DESIGN AND DEVELOPMENT OF A LIME APPLICATOR ATTACHMENT TO TRACTOR OPERATED ROTAVATOR

By,

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(2014 - 18 - 115)

DEPARTMENT OF FARM POWER MACHINERY AND ENERGY

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

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THESIS

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

KERALA, INDIA

2017

DECLARATION

I hereby declare that this thesis entitled **"Design and development of a lime applicator attachment to tractor operated rotavator"** is a bonafide record of research work done by me during the course of research 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.

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Certified that this thesis entitled **“Design and development of a lime applicator attachment to tractor operated rotavator”** is a bonafide record of research work done independently by **Mr. Salsan, K (2014-18-115),** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to him.

Place: Tavanur | **Dr. Preman, P. S.**
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We, the undersigned, members of the advisory committee of **Mr. Salsan, K (2014-18-115)** a candidate for the degree of Master of Technology in Agricultural Engineering majoring in Farm Power and Machinery agree that the thesis entitled **"Design and development of a lime applicator attachment to tractor operated rotavator"** may be submitted by **Mr. Salsan, K.,** in partial fulfilment of the requirement for the degree.

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LIST OF SYMBOLS AND ABBREVATIONS

Abbreviations/Notation	**Description**
%	Percentage
°	Degree
AICRP	All India Coordinated Research Project
Anon.	Anonymous
cm	Centimetre (s)
CAD	Computer Aided Design
et. al	And others
Fig.	Figure
g	Gram (s)
GI	Galvanized iron
ha	Hectare
ha h^{-1}	Hectare per hour
hp	Horse power
h	hour
i. e.	That is
ICAR	Indian Council of Agricultural Research
IS	Indian standard
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	Kilogram
kg h^{-1}	Kilogram per hour
kg cm^{-2}	Kilogram per centimetre square
kg ha^{-1}	Kilogram per hectare
km h^{-1}	Kilometre per hour
KW	Kilo Watt

$l\ h^{-1}$	Litre per hour
$l\ ha^{-1}$	Litre per hectare
m	metre
min	minutes
mm	Millimetres
MS	Mild steel
MT	million tonnes
Nos.	Numbers
pH	hydrogen ion concentration
PoP	Package of Practice
rpm	Revolutions per minutes
Rs.	Rupees
$Rs\ ha^{-1}$	Rupees per hectare
s	second
SS	Stainless steel
viz.	namely

CHAPTER I

INTRODUCTION

Green revolution in India has contributed numerous new varieties of crops and fertilizers for better agriculture. It helped India to attain major positions among other countries. In India the total food grain production during the year 2014-15 was 257.07 million tonnes, it is less compared to year 2013-14. During 2013-14 the production was 265.57 million tonnes which is lowered by 8.5 million tonnes (Dangar *et al.*, 2014). If we move to the rice production it also reduced to 3.61 million tonnes compared to the previous year. In 2013-14 the rice production was 106.65 million tonnes and in 2014-15 it is reduced to 103.04 million tonnes.

The major problem is that soil fertility is reducing year by year. The primary reason is the high level of acidity in the soil. Acidity will reduce the plant growth. It inhibits the absorption of the plant nutrient like nitrogen, phosphorus and potassium. For plants like legumes they can’t grow in the acidic soils. For easy absorption of nutrients from the soil lime application is needed. Lime application of soil will be reduce the acidity of the soil. Proper liming is one of the most crucial crop management activity. Excess lime application to soil will also affect the soil productivity.

The soil acidity is the major constraint for rice soil in wetland region in Kerala. The unique morphology, climate, hydrology and other environmental factors lead to the formation of acidic soils. The principle factor is the nature of parental material. The soil types in Kerala have developed from acidic parental rocks under the humid tropical environment. The high rainfall and humidity will rapidly wash away the bases from the soil. Seventy per cent of the soils in Kerala are weathered lateritic soil. These soils have pH ranging from 4.5 to 6.0, whereas the waterlogged areas like Kole, Kaipad and Kuttanad region land have ultra-acidic soil, having pH range less than 3.5. These are the main regions for paddy cultivation in Kerala. Regular liming practices are needed as part of the soil fertility management strategies to augment food production in Kerala state.

There are several reasons for the changes due to acidity of soils. Leaching of land due to high rain fall, minerals loss during the crop removal and the major problem is that high rate of application of modern chemicals to the field in terms of fertilizers and herbicide, which are the major contributors. The chemical fertilizers will nourish the plants and microbes but it will also harmfully affect the soil structure and the life span of soil. Major problem is that they are concentrated and water soluble.

The best time of lime application on field is during ploughing, since no crop was there. Addition of Calcium and Magnesium rich materials to soil in various forms, including limestone, lime and dolomite is known as liming. Liming neutralizes soil acidity and increases activity of soil bacteria. When the pH is lower than 5.5 the addition of lime is absolutely necessary. When pH varies between 5.5 and 6.5 liming is advisable. In paddy lime is applied at a rate of 600 kg ha^{-1} in two split doses. The first dose of 350 kg ha^{-1} as basal dressing is applied at the time of first ploughing, and the second dose as top dressing about one month after sowing/transplanting at a rate of 250 kg ha^{-1} (KAU, 2011). But, oversupply of lime may result in harm or damage to plant life. Lime is a basic chemical, the effect of it makes the soil more basic which in turn neutralizes the soil.

Crop yields can be significantly affected by soil pH. The pH of the soil plant-root zone influences the capacity of plants to obtain essential nutrients from the soil. In the event that the soil pH decreases beyond a certain level, the solubility of Aluminum and Manganese increases, bringing toxicity which lead to lower crop yield. Soil acidity influences plant growth in different ways. Toxicity brought on by increased mobility of soil Aluminum, is the one of the serious impacts.

The major benefit of liming is that, it will improve the physical, chemical and biological properties of soil. It reduces the toxicity of Manganese and Aluminum ions, improves soil microbial activity, make a better structure to soil by changing the physical condition and increases the symbiotic nitrogen fixation by legumes etc. It also provides Calcium and Magnesium ions when these nutrients are deficient at lower pH and also improves nutrient availability of the soil. When pH changes to a range of 6.0 - 7.0 the availability of the Phosphorus and Molybdenum also increases, and absorption of other micronutrients increases while pH decreases. It also helps to enhance the herbicide effectiveness.

Usually lime is being applied manually for all crops. In addition to the non-uniformity in application, the manual application of lime causes health hazards so that labours are reluctant to do this job. Moreover it is a costly practice and present labour cost is more than Rs. 700 for male worker in Kerala. Manual lime application followed by tractor ploughing makes an expense of more than Rs. 1900 per hectare. If this work could be done mechanically it will help the farmer to save money and reduce health hazards.

Hence, a mechanical means of lime application is inevitable. If a mechanical system is developed it will provide safe and hazard free application of lime in field. It will also be a cost effective method. Ploughing the field and lime application if done simultaneously will make the operation more cost effective, less time consuming and reduce the labor cost of the farmer. Hence, it is decided to design and develop a lime applicator attachment to tractor operated rotavator for lime application purpose.

An ideal lime application machine should be such that, it leads to reduction of drudgery and easy operation. Both ploughing and liming will be done in single operation. The machine should have uniformity in application. The machine must be available at affordable price to buyers and cheaper than imported machines used for the same purpose. The materials used for fabrication should be readily available. The machine should be adaptable to the all climatic conditions.

With these factors in view, the project was undertaken with the following objectives.

1. To design and develop a suitable metering mechanism for a lime applicator.

2. To develop a lime applicator attachment for tractor drawn rotavator.

3. To carry out field testing and evaluation of lime applicator attachment to a rotavator.

CHAPTER II

REVIEW OF LITERATURE

The past research works relating to the studies on paddy lime application, advantage of lime application, lime application method, different metering mechanisms, design criteria of different components and performance evaluation are reviewed in this chapter. This review helped towards the design of a metering mechanism and development of a proto type lime applicator as an attachment to tractor drawn rotavator. The literature reviews were grouped under the following sections.

1. Paddy lime application
2. Advantages of lime application
3. Studies on metering mechanism
4. Studies on design of components and development
5. Performance evaluation

2.1 Paddy lime application

Howeler and cadavid (1975) studied about yield reduction of the upland rice grown in acidic soil due to aluminum toxicity. The field experiment showed that the area required lime application.

Nayak and Prasanna (2007) made a study about soil pH and its role in cyanobacteria abundance and diversity in rice field soils. They selected 52 soil samples and conducted qualitative and quantitative studies. They understood that the highest percentage of abundance of heterocystous was observed in pH 8.1 and more Shannon's diversity in pH 6.9. In this study they observed optimal growth of cyanobacteria in pH range 7.0 – 10 with lower limit of 6.5 – 7.0.

2.2 Advantages of lime application

Valeur *et al*. (2002) tried to find the Sulphur mineralization in forest soil as influenced by the different rate of lime application, and they conducted laboratory experiments by incubation technique using the SO_4^{2-}. It helped to find the net Sulphur mineralization during leaching in incubation period. In these studies they treated the plots with dolomite the rate of 0 (D0), 0.16 (D1), 0.35 (D2), 0.88 (D3) kg m^{-2}. As a result they found that plot where highest lime application got lowest Carbon to Sulphur ratio and liming effect of Carbon & Sulphur mineralization is just opposite D0 > D1 > D2 > D3.

Caires *et al*. (2006) conducted a study during the period of 1998 to 2003 in southern Brazil, about the lime application in the establishment of nodal system for grain crop production. He evaluated the grain production and soil properties after the application of dolomite lime.

Johnson *et al.* (2010) studied on variable-rate lime application in Louisiana sugarcane production systems. They investigated the variable rate lime application in the 3 years sugarcane crop cycle, in 3 locations. The results from the three experiments showed that lime application methods consistently improved sugarcane yields. They also found that the variable rate lime application method gave higher sugar cane yield compared to the conventional model.

Moore *et al*. (2012) conducted a response study about the dolomite application for soil and sugar maple after 15 years period of time. In 1994 for the study they applied dolomite lime into the field. In those studies they found the soil responding strongly to lime. The organic carbon content, pH in forest, organic matter, Nitrogen concentration and C/N ratio changed linearly with the lime rate. After lime application for the 15 years the forest pH increased from 3.95 ± 0.08 and control treatment up to 6.25 ± 0.12. As the result they found that appropriate lime addition could correct the base cation deficiencies and gave beneficial effect and sugar maple nutrition, growth and regeneration.

Rakesh *et al.* (2014) studied the productivity, quality and soil health as influenced by lime in rice bean cultivars in foothills of North-Eastern India. The experiment used a split-plot design with four levels of lime (control, 0.2, 0.4 and 0.6 t ha^{-1}) in main plots and four rice bean cultivars (RBS-16, RBS-53, PRR-2, and RCRB-4) in sub-plots with three replicates. These area were sowed at a seeding rate of 30 kg ha^{-1} in September in 2010 and 2011. Lime was applied in the furrow 15 days before the sowing followed by fertilizer application. The results revealed that increasing levels of lime (in the furrow) from 0 to 0.6 t ha^{-1} significantly increased growth, yield attributes and yield. The area applied with high rate of lime at 0.6 t ha^{-1}, increased the grain, straw and biological yield etc. compared to the other level (0.2 and 0.4 t ha^{-1}).

2.3 Studies on metering mechanism

The metering devices are those that meter the seed, fertilizer or powder from the hopper and deposited it into the delivery systems and that conveys the things into the delivery bed. However, the metering mechanism parameters could be referred according to the previous literature as shown below.

Wanjura and Hudspeth (1969) reported that for easy free fall of seed to the bottom of the soil trench, the metering device on a seeder should be located as low as possible.

Sharma *et al*. (1983) designed and developed a single row seed cum fertilizer drill. It consists of a frame of dimension 40 × 40 × 3 mm, made up of mild steel angle iron and a rectangular box with a capacity of 5 kg for seed and fertilizer. They provided separated fluted roller assembly with both fertilizer and seed to ensure uniform dropping of seed and fertilizer.

Kepner *et al.* (1987) noticed that, metering the tuber seed flow has mainly two aspects. The one is the metering rate, and the other one was seeds must be signaled in precision planters. The metering rate refers to the number of seeds that are released from the hopper per unit time. To ensure the desired final plant population metering rate is important in any planter. The seeds must be signaled to allow placement of seeds at uniform spacing in each row.

Anon. (1986b) reported the development of tractor drawn cultivator planter for sowing maize and groundnut. The implement consist of nine tine tractor drawn cultivator attached with planting mechanism. Nine discs of 0.25 m diameter with eighteen cups per disc attached or mounted on a shaft at 0.225 apart formed the seed metering mechanism. A two stage chain and sprocket drive transmit the power from ground wheel to the main shaft. Depending on type of travel pattern to mark the next row over which next pass of planter has to start, a row maker was fitted on either sides of the cultivator. Forward operating speed of 0.94 m/s was obtained in the field trials which was slightly less than the recommended forward speed of 0.98 m/s (25 rpm of seed metering disc). On an average 4.0 ha was covered in eight hours and 90% of population was obtained. When compared to the conventional method the above implement saved 43.35 man hours per ha and 90% time.

Kepner *et al.* (1987) reported automatic potato planters have vertical, rotating picker wheels with devices to either pierce or grip individual seed pieces and then drop them into the furrow. Picker pin type is the most common type mechanism, it consists of two arms each arm or head of the picker wheel had two sharp picking pins that pierce a seed piece in the picking chamber carry it over to the front, and it releases the seeds above the furrow. The position of the picker pins was situated in each head, it is adjustable to accommodate various sizes of seed pieces. The speed ratio between the ground wheels and the picker wheels depends upon the spacing of seed pieces in the row.

Anon. (1988) developed and evaluated a tractor drawn direct seeder for upland rice. To change the seed rate the unit consisted of cup feed type seed metering mechanism. The speed of the seed metering discs were recorded to be less than 30 rpm or the peripheral speed of the cups to be less than 0.362 m s^{-1}. Field trials indicated that an established hill population of 65 hills per m^2 can be obtained using the seeder and 54 hills per m^2 by conventional method of broadcasting as against the recommended hill population of 66 hills per m^2. It also recorded an increase in yield of 10 to 20 % over broadcasting method.

Roller type feed seed metering mechanism have two rollers with 45^0 inclined ends, it is connected with the hexagonal shaft. Gap width has given for adjusting the roller. Rollers rotated on circular tube placed above the hopper. After conducting the performance evaluation of the study of positive feed mechanism worked satisfactory for the metering of wheat, barley, and lentil seeds. Also found a linear relation between the gap between the rollers and the seeding rate. For the satisfactory distribution the minimum gap should be 6 mm for wheat and 9.5 mm for barley. For lentil seeds only 5 mm gap was needed. The mechanism in the five row animal-drawn seed drill was got satisfactory results, (Bensal *et al.* 1989).

Vershney *et al*. (1991) reported that fluted roller for metering mechanism of seed and adjustable opening mechanism for fertilizer results better efficiency for placement of seed and fertilizer, and it opens new mechanism for seed cum fertilizer drill for better operating system.

Srivastava *et al.* (1995) showed that variable size orifices was the oldest technology for seed metering devices. Due to the simplicity of technology it was still in use for metering in many modern planting machinery. In this study they showed that, changing the orifice size regulates the volumetric flow rate proportionally. For clarifying, they added a seed hopper design which should have an active means to prevent bridging of the tuber seeds. After the study, they concluded and reported that the most popular systems for seed metering are the inclined planes, and the fluted wheel. These means are positioned at the bottom of the seed hopper, so that tuber seed can flow into the inlet opening orifice by gravity.

Mathanker and Mathew (2002) conducted a study and observed that picker wheel type and horizontal disk cell type metering mechanisms perform well under suitable working conditions. They tested planting mechanisms in various linear (peripheral) speeds, it resulted that while the linear speed varied from 5.5 to 18.1 m $min.^{-1}$, the percentage of cell filled varies from 28 to 43 %, physical damage from 6.5 to 16 % and missing cells percentage from 12 to 14.2 % respectively for the picker wheel type metering mechanism. And for the horizontal disc cell type metering mechanism, the linear speed varied from 5.1 to 21.7 m $min.^{-1}$, per cent cell filled varies from 80 to 99 and physical damage from 1 to 3 respectively. Hence they observed that picking wheel mechanism was found suitable for automatic ginger planters with optimum linear speed in the range of 10-12 m $min.^{-1}$ and horizontal disc cell mechanism was found suitable for semi-automatic ginger planters with optimum linear speed range of 5-8 m $min.^{-1}$.

Lukin *et al*. (2003) conducted a study to determine the optimal frequency and quality of the agricultural lime application to the low pH soil. For this studies they developed a model and found response to lime application with change of pH and the continuous cropping.

Jayan and Kumar (2004) investigated the design of planter in relation to the physical properties of seeds. They reported that in absence of devices for the positive removal of seeds from the cells of the plate, seeds drop by gravity and as the peanut seeds are non-spherical, they move slowly leading to the variation in seed spacing. In order to achieve the uniformity in seed spacing and accuracy in seed rate, it is essential to use the metering plate with size of cells matching to the size of seeds.

Maleki *et al. (*2006) evaluated seed distribution uniformity of a multi-flight auger as a grain drill metering device. This study intended to develop a multi-flight auger as a seed metering device for and feeding device for grain drills. Primarily they designed and evaluated the seed spacing at three travel speed. Then they found the coefficient of uniformity in the lab study. The design parameters were auger groove depth (and width), number of grooves or flights, auger outer diameter and rotational speed. After the study they understand uniformity increased with increasing outer diameter of auger, depth and width of grooves, number of auger flights and rotational speed of the auger. After that it was compared with the flouted-roller mechanism, then they found that the coefficient of uniformity of the multi-flight auger mechanism is significantly more than that of fluted roller mechanism.

Tola *et al.* (2008) worked on granular fertilizer application rate control system with integrated output volume measurement in precision agriculture. This study was to develop a fertilizer rate control system, using a real-time fertilizer discharge sensor to enable variable-rate application with a significant reduced error compared to current systems. They tested the fertilizer output rate for the different operating speed (0.45, 0.91 and 1.36 ms^{-1}) and distances (1, 2, 3, 4 and 5 m). In this test they understand that the fertilizer target rate and output were controlled precisely, and also the automatic setting for the target fertilization rate also performed well.

Ozturk *et al*. (2012) conducted a study about the optimization of seed flow evenness of fluted rollers used in seed drills, by using Taguchi method. The purpose of the study is to optimize the seed flow evenness in seed drills of the fluted feed rolls mechanism. Wheat was selected as the experimental crop. Test conducted according to Taguchi optimization method and L_9 orthogonal array is selected and selected three shape of fluted rollers having length 5, 10 and 15 mm and axis rotational speed 25, 30, and 35 min^{-1} respectively. The minimum coefficient of variation was obtained at the flute shape of trapezoid fluted roller, flute length of 15 mm and axis rotation speed of 35 min^{-1}. Coefficient of variation for wheat was obtained as 2.87 at the optimum conditions.

Kumar *et al.* (2014) designed and developed a power tiller operated seed-cum-fertilizer till drill machine for the purpose of simultaneous both seeding and ploughing. For this study they developed a seed-cum-fertilizer box for the tiller and four fluted roller as the metering mechanism for the fertilizer and simple knob mechanism for the seeds, and a ground wheel provided for taking drive for the metering mechanism. Four rigid tines were provided for seeding the seed and fertilizer for the grooves makes. As per the design consideration they fabricated and tested the machine. The machine gave satisfactory result.

Singh and Nikhade (2014) conducted an experiment on calibration and field performance of animal-drawn MPT seed cum fertilizer drill machine for paddy cultivation. For the sowing purpose the fluted roll was used as the metering mechanism. They conducted a Laboratory test to calibrate, and it was found that desired seed rate was 76.8 kg ha^{-1} at 10 mm exposure length of fluted roller. The desired seed rate was ensured by adjusting of the exposed length of flutes.

Guptha and vermal (2016) developed and tested a power tiller operated multi-crop seed cum fertilizer drill. For metering the seed and the fertilizer the metering mechanism has been modified by using nylon roller suitable for multiple use and for easy use. The performance of metering of different rollers was also found within acceptable range except in case of pea and found acceptable for sowing Wheat, Maize, Green gram, Bengal gram, Jowar and Rajmah crop. The performance of fluted roller mechanism for metering fertilizer (DAP) was also given desired range. It was from 36 kg ha^{-1} to 221 kg ha^{-1}.

2.4 Studies on design of components and development

The proper inclination of the conveying tube or chute will help easy transfer of the seeds or powder to the furrow or to the ground with correct timing.

Devnani (1991) showed that the inclination of the seed delivery tube from vertical was kept smaller than 20° provided easy free fall of the seed into the furrow opening.

Trapezoidal shape of seed and fertilizer boxes are generally used in the machine for easy flow of seed and fertilizer to the metering mechanism from the hopper bottom. While designing the hopper for the manually operated seed-cum fertilizer drill for wheat crop, the seed box side slope to the horizontal was made more than that of the angle of repose of wheat (23° - 28°) for easy flowing of seed to the metering mechanism (Sharma and mukesh, 2010).

2.5 Performance evaluation

Bensal *et al*. (1989) conducted a study using roller type seed metering mechanism in five row animal–drawn seed drill and reported the seed application rate in different parameters. They changed the gap width to 18.5mm, the seed drill shaft to wheat speed ratio was changed from 0.81 to 1.69 had gave a positive result for lentil seeds and wheat. But in the case of barley gave a highly variable seed rate. Therefore for barley they considered 18.5 mm gap and 1.69 speed ratio or 14 mm gap with 1.69 speed ratio.

Field study conducted on seed drill resulted that draft for the shoe type furrow opener was recommended a 20 kg_f for the light soil and 30-35 kg_f for the heavy soil (Devnani. 1991).

Analysis study on Naveen seed cum fertilizer drill of CIAE Bhopal showed best results in term of highest return and also cost-benefit ratio. Study showed that

Naveen seed cum fertilizer drill provides highest return of Rs.4693.75/ha and cost-benefit ratio of 1.35 (Behera *et al*. 1995).

Qasim and Verma (1995) studied on Indira seed drill and gave the information that Indira seed drill cover 0.8-1.0 ha per day with draft requirement of 25-30 kg_f. In this study it is found that Indira seed drill performed better for line sowing in loam clay soil.

The field capacity of a farm machine was the rate at which it performs its primary function that is, the number of hectares that can be worked per hour or the number of tones of that could be harvested per hour. Measurements or estimates of machine capacities were used to schedule field operations, power units, and labour, and to estimate machine operating costs. The most common measure of field capacity for agricultural machines was expressed in hectares covered per hour of operation (Hanna. 2001).

Macmillan (2002) defined wheel-slip as the proportional measure by which the actual travel speed of the wheel falls short of (or exceeds) the "theoretical" speed and in terms of measurement. The prediction and presentation of tractor performance and slip was the single most important and these are dependent parameter.

According to Grisso *et al*. (2010) reported that farmers should consider numerous ways to estimate or measure the fuel consumption and reduce fuel consumption. But, the first step was to determine how much fuel is being used for a particular field operation and compared it to average usage. This measurement can be completed by filling the fuel tank of the tractor before and after a field operation and measure the difference, noting the number of hectares covered.

Depending on the type of fuel used in the machine and the amount of time a tractor or machine was used, fuel and lubricant costs will usually represent at least 16 per cent to over 45 per cent of the total machine costs (Siemens and Bowers. 1999). Reference from the above statement, Grisso (2010) analyzed on the fact that fuel consumption rate of machine plays an important role in the selection and management of tractors and other agriculture machineries.

Singh and Nikhade (2014) conducted an experiment study of calibration and field performance of MPT seed cum fertilizer drill machine for paddy cultivation. This test was conducted in Raipur IGKV in 0.05 ha field having the pH value 7.5 and the electrical conductivity 0.25. Field study resulted that the field capacity of the seed cum fertilizer was 0.085 ha h^{-1} and field efficiencies was 73.9 % respectively. During the field test they found the draft and power requirement of the seed-cum fertilizer drill was 53.7 kg_f and 0.4 hp.

Kumar *et al.* (2014) designed and developed a power tiller operated seed-cum-fertilizer till drill machine for the purpose of simultaneous seeding of wheat and ploughing the field. The main design consideration of the study were to place seed and fertilizer with tractive type of tynes while rotting in the field with rotary tiller. Both seeding and ploughing were carried out simultaneously. The seeding and ploughing done simultaneously reduced the fuel consumption of the machine and moisture content of soil. It also saved the cost of operations and the operational time.

Crop	**Wheat**
1. Fuel consumption, *l* h^{-1}	1.04
2. Theoretical field capacity, ha h^{-1}	0.13
3. Effective field capacity, ha h^{-1}	0.11
4. Operational speed, km h^{-1}	1.67
5. Wheel slip, %	8.00
6. Cost of operation, Rs ha^{-1}	1413.00

(Kumar *et al*. 2014)

Guptha and vermal (2016) developed and tested a power tiller operated multi-crop seed cum fertilizer drill. After the field test of the machine they reported that the wheel slip of power tiller was found to be 2.08 per cent and wheel skid of the machine was found to be 16.96 per cent. Draft requirement of the machine was measured as 55 kg_f and field capacity was 0.137 ha h^{-1} with field efficiency of 72 per cent. They analyzed that wheel slip and wheel skid measured was quite acceptable range and draft requirement of the machine was within the acceptable range of power tiller.

CHAPTER III

MATERIALS AND METHODS

The methodology adopted for the design and development of a proto type lime applicator as an attachment to tractor operated rotavator, laboratory testing and protocol followed for the performance evaluation of the developed unit are detailed in this chapter.

3.1 PHYSICAL CHARACTERISTICS OF LIME

The physical characteristics of lime considered for this study are moisture content, fineness, angle of repose and bulk density. These characteristics are directly influencing the selection of metering mechanism of proto type lime applicator (Howard and Herbert., 1963; Sacilik *et al.*, 2007; Zewdu and Solomon., 2007).

3.1.1 Moisture content of lime

Moisture content is the percentage of water present in a given lime sample (Ajayi, 2012). The variation in amount of moisture content in the lime is affecting its discharge through the metering mechanism of proto type lime applicator. Moisture content was found out by oven dry method following standard test procedures (Punmia *et al.*, 2005) (Plate 3.1 (a) & (b)). According to Singh and Chowdhary (1997), the test was carried out by collecting lime sample in a clean container (initial weight was noted) and placed in an oven under controlled temperature between 105°C to 110°C for a time period of 24 hours (final weight was noted). The procedure was repeated and replicated for six samples. The moisture content of lime was calculated by following expression (Rao, 1994; Murthy, 1995; Ajayi, 2012).

$$\text{Moisture content of lime (wb), percentage} = \frac{w_i - w_f}{w_i} \times 100 \quad \text{………... (3.1)}$$

where,

w_i = initial weight of the lime, gm

w_f = final weight of the lime, gm

3.1.2 Fineness of lime

Particle size analysis helps to found out the percentage of various sizes of particles in the dry sample (Punmia *et al.,* 2005). The fineness of lime affects the discharge of lime through the metering mechanism of proto type lime applicator. The particle size analysis of the lime was done using sieve analysis method with the help of mechanical sieve shaker. In the sieve shaker, the sieves were arranged in an order of 2 mm, 1 mm, 600 µm, 425 µm, 300 µm, 212 µm, 150 µm, and 75 µm sizes (IS: 460-1962) (Plate 3.2 (a)). The shaking is performed for 10 min. duration. The duration of shaking depends on the size and shape of the particles. The lime retained in each sieve was then weighed and calculate the uniformity coefficient. (Plate 3.2 (b)).

3.1.3 Angle of repose

Angle of repose, is nothing but the angle made by the material with the horizontal surface when piled from a known height. It is expressed in degree. The angle of repose influences the design of hopper of proto type lime applicator. For measuring the angle of repose, the lime sample was filled into a conical cylinder and kept it horizontal. The conical cylinder was then raised slowly allowing the lime powder to flow out and take up a natural slope in the form of cone. (Sahay and Singh, 1994). The angle of repose was calculated by the following expression (Mohsenin, 1996).

$$\text{Angle of repose, } \theta = \tan^{-1}\left(\frac{H}{r}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.2)}$$

where,

θ = the angle of repose, degree

H = the height of heap, mm and

r = the radius of the heap, mm

(a) Dry hot oven (b) Determination of weight

Plate 3.1 Determination of moisture content by hot oven method.

(a) Mechanical sieve shaker (b) Determination of weight

Plate 3.2 Sieve analysis of lime sample using mechanical sieve shaker.

3.1.4 Bulk density

Bulk density is the total mass of lime per unit of its total volume (Punmia *et al.,* 2005). The bulk density of lime decides requirements of hopper volume of proto type lime applicator. It was found out by measuring the volume of known weight of lime samples and the mean value was taken. The bulk density of the lime sample was calculated by the following expression (Punmia *et al.*, 2005; NLA, 2007).

$$\text{Bulk density } (\delta),\ \text{kg m}^{-3} = \frac{M}{V} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

where,

M = Total mass of the lime, kg

V = Volume of container, m^3

3.2 APPLICATION RATES OF LIME FOR PADDY

The application rate of lime for paddy was selected according to the Kerala Agriculture University's package of practices and recommendations. For paddy, a total quantity of 600 kg ha^{-1} of lime should be applied in two split doses. The first dose of 350 kg ha^{-1} as basal dressing is applied at the time of first ploughing. The second dose at the rate of 250 kg ha^{-1}as top dressing is to be applied about one month after sowing/transplanting (KAU, 2011). The present study is dealing with the basal application of lime using proto type lime applicator.

3.3 SELECTION OF METERING MECHANISM

Metering mechanism is the major part of sowing machine and its function is to distribute seeds, fertilizers, lime etc. uniformly at the desired rates (Sharma and Mukesh, 2010).

The types of metering mechanisms used in seed drills and seed cum fertilizer drills are flutted roller, cup-feed, star type, screw type, auger type etc. (Sharma and Mukesh, 2010). Since, the physical appearance of the lime is in a fine textured form and large amount of lime is to be discharged through the metering mechanism for paddy crop, the above type of metering mechanism could not be used for present study. Instead, a single shaft baffle type metering mechanism was selected and fabricated. The functionality checking of the selected metering mechanism was carried out in laboratory.

3.4 FUNCTIONAL MODEL OF LIME APPLICATOR

The functional model consist of hopper, frame, pair of bearing with case, single shaft baffle type metering mechanism, discharge chute, agitator, handle and sprocket and chain drive (Fig. 3.1). The functional model of lime applicator was tested for its suitability and uniform discharge at laboratory conditions (Plate 3.3).

3.4.1 Hopper

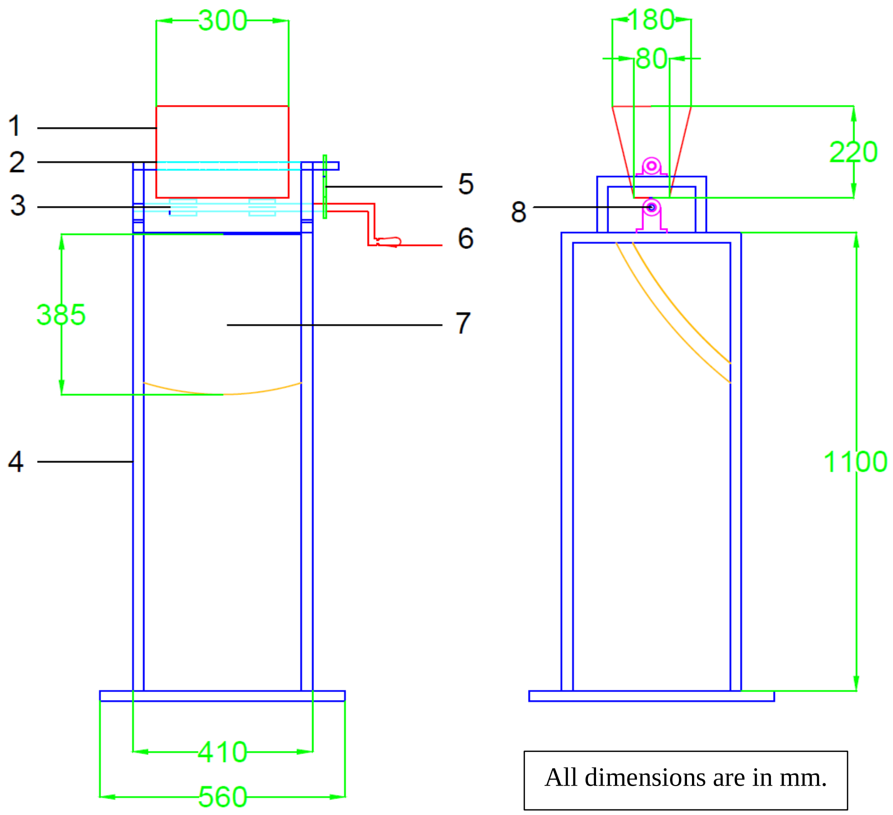
A trapezoidal shape was generally used for hopper in seed drills and seed cum fertilizer drills (Sharma and Mukesh, 2010). Considering the angle of repose of lime, a trapezoidal shape was selected for the hopper in the functional model lime applicator. The hopper was fabricated with 16 gauge GI sheet. The size of the hopper was 300 × 180 mm and 300 × 80 mm respectively at top and bottom with a height of 220 mm. Two numbers of openings of size 65 × 10 mm were provided at the bottom of the hopper for the discharge of lime (Plate 3.4 (a)).

3.4.2 Frame

For fixing all the components of functional model of lime applicator, a rectangular frame was selected. It was fabricated from 12.5 × 12.5 mm GI square pipe of 410 mm respectively for length and width with a height of 1100 mm (Plate 3.4 (g)).

3.4.3 Bearing with case

Friction between rotating components of machines would lead to severe wearing of its rotating components. Considering frictional resistance and smooth rotation, two pair of P 204 (Plate 3.4 (b)) bearing with case was selected and used for smooth function of agitator and metering mechanism in functional model lime applicator.



1. Hopper
2. Agitator
3. Single shaft baffle type metering mechanism
4. Frame
5. Sprockets and chain
6. Handle
7. Discharge chute
8. Bearing with case

All dimensions are in mm.

Fig 3.1 Functional model of lime applicator

1. Sprockets and chain
2. Single shaft baffle type metering mechanism
3. Handle
4. Frame
5. Hopper
6. Agitator
7. Discharge chute

Plate 3.3 Functional model of lime applicator

3.4.4 Single shaft baffle type metering mechanism

Considering the fineness and uniformity in application of lime, single shaft baffle type metering mechanism was selected for functional model of lime applicator. This metering mechanism was fabricated with four rectangular pieces of MS sheet of size 60 × 10 mm welded at periphery of MS shaft of 20 mm diameter. The metering mechanism was provided below the two number of rectangular openings provided beneath the hopper. It was also provided with a 50 mm diameter sprockets and chain drive. A handle was given to rotate the metering mechanism manually. The speed ratio between the drive handle and the metering shaft was kept 1:1 (Plate 3.4 (e)).

3.4.5 Discharge chute

For discharging lime coming from metering mechanism a discharge chute was selected. It was fabricated from 18 gauge MS sheet in a size of 280 × 360 mm. Considering the angle of repose of lime, the discharge chute was fixed below the metering mechanism at an angle of 50° (Plate 3.4 (f)).

3.4.6 Agitator

For smooth flow of lime from hopper bottom to metering mechanism, a stirring action was necessary in the lime. Hence, an agitator was selected. It was made by of welding L shaped 10 mm MS rod at a spacing of 50 mm on the periphery of MS shaft of length 450 mm and diameter 20 mm. The drive for rotation of agitator was taken from the shaft of metering mechanism with sprockets and chain (Plate 3.4 (c)).

3.4.7 Handle

A handle was selected to rotate the metering mechanism manually to conceptualize the working of the model of lime applicator. It was made of wood of length 120 mm and diameter 25 mm.

3.4.8 Sprocket and chain drive

A pair of sprocket and chain drive was used for transmitting the rotational power from the handle to the metering mechanism and from metering mechanism to the agitator. Sprockets of 50 mm diameter were fixed on shaft of both metering mechanism and agitator at a speed ratio 1:1 (Plate 3.4 (d)).

3.5 DESIGN OF PROTO TYPE LIME APPLICATOR ATTACHMENT TO TRACTOR OPERATED ROTAVATOR

Based on literature review and laboratory studies the following theoretical design considerations are considered and discussed.

3.5.1 Design considerations for the development of proto type lime applicator

The following assumption were considered for the design of proto type lime applicator attachment to tractor operated rotavator.

i. The discharged lime should be thoroughly mixed with soil by rotavator.

ii. The total power requirement should not exceed the horse power of general purpose tractor.

iii. The operating width of the lime applicator should cover the track width of tractor.

iv. Should not cause soil compaction which might be affected with the growth of crop.

v. The lime applicator should be simple in operation.

vi. The designed lime applicator should have auto-driven metering mechanism.

vii. Easy to manufacture and cheap in cost.

(a) Hopper

(b) Bearing with case

(c) Agitator

(d) Sprockets and chain

(e) Single shaft baffle type metering mechanism

(f) Discharge chute

(g) Frame

Plate 3.4 Components of functional model of lime applicator

3.5.2 Design of functional components of proto type lime applicator

3.5.2.1 Design of hopper for proto type lime applicator

A trapezoidal shape was selected to the hopper of the lime applicator to enable a free flow of lime towards the metering mechanism.

Length of the seed hopper (L) = Effective width of the lime applicator

Effective width of lime applicator = Effective width of the rotavator

= 160 cm

Application rate of lime for paddy = 350 kg ha^{-1} (KAU, 2011)

Assume the tractor speed is 2.6 km h^{-1} and field efficiency 80 percent.

Actual field capacity of lime applicator =

$$\frac{\text{Speed} \times \text{effective width of lime applicator} \times \text{field efficiency}}{10}$$

where,

Speed, km h^{-1} = 2.6

Field efficiency, percent = 80

Effective width of lime applicator, cm = 160

= 1.6 m

$$= \frac{2.6 \times 1.6 \times 0.8}{10}$$

= 0.33 ha h^{-1}

Amount of lime applied in field in one hour

= Discharge rate of lime × Area covered × Time

where,

Discharge rate, kg ha^{-1} = 350

Area covered, ha = 0.33

Time, h = 1

Amount of lime applied in field in one hour $= 350 \times 0.33 \times 1$

$= 115.5 \text{ kg h}^{-1}$

Volume of hopper $= \frac{\text{Weight of lime}}{\text{Bulk density}}$

where,

Bulk density of lime, kg m^{-3} = 914

Weight of lime, kg h^{-1} = 115.5

Therefore,

Volume of the hopper (V_s) $= \frac{155.5}{914}$

$= 0.126 \text{ m}^3$

Volume hopper obtained as per above calculation was 0.126 m^3, considering difficulty in handling the lime applicator during actual use with this volume half the size of hopper was selected. Hence the volume was 0.065 m^3.

Volume of the hopper = Area × Length of hopper

Total area of hopper, (At) = Area 1 + Area 2 (From Fig. 3.2)

Area 1 $= t_1 \times h_1$

Area 2 $= \frac{1}{2}(a + a + l + l) \times h_2$

At $= t_1 \times h_1 + \frac{1}{2}(a + a + l + l) \times h_2$

$= t_1 \times h_1 + \frac{1}{2}(2a + 2l) \times h_2$

From (Fig.3.2) $\frac{h2}{l} = \tan\theta$

$h_2 = 1 \times \tan\theta$

Also,

$t_1 = 2l + a$ (From Fig. 3.2)

So the total area become,

Area $= t_1 \times h_1 + \frac{1}{2}(2a + 2l) \times (1 \times \tan\theta)$

Assume the value of t_1 = 0.46 m (t_1 is taken as the same or less than the width of rotavator for equally distribution of hopper weight on the rotavator) and a = 0.08 m and also take the value of θ = 54° (angle of repose of lime was 48°, here θ was more than that angle of repose.)

Hence,

$$2l = t_1 - a$$

$$= 0.46 - 0.08$$

$$l = 0.19 \text{ m}$$

Volume of hopper $= [t_1 \times h_1 + \frac{1}{2}(2a + 2l) \times (1 \times \tan\theta)] \times L$

$$0.065 \text{ m}^3 = [0.46\, h_1 + \frac{1}{2}(2(0.08) + 2(0.19)) \times (0.19 \times \tan 54)]\ 1.6$$

$$0.065 \text{ m}^3 = 0.736\, h_1 + 0.113$$

h_1 = 0.065 = 0.07 m (0.01 m is added with 0.07 m. hence, to fix door to open)

$$h_1 = 0.07 + 0.01 = 0.08 \text{ m}$$

$$h_2 = l \times \tan\theta$$

$$= 0.19 \times \tan 54$$

$$= 0.26 \text{ m}$$

Total height (H) $= h_1 + h_2$

$$= 0.08 + 0.26$$

$$= 0.34 \text{ m}$$

The height of frame is taken as the minimum height at which operator would see whole unit attached lime applicator from the operator's seat. Therefore the frame height is assumed as 0.85 m. Length (L) and width (W) of the hopper door is considered as same as the length and top width of the hopper.

3.5.2.2 Design of metering mechanism

The selected metering mechanism was single shaft baffle type metering mechanism. The baffles are welded on the periphery of 20 mm diameter MS shaft. The metering mechanism was housed inside a cylindrical metallic casing of length 200 mm and 75 mm inside diameter (Fig. 3.3).

Therefore,

The height of a single baffle (H), cm

= Inside diameter of casing – shaft diameter – 2a

where,

a = the clearance between baffle and cylindrical casing.

= [7.5 – 2 – 2(0.15)] / 2

= 2.60 cm

Four number of baffles were fixed on the periphery of MS shaft at 90°.

Length of single baffle, L = Length of cylindrical casing – 2b

where,

b = the clearance between baffle and cylindrical side of casing.

= 20 – (2 ×1)

= 18 cm

For discharge of lime from metering mechanism four slits were made at bottom of cylindrical casing.

Dimension of the slits 18 cm length and 0.3 cm width.

Area of one slit = 18 × 0.3 = 2.4 cm^2

Total area = 4 × 2.4 = 9.6 cm^2

The application rate of lime decided by the volume of lime discharged from four slits. It was depend upon the rpm of the baffle type metering mechanism rotation. From one revolution of metering mechanism four baffle were rotated. Therefore,

Volume of lime discharged = Height of baffle × Area of slit

$= 2.6 \times 9.6 = 24.96 \text{ cm}^3$

Volume of lime discharge during one revolution, maximum

$= 24.96 \times 4 = 99.84 \text{ cm}^3$

3.5.2.3 Design of lime discharge chute

Discharge chute was made for the discharge of the lime from metering mechanism to ahead of rotavator front side.

Height of the chute (C)

= Total height of frame – (hopper height + height of metering mechanism) / sin θ

where ,

θ = angle of discharge chute with horizontal = 61° (which was greater than the angle of repose of lime)

C = 0.85 – (0.34 + 0.108) / sin 61

Height of the chute (h) = $\frac{40.2}{\sin 61}$

= 45.9 cm

Width of chute = Length of cylindrical casing + 2c

where,

c = the clearance between discharge chute and metallic cylinder.

= 20 + 2(1) = 22 cm

To avoid hindrance to PTO shaft connection, middle chute alone was made in inverted 'Y' shape. Dimensions were the same.

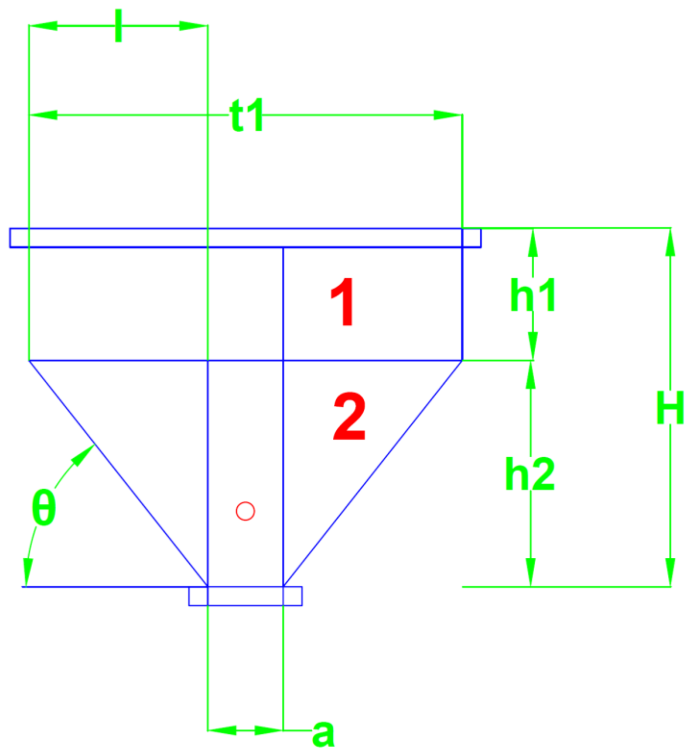


Fig. 3.2 Cross section of hopper

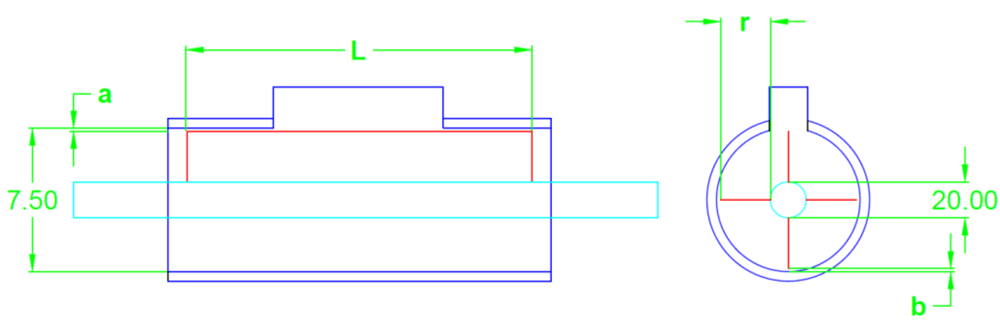


Fig. 3.3 Metering mechanism

3.6 DEVELOPMENT OF PROTO TYPE LIME APPLICATOR AS AN ATTACHMENT TO TRACTOR OPERATED ROTAVATOR

The proto type lime applicator was developed to attach with a tractor drawn rotavator for applying lime for paddy. The proto type lime applicator consists of a hopper, main frame, metering mechanism, lime discharge chute, agitator and a sprocket and chain with a drive box-assembly. The drive to the proto type lime applicator was taken from the tractor-PTO via roatavator drive shaft. The proto type lime applicator attached with rotavator was easily hitched to tractor through three-point linkage. It was easy to transport with tractor. Fig. 3.4 and Plate 3.5 shows the prototype lime applicator.

3.6.1 Hopper

GI sheet of 16 gauge thickness was selected for making the hopper. The GI sheet which is comparatively less in chemical reaction with the lime in long use. Considering the angle of repose of lime, the hopper was made at an angle of 54° which was more than that of the angle of repose of lime. A hinged door made from GI sheet of 18 gauge thickness with frame of 25 mm diameter MS pipe was fitted at the top of the hopper. The door helped for filling and preventing lime from drift. MS rod of 10 mm diameter and 400 mm length was fitted to the door to keep it open. As a reinforcement, two rectangular frames of 1600 × 460 mm and 1600 × 80 mm in sizes made from 25 × 25 mm GI square pipe were fitted respectively at the top and bottom of the hopper (Fig. 3.5).

3.6.2 Main Frame

The main frame accommodated all the components of the proto type lime applicator. It was made from 50 × 37.5 mm and 25 × 25 mm GI square pipe. Four pieces of MS plate of size 100 × 90 mm and thickness 5 mm were welded on the main frame respectively at four bottom sides. During fitting the proto type lime applicator the plates were bolted respectively on four side of the rotavator (Fig. 3.6).

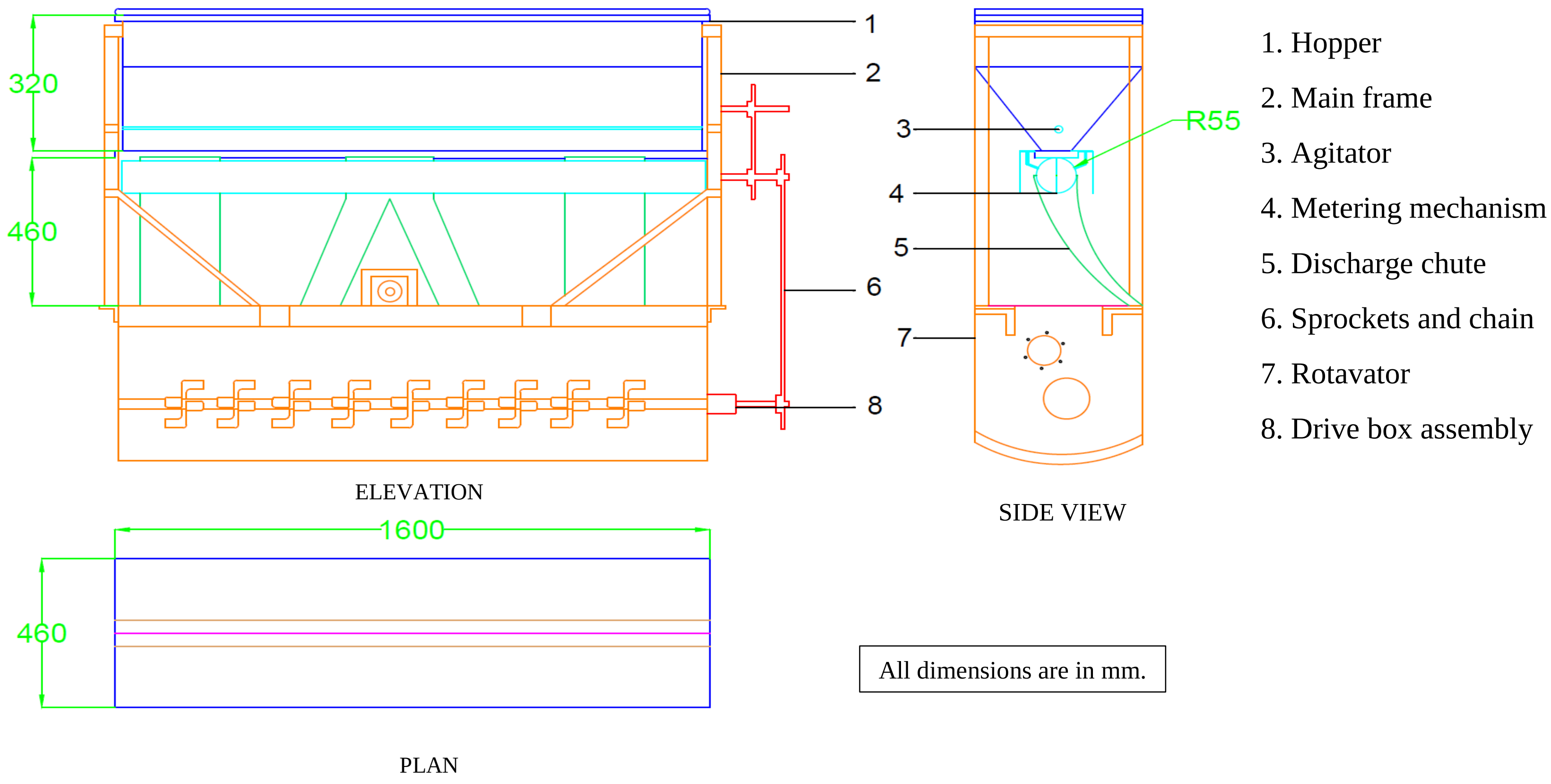


Fig 3.4 Developed proto type lime applicator

Front view

Side view

Plate 3.5 Different views of proto type lime applicator attachment

3.6.3 Metering mechanism

Considering the fineness and uniformity in application of lime, a single shaft baffle type metering mechanism was selected for prototype lime applicator. The metering mechanism was fixed below the three number of opening provided beneath the hopper. The metering mechanism was fabricated using four rectangular piece of MS sheet of size 180 × 32 mm welded on the periphery of 20 mm MS shaft. The metering mechanism was placed inside a cylindrical casing made from GI pipe. The thickness, length and inside diameter of cylindrical casing were 5 mm, 200 mm and 75 mm respectively. Under the cylindrical casing, the four slits are provided for discharge of lime. The metering mechanism was rotated inside the cylindrical casing and metered the lime outside. The drive shaft was made up of MS shaft of 20 mm diameter. Three number of metering mechanism was selected in tune with the application rate of lime for paddy (Fig. 3.7).

3.6.4 Lime discharge chute

The lime discharge chute was made for the safe disposal of the lime from metering mechanism to ahead of rotavator. The discharge chute was made up of GI sheet of 18 gauge thickness. Each discharge chutes were provided under each metering mechanism of the lime applicator. The discharge chutes were stand in vertical in position under the metering mechanism and its ends were exposed ahead of rotavator at an angle 61^{o} with the horizontal, because the lime was delivered in front of the blades, for proper mixing with soil during ploughing. Both left and right discharge chutes were in a dimension of 460 × 220 × 120 mm and 460 × 220 × 30 mm in respectively at top and bottom portions. To avoid hindrance to PTO shaft connection, middle chute was made in inverted ‘Y’ shape but the dimensions were same (Fig. 3.8).

3.6.5 Agitator

The purpose of agitator was to stir the lime to enable easy flow of lime from hopper bottom to metering mechanism. Due to the moisture affinity of the lime, it becomes clods and is jammed in the hopper. Agitator enable easy flow of the lime to metering mechanism through the holes provided under the hopper. It was made by fastening two rectangular pieces of 10 × 10 mm size welded GI wire mesh with dimension of 1580 × 50 mm in double layer on the periphery of 20 mm diameter MS shaft.

3.6.6 Sprockets and chain with drive box assembly

The drive box assembly was used to transfer rotary power from the rotavator shaft to metering mechanism. The drive box assembly was made up of 100 mm length SS pipe of 75 mm diameter. Inside the SS pipe, an hexagonal socket of 30 mm side length made from 5 mm thick MS flat and it was welded and filled inside the pipe. The hexagonal socket couple with rotating nut inside of rotavator and transmit the power to a MS shaft of length 200 mm and diameter 20 mm, over which the sprocket was fixed. For friction free rotation of the MS shaft a P 204 ball bearing was used inside the SS pipe. Fig 3.9 shows the sprockets and chain with drive box assembly.

Sprockets in desired speed ratio were selected and used in tune with the application rate of lime for paddy.

3.7 ROTAVATOR

Tractor drawn rotavator is an excellent secondary rotary tillage implement for paddy cultivation. It churns, mixes and disperses the finer soil particle in muddy conditions. It works on the principle of rotary motion. It takes drive from tractor PTO shaft and transmit it to tynes through reduction gears (Sharma and Mukesh, 2010). For the present study, the rotavator used was SRT-5 model made by M/s Shaktiman Farm Implements Pvt. Ltd, Rajkot, Gujarat. It is having a working width of 1600 mm, weight 499 kg. It consists of 36 L shaped blades with multi speed gear drive system.

3.8 PRIME MOVER

The proto type lime applicator as an attachment to tractor drawn rotavator requires sufficient torque for both ploughing and lime application. Considering the torque requirement a 65 hp John Deere tractor was selected for the present study. The specifications of the tractor was shown in Appendix IX.

3.9 SELECTION OF VARIABLES

The parameters of proto type lime applicator such as engine rpm and size of the sprocket for both agitator and metering mechanism were influenced the application rate of lime applicator. These parameters were optimized to achieve the lime application rate of 350 kg ha^{-1} (KAU, 2011). The selected independent variable for the study are speed of the tractor, speed ratio between rotavator and metering mechanism and speed ratio between rotavator and agitator.

3.9.1 Speed of the tractor (S)

Speed of the tractor selected as the variable for the study. It is directly influenced the application rate of lime. Speed of the tractor was selected as the combination of engine rpm of tractor and the forward gear speed, and it is measured in km h^{-1}.

3.9.1.1 Engine rpm of tractor (E)

It was the designed engine revolutions per minute, and the rpm range of selected 65 hp John Deere tractor is 800 – 2350. It was directly influenced the application rate of lime.

3.9.1.2 Forward speed (L)

It was the designed tractor distance covered by the tractor in unit time, and the speed range of selected 65 hp John Deere tractor is 0 – 30 km h^{-1}. It was directly influenced the application rate of lime.

3.9.2 Speed ratio between rotavator and metering mechanism (P)

It was the speed ratio between rotavator and metering mechanism of the proto type lime applicator. It was directly influenced the application rate of lime.

3.9.3 Speed ratio between rotavator and agitator sprocket (A)

It was the speed ratio between rotavator and agitator of the proto type lime applicator. It was directly influenced the application rate of lime so, it was selected as the variable for the study.

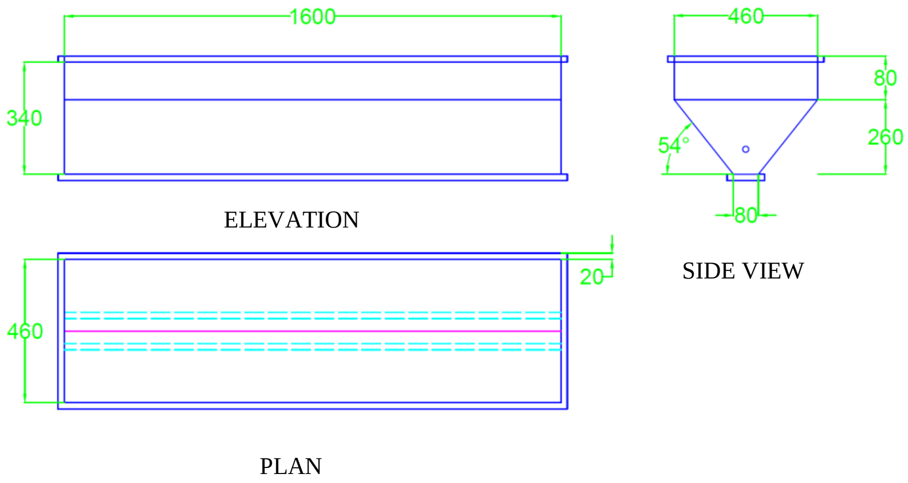


Fig. 3.5 Hopper

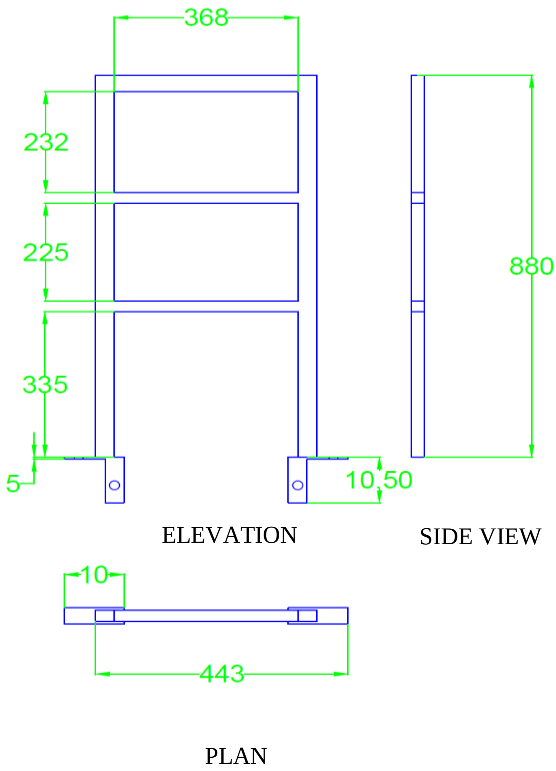


Fig. 3.6 Main frame

All dimensions are in mm.

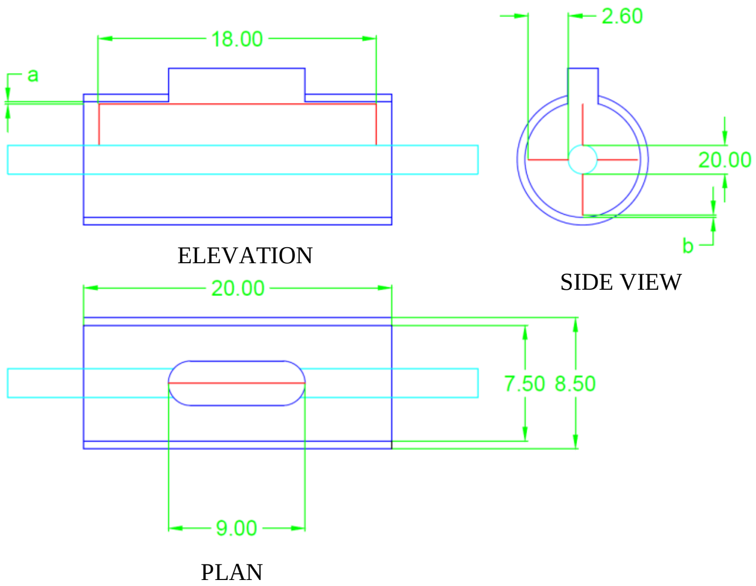


Fig. 3.7 Single shaft baffle type metering mechanism

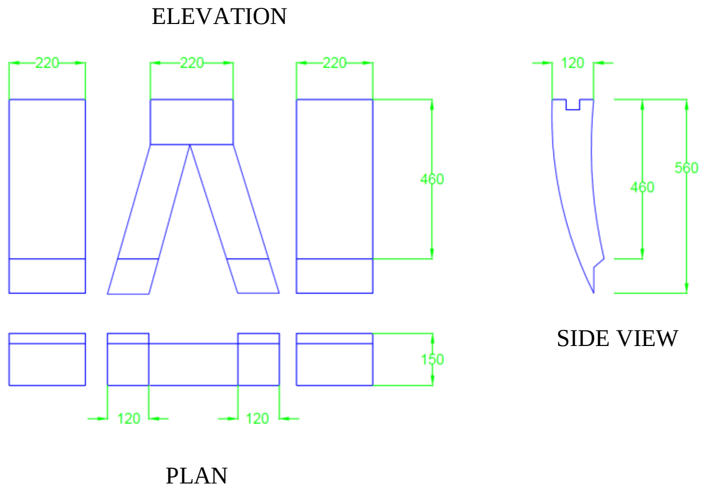


Fig. 3.8 Lime discharge chute

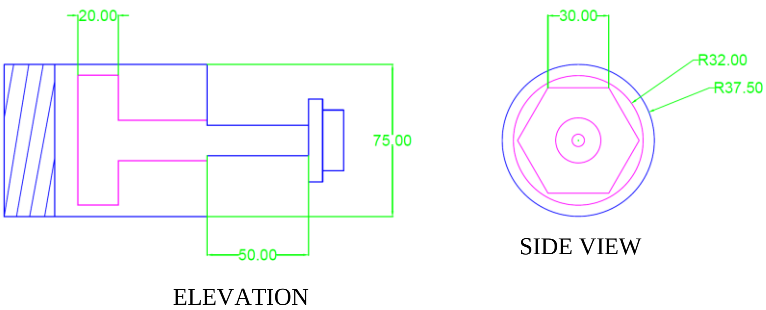


Fig. 3.9 Drive box assembly

All dimensions are in mm.

3.10 LEVELS OF VARIABLES

For each variable different levels were selected for the present study. The variables are speed of the tractor that is a combination of engine rpm and forward speed, speed ratio between rotavator and metering mechanism and speed ratio between rotavator and agitator. These three independent variables are influencing the application rate of lime. A total of 48 treatments and each one were replicated in three times.

Table 3.1 Description of levels of variables

Sl. No.	Description of variables	Selected levels	No. of levels
1	Speed of tractor, km h^{-1} (S)	2.40 (S_1) 2.60 (S_2) 2.48 (S_3) 2.80 (S_4) 2.56 (S_5) 2.90 (S_6) 2.61 (S_7) 3.10 (S_8)	8
a	Engine rpm of tractor (E)	1600 (E_1) 1800 (E_2) 2000 (E_3) 2200 (E_4)	4
b	Forward speed of tractor (L)	L1 L2	2
2	Speed ratio between rotavator and metering mechanism (P)	1 : 1.5 (P_1) 1 : 2.0 (P_2) 1 : 2.5 (P_3)	3
3	Speed ratio between rotavator and agitator (A)	1 : 1.5 (A_1) 1 : 2.0 (A_2)	2

Replication = 3

Total number of treatments = $8 \times 3 \times 2 \times 3 = 144$

3.11 LABORATORY TEST

Laboratory test of proto type lime applicator was conducted in research workshop, KCAET Tavanur. The proto type lime applicator as an attachment to tractor drawn rotavator was attached to 65 hp John Deere tractor through three-point linkage. It was lifted by the hydraulic system of tractor and conducted the laboratory test in different engine speed of the tractor with different speed ratios of metering mechanism and agitator.

3.11.1 Effect of selected levels of variables on application rate of lime

The effects of selected levels of variables on the application rate of lime at selected levels of engine rpm of tractor (E) at selected levels of variables viz. speed ratios of metering mechanism (P) and agitator (A) during laboratory test were noted.

3.12 LOCATION OF STUDY

The field was selected considering availability of water and appropriate amount of sunlight. Paddy was the major crop cultivated in the selected field during the previous years. The soil in the selected field was sandy loam. An area of 30 cent in (0.121 ha) ‘F’ block and 35 cent (0.141 ha) in ‘A’ block of Instructional Farm, KCAET, Tavanur was selected for the present study. The areas were situated respectively at 10.8549^{o} N latitude and 75.9879^{o} E longitude, 10.8561^{o} N latitude and 75.9900^{o} E longitude.

3.13 FIELD SOIL PROPERTIES

Application of lime in soil mainly depends upon the test results of the soil properties namely soil moisture content, bulk density and soil pH (Kalara, 1995; Robichaud *et al*, 2004).

3.13.1 Soil moisture content

Soil moisture content is the percentage of water present in a given soil sample (Ajayi, 2012). The soil moisture content in the field was tested by using a portable soil moisture meter. The moisture content of the different locations in the field were checked by using this equipment. The soil moisture content is expressed in percentage.

3.13.2 Soil bulk density

Bulk density is the total mass of the soil per unit of its total volume (Punmia *et al.,* 2005). Soil bulk density was determined by core cutter method. Cylindrical core samples were collected randomly from the field by core cutter. The diameter and length of core sampler were measured. The core sample was kept in a dry oven at 108° C for 8 hours. After taking out samples from oven, allowed for normal cooling and weighed by using balance. The soil bulk density was calculated by following expression ((Punmia *et al.,* 2005).

$$\text{Bulk density of soil, g cm}^{-3} = \frac{M}{V}$$

$$= 4M/\pi D^2 L \ldots\ldots\ldots\ldots (3.4)$$

where,

M = mass of the oven dried sample, gm

D = diameter of cylindrical core sampler, cm

L = length of cylindrical core sampler, cm

V = volume of cylindrical core sampler, cm^3

3.13.3 Soil pH

The soil pH is the measure of acidity or alkalinity in soils. pH is defined as the negative logarithm of the activity of hydrogen ions concentration in a solution (Anon, 2013 and Anon, 1999). The soil pH before and after the field test were measured using the portable pH meter.

Location were marked for collecting soil samples from the field and samples were collected from respective locations. The collected soil samples were mixed with distilled water. Kept it for setting. Way out the water and dipped the calibrated pH meter into in it (Anon, 1998). It shows the pH value of the solution in the equipment screen.

3.14 FIELD PERFORMANCE EVALUATION OF PROTOTYPE LIME APPLICATOR

The developed proto type as an attachment to tractor drawn rotavator lime applicator was tested for field performance. A John Deere 5065-E, 65 hp tractor was used to attach the proto type lime applicator for field evaluation. The field performance evaluation was carried out for 144 treatments of the combination of speed of tractor, speed ratios of metering mechanism and agitator.

3.14.1 Optimization of application rate of lime

From the laboratory test of proto type lime applicator, mean values of application rate of lime at selected levels of engine rpm (S), speed ratios of metering mechanism (P) and agitator (A) were selected and expressed in kg h^{-1}. The mean values were converted to kg ha^{-1} by dividing with field capacities obtained at selected levels of speed of tractor during field performance evaluation of proto type lime applicator.

3.14.2 Effect of selected levels of variables on application rate of lime

The effects of selected levels of variables on the application rate of lime at selected levels of speed of tractor (E) at selected levels of variables viz. speed ratios of metering mechanism (P) and agitator (A) during field performance evaluation were noted.

3.14.3 Fuel consumption

Fuel consumption of the tractor was the amount of fuel consumed to cover a known distance with lime applicator attachment. For measuring fuel consumption, an external fuel consumption measuring jar was attached with the tractor fuel tank to determine the fuel consumption of the tractor during performance evaluation of lime applicator. The fuel consumption was measured in both l h^{-1} and l ha^{-1}.

Plate 3.6 Portable soil moisture meter

Plate 3.7 Soil sampling by core cutter

Plate 3.8 Portable pH meter.

3.14.4 Wheel slippage

Wheel slippage or travel reduction is defined as the distance travelled by the tractor in a given number of revolutions of the drive wheel decreases when the wheel slips. For finding slippage of tractor, the number of revolutions of rear wheel for 20 m with lime applicator and without lime applicator for all the treatments were recorded (Kepner *et al.*, 1987). For each number of counting revolutions, a chalk mark was made at a point of the tractor rear wheel. The slippage of the tractor in percentage was calculated by following expression.

$$\text{Wheel slippage, \%} \quad = \quad \frac{C-D}{C} \, X\, 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.5)$$

where,

C = Number of revolution of rear wheel for 20 m for loaded condition.

D = Number of revolution of rear wheel for 20 m for no load condition.

3.14.5 Theoretical field capacity

The theoretical field capacity was the area intended to cover per hour by an implement at rated speed (Kepner *et al.*, 1987). Effective width of proto type lime applicator and speed of the tractor were measured by standard test procedure. Theoretical field capacity (Ft) was calculated using following expression.

$$\text{Theoretical field capacity (Ft), ha h}^{-1} \quad = \quad \frac{SW}{10} \ \ldots\ldots\ldots\ldots\ (3.6)$$

where,

S = Average speed of machine, km h^{-1}

W = Rated width of machine, m

3.14.6 Actual Field capacity

The actual field capacity or effective field capacity (Fa) was determined by measuring the actual area covered by the proto type lime applicator per hour following standard test procedures (Kepner *et al.*, 1987; Metha *et al*, 2005).

3.14.7 Field efficiency

Field efficiency (Fe) is the ratio of effective field capacity to the theoretical field capacity (Kepner *et al*, 1987; Bakhtiari, 2009; Turbatmath, 2011). It is calculated by following expression.

$$\text{Field efficiency (Fe), \%} = \frac{Fa}{Ft} \times 100 \qquad \text{(3.7)}$$

where,

Fa = Actual field capacity of proto type of lime applicator, ha h^{-1}.

Ft = Theoretical field capacity proto type of lime applicator, ha h^{-1}.

1.15 STATISTICAL ANALYSIS

The statistical analysis of the study was conducted with the analysis of variance procedure, using factorial test. In this test, three variables namely speed of tractor (S), speed ratios of metering mechanism (P) and agitator (A) were selected. A completely randomized design of data were carried out by using 144 treatments from the combination of laboratory and field application rates of lime by proto type lime applicator. The data was statistically analyzed.

3.16 COST ECONOMICS

Fixed cost and variable cost of the proto type lime applicator attachment to tractor drawn rotavator was calculated as per the procedure described by IS: 9164-1979. From the field capacity of the proto type lime applicator, the cost of operation per hectare and cost of operation per hour was calculated (RNAM, 1983).

Similarly, conventional method of lime application was carried out by hand and area and time were recorded. Accordingly, capacity of the manual labours (man-hours ha^{-1}) was determined. Based on this, the cost of manual application of lime followed by tractor ploughing was also find out and compared with the cost of operation of the proto type lime applicator.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter deals with the results of physical characteristics of lime, design and development of functional model lime applicator and prototype lime applicator. Field performance evaluation of prototype lime applicator and its cost economics are also carried out and presented in this chapter.

4.1 PHYSICAL CHARACTERISTICS OF LIME

The Physical characteristics of lime such as moisture content, fineness of lime, angle of repose and bulk density which influenced the performance of the lime applicator were determined.

4.1.1 Moisture content of lime

The moisture content of lime sample calculated by oven dry method as explained in the section 3.1.1, was shown in Appendix I. The average value of moisture content of lime was 0.54 percent.

4.1.2 Fineness of lime

The fineness of lime was determined by sieve analysis as explained in section 3.1.2 and obtained data are given in Appendix II. A particle size distribution curve drawn using the data was shown in Appendix II.

4.1.3 Angle of repose

The angle of repose of lime was determined as explained in section 3.1.3 and it is found out as 48°. Based on this angle of repose, angle of hopper was decided.

4.1.4 Bulk density

Bulk density of lime was determined as explained in section 3.1.4 and it is found out as 0.914 g cm^{-3}. Based on this value, hopper volume was decided.

4.2 APPLICATION RATE OF LIME FOR PADDY

As explained in section 3.2, the application rate of lime for proto type lime applicator was decided as 350 kg ha^{-1} as basal dressing of paddy.

4.3 SELECTION OF METERING MECHANISM

For functionality checking, of a single shaft baffle type lime metering mechanism was fabricated as explained in section 3.3. It was tested in laboratory and found successfully in metering of lime.

4.4 FUNCTIONAL MODEL OF LIME APPLICATOR

A functional model of lime applicator consisting of hopper, frame, pair of bearing with case, single shaft baffle type metering mechanism, discharge chute, agitator, handle and sprockets and chain drive was fabricated and tested for its working. The specification of the functional model lime applicator was given in Table 4.1.

4.4.1 Hopper

A trapezoidal shape hopper was fabricated as explained in section 3.4.1. The shape of hopper was selected because, angle of repose of lime was 48° which is less than the angle of hopper 61° that found steady flow of lime from hopper to metering mechanism.

4.4.2 Frame

Frame was fabricated as explained in section 3.4.2 and all components of functional model lime applicator were fixed to it.

4.4.3 Bearing with case

A pair of P 204 bearing with case used in the functional model lime applicator was enabled smooth rotation respectively for metering mechanism and agitator.

Table 4.1 Specifications of functional model lime applicator

Serial no	Components	Dimension
1	**Hopper**	
	Shape	Trapezoidal
	Length, mm	300
	Top width, mm	180
	Bottom width, mm	80
	Height, mm	220
2	**Metering mechanism**	
	Type	Baffle type
	Length of shaft, mm	300
	Diameter of shaft, mm	20
	Length of baffle, mm	65
	Width of baffle, mm	10
	Height of baffle, mm	10
3	**Discharge chute**	
	Height, mm	385
	Width, mm	260
	Angle, degree	50
4	**Frame**	
	Height, mm	1100
	Width, mm	410
5	**Agitator**	
	Type	L shape
	Length of shaft, mm	300
	Diameter of Shaft, mm	20
6	**Rotating handle**	Wooden handle
7	**Sprocket and chain drive**	
	Speed ratio	1 : 1

4.4.4 Single shaft baffle type metering mechanism

A Single shaft baffle type metering mechanism was fabricated as explained in section 3.4.4. This metering mechanism helped to achieve successful in metering with respect to fineness and uniformity in application of lime.

4.4.5 Discharge chute

The discharge chute made for discharging lime from metering mechanism. It was fabricated as explained in section 3.4.5

4.4.6 Agitator

Agitator was fabricated as explained in section 3.4.6. Stirring action of the agitator ensured a smooth flow of lime from hopper bottom to metering mechanism.

4.4.7 Handle

Handle was fabricated as explained in section 3.4.7 enabled the functionality testing of the functional model of lime applicator and succeeded the same.

4.4.8 Sprockets and chain drive

As explained in section 3.4.8, sprockets were used to get desirable speed ratio to agitator and metering mechanism. Power was transmitted successfully to the agitator from the handle through the metering mechanism by sprockets and chain drive.

4.5 DESIGN OF PROTO TYPE LIME APPLICATOR ATTACHMENT TO TRACTOR OPERATED ROTAVATOR

The components of proto type lime applicator namely hopper, frame, metering mechanism and discharge chute were designed as explained under section 3.5. The design dimension of these components were shown in Table 4.2.

Table 4.2 Designed dimensions of the proto type lime applicator

Serial no.	Designed components	Dimension (mm)
1	**Hopper**	
	i. Shape	Trapezoidal
	ii. Total length, mm	1600
	iii. Top width, mm	460
	iv. Bottom width, mm	80
	v. Height of hopper, mm	320
	vi. Angle of repose, degree	54
	Hopper door	
	i. Length of door, mm	1600
	ii. Width of door, mm	460
2	**Main frame**	
	i. Height of frame, mm	880
	ii. Width of frame, mm	443
3	**Metering mechanism**	
	i. Type	Baffle type
	ii. Number of metering mechanism	3 nos.
	iii. Cylinder diameter placed the metering mechanism, mm	75
	iv. Diameter of the shaft, mm	20
	v. Number of baffle per each shaft	4 nos.
	vi. Angle with which each shaft, degree	90
	vii. Height of single baffle, mm	26
	viii. Length of each baffle, mm	180
4	**Lime discharge chute**	
	i. Total number of chute	3 nos
	ii. Height of the chute, mm	460
	iii. Width of chute, mm	220
	iv. Inclination of chute, degree	61

4.6 DEVELOPMENT OF PROTO TYPE LIME APPLICATOR AS AN ATTACHMENT TO TRACTOR OPERATED ROTAVATOR

The proto type lime applicator as attachment to tractor operated rotavator was fabricated as explained in section 3.6. the proto type lime applicator consist of a hopper, main frame, metering mechanism, lime discharge chute, agitator and sprockets and chain with a drive box assembly.

4.6.1 Hopper

The hopper was fabricated as explained in section 3.6.1. A slope of 54° greater than the angle of repose of lime 48° was selected to ensure steady flow of lime from the hopper to metering mechanism.

4.6.2 Main frame

The main frame was fabricated as explained in section 3.6.2. All components of the proto type lime applicator were fitted to the main frame.

4.6.3 Metering mechanism

The metering mechanism was fabricated as explained in section 3.6.3. It successfully discharged lime at desired application rate and uniformity.

4.6.4 Lime discharge chute

Lime discharge chute was fabricated as explained in section 3.6.4. It successfully disposed the lime coming from metering mechanism to ahead of rotavator.

4.6.5 Agitator

The agitator was fabricated as explained in section 3.6.5. It enabled the clods of lime to brake and successfully discharged it from hopper bottom to metering mechanism.

4.6.6 Sprockets and chain with drive box assembly

Drive box assembly was fabricated as explained in section 3.6.6. It was coupled with rotavator shaft and rotary power from the rotavator shaft to the agitator via metering mechanism was successfully transfered during operation of the proto type lime applicator attached with tractor.

4.7 ROTAVATOR

A SRT-5 model Shakthiman rotavator was used to attach the proto type lime applicator with tractor and successfully evaluated in both laboratory and field.

4.8 PRIME MOVER

A 65 hp John Deere tractor was used for the performance evaluation of the proto type lime applicator as an attachment to tractor drawn rotavator in both laboratory and field. The performance evaluation with the tractor was successfully carried out.

4.9 SELECTION OF VARIABLES

The variable selected for the study as explained under section 3.9 were speed of tractor, speed ratio between rotavator and metering mechanism and speed ratio between rotavator and agitator. Each treatment were replicated in three times.

4.10 LEVELS OF VARIABLES

The levels of variables as explained under the section 3.10 selected as follows,

(i) Speed of the tractor – 8 levels

(a) Engine rpm of tractor – 4 levels

(b) Forward speed of tractor – 2 levels

(ii) Speed ratio between rotavator and metering mechanism – 3 levels

(iii) Speed ratio between rotavator and agitator – 2 levels

Replication = 3

Total number of treatment = $8 \times 3 \times 2 \times 3$

= 144

A total of 144 treatment were studied.

4.11 LABORATORY TEST

Laboratory test of proto type lime applicator attachment to the tractor operated rotavator was successfully carried out in Research workshop, KCAET, Tavanur. The application rate of lime in each treatment was noted and given in Appendix V. Mean values of the application rate were calculated and given in Appendix VI.

4.11.1 Effect of selected levels of variables on application rate of lime

Fig. 4.1 shows the interactive effects of selected levels of engine rpm (E), speed ratios of metering mechanism (P) and agitator (A) on application rate of lime during laboratory testing of proto type lime applicator as an attachment to tractor drawn rotavator. From the Fig. 4.1, it is observed that the application rate of lime was increasing with increasing in engine rpm. It is because, when engine rpm increases rotavator speed also increases which in turn increased the rotational speed of metering mechanism and agitator that lead to more application rate of lime.

4.12 LOCATION OF STUDY

The field selected for the present study as detailed in section 3.12 was in ‘F’-block and ‘A’- block of Instructional Farm, KCAET, Tavanur.

4.13 FIELD SOIL PROPERTIES

Soil properties such as soil moisture content, bulk density and soil pH was detailed 3.13 were determined.

4.13.1 Soil moisture content

The soil moisture content was determined using the portable soil moisture meter as explained in section 3.13.1and was found out as 16.2 %.

4.13.2 Soil bulk density

Bulk density of the soil was determined by core cutter method as explained in section 3.13.2. Recorded values and its calculations were given in Appendix III. The average bulk density was 1.784 g cm^{-3}.

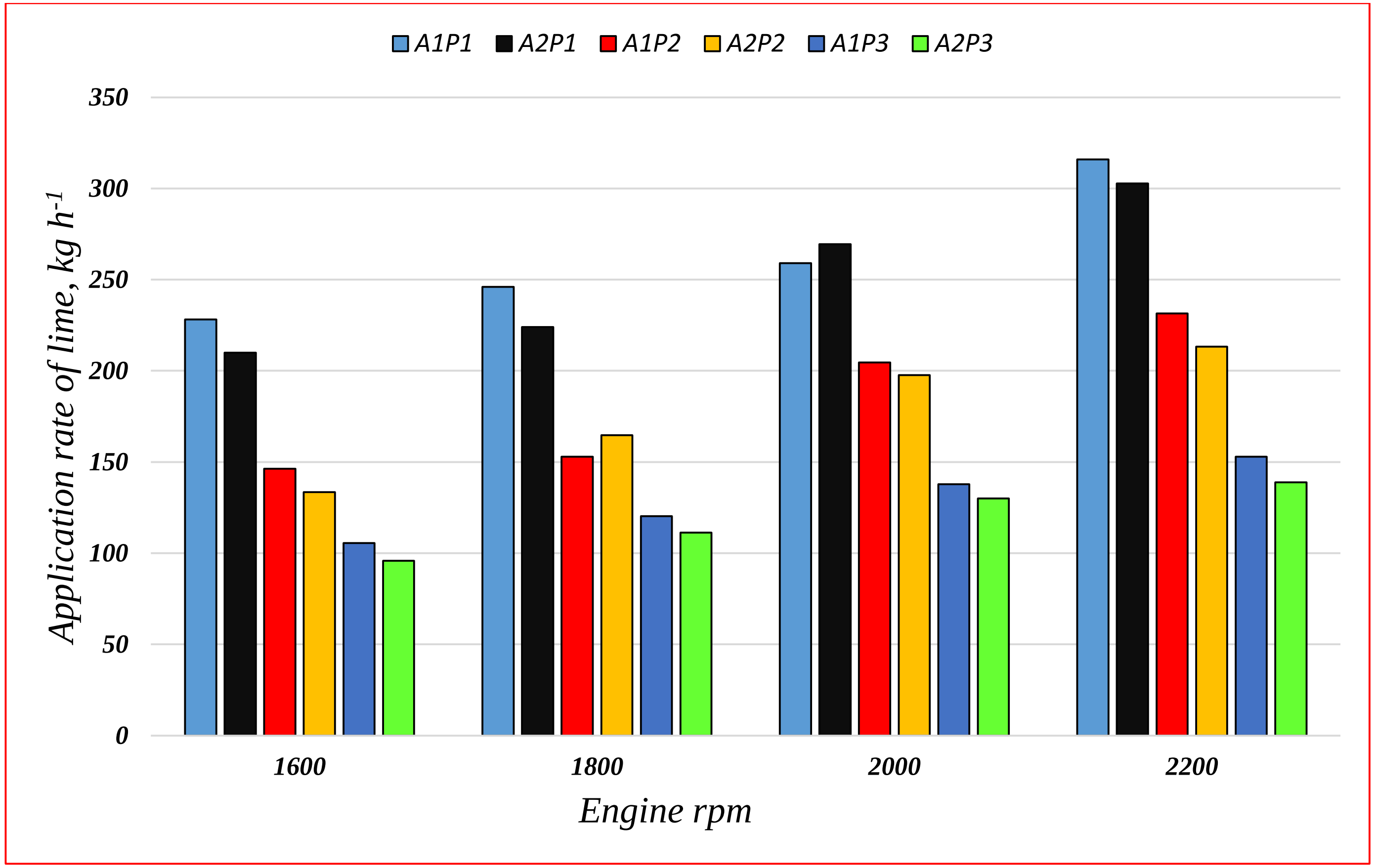


Fig. 4.1 Application rate of lime for selected levels of engine rpm (E) at selected levels of speed ratios of metering mechanism (P) and agitator (A) under laboratory test of proto type lime applicator.

4.13.3 Soil pH

The soil pH before and 7 days after the field test were measured using the portable pH meter as explained in section 3.13.3 and the values were given in Appendix IV. Fig. 4.2 shows the pH value before and 7 days after lime application. From the Fig. 4.2 it was observed that pH value was increased after application of lime. This was because of effective in co-corporation of lime with soil by using proto type lime applicator.

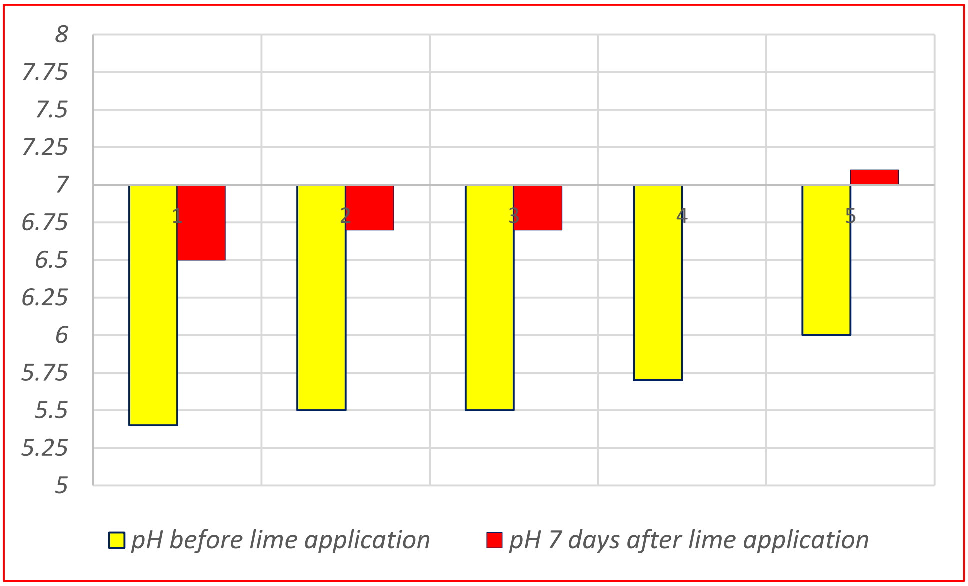


Fig. 4.2 Soil pH before and after lime application.

4.14 FIELD PERFORMANCE EVALUATION OF PROTOTYPE LIME APPLICATOR

The field performance evaluation of the proto type lime applicator as an attachment to tractor drawn rotavator was successfully carried out as explained under section 3.14. The application rate of lime for all 144 treatments were calculated and given in Appendix VII. Mean values of application rate were also calculated and given in Appendix VIII.

4.14.1 Optimization of application rate of lime

As explained in section 3.14.1 field capacities were found out and shown in Table 4.3. Accordingly, corresponding mean values of application rate of lime in kg ha^{-1} during the field performance evaluation of proto type lime applicator were found out and give in Appendix VIII.

Table 4.3 Field capacities of proto type lime applicator at selected levels of speed of tractor.

Engine rpm	Field capacity, ha h^{-1}	
	L_1	L_2
1600 (E_1)	0.36	0.39
1800 (E_2)	0.372	0.42
2000 (E_3)	0.384	0.435
2200 (E_4)	0.391	0.465

4.14.2 Effect of selected levels of variables on application rate of lime

Fig. 4.3 shows the interactive effects of selected levels of speed of tractor (S), speed ratios of metering mechanism (P) and agitator (A) on application rate of lime during the field performance evaluation of proto type lime applicator as an attachment to tractor drawn rotavator. From the Fig. 4.3, it is observed that the application rate of lime was increasing with increasing in engine rpm. It is because, when engine rpm increases the rotavator speed increases which in turn increased the rotational speed of metering mechanism and agitator that lead to more application rate of lime.

4.14.3 Fuel consumption

As explained in section 3.14.3 fuel consumption of tractor during performance evaluation of lime applicator was found out as 3.7 *l* h^{-1} and 26 *l* ha^{-1}.

4.14.4 Wheel slippage

The wheel slippage of tractor attached with lime applicator was found out as explained in section 3.14.4, and given in Appendix XI. The wheel slippage was 11.67 %.

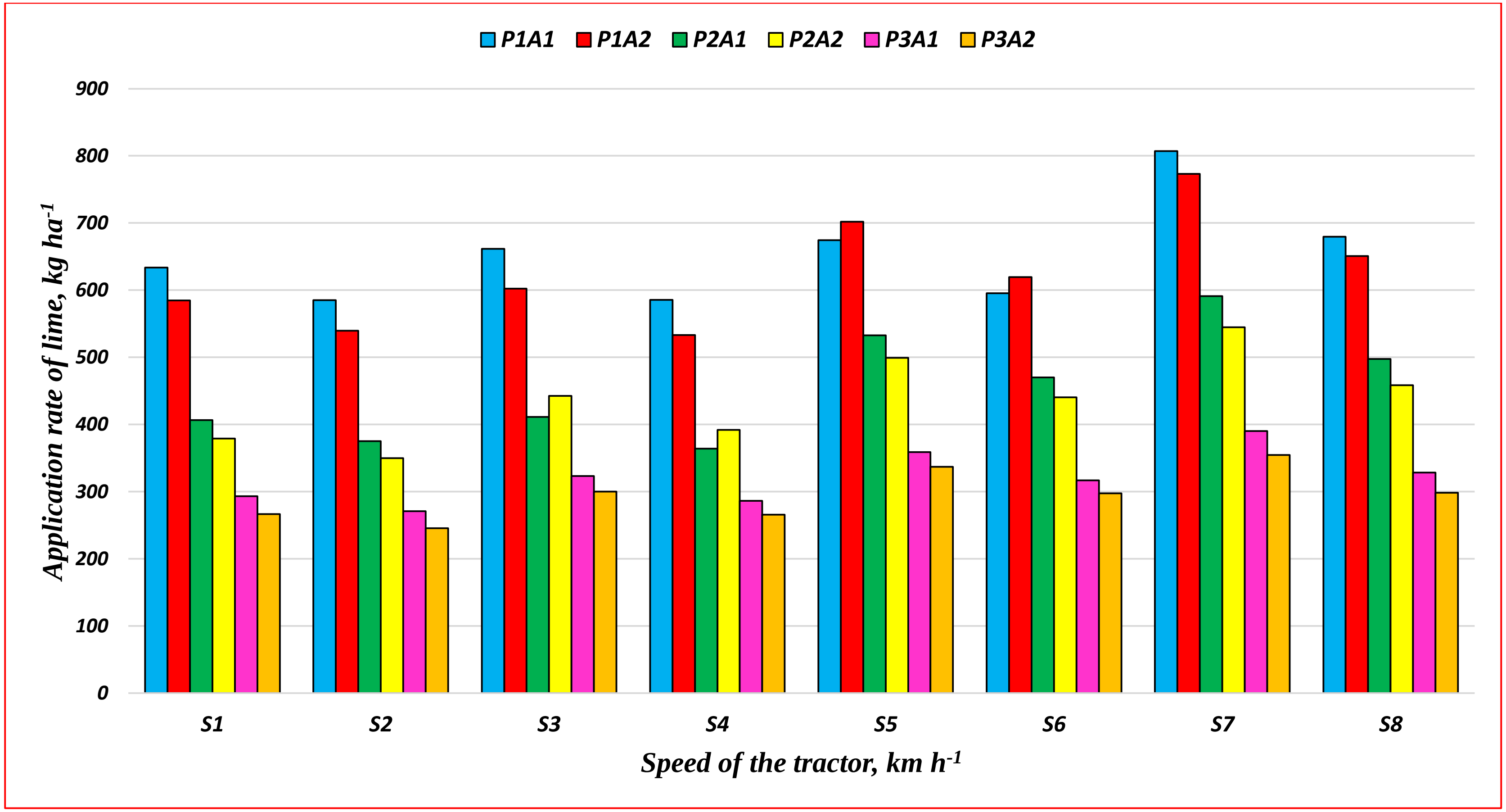


Fig 4.3 Application rate of lime for selected levels of speed of tractor (S) at selected levels of speed ratios of metering mechanism (P) and agitator (A) under field performance evaluation of proto type lime applicator.

4.14.5 Theoretical field capacity

As explained in section 3.14.5 the theoretical field capacity of the proto type lime applicator was found out as 0.39 ha h^{-1} and given in Appendix XI.

4.14.6 Actual Field capacity

As explained in section 3.14.6 the actual field capacity of the proto type lime applicator was found out as 0.33 ha h^{-1} and given in Appendix XI.

4.14.7 Field efficiency

As explained in section 3.14.7 the field efficiency of the proto type lime applicator was found out as 84 % and it was given in Appendix XI.

4.15 STATISTICAL ANALYSIS

After the performance evaluation of proto type lime applicator the result was computed using analysis of variance procedure. The analysis of variance of field data study was shown in Table 4.4.

Analysis of variance was studied for the application rate of lime in kg ha^{-1} with respect to the tractor speed and the speed ratios of metering mechanism and agitator. The special feature of this lime application for paddy crop is that, an output 350 kg ha^{-1} was most desirable as per the PoP (Anon, 2011). As such, the critical difference was found out based on the analysis of variance procedure co-opting the completely randomized design with treatments in the factorial test at 8 levels of speed of tractor, 2 levels of speed ratio of agitator and 3 levels of speed ratio of metering mechanism.

Using the analysis of variance test, a special range for identifying test treatment combination was developed as 350 ± CD. All the observations which lie between these limits of 350 + CD and 350 – CD (335 to 365) were identified. The identification procedure resulted in the following ideal speed and speed ratios combination setup.

Table 4.4 Analysis of variance of application rate of lime applied in field at selected speed of the tractor and the speed ratios of metering mechanism and agitator.

Sources	DF	SS	MS	F value	Remarks
Speed of tractor (S)	7	474776.24	67825.18	823.00	*
Speed ratio between agitator and rotavator (A)	1	20824.61	20824.61	252.69	*
S × A	7	5285.02	755.00	9.16	*
Speed ratio between metering mechanism and rotavator (P)	2	2600151.2	1300075.89	15775.33	*
S × P	14	52621.00	3758.64	45.60	*
A × P	2	328.38	164.19	1.99	*
S × A × P	14	16954.36	1011.03	14.69	*
Error	96	7911.54	82.41		

CV = 1.96%   * = Significant at 5% level   NS = Not significant

From this it can be concluded that,

i. A total of four different combinations, complying with the special range were identified. They are given in the Table 4.5.

ii. Level of speed ratio of metering mechanism P_3 was the best with the speed ratios of agitator A_1 and A_2, at tractor moves with an engine rpm 2000 in L_1 gear.

iii. It was found that the resulting forward speed for the optimized operation was 2.56 km h^{-1}.

iv. A combination of speed ratio of metering mechanism P_2 and agitator speed ratio A_1 was also showed a better result at tractor engine rpm of 1800 in L_2 gear, with respect to desirable lime application rate of lime.

v. For the above combination, another advantage is that, when the tractor in L_2 gear, a low engine rpm of 1800 was sufficient for achieving desired application rate of lime successfully.

vi. Another combination of speed ratio of metering mechanism P_3, speed ratio of agitator A_2 and an engine rpm of 2200 in L_2 gear was also showed a better value in respect of desirable application rate of lime.

Table 4.5 Application rate of lime for getting desired value in the range of 350 ± CD.

SI. No	Tractor speed and speed ratios of metering mechanism and agitator for getting desired application rate of lime.				Application rate of lime kg ha^{-1}
	Gear used	Engine rpm	Agitator speed ratio	Metering mechanism speed ratio	
1	L_2	1800	A_1	P_2	364.29
2	L_1	2000	A_1	P_3	359.03
3	L_1	2000	A_2	P_3	337.15
4	L_2	2200	A_2	P_3	354.53

4.16 Cost economics

Cost of operation of the proto type lime applicator as an attachment to tractor drawn rotavator as explained in section 3.16 was found as 567.15 Rs $h^{-1}$and 1718.63 Rs ha^{-1} and manual lime application followed by tractor ploughing was 627.12 Rs $h^{-1}$and 1985.21 Rs ha^{-1}. The cost economics calculation was given in Appendix XI.

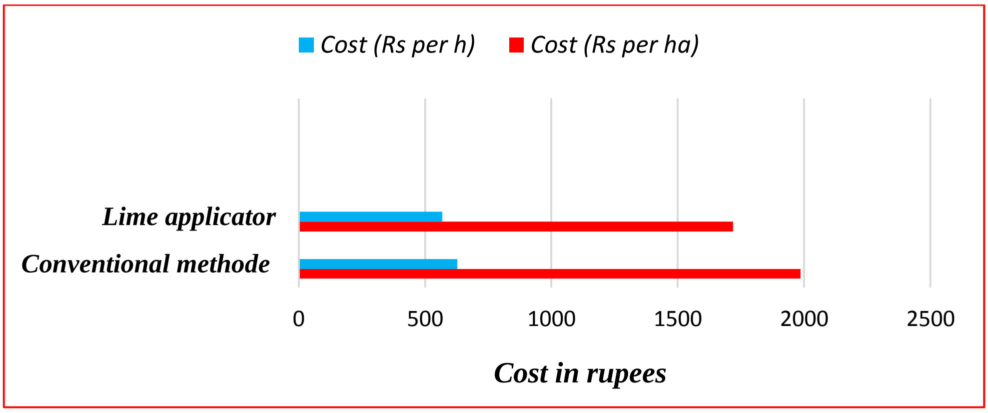


Fig. 4.4 Cost economics of proto type Vs Manual lime application.

From Fig. 4.4 shows the comparison of cost of lime application by proto type lime applicator and manual application followed by tractor ploughing. From the Fig. 4.4 a cost saving of 59.97 Rs $h^{-1}$and 266.58 Rs ha^{-1} with proto type lime applicator over manual lime application followed by tractor ploughing was observed. Also, a time saving of 2 h ha^{-1} over the manual lime application followed by tractor ploughing was achieved with proto type lime applicator attachment.

CHAPTER V

SUMMARY AND CONCLUSIONS

The present study was undertaken to design and develop a lime applicator attachment with tractor drawn rotavator for uniform application of lime along with soil tillage. Acidity inhibits the absorption of the plant nutrient like nitrogen, phosphorus and potassium. Lime application is used to reduce the acidity of the soil and to enhance plant root for easy absorption of nutrients for better yield.

The soil acidity is the major constrain for rice soil of wetland region in Kerala. The unique morphology, climate, hydrology and other environmental factors lead to the formation of acidic soils. The high rainfall and humidity will rapidly wash away the bases from the soil. A 70 per cent of the soils in Kerala are weathered lateritic soil. These soils have pH ranging from 4.5 to 6.0.

In paddy lime is applied at a rate of 600 kg ha^{-1} in two split doses. First dose of 350 kg ha^{-1} as basal dressing is applied at the time of first ploughing. Second dose of 250 kg ha^{-1} as top dressing is applied about one month after sowing/transplanting. Surplus rate of application of lime lead to excess in alkalinity which may harm or damage the plant.

Usually lime is being applied manually for all crops. In addition to the non-uniformity in application, the manual application of lime causes health hazards and so labourers are reluctant to do this job. Moreover it is a costly practice. The present labour cost of Kerala is more than Rs. 700 for male worker. Manual lime application to followed by tractor ploughing makes an expense of more than 1900 Rs ha^{-1}. If this work could be done mechanically will help the farmer to save cost, time and prevent from health hazards.

A mechanical means of lime application is inevitable. If a mechanical system is developed it will provide safe and hazard free application of lime in field. It will also be a cost effective method. Simultaneous operation of ploughing and lime application make a cost effective and less time consuming. Hence, it is decided to design and develop a lime applicator attachment to tractor operated rotavator for applying lime for paddy. The unit was developed as a rear mounted attachment to four wheel tractor to having 45 to 65 hp attached with rotavator. The power output to the lime applicator attachment was taken from the rotavator shaft.

The field performance evaluation of developed lime applicator was held in Instructional Farm, KCAET, Tavanur. During the field performance evaluation, the soil moisture content, bulk density and soil pH were found as 16.2 %, 1.73 g cm^{-3} and 5.6 respectively. The data taken during the field evaluation were statistically analyzed. Application rate of lime was increased with increase in engine rpm of tractor. It is because, when engine rpm increases rotavator speed also increases which in turn increased the rotational speed of metering mechanism and agitator.

From the statistical analysis, a special range of rate of application of lime of 335 - 360 kg ha^{-1} with a critical difference of 15 kg ha^{-1} was obtained. In the statistical analysis four different combinations, complying with the special range were identified. Level of speed ratio of metering mechanism P_3 was the best with the speed ratios of agitator A_1 and A_2, at tractor moves with an engine rpm 2000 in L_1 gear. It was found that the resulting forward speed for the optimized operation was 2.56 km h^{-1}. A combination of speed ratio of metering mechanism P_2 and agitator speed ratio A_1 was also showed a better result at tractor engine rpm of 1800 in L_2 gear, with respect to desired application rate of lime. For the above combination, another advantage is that, when the tractor in L_2 gear, a low engine rpm of 1800 was sufficient for achieving desired application rate of lime successfully. Another combination of speed ratio of metering mechanism P_3, speed ratio of agitator A_2 and an engine rpm of 2200 in L_2 gear was also showed a better value in respect of desirable application rate of lime.

For applying lime with proto type lime applicator in an area of 0.4 ha, a time of 1.2 hrs was taken. The actual field capacity, theoretical field capacity and field efficiency were calculated as 0.33 ha h^{-1}, 0.39 ha h^{-1} and 84 per cent respectively. The corresponding forward speed obtained was 2.56 km h^{-1} with wheel slippage of 11.67 per cent. Fuel consumption was 3.7 *l* h^{-1} and 26 *l* ha^{-1}.

Cost of operation of the proto type lime applicator as an attachment to tractor drawn rotavator was found as 567.15 Rs h^{-1} and 1718.63 Rs ha^{-1} and manual lime application followed by tractor ploughing was 627.12 Rs $h^{-1}$and 1985.21 Rs ha^{-1}. A cost saving of 59.97 Rs $h^{-1}$and 266.58 Rs ha^{-1} with proto type lime applicator over manual lime application followed by tractor ploughing was observed. Also, a time saving of 2 h ha^{-1} over the manual lime application followed by tractor ploughing was achieved with proto type lime applicator attachment.

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Appendix I

Determination of moisture content of lime used for field performance evaluation of proto type lime applicator.

Mass of container, (m_1), gm	Mass of container + wet soil, (m_2), gm	Mass of container + dry soil, (m_3), gm	Moisture content in dry basis, percentage
22.54	51.64	51.48	0.55
25.08	54.08	53.92	0.55
26.25	53.8	53.65	0.55
25.19	56.43	56.26	0.55
30.57	65.88	65.7	0.51
36.02	78.42	78.2	0.52
Average moisture content, %			**0.54**

Sample calculations:

Mass of container (m_1), gm = 22.54

Mass of container + wet soil (m_2), gm = 51.64

Mass of container + dry soil (m_3), gm = 51.48

Moisture content, % = $[(m_2 - m_3) / (m_3 - m_1)] \times 100$

= $[(51.64 - 51.48) / (51.48 - 22.54)] \times 100$

= $[0.16/28.94] \times 100$

= 0.0055×100

Moisture content, % = 0.55

Average moisture content, (%) = 0.54

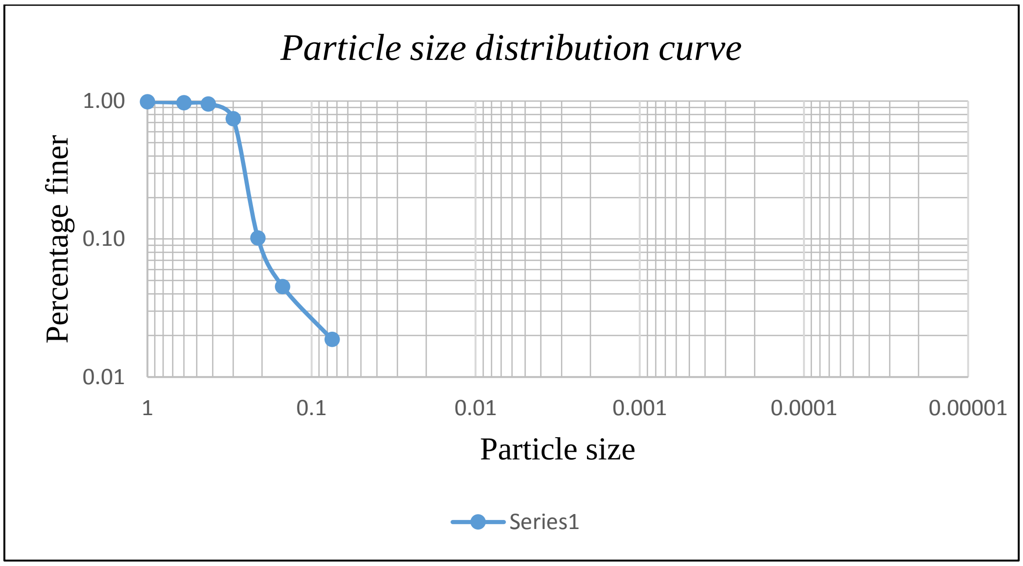
Appendix II

Particle size distribution – Sieve analysis data of lime

Si. No	IS sieve size, µm	Mass of lime retained, gm	% Retained	Cumulative % retained	Cumulative % finer, gm
1	2 mm	2	0.66	0.66	99.34
2	1 mm	2	0.66	1.32	98.68
3	600	4.5	1.50	2.82	97.18
4	425	5.5	1.83	4.65	95.35
5	300	62.5	20.83	25.48	74.52
6	212	193	64.33	89.81	10.19
7	150	17	5.66	95.47	4.53
8	75	8	2.66	98.13	1.87
9	Retainer	5.5	1.83	99.96	0.04

Total mass of the sample, gm = 300

Mass of lime passing through 75 µm sieve, gm = 5.5



Appendix III

Determination of bulk density of soil collected from the test field.

Mass of core cutter, gm	Mass of core cutter + wet soil, gm	Mass of wet soil, Gm	Height of core cutter, cm	Internal diameter, cm	Volume, cm^3	Bulk density, g cm^{-3}
924.5	2538.5	1614.0	12.8	9.5	906.83	1.779
924.5	2558.5	1634.0	12.8	9.5	906.83	1.801
924.5	2547.5	1623.0	12.8	9.5	906.83	1.789
924.5	2525.5	1601.0	12.8	9.5	906.83	1.765
Average soil bulk density, g cm^{-3}						**1.784**

Sample calculations:

Mass of core cutter, gm = 924.5

Mass of core cutter + wet soil, gm = 2538.5

Mass of wet soil, gm = 1614.0

Height of core cutter, cm = 12.8

Internal diameter, cm = 9.5

Volume, cm^3 = 906.83

Bulk density, g cm^{-3} = Mass/ volume

= 1.779

Average soil bulk density, g cm^{-3} = 1.784

Appendix IV

Soil pH before and after lime application.

No. of sample	pH value before lime application	pH value 7 days after lime application
1	5.4	6.5
2	5.5	6.7
3	5.5	6.7
4	5.7	7.0
5	6.0	7.1
Average pH	**5.6**	**6.8**

Appendix V

Application rate of lime at selected levels of engine rpm (E), speed ratio of metering mechanism (P), and speed ratio of agitator (A) under laboratory test of proto type lime applicator.

Sl. No.	Treatments	Application rate of lime, kg h^{-1}
1	$E_1P_1A_1 R_1$	228.00
2	$E_1P_1A_1 R_2$	227.00
3	$E_1P_1A_1 R_3$	229.50
Mean		**228.16**
4	$E_1P_1A_2 R_1$	210.00
5	$E_1P_1A_2 R_2$	210.5.
6	$E_1P_1A_2 R_3$	211.00
Mean		**210.00**
7	$E_1P_2A_1 R_1$	147.00
8	$E_1P_2A_1 R_2$	145.50
9	$E_1P_2A_1 R_3$	145.50
Mean		**146.33**
10	$E_1P_2A_2 R_1$	133.20
11	$E_1P_2A_2 R_2$	133.00
12	$E_1P_2A_2 R_3$	134.20
Mean		**133.46**
13	$E_1P_3A_1 R_1$	105.6
14	$E_1P_3A_1 R_2$	105.00
15	$E_1P_3A_1 R_3$	106.20
Mean		**105.60**
16	$E_1P_3A_2 R_1$	96.60
17	$E_1P_3A_2 R_2$	95.20
18	$E_1P_3A_2 R_3$	95.80
Mean		**95.87**
19	$E_2P_1A_1 R_1$	246.00
20	$E_2P_1A_1 R_2$	245.10
21	$E_2P_1A_1 R_3$	247.00
Mean		**246.03**
22	$E_2P_1A_2 R_1$	225.00
23	$E_2P_1A_2 R_2$	223.00
24	$E_2P_1A_2 R_3$	224.00
Mean		**224.00**
25	$E_2P_2A_1 R_1$	153.00
26	$E_2P_2A_1 R_2$	152.00
27	$E_2P_2A_1 R_3$	154.00
Mean		**153.00**
28	$E_2P_2A_2 R_1$	164.40

29	$E_2P_2A_2\,R_2$	164.00
30	$E_2P_2A_2\,R_3$	165.50
Mean		**164.63**
31	$E_2P_3A_1\,R_1$	120.00
32	$E_2P_3A_1\,R_2$	122.00
33	$E_2P_3A_1\,R_3$	119.00
Mean		**120.33**
34	$E_2P_3A_2\,R_1$	111.00
35	$E_2P_3A_2\,R_2$	110.00
36	$E_2P_3A_2\,R_3$	113.00
Mean		**111.33**
37	$E_3P_1A_1\,R_1$	258.00
38	$E_3P_1A_1\,R_2$	260.00
39	$E_3P_1A_1\,R_3$	259.00
Mean		**259.00**
40	$E_3P_1A_2\,R_1$	270.60
41	$E_3P_1A_2\,R_2$	270.00
42	$E_3P_1A_2\,R_3$	268.00
Mean		**269.53**
43	$E_3P_2A_1\,R_1$	205.20
44	$E_3P_2A_1\,R_2$	204.00
45	$E_3P_2A_1\,R_3$	204.50
Mean		**204.57**
46	$E_3P_2A_2\,R_1$	197.60
47	$E_3P_2A_2\,R_2$	197.00
48	$E_3P_2A_2\,R_3$	197.50
Mean		**197.70**
49	$E_3P_3A_1\,R_1$	138.60
50	$E_3P_3A_1\,R_2$	138.00
51	$E_3P_3A_1\,R_3$	137.00
Mean		**137.87**
52	$E_3P_3A_2\,R_1$	129.00
53	$E_3P_3A_2\,R_2$	130.00
54	$E_3P_3A_2\,R_3$	129.40
Mean		**129.97**
55	$E_4P_1A_1\,R_1$	318.00
56	$E_4P_1A_1\,R_2$	314.00
57	$E_4P_1A_1\,R_3$	316.00
Mean		**316.00**
58	$E_4P_1A_2\,R_1$	304.20
59	$E_4P_1A_2\,R_2$	302.00
60	$E_4P_1A_2\,R_3$	302.00
Mean		**302.75**
61	$E_4P_2A_1\,R_1$	230.40

62	$E_4P_2A_1 R_2$	231.00
63	$E_4P_2A_1 R_3$	233.00
Mean		**231.47**
64	$E_4P_2A_2 R_1$	214.20
65	$E_4P_2A_2 R_2$	212.00
66	$E_4P_2A_2 R_3$	213.50
Mean		**213.23**
67	$E_4P_3A_1 R_1$	153.00
68	$E_4P_3A_1 R_2$	152.20
69	$E_4P_3A_1 R_3$	153.30
Mean		**152.83**
70	$E_4P_3A_2 R_1$	139.20
71	$E_4P_3A_2 R_2$	138.20
72	$E_4P_3A_2 R_3$	139.00
Mean		**138.80**

Appendix VI

Mean of application rate of lime at selected levels of engine rpm (E), speed ratio of metering mechanism (P), and speed ratio of agitator (A) under laboratory test of proto type lime applicator.

Sl. No.	Treatments	Application rate of lime, kg h^{-1}
1	$E_1P_1A_1$	228.16
2	$E_1P_1A_2$	210.00
3	$E_1P_2A_1$	146.33
4	$E_1P_2A_2$	133.46
5	$E_1P_3A_1$	105.60
6	$E_1P_3A_2$	95.87
7	$E_2P_1A_1$	246.03
8	$E_2P_1A_2$	224.00
9	$E_2P_2A_1$	153.00
10	$E_2P_2A_2$	164.63
11	$E_2P_3A_1$	120.33
12	$E_2P_3A_2$	111.33
13	$E_3P_1A_1$	259.00
14	$E_3P_1A_2$	269.53
15	$E_3P_2A_1$	204.57
16	$E_3P_2A_2$	197.70
17	$E_3P_3A_1$	137.87
18	$E_3P_3A_2$	129.97
19	$E_4P_1A_1$	316.00
20	$E_4P_1A_2$	302.75
21	$E_4P_2A_1$	231.47
22	$E_4P_2A_2$	213.23
23	$E_4P_3A_1$	152.83
24	$E_4P_3A_2$	138.80

Appendix VII

Application rate of lime at selected levels of speed of tractor (S), speed ratios of metering mechanism (P), and agitator (A) under performance evaluation of proto type lime applicator.

Sl. No.	Treatments	Application rate of lime, kg ha^{-1}
1	$S_1P_1A_1R_1$	588.46
2	$S_1P_1A_1R_2$	630.55
3	$S_1P_1A_1R_3$	637.50
Mean		**633.80**
4	$S_1P_1A_2R_1$	583.33
5	$S_1P_1A_2R_2$	584.72
6	$S_1P_1A_2R_3$	586.11
Mean		**584.72**
7	$S_1P_2A_1R_1$	408.33
8	$S_1P_2A_1R_2$	404.16
9	$S_1P_2A_1R_3$	406.94
Mean		**406.47**
10	$S_1P_2A_2R_1$	380.00
11	$S_1P_2A_2R_2$	379.44
12	$S_1P_2A_2R_3$	379.77
Mean		**379.05**
13	$S_1P_3A_1R_1$	293.33
14	$S_1P_3A_1R_2$	291.66
15	$S_1P_3A_1R_3$	295.00
Mean		**293.33**
16	$S_1P_3A_2R_1$	268.33
17	$S_1P_3A_2R_2$	264.44
18	$S_1P_3A_2R_3$	266.11
Mean		**266.27**
19	$S_2P_1A_1R_1$	584.61
20	$S_2P_1A_1R_2$	582.05
21	$S_2P_1A_1R_3$	588.46
Mean		**585.05**
22	$S_2P_1A_2R_1$	538.46
23	$S_2P_1A_2R_2$	539.74
24	$S_2P_1A_2R_3$	541.02
Mean		**539.74**
25	$S_2P_2A_1R_1$	376.92
26	$S_2P_2A_1R_2$	373.07
27	$S_2P_2A_1R_3$	375.67
Mean		**375.20**
28	$S_2P_2A_2R_1$	341.53

29	$S_2P_2A_2 R_2$	341.02
30	$S_2P_2A_2 R_3$	344.10
Mean		**349.89**
31	$S_2P_3A_1 R_1$	270.76
32	$S_2P_3A_1 R_2$	269.23
33	$S_2P_3A_1 R_3$	272.30
Mean		**270.76**
34	$S_2P_3A_2 R_1$	247.69
35	$S_2P_3A_2 R_2$	244.10
36	$S_2P_3A_2 R_3$	245.64
Mean		**245.79**
37	$S_3P_1A_1 R_1$	661.29
38	$S_3P_1A_1 R_2$	658.87
39	$S_3P_1A_1 R_3$	663.97
Mean		**661.37**
40	$S_3P_1A_2 R_1$	604.83
41	$S_3P_1A_2 R_2$	599.46
42	$S_3P_1A_2 R_3$	602.15
Mean		**602.15**
43	$S_3P_2A_1 R_1$	411.29
44	$S_3P_2A_1 R_2$	408.60
45	$S_3P_2A_1 R_3$	413.97
Mean		**411.29**
46	$S_3P_2A_2 R_1$	441.93
47	$S_3P_2A_2 R_2$	440.86
48	$S_3P_2A_2 R_3$	444.89
Mean		**442.55**
49	$S_3P_3A_1 R_1$	322.58
50	$S_3P_3A_1 R_2$	327.97
51	$S_3P_3A_1 R_3$	319.89
Mean		**323.46**
52	$S_3P_3A_2 R_1$	298.38
53	$S_3P_3A_2 R_2$	295.69
54	$S_3P_3A_2 R_3$	303.76
Mean		**300.08**
55	$S_4P_1A_1 R_1$	585.71
56	$S_4P_1A_1 R_2$	583.57
57	$S_4P_1A_1 R_3$	588.09
Mean		**585.78**
58	$S_4P_1A_2 R_1$	535.71
59	$S_4P_1A_2 R_2$	530.95

60	$S_4P_1A_2\,R_3$	533.33
Mean		**533.33**
61	$S_4P_2A_1\,R_1$	364.28
62	$S_4P_2A_1\,R_2$	361.90
63	$S_4P_2A_1\,R_3$	366.66
Mean		**364.28**
64	$S_4P_2A_2\,R_1$	391.42
65	$S_4P_2A_2\,R_2$	390.47
66	$S_4P_2A_2\,R_3$	394.04
Mean		**391.97**
67	$S_4P_3A_1\,R_1$	285.71
68	$S_4P_3A_1\,R_2$	290.47
69	$S_4P_3A_1\,R_3$	283.33
Mean		**286.50**
70	$S_4P_3A_2\,R_1$	264.28
71	$S_4P_3A_2\,R_2$	261.90
72	$S_4P_3A_2\,R_3$	269.04
	Mean	**265.78**
73	$S_5P_1A_1\,R_1$	671.87
74	$S_5P_1A_1\,R_2$	677.08
75	$S_5P_1A_1\,R_3$	674.47
Mean		**674.47**
76	$S_5P_1A_2\,R_1$	704.68
77	$S_5P_1A_2\,R_2$	703.12
78	$S_5P_1A_2\,R_3$	697.91
Mean		**701.82**
79	$S_5P_2A_1\,R_1$	534.37
80	$S_5P_2A_1\,R_2$	531.25
81	$S_5P_2A_1\,R_3$	532.55
Mean		**532.70**
82	$S_5P_2A_2\,R_1$	501.56
83	$S_5P_2A_2\,R_2$	497.39
84	$S_5P_2A_2\,R_3$	498.69
Mean		**499.21**
85	$S_5P_3A_1\,R_1$	360.93
86	$S_5P_3A_1\,R_2$	359.37
87	$S_5P_3A_1\,R_3$	356.77
Mean		**359.01**
88	$S_5P_3A_2\,R_1$	335.93
89	$S_5P_3A_2\,R_2$	338.54
90	$S_5P_3A_2\,R_3$	336.97
Mean		**337.13**
91	$S_6P_1A_1\,R_1$	593.10

92	$S_6P_1A_1\,R_2$	597.70
93	$S_6P_1A_1\,R_3$	595.40
Mean		**595.40**
94	$S_6P_1A_2\,R_1$	622.06
95	$S_6P_1A_2\,R_2$	620.68
96	$S_6P_1A_2\,R_3$	616.09
Mean		**619.54**
97	$S_6P_2A_1\,R_1$	471.72
98	$S_6P_2A_1\,R_2$	468.96
99	$S_6P_2A_1\,R_3$	470.11
Mean		**470.25**
100	$S_6P_2A_2\,R_1$	442.75
101	$S_6P_2A_2\,R_2$	439.08
102	$S_6P_2A_2\,R_3$	440.22
Mean		**440.68**
103	$S_6P_3A_1\,R_1$	318.62
104	$S_6P_3A_1\,R_2$	317.24
105	$S_6P_3A_1\,R_3$	314.94
Mean		**316.91**
106	$S_6P_3A_2\,R_1$	296.55
107	$S_6P_3A_2\,R_2$	298.85
108	$S_6P_3A_2\,R_3$	297.47
Mean		**397.60**
109	$S_7P_1A_1\,R_1$	812.26
110	$S_7P_1A_1\,R_2$	802.04
111	$S_7P_1A_1\,R_3$	807.15
Mean		**807.15**
112	$S_7P_1A_2\,R_1$	777.01
113	$S_7P_1A_2\,R_2$	771.39
114	$S_7P_1A_2\,R_3$	771.39
Mean		**733.18**
115	$S_7P_2A_1\,R_1$	588.50
116	$S_7P_2A_1\,R_2$	590.03
117	$S_7P_2A_1\,R_3$	595.14
Mean		**591.21**
118	$S_7P_2A_2\,R_1$	547.12
119	$S_7P_2A_2\,R_2$	541.50
120	$S_7P_2A_2\,R_3$	545.33
Mean		**544.64**
121	$S_7P_3A_1\,R_1$	390.80
122	$S_7P_3A_1\,R_2$	388.76
123	$S_7P_3A_1\,R_3$	391.57

Mean		**390.37**
124	$S_7P_3A_2\ R_1$	355.55
125	$S_7P_3A_2\ R_2$	353.00
126	$S_7P_3A_2\ R_3$	355.04
Mean		**354.53**
127	$S_8P_1A_1\ R_1$	683.87
128	$S_8P_1A_1\ R_2$	675.26
129	$S_8P_1A_1\ R_3$	679.56
Mean		**679.56**
130	$S_8P_1A_2\ R_1$	654.19
131	$S_8P_1A_2\ R_2$	649.46
132	$S_8P_1A_2\ R_3$	649.46
Mean		**650.96**
133	$S_8P_2A_1\ R_1$	495.48
134	$S_8P_2A_1\ R_2$	496.77
135	$S_8P_2A_1\ R_3$	501.07
Mean		**497.76**
136	$S_8P_2A_2\ R_1$	460.64
137	$S_8P_2A_2\ R_2$	455.91
138	$S_8P_2A_2\ R_3$	459.13
Mean		**458.55**
139	$S_8P_3A_1\ R_1$	329.03
140	$S_8P_3A_1\ R_2$	327.31
141	$S_8P_3A_1\ R_3$	329.67
Mean		**328.66**
142	$S_8P_3A_2\ R_1$	299.35
143	$S_8P_3A_2\ R_2$	297.20
144	$S_8P_3A_2\ R_3$	298.92
Mean		**298.49**

Appendix VIII

Mean of application rate of lime at selected levels of speed of tractor (S), speed ratios of metering mechanism (P), and agitator (A)) under performance evaluation of proto type lime applicator.

Sl. No.	Treatments	Application rate of lime, kg ha^{-1}
1	$S_1P_1A_1$	633.80
2	$S_1P_1A_2$	584.72
3	$S_1P_2A_1$	406.47
4	$S_1P_2A_2$	379.05
5	$S_1P_3A_1$	293.33
6	$S_1P_3A_2$	266.78
7	$S_2P_1A_1$	585.05
8	$S_2P_1A_2$	539.74
9	$S_2P_2A_1$	375.20
10	$S_2P_2A_2$	349.89
11	$S_2P_3A_1$	270.76
12	$S_2P_3A_2$	245.79
13	$S_3P_1A_1$	661.37
14	$S_3P_1A_2$	602.15
15	$S_3P_2A_1$	411.29
16	$S_3P_2A_2$	442.55
17	$S_3P_3A_1$	323.46
18	$S_3P_3A_2$	300.08
19	$S_4P_1A_1$	585.78
20	$S_4P_1A_2$	533.33
21	$S_4P_2A_1$	364.28
22	$S_4P_2A_2$	391.97
23	$S_4P_3A_1$	286.50
24	$S_4P_3A_2$	265.78
25	$S_5P_1A_1$	674.47
26	$S_5P_1A_2$	701.82
27	$S_5P_2A_1$	532.70
28	$S_5P_2A_2$	499.21
29	$S_5P_3A_1$	359.01
30	$S_5P_3A_2$	337.13
31	$S_6P_1A_1$	595.40
32	$S_6P_1A_2$	619.54
33	$S_6P_2A_1$	470.25
34	$S_6P_2A_2$	440.68
35	$S_6P_3A_1$	316.91
36	$S_6P_3A_2$	297.60
37	$S_7P_1A_1$	807.15

38	$S_7P_1A_2$	773.18
39	$S_7P_2A_1$	591.21
40	$S_7P_2A_2$	544.64
41	$S_7P_3A_1$	390.37
42	$S_7P_3A_2$	354.53
43	$S_8P_1A_1$	679.56
44	$S_8P_1A_2$	650.96
45	$S_8P_2A_1$	497.76
46	$S_8P_2A_2$	458.55
47	$S_8P_3A_1$	328.66
48	$S_8P_3A_2$	298.49

Appendix IX

Specifications of the tractor used for performance evaluation of proto type lime applicator.

Manufacturer	John Deere
Model	5065-E
Engine	65 hp, 2400 rpm, 3 cylinder, Rotary FIP, Turbo
Air filter	Dry type, fuel element
Transmission	
Clutch	Dual
Gear box	9 forward + 3 reverse, Collar shift
Hydraulics	
Lifting capacity, kgf	1800 at lower link ends
3-point linkage	Category II, Automated draft and depth control
Steering	Power
Steering column	Tilt up to 25 degree
Power Take Off	Independent, 6 splines
RPM	540 @ 2376 E-rpm
Wheels and Tires	
Front	6.5 × 20, 8PR
Rear	16.9 × 30, 12PR
Fuel tank capacity	68 Liters
Electrical systems	88 Ah, 12 volt battery, 40 Amp
	2.5 kW starter motor, Alternator
Dimensions and weight	
Total weight, kg	2290
Wheel base, mm	2035
Overall length, mm	3540
Overall width, mm	1885
Turning radius, mm	3181
Ground clearance, mm	470

Appendix X

Cost economics of lime application

A. Cost of operation of proto type lime applicator

1. Tractor

Assumptions

Initial cost of tractor (C), Rs	:	10, 00,000
Useful life (IS 9164:1979), (L), years	:	10
Annual usage (IS 9164:1979), (H), hours	:	1000
Interest rate, (i), per cent	:	12

Fixed cost

a. Depreciation, Rs h^{-1} $= \frac{C - S}{L \times H}$

$= \frac{10,00,000 - 100000}{10 \times 1000}$

$= 90$

b. Interest on capital, Rs h^{-1} $= \frac{C + S}{2} \times i$

$= \frac{10,00,000 + 1,00,000}{2 \times 1000} \times \frac{12}{100}$

$= 66$

c. Insurance and taxes (1.5 % of initial cost of tractor), Rs h^{-1}

$= \frac{10,00,000}{1000} \times \frac{1.5}{100}$

$= 15$

d. Housing (0.5% of initial cost of tractor), Rs h^{-1}

$= \frac{10,00,000}{1000} \times \frac{0.5}{100}$

$= 5$

Total fixed cost (a + b + c + d), Rs h^{-1} = 176

Variable cost

a) Average diesel consumption, l h^{-1} = 3.5

Fuel cost, Rs h^{-1} $= 3.5 \times 55$

$= 192.5$

b) Lubrication (10% of fuel cost) , Rs h^{-1} $= 192.5 \times \frac{10}{100}$

$= 19.25$

c) Repair and maintenance (5 % of initial cost of tractor) , Rs h^{-1}

$$= \frac{10,00,000}{1,000} \times \frac{5}{100}$$

$$= 50$$

d) Operator wages (Rs. 700/day of 8 hours) , Rs h^{-1}

$$= \frac{700}{8} = 87.5$$

Total variable cost (a + b + c + d), Rs h^{-1} = 349.25

Total operating cost of tractor = 525.25

2. Rotavator

Assumption

Initial cost of tractor (C), Rs	:	65,000
Useful life (IS 9164:1979), (L), years	:	10
Annual usage (IS 9164:1979), (H), hours	:	1000
Interest rate, (i), per cent	:	12

Fixed cost

Depreciation, Rs h^{-1}

$$= \frac{C - S}{L \times H}$$

$$= \frac{65,000 - 6,500}{10 \times 1000}$$

$$= 5.85$$

Interest on capital, Rs h^{-1}

$$= \frac{C + S}{2} \times i$$

$$= \frac{65000 + 6500}{2 \times 1000} \times \frac{12}{100}$$

$$= 4.29$$

Insurance and taxes (1 % of initial cost of rotavator), Rs h^{-1}

$$= \frac{65,000}{1000} \times \frac{1}{100}$$

$$= 0.65$$

Housing (0.5 % of initial cost of rotavator), Rs h^{-1}

$$= \frac{65,000}{1000} \times \frac{0.5}{100}$$

$$= 0.325$$

Total fixed cost, Rs h^{-1} = 11.115

Variable cost

Repair and maintenance (5 % of initial cost of tractor), Rs h^{-1}

$$= \frac{65,000}{1,000} \times \frac{5}{100}$$

$$= 3.25$$

Total operating cost of rotavator = 14.37

3. Proto type lime applicator

Assumptions

Initial cost of lime applicator (C), Rs	:	18,000
Useful life (IS 9164:1979), (L), years	:	10
Annual usage (IS 9164:1979), (H), hours	:	1000
Interest rate, (i), per cent	:	12

Fixed cost

Depreciation, Rs h^{-1} $= \frac{C - S}{L \times H}$

$$= \frac{18000-1800}{10 \times 100}$$

$$= 16.20$$

Interest on capital, Rs h^{-1} $= \frac{C + S}{2} \times i$

$$= \frac{18,000 + 1800}{2 \times 1000} \times \frac{12}{100}$$

$$= 1.19$$

Insurance and taxes (1.5 % of initial cost of tractor), Rs h^{-1}

$$= \frac{18,000}{1000} \times \frac{1.5}{100}$$

$$= 0.27$$

Housing (0.5 % of initial cost of tractor), Rs h^{-1}

$$= \frac{18000}{100} \times \frac{0.5}{100}$$

$$= 0.9$$

Total fixed cost, Rs h^{-1} = 18.56

Variable cost

Repair and maintenance (5 % of initial cost), Rs h^{-1}

= $\frac{18000}{100} \times \frac{5}{100}$

= 9

Total variable cost, Rs h^{-1} = 9

Total operating cost of lime applicator = 27.56

Total operating cost of tractor, rotavator and proto type lime applicator,

Rs h^{-1} **=** 1 + 2 + 3

= 567.15

Total operating cost of tractor, rotavator and proto type lime applicator,

Rs ha^{-1} = 567.15 ÷ 0.33

= 1718.63

B. Cost of operation of Manual lime application and ploughing with tractor drawn rotavator

I. Total operating cost of tractor and rotavator, Rs h^{-1} = 1 + 2

= 539.62

II. Operator wages, Rs h^{-1} (from'd' of section 'A') = 87.5

Assuming 2 hours are needed for applying 1 ha of land manually.

Total cost of lime application, Rs h^{-1} **=** I + II

= 627.12

Total cost of lime application, Rs ha^{-1} **=** 1635.21 + 350

= 1985.21

Appendix XI

Field performance evaluation of proto type lime applicator

Total area covered, ha	=	0.4
Total time taken, h	=	1.2
Actual field capacity (Fa), ha h^{-1}	=	$\frac{0.4}{1.2}$
	=	**0.33**
Theoretical field capacity (Ft), ha h^{-1}	=	$\frac{2.6 \times 1.5}{10000}$
	=	**0.39**
Field efficiency (Fe), %	=	$\frac{\text{Fa}}{\text{Ft}}$ x 100
	=	**84**
Wheel slippage, %	=	$\frac{6 - 5.3}{6}\ X\ 100$
	=	**11.67**

DESIGN AND DEVELOPMENT OF A LIME APPLICATOR ATTACHMENT TO TRACTOR OPERATED ROTAVATOR

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Lime application is used to reduce the acidity of the soil and to enhance plant root for easy absorption of nutrients for better yield. Usually lime is being applied manually for all crops. In addition to the non-uniformity in application, the manual application of lime causes health hazards and so labourers are reluctant to do this job, moreover it is a costly practice. Hence, a mechanical means of lime application is inevitable.

To apply lime mechanically, an investigation was undertaken to design and develop a lime applicator attachment with tractor drawn rotavator, which simultaneously applying lime and till the soil. The unit was developed as a rear mounted attachment to four wheel tractor to having 45 to 65 hp attached with rotavator. The power output to the lime applicator attachment was taken from the rotavator shaft. This study deals with the basal dressing of lime for paddy at the rate of 350 kg ha^{-1} as per the recommendation of Kerala Agricultural University Package and practices recommendations, 2011.

The major components of the lime applicator attachment was hopper, metering mechanism, lime discharge chute, agitator and sprockets and chain with box assembly. The trapezoidal hopper was made up of galvanized iron sheet folded in 54° having dimension of 1600 × 460 × 340 mm. Single shaft baffle type metering mechanism with drive taking from the rotavator was used to metering lime.

The field performance evaluation of developed lime applicator was held in Instructional Farm, KCAET, Tavanur. During the field performance evaluation, the soil moisture content, bulk density and soil pH were found as 16.2 %, 1.73 g cm^{-3} and 5.6 respectively. The data taken during the field evaluation were statistically analyzed. Application rate of lime was increased with increase in engine rpm of tractor. It is because, when engine rpm increases rotavator speed also increases which in turn increased the rotational speed of metering mechanism and agitator.

From the statistical analysis, a special range of rate of application of lime of 335 - 360 kg ha^{-1} with a critical difference of 15 kg ha^{-1} was obtained. A value near to the desired rate of application of lime of 350 kg ha^{-1} was resulted at 2000 rpm of tractor engine under L_1 gear with speed ratio of metering mechanism P_3. Similar results equivalent to desired rate of application of lime was achieved at 1800 and 2200 rpm with speed ratio of metering mechanism P_2 and P_3. The corresponding forward speed obtained was 2.56 km h^{-1} with wheel slippage of 11.67 per cent. Fuel consumption was 3.7 *l* h^{-1} and 26 *l* ha^{-1}.

For applying lime with proto type lime applicator in an area of 0.4 ha, a time of 1.2 hrs was taken. The actual field capacity, theoretical field capacity and field efficiency were calculated as 0.33 ha h^{-1}, 0.39 ha h^{-1} and 84 per cent respectively.

Cost of operation of the proto type lime applicator as an attachment to tractor drawn rotavator was found as 567.15 Rs h^{-1} and 1718.63 Rs ha^{-1} and manual lime application followed by tractor ploughing was 627.12 Rs $h^{-1}$and 1985.21 Rs ha^{-1}. A cost saving of 59.97 Rs $h^{-1}$and 266.58 Rs ha^{-1} with proto type lime applicator over manual lime application followed by tractor ploughing was observed. Also, a time saving of 2 h ha^{-1} over the manual lime application followed by tractor ploughing was achieved with proto type lime applicator attachment.