rowspan="7">Engine</td><td colspan="3">Model</td><td>GZ460-P-CHN</td></tr>
<tr><td colspan="3">Type</td><td>Water-cooled, 4-cycle,
2-cylinder OHC gasoline engine</td></tr>
<tr><td colspan="3">Total displacement (L {cc})</td><td>0.456 {456}</td></tr>
<tr><td colspan="3">Output revolution speed
(kW {PS}/ rpm)</td><td>85 {11.5}/ 3600
MAX [12.5 {17.0}]</td></tr>
<tr><td colspan="3">Applicable fuel</td><td>Unleaded gasoline for automobile</td></tr>
<tr><td colspan="3">Fuel tank capacity (L)</td><td>17</td></tr>
<tr><td colspan="3">Starting system</td><td>Starting motor</td></tr>
<tr><td colspan="4">Fuel consumption (kg h^{-1} m^{-2})</td><td>3.6 to 8.5</td></tr>
<tr><td rowspan="4"></td><td colspan="3">Steering system</td><td>Integral power steering</td></tr>
<tr><td rowspan="3">Wheel</td><td>Type</td><td>Front wheel</td><td>No-puncture tire</td></tr>
<tr><td></td><td>Rear wheel</td><td>Rubber lug with thick rim</td></tr>
<tr><td>00 x width</td><td>Front wheel (mm{inch})</td><td>650{25.59} x 95{3.74}</td></tr>
</table>

<table>
<tr><td rowspan="5">Travelling Portion</td><td rowspan="3"></td><td>00 x
rim width</td><td>Rear wheel
(mm{inch})</td><td>900{35.43} x 50{1.97}</td></tr>
<tr><td rowspan="2">Tread</td><td>Front wheel
(mm{inch})</td><td>1165 {45.87}</td></tr>
<tr><td>Rear wheel
(mm{inch})</td><td>1200 {47.24}</td></tr>
<tr><td colspan="3">Shifting system</td><td>Hydrostatic transmission HST</td></tr>
<tr><td colspan="3">Number of shifting positions</td><td>HST main shift: Variable speeds for forward and reverse: No clutch
[sub shift: 2 positions]</td></tr>
<tr><td rowspan="6">Planting portion</td><td colspan="3">Planting system</td><td>Rotary, forced planting</td></tr>
<tr><td colspan="3">Number of planting rows</td><td>6</td></tr>
<tr><td colspan="3">Distance between rows (cm)</td><td>30</td></tr>
<tr><td colspan="3">Hill space (cm)</td><td>*12,14,16,18,21</td></tr>
<tr><td colspan="3">Planting depth (cm)</td><td>*2- 5.3 [5 positions]</td></tr>
<tr><td colspan="3">Number of hills per 3.3 m^2</td><td>*90,80,70,60,50</td></tr>
<tr><td rowspan="3">Seedling condition</td><td colspan="3">Seedling type</td><td>Seedling mat</td></tr>
<tr><td colspan="3">Seedling height (cm)</td><td>8 to 25</td></tr>
<tr><td colspan="3">Number of leaves (leaves)</td><td>2.0 to 4.5</td></tr>
<tr><td colspan="4">Operation speed (m s^{-1})</td><td>0 to 1.62</td></tr>
<tr><td colspan="4">Operation efficiency estimated value
(a h^{-1} {min/10a})</td><td>Max. 61 {9.8}</td></tr>
</table>

3.4.1.1. Theoretical field capacity

It is the function of speed of transplanter and the width of operation expressed in ha hr^{-1} and it was calculated by the following equation:

$$\text{TFC} = \frac{w \times s}{c}$$

... (Mehta *et al.*, 1995)

Where,

TFC = Theoretical field capacity, ha h^{-1}

w = Operating width of the transplanter, m

s = Transplanting speed, km h^{-1}

c= Constant, 10

3.4.1.2. Actual field capacity

The actual or effective field capacity is the actual rate of coverage by the machine i.e., area covered, based upon the total working time and it can be calculated by the following equation:

$$\text{AFC} = \text{A/T}$$

... (Mehta *et al.*, 1995)

Where,

AFC = Actual field capacity, ha h^{-1}

A= Total transplanted area, ha

T= Total operating time for transplanting, h

3.4.1.3. Field efficiency

It is the ratio between the productivity of a machine under field conditions and the theoretical maximum productivity and it can be calculated by the following equation:

$$E_f = \frac{AFC}{TFC} \times 100$$

... (Mehta *et al.*, 1995)

3.4.2. Fertilizer Distributor and Metering Device

3.4.2.1. Selection of Functional Component

The operating process of a fertiliser distributor consists of following phases:

i) Power transfer mechanism
ii) Transfer of fertilizer from the storage space
iii) Dispersal of fertilizer
iv) Even spreading over the field

i. Power transfer mechanism

A drive should be selected for taking the power from the transplanter for the operation of the metering device.

ii. Transfer of fertilizer from the storage space

The fertilizer is transferred to the delivery window by the friction and adhesion between the particles and the working surface of the disk. The fertilizer hopper should carry enough quantity of seed during the operation. The volume of fertilizer hopper has to be designed so that frequent filling of hopper should be avoided.

iii. Dispersal of fertilizer

The rate of removal of the fertilizer by the plate from the hopper depends upon the area of the window and average linear velocity of the particles calculated using the density of fertilizer. The fertilizer is fed in a continuous stream and hence its motion over the disk or roller is, by and large, governed by the nature of cohesion between particles.

iv. Even spreading of fertilizer

A metering device should offer a uniform spreading of fertilizer in the field. But in the case of basal application, it is broadcasted which minimizes the option of even spreading.

3.5. DEVELOPMENT OF VARIOUS COMPONENTS

3.5.1. Power transfer mechanism

The rear wheel was treated as the drive wheel. Here 1:1 speed ratio is considered.

The maximum rpm obtained from the wheel is given by

$$N = \frac{v}{2\pi r}$$

Where,

V is the velocity of the transplanter in m s^{-1}

r is the radius of the rear wheel in m

The drive was taken from the rear wheel by extending the hexagonal wheel hub to a length which doesn’t interrupt the drive mechanism by the front wheel. A sprocket was bolted to the hexagonal shaft which helped in transferring the power to the metering device through an intermediate shaft. The intermediate shaft consists of two sprockets, one for receiving power from the wheel and the other to transfer that power to the roller. Both the sprockets were bolted to a bearing holder.

3.5.2. Fertiliser Applicator

3.5.2.1. Main frame

The main frame of applicator was made-up by using M.S angle which was attached to transplanter. The main frame was made in rectangular shape with dimensions 1500 × 300 × 330 mm as length, breadth and height. The frame was designed to support hopper, metering shaft, sprocket and bearings. The frame was welded with four legs to attach the frame or applicator to front part of rice transplanter. Hopper was fixed on the main frame by welding. Metering shaft was passed below along the hopper. The main frame was welded with two bars to support metering shaft. Metering mechanism was driven by rear wheel. The rear wheel was connected to metering device by using chains and sprockets.

3.5.2.2. Fertiliser Box

Fertiliser box is a most important component of applicator for the storage of fertilizer mixture. The volume of fertilizer hopper has to be designed so that frequent filling of hopper should be avoided. The hopper was fabricated using G.I. sheet of 2 mm thickness. Hopper for basal fertiliser applicator was designed to hold and supply fertiliser to the flute of the metering rotor properly. . The cross-section of hopper was trapezoidal. The selection of the shape of hopper was done with the basic consideration that the hopper should carry desired quantity of fertilizer and the fertiliser should picked up easily towards the delivery roller.

The transplanter can carry about 12 mats and theoretically, it is said that 80 mats will cover an area of 1 acre. The capacity of the hopper depends upon the amount of fertilizer to be carried for applying 12 mats transplanting area and for 1 acre almost seven times refilling of mat is required. Here, we are considering the volume of the hopper for 48 mats, i.e., refilling of hopper at the fourth refill of the mat.

Volume of the fertilizer box is given by,

$$V = 4 \times \text{Volume of fertilizer applied per } m^2 \times \text{Area covered by 12 mats}$$

Considering a trapezoidal cross section, dimensions of the hopper is determined using the following equation.

$$\text{Volume of the hopper} = \frac{1}{2} (H \times (a + b)) \times L$$

Where,

H is the height of the hopper in m

L is the required length of the hopper in m

a and b is the top and bottom width of the hopper respectively in m

3.5.2.3. Metering Device

The metering mechanism helps to meter the fertiliser with its uniform rate and spacing. The metering mechanism maintains the application rate of the applicator. Fluted roller metering mechanism was selected, because the fertilisers were nearly powdered. The roller was made of nylon rod. Three roller were designed with 4 flutes each on metering roller. Fluted roller consists of a rotary element for displacing fertilizer from a stationary seed-guiding cup and is called a feed roller. Here, feeding cup is excluded. Fertilisers are picked up in the flutes and dropped on the top soil. While designing the metering mechanism for fertilisers, prime considerations were given to use simple design, not to cause any mechanical damage to fertilizer particles and easily pick required quantity of fertiliser per flute. The design of fluted roller metering device for applicator involved determining the number of flutes on metering roller, shape and depth of cup and depending upon the required planting pattern.

The dimensions of the flute can be calculated using the following equation,

$$D_f^2 = \frac{V}{n \times \frac{\pi}{4} \times \frac{1}{2} \times L \times N}$$

Where,

D_f is the diameter of a single flute in m

V is the volume of the fertilizer to be applied in one hectare in m^3

N is the number of flutes

L is the total length of the roller in m

N is the number of revolution of the rear wheel

Results and Discussions

CHAPTER IV

RESULTS AND DISCUSSIONS

The results of the investigations carried out for fertilizer properties, details of fertilizer applicator attachments developed for four wheeled riding type rice transplanters are described in this chapter. Based on the materials and methods of study, the fertilizer applicator attachment was fabricated.

4.1 FERTILISER REQUIREMENT

The commonly used fertilizers in wetlands are urea containing nitrogen (46:0:0), factumphos i.e., ammonium phosphate sulphate consisting of 16% N, 20% P and traces of sulphur (16:20:0) and muriate of potash with 60% K (0:0:60).

Theoretically,

$$\text{Amount of fertilizer material (kg)} = \frac{\text{Recommended rate } (kg\ ha^{-1}) \text{ x Area (ha)}}{\text{\% Nutrient in fertilizer material}}$$

From table 3.1, considering high yielding medium duration varieties in wetland (90+45+45 (kg/ha)), for one hectare land the total amount of fertilizer required is calculated as follows:

$$\text{Amount of factumphos (16:20:0)} = \frac{\text{45kg of } P_2O_5 \text{ per ha x 1 ha}}{0.2} = 225 \text{ kg ha}^{-1}$$

$$\text{Amount of urea (46:0:0)} = \frac{\text{90kg of N – kg from 225kg 16:20:0 per ha x 1 ha}}{0.46}$$

$$= \frac{90 - (225 \text{ x } 0.16)}{0.46} = 117.39 \text{ kg ha}^{-1}$$

Amount of potash (0:0:60) $= \frac{45\text{kg of } K_2O \text{ per ha x 1 ha}}{0.6}$ = 75 kg ha^{-1}

From table 3.2, the fraction of fertilizer to be applied as basal application is obtained. Therefore, for one hectare land, 58.7 kg urea, 37.5 kg of potash and 225 kg of factumphos is required. Due to the presence of nitrogen in factumphos, application of urea is limited.

Practically, for a blanket recommendation of NPK (90 + 45 + 45) kg ha^{-1} wetland medium duration varieties, the basal application of urea, factumfos and potash are 97.65 kg ha^{-1}, 281.25 kg ha^{-1} and 37.35 kg ha^{-1} respectively which is almost similar to theoretical value.

Therefore, total quantity of fertilizer utilized for basal application per hectare is 416.25 kg.

4.2 PHYSICAL PROPERTIES OF FERTILISERS

4.2.2 Angle of Repose

Angle of repose of different mixtures of fertilizer in the proportion used for basal application was determined using the standard method and the measured angle of repose is as follows:

TABLE 4.1 Angle of Repose of different fertilizer mixture

FERTILISER MIXTURE	HEIGHT OF HEAP (cm)	RADIUS OF HEAP (cm)	ANGLE OF REPOSE (degree)
Urea + Rajphos + Potash	8	14	30^{o}
Urea + Factumphos + Potash	4.5	13	19.1^{o}

Actually, for a particular fertilizer the angle of repose ranges from 40^{o} to 55^{o} according to Moring. But, in the study a mixture for basal application is used were an angle of 30° was obtained as the steepest angle of descent without slumping from table 4.1.

4.2.3 Bulk Density

The same mixture as used for the determination of the angle of repose was used for the determination of the bulk density.

TABLE 4.2 Bulk Density of different fertiliser mixture in (kg m^{-3})

FERTILISER MIXTURE	VOLUME OF CONTAINER (mL)	AMOUNT OF FERTLISER (g)	BULK DENSITY (g mL^{-1})
Urea + Rajphos + Potash	500	553.4	1.1068
Urea + Factumphos + Potash	500	461.6	0.9232

From table 4.2 average bulk density was obtained for the mixture as 1000 kgm^{-3}. This bulk density determination is useful in the design of fertilizer box.

4.3 CONCEPT OF DESIGN

4.3.1 **Study of KUBOTA Rice Transplanter**

The theoretical field capacity, actual field capacity and the field efficiency of the rice transplanter was calculated by operating it in a field.

4.3.1.1 Theoretical field capacity

The working width of the KUBOTA rice transplanter is 1.8 m and the operation speed of the same is 1.62 m s^{-1} i.e.,

$$\text{TFC} = \frac{w \times s}{c}$$

$$= \frac{1.8 \times 5.832}{10}$$

$= 1.05$ ha hr^{-1}

The theoretical field capacity of the transplanter was about 1.05 ha hr^{-1}

4.3.1.2 Actual field capacity

The time taken for covering a particular area was determined for the experimental field and it was noted as 0.57 hr for covering 1162.8 m^2.

$$AFC = A/T$$

$$= \frac{1162.8}{10000 \times 0.57}$$

$= 0.204$ ha hr^{-1}

After the operation, the actual field capacity was calculated to be 0.204 ha hr^{-1}.

4.4 DEVELOPMENT OF VARIOUS COMPONENTS

4.4.1 Power transfer mechanism

The maximum rpm obtained from the wheel is given by

$$N = \frac{v}{2\pi r}$$

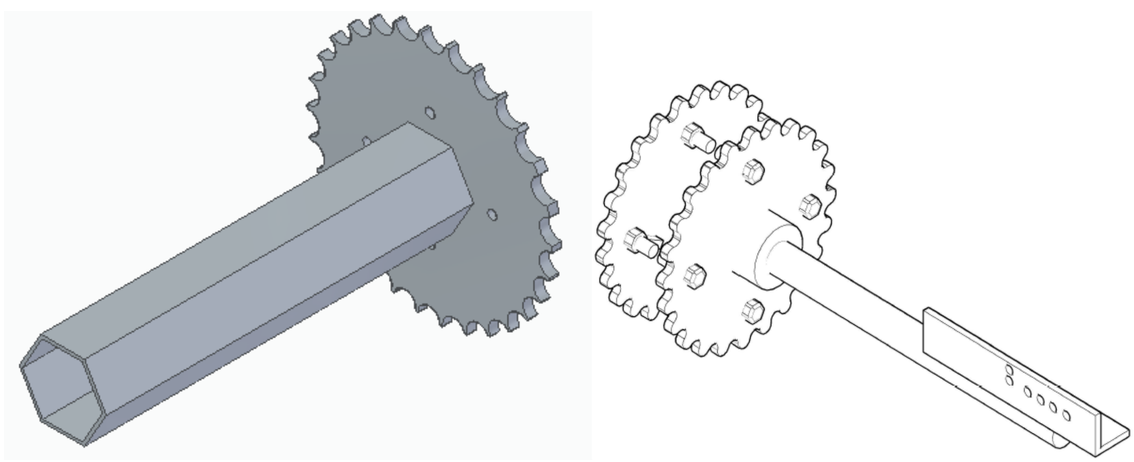
From table 3.3, it is noted that the operating speed of the transplanter is 1.62 ms^{-1} and the diameter of the rear wheel from where drive is obtained is 0.9 m.

$$N = \frac{1.62}{2 \times \pi \times 0.45}$$

$$= 0.57 \text{ rps}$$

$$= 34.2 \text{ rpm}$$

The power is transmitted through the drive wheel using the shaft as shown in figure 4.1 (a) to the metering device with the help of two sets of chain and sprocket mechanism (figure 4.1 (b)) for the accurate power transmission as shown in the plate 4.1. Here the power comes from the drive wheel, it drives the idler sprocket then the idler sprocket transmits the power to the shaft of metering device simultaneously.



(a) (b)

Figure 4.1: Schematic diagram showing (a) Hexagonal shaft hub for rear wheel with drive sprocket, and (b) Intermediate shaft with bearing and idler sprocket to transmit power from drive to shaft of metering device

Plate 4.1: Power transfer mechanism fabricated in the KUBOTA rice transplanter

The speed ratio of rear wheel and metering unit is calculated as:

$$\frac{N_1}{N_2} = \frac{N_2}{N_3} = \frac{N_3}{N_4}$$

Where,

N_1 = Number of teeth in sprocket of rear wheel = 43

N_2 = Number of teeth in first follower sprocket = 43

N_3 = Number of teeth in second follower sprocket = 43

N_4 = Number of teeth in sprocket of fertilizer metering device = 43

Thus the speed ratio is 1:1 for the whole metering assembly. The number of revolution per minute of the rear wheel was same as that of revolution in the fertilizer metering unit.

4.4.2 Fertiliser Applicator

Various components of the fertilizer applicator were designed and fabricated according to the design.

4.4.2.1 Fertiliser Box

As 80 mats are used for transplanting 1 acre of land, 12 mats will cover approximately 600 m^2 of land and 416.25 kg of fertilizer was applied per square metre of area.

$$\text{Volume of fertilizer applied per } m^2 = \frac{\text{Amount of fertilizer in kg}}{\text{Bulk density of fertilizer in kg per } m^3}$$

$$= (416.25 \times 10^{-4}) / 923.2$$

$$= 4.51 \times 10^{-5}\ m^3$$

Volume of the fertilizer box is given by,

$$V = 4 \times \text{Volume of fertilizer applied per } m^2 \times \text{Area covered by 12 mats}$$

$$= 4 \times 4.51 \times 10^{-5} \times 600$$

$$= 0.10824\ m^3$$

Considering a trapezoidal cross section, dimensions of the box is determined using the following equation.

$$\text{Volume of the fertilizer box} = \tfrac{1}{2}\,(H \times (a + b)) \times L$$

Let the height of the fertilizer box be 0.35 m and the working width of the transplanter will be the length of the storage unit which will be 1.8 m. Volume of the fertiliser was calculated as 0.10824 m^3, i.e., 100 kg of fertiliser. The angle of repose for fertilizer ranges from 40º to 55º (according to Moring), therefore it was taken as 50º.

The top width of the hopper, 'a' is calculated as H= a × tanθ

Therefore, a = 2 × (H/tanθ)

=2 × (0.35 / tan50)

= 0.587 m

Then, the volume of the fertilizer box = ½ (0.30 × (0.587+b)) × 1.8

0.10824 = ½ (0.30 × (0.587+b)) × 1.8

Which gives the bottom width as, b= 0.09 m

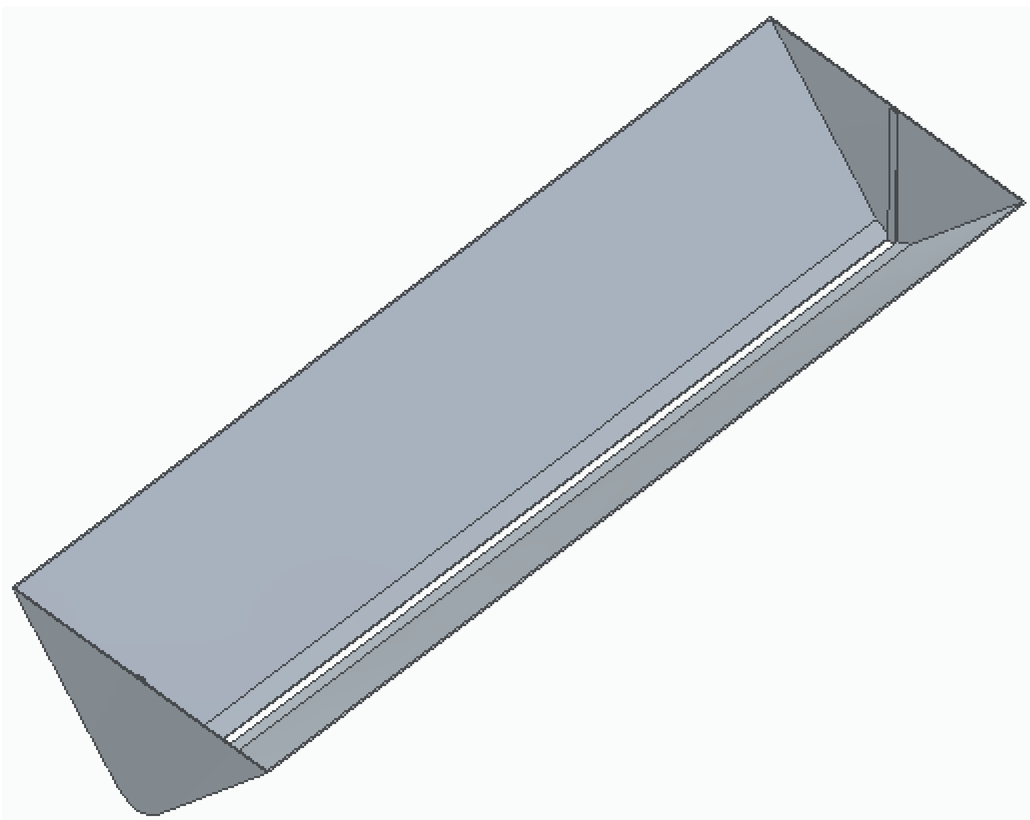


Figure 4.2: Schematic representation of fertilizer box with feeding slot

Plate 4.2: Fertiliser box being attached to the transplanter

4.4.2.2 Metering device

As the speed ratio is taken as 1: 1, the same number of revolutions will be transferred as that of the rear wheel. The number of revolutions covered by the rear wheel can be calculated.

Circumference of rear wheel $= 2\pi r$

$= 2 \times \pi \times 0.45$

$= 2.827 m$

Area covered in one revolution = Cirumference × Width of operation

$= 2.827 \times 1.8$

$= 5.09\ m^2$

Number of revolution of rear wheel to cover one hectare land $= 1/\ (5.09 \times 10^{-4})$

$= 1965$

Thus, knowing the volume of fertilizer to be applied for 1 ha land and number of revolutions covered in 1 ha can be used to calculate the volume of flutes.

The dimensions of the flute can be calculated using the following equation,

$$D_f^2 = \frac{V}{n \times \frac{\pi}{4} \times \frac{1}{2} \times L \times N}$$

$$D_f^2 = \frac{0.451}{4 \times \frac{\pi}{4} \times \frac{1}{2} \times 1.8 \times 1965}$$

$$= 8.1 \times 10^{-5}$$

Therefore, $D_f = 9 \times 10^{-3}$m

$\approx$ 1cm

Figure 4.3: Schematic diagram of metering device with shaft

Plate 4.3: Fabrication of metering unit with power transferring sprocket and shaft

Plate 4.4: Developed fertilizer metering device for the transplanter

Summary and Conclusions

CHAPTER V

SUMMARY AND CONCLUSION

Mechanization in rice transplanting is utmost important to overcome labour shortage, agronomical requirements and delay in transplanting. For proper growth and higher yields, application of fertilizer is very essential. The fertilizers were applied in paddy field in two or three splits. The farmer's practice of broadcasting was one day before transplanting or just before transplanting. In wetland paddy cultivation, only 30-40% of fertiliser applied is successfully utilized (Datta *et al*., 1978). The remaining fertilizer was wasted by runoff, leaching, evaporation and de-nitrification. Very few manually operated fertiliser applicators are used for application of fertilizer. To save the time, money and avoiding labour shortage problem an attempt was made to develop fertiliser applicator attachment for 4- wheel drive riding type rice transplanter.

The developed fertiliser applicator attachment consists of fertilizer box, metering mechanism, and power transfer system. The components were designed, developed and fabricated as per considerations. This could transplant six rows of rice plants at one time and fertilizer was incorporated with soil. Thus, it is worthwhile to recommend the machine to farmers.

Suggestions for future works:

- The present design of fertilizer applicator attachment doesn't have a system for engaging and disengaging the metering unit while taking turns. Thus a proper clutch mechanism is to be incorporated.
- Design optimization in terms of shaft diameter, frame cross section etc. is to be done.

- Fertilisers have a great effect due to the moisture content in the environment. An enclosure for the fertilizer metering mechanism is to be provided for reducing losses.

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DEVELOPMENT OF FERTILISER APPLICATOR FOR 4- WHEEL DRIVE RICE TRANSPLANTER

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ABSTRACT

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ABSTRACT

Mechanization in rice transplanting is utmost important to overcome labour shortage, agronomical requirements and delay in transplanting. For proper growth and higher yields, application of fertilizer is very essential. The fertilizer was applied in paddy field in two or three splits of equal dose. The farmer's practice of broadcasting was one day before transplanting or just before transplanting. In wetland paddy cultivation, only 30-40% of fertiliser applied is successfully utilized (Datta *et al*., 1978). The remaining fertilizer was wasted by runoff, leaching, evaporation and de-nitrification. Usually the fertilizer is applied manually. To save the time, money and avoiding labour shortage problem an attempt was made to develop fertilizer applicator attachment for four wheel drive rice transplanter.

The developed fertiliser applicator attachment consists of hopper, metering mechanism, chain and sprocket system. The components were designed, developed and fabricated as per considerations. The overall dimensions of frame of fertiliser applicator were 1500 × 300 × 330 mm as length, breadth and height respectively and constructed using mild steel. The fertilizer box was designed for carrying around 100 kg of fertilizer at a time and was designed such that it is refilled after every fourth refilling of mat. It was having a height of 0.35 m and was 1.8 m long and attached to the frame. The speed ratio considered was 1:1. Fluted roller type metering device was constructed using nylon rod for the transfer of fertilizer to the field. The metering rate is adjusted by provided a required depth of flute. All the components were assembled as required.