DESIGN, DEVELOPMENT AND TESTING OF A POWER OPERATED PADDY HILL SEEDER

by

BANDI NAGESWAR

(2017-18-012)

THESIS

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

(Farm Machinery and Power Engineering)

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

DEPARTMENT OF FARM MACHINERY AND POWER ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, TAVANUR - 679 573

KERALA, INDIA

2019

DECLARATION

I hereby declare that this thesis entitles **"Design, Development and Testing of a Power Operated Paddy Hill Seeder"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title of any other University or Society.

Place: Tavanur

Date: 08/08/19

BANDI NAGESWAR

(2017-18-012)

CERTIFICATE

Certified that this thesis entitled **"Design, Development and Testing of a Power Operated Paddy Hill Seeder"** is a record of research work done independently by **BANDI NAGESWAR (2017-18-012)** 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

Date : 8/8/2019

Dr. Manoj Mathew 8/8/19
(Chairman, Advisory Committee)
Professor
Dept.of FMPE
Rice Research station,
Moncompu, Alappuzha.

CERTIFICATE

We, the undersigned members of the advisory committee of **Mr. BANDI NAGESWAR,** a candidate for the degree of Master of Technology in Agricultural Engineering with major in Farm Power, Machinery and Energy, agree that the thesis entitled **"Design, Development and Testing of a Power Operated Paddy Hill Seeder"** may be submitted by **Mr. BANDI NAGESWAR** in partial fulfillment of the requirement for the degree.

Place: Tavanur

Date : 8/8/2019

Dr. Manoj Mathew
(Chairman)
Professor
Dept.of FMPE
Rice Research station,
Moncompu, Alappuzha.

Members

8/8/19

Dr. Jayan P.R.
Professor and Head
Dept. of FMPE
KCAET, Tavanur

Er. Shivaji K.P.
Assistant Professor
Dept. of FMPE
KCAET, Tavanur

Dr. Moosa P.P
Asst. Professor
Dept. of soil science and Agril.Chemistry
RARS, Pattambi

Dedication

This thesis is dedicated to my Guide, Daughter, Wife, Mother, Father and Brother, who sacrificed much to bring me up to this level and to my lovely family members for the devotion they made to make my life successful.

ACKNOWLEDGEMENT

It is a matter of pleasure to glance back and recall the path one traversed during the days of hard work. It is still great at this juncture to recall all the faces and spirits in the form of teachers, friends, near and dear ones. I would consider this work nothing more than incomplete without attending to task of acknowledging the overwhelming help i received during this endeavor of mine.

First of all, I would like to extend my deepest sense of gratitude heartfelt thanks to my learned advisor ***Dr. Manoj Mathew.,*** *Professor (FPME), Rice Research Station, Moncompu , Alappuzha for his constant inspiration and encouragement, timely help, valuable advice, moral support, constructive criticism and friendly attitude throughout the study period. I am immensely grateful to him for his genuine guidance, impeccable advice, recurring encouragement, sustained interest, kind treatment and above all, his affectionate way of dealing the things throughout the course of my investigation, which helped me to consummate the research work.*

It is my pleasure to pay tribute to ***Dr. Sathian.KK.,*** *Dean (Ag. Engg.), Kelappaji College of Agricultural Engineering and Technology, Tavanur, for his advice and guidance rendered during this study.*

I avail this opportunity to express my sincere thanks to my advisory committee members ***Dr. Jayan P.R.***, *Professor and Head, Department of Farm Power, Machinery and Energy, Kelappaji College of Agricultural Engineering and Technology, Tavanur.*

I place my special thanks to, ***Dr. Shaji James P,*** *Professor,* ***Er. Shivaji K.P and Er. Suma Nair,*** *Assistant Professor, Department of Farm Power, Machinery and Energy, KCAET, Tavanur, for their valuable guidance, profound suggestions and constant encouragement and advice throughout the project work.*

Dr. Habeeburrahman, P.V., *Programme Co-ordinator, KVK, Malappuram, for their valuable counsel, note- worthy guidance and cordial co-operation during my research programme.*

I offer my sincere and well devoted thanks to **Sri. Shyam Prakash P.K,** Farm manager, KCAET, Tavanur for their immense helps and deemed support to complete the research successfully.

I express my sincere and well devoted thanks to **Sri. Basavaraj Patil,** Ph. D. Scholar, **Er.Venkata Reddy,** Ph. D. Scholar, friend**Er. Dipak S. Khatawkar,**Ph. D. Scholar, Dept. FMPE for her valuable suggestions, helpful advice and helped to carry out the statistical analysis of the research outcomes and its interpretations.

I also feel happy to express my heartfelt thanks to my nearest and dearest friends **Er. Prasangh Rank, Er. Nandulal, Er. Arya KT, Er. Rinju Lucose, Er. Amrutha and Er. Athira** for them boundless help and caring me in every step of my studies and research work, with them support.

I would like to place my special thanks to my close friend **Er. Amaldev .DJ,** for his sincere help and support during my study.

I am grateful to thank **Sri. Rahul, Sri. Sudheer V, Mr. Lithin, and Mr. Srikanth,** research work shop technician, for their technical assistance, commitments and high co-operation during the development of the prototype and testing activities.

I express my thanks to all the faculty **members of Library**, KCAET, Tavanur, for their ever willing help and cooperation. I express my sincere thanks and gratitude to **Kelappaji College of Agricultural Engineering & Technology** for giving me an opportunity to undergo my P.G studies and **Kerala Agricultural University** for providing me the KAU merit scholarship and for having proffered me a chance to study in this institution.

Words are inadequate to express my heartfelt gratitude to my best half **Smt. Bandi Wagdevi** and my daughter **Sri. Bandi Nishitha Reddy** for their everlasting love and affection, help, support, incessant motivation and constant encouragement throughout my life.

*Words are inadequate to express my heartfelt gratitude to my beloved parents **Sri. Bandi Nagireddy** and **Smt. Prameela** for their everlasting love and affection, help, support, incessant motivation and constant encouragement throughout my life.*

*Words are inadequate to express my heartfelt gratitude to my beloved none another than my parents **Sri. Challa Mohanreddy** and **Smt. Challa Padma** for their everlasting love and affection, help, support, incessant motivation and constant encouragement throughout my life.*

*I am greatly indebted to my lovely brother **Mr. Bandi Mohanreddy** for his valuable advice, encouragement and support during the course of study.*

*I am greatly indebted to my lovely brother-in-law **Mr. Challa Ragotham Reddy** for his valuable advice, encouragement and support during the course of study.*

I have been highly fortunate and lucky to express my heartfelt respect to my dearest sisters and my relatives for their kind blessings and well wishes showed on me.

One last word; since it is practically impossible to list all contributions to my work, it seems proper to issue a blanket of thanks for those who helped me directly or indirectly during the course of my study.

BANDI NAGESWAR

CONTENTS

Chapter No.	Title	Page No.
	LIST OF TABLES	i
	LIST OF FIGURES	ii
	LIST OF PLATES	iii
	SYMBOLS AND ABBREVIATIONS	iv
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	5
III	MATERIALS AND METHODS	18
IV	RESULTS AND DISCUSSION	43
V	SUMMARY AND CONCLUSION	59
	REFERENCES	61
	APPENDICES	65
	ABSTRACT	

LIST OF TABLES

Table No.	Title	Page No.
1.1	Top ten rice cultivating states statistic in India	1
4.1	Physical dimensions of dry paddy seeds	44
4.2	Bulk density and true density of dry paddy seeds	45
4.3	Angle of repose of dry paddy seeds	45
4.4	Physical dimensions of pre-germinated paddy seeds	46
4.5	Bulk density and true density of pre-germinated paddy seeds	47
4.6	Angle of repose of pre-germinated paddy seeds	47
4.7	Design specifications of paddy hill seeder	48
4.8	Calibration of paddy hill seeder	49
4.9	Effect of cell size, forward speed and transmission ratio on seed rate and seed damage	50
4.10	Effect of forward speed, transmission ratio and cell size on performance of paddy hill seeder	53

LIST OF FIGURES

Plate No.	Title	Page No.
3.1	Cross sectional view of main seed hopper	25
3.2	Cross sectional view of secondary seed box	27
3.3	Cross sectional view of seed metering roller	28
3.4	crank rocker drive for seed metering mechanism	29
3.5	power transmission system	30
3.6	Opening and closing mechanism of seed tube for dropping seeds	33
3.7	Power operated paddy hill seeder (side view)	36
4.1	Effect of cell size forward speed and transmission ratio on seed rate	51
4.2	Effect of cell size, forward speed and transmission ratio on damaged seed	52
4.3	Effect of forward speed and transmission ratio on mean hill spacing	54
4.4	Effect of forward speed, transmission ratio and cell size on missing index	55
4.5	Effect of forward speed, transmission ratio and cell size on multiple index	56
4.6	Effect of forward speed, transmission ratio and cell size on quality feed index	57

LIST OF PLATES

Fig. No.	Title	Page No.
3.1	Plate 1 Power transmission system	31

SYMBOLS AND ABBREVIATIONS

Symbols		Abbreviations
<	:	Less than
>	:	Greater than
%	:	Per cent
±	:	Plus or minus
×	:	Multiplication
÷	:	Division
≤	:	Less than or equal to
≥	:	Greater than or equal to
°	:	Degree
°C	:	Degree centigrade
ASAE	:	American Society of Agricultural Engineers
cm	:	Centimeter
cm^2	:	Square centimeter
CV	:	Coefficient of variation
db	:	dry basis
DC	:	Direct current
et al.	:	and others
etc.	:	et cetera

Fig.	:	Figure
g	:	Gram
g cm^{-3}	:	Gram per cubic centimeter
GI	:	Galvanized iron
H	:	Height
ha	:	Hectare
hp	:	Horse power
h	:	Hour
ha day^{-1}	:	Hectare per day
ha h^{-1}	:	Hectare per hour
IS	:	Indian standards
KAU	:	Kerala Agricultural University
KCAET	:	Kelappaji College of Agricultural Engineering and Technology
kg	:	Kilogram
kg ha^{-1}	:	Kilogram per hectare
kg h^{-1}	:	Kilogram per hour
kg m^{-3}	:	Kilogram per cubic meter
kg min^{-1}	:	Kilogram per minute
km h^{-1}	:	Kilometer per hour
kW	:	Kilo Watt

L	:	Length
LHS	:	Left hand side
$l\ h^{-1}$	:	Litre per minute
m	:	Meter
$m\ min^{-1}$	:	Meter per minute
mm	:	Millimeter
mm^2	:	Square millimeter
mm^3	:	Cubic millimeter
Mha	:	Million hectare
$m\ s^{-1}$	:	meters per second
MT	:	Million Tons
RHS	:	Right hand side
rpm	:	Revolutions per minute
$Rs\ ha^{-1}$	:	Rupees per hectare
$rad\ s^{-1}$	:	Radian per second
R^2	:	Regression coefficient
S	:	Skewness ratio
SD	:	Standard deviation
Sl. No.	:	Serial Number
viz.	:	Namely

UCD(CU)		Uniformity coefficient of distribution
W	:	Width
Wb	:	Wet basis
α	:	Alpha
θ	:	Theta
μ	:	mue
π	:	Pi
ρ	:	Rho

16

INTRODUCTION

CHAPTER I

INTRODUCTION

Rice *(Oryza sativa)*, is the world's most important cereal crop and is the staple food for more than half of the world's population. Also, the rice is ranked third in world cereal crop production after wheat and maize. About 90% of the world's rice (146.7 million ha of area with a production of 673.6 million tons of paddy) is cultivated and produced in Asia. India is the second largest producer of rice with 104 million tons after China having 207 million tons rice among countries in the world. Above facts revealed that rice is one of the most important crops in India and it occupies 24% of gross cropped area of the country, with 45 million ha of cultivated area. (Anonymous, 2014).

The average rice yield in India is 3.5 t ha^{-1}, as compared to 4.7 t ha^{-1} in China and world average of 4.5 t ha^{-1}. However, there is drastic variation in average yield of rice in different states (FAO, 2015). The maximum average yield is 3.8 t ha^{-1} in Punjab and lowest yield is 0.97 t ha^{-1} is recorded in Himachal Pradesh. The yield gap between different states is one of the reasons for the poor national average yield and total production.

Top 10 rice producing states in India

S.No	State/ UT	Rice (MT)	Area (M.ha)	Average Yield (kg/ha)
1	West Bengal	14.71	5.38	2731.38
2	Uttar Pradesh	12.22	2.62	2082.36
3	Andhra Pradesh+ Telangana	11.56	3.80	3036.35
4	Punjab	11.10	2.89	3837.94
5	Orissa	8.28	4.16	1988.84
6	Bihar	6.37	3.26	1951.40
7	Chhattisgarh	6.02	3.80	1581.00
8	Tamilnadu	5.83	1.82	3190.75
9	Assam	4.86	2.27	2134.77
10	Haryana	4.00	1.28	3112.67

Sources:http://www.mospi.gov.in/statistical-year-book-india/2016/177

With the present rate of growing population, India would require an estimated production of 120 million tonnes of rice per year by 2030 (CRRI, 2011). The projected demand has to be met against the odds like declining land and water resource, scarcity of labour and costly inputs which are making rice cultivation too expensive.

The cost of rice cultivation can be reduced and makes rice cultivation more profitable is the need of the hour to the rice farmers. The possibility of expanding the area under rice in the near future is limited and the potential for expanding the area under rice in rain fed lands is other options. However, the ever increasing population invariably demands higher production in rice and wheat food grain. Therefore, the annual demand of rice is increasing compared to other food grains. Moreover additional areas under rice cultivations and substantially increasing rice yields of the existing varieties are the options that we have at our end. Additional extra rice has to come through by increasing rice production and productivity respectively. The major challenge to attain this gain is to be with less input resources and labour while maintaining the environmental sustainability of rice based ecosystems.

The rice crop is established by broadcasting, drilling and transplanting methods. The dry or pre-germinated paddy seeds of about 100 kg ha^{-1} or more are sown by manual broadcasting. While dry paddy seeds are either manually broadcasted or drilled by tractor drills and animal powered drills on dry rainfed paddy lands. However, manual drum seeders are now popularity used for sowing pre-germinated paddy seeds on wetlands. The manual drum seeders sow about 35-40 $kgha^{-1}$ of paddy seeds compared to 100-140 kg ha^{-1} by manual broadcasting. Now, the mat seedlings are used for manual as well as mechanized transplanting. The land area for raising nursery can be reduced to about 100 sq. m. for hectare compared to tenfold area required for root washed seedlings. The mechanized transplanting is popular since diverse types of machines are available in the market to suit the local requirements of the rice fields in upland and low land conditions. However, the mat seedling and transplanters have not gained much

19

popularity due to the management of nursery and fields which are not established properly for easy accessibility of mechanical transplanters inspite of the advantages of controlling weeds. Mechanical transplanters have high initial cost, poor traction and sinkage are other reasons for the lack of wider adoption in Indian conditions. In addition, it is estimated that transplanted rice needs about 3000-5000 liters of water to produce one kg of rice grain which is 3 to 5 times more than for other cereals like wheat, corn etc. At global level 70-80 percent of fresh water is used in agriculture (Pathak*et al.*,2011). Moreover puddling and transplanting operations consume about 30% of total water availability of rice.

Direct seeding of dry and pre-germinated paddy seeds have gained popularity due to the direct establishment of plants without uprooting and transplanting which takes some time for plants to establish from physiological shocks caused due to uprooting. Also, the weeds are controlled successfully by applying suitable weedicides at appropriate growth stages of paddy. In dry seeding application of paddy in low wetlands, the water is drained systematically as the seeds starts sprouting and an early emergence of weeds are controlled initially and later the weeds are controlled by weedicides. Thus, direct seeding offers great advantage in the management of seed material, labour, cost and inputs management on the way to establish the rice crop without much differential difference in yield reduction compared to other rice establishing methods. The direct seeding of rice technique offers viable option to reduce the limitations of transplanted paddy. Direct seeded rice (DSR) was a common practice before green revolution in India, is becoming popular once again because of its potential to save water and labour (Gupta *et al.,* 2006).

Direct seeded rice removes puddling and drudgery of transplanting as well as saves of water. The success of DSR mainly attributed to timely sowing, reduced cost of cultivation, seed rate, fertilizer, water and equal or higher yield as compared to transplanting. DSR is currently being practiced in China, Malaysia, Thailand, Vietnam, Philippines, and Sri Lanka. About 95% of the rice grown in Sri Lanka is direct-seeded (wet- and dry-seeding) (Pandey and Velasco, 2002).

Nevertheless, the problems with existing seed drills are their unequal seed placement in a row, excess seed dropping, the ground wheels get stuck with soils which result in ground wheel slip or skid in loose soils (Srigiri*et al.*, 2013).However, it is well known that seed drills for direct seeding have very high seed rates (80–120 $kgha^{-1}$) because of the non-availability of drills fitted with precise seed-metering mechanisms. In fact in some parts of the country, high seeding rate resulted in nitrogen (N) deficiency and caused a substantial reduction in grain yield (Mahajan*et al.,* 2013). Even though the manual drum type direct seeders and tractor drills sow paddy seeds in lines but the distribution of seeds along the lines are not uniform and widely dispersed along the lines. Therefore, the placement of paddy seeds in correct quantity in hills spacing is desired to achieve optimum plant population.

Therefore, it is imperative to design an appropriate precision hill seeder for sowing precision number of seeds to maintain correct seed rate and at correct spacing to attain correct population. The Yanji mechanical transplanter is widely adopted in Kerala since it is a single ground wheel driven traction machine with a float supporting most of its weight. It can easily maneuver in rice fields of low wet lands having soils with poor traction in addition to its simplicity and low cost. Since majority areas of rice in Kerala are under wetlands, it is prudent to develop a precision paddy hill seeder since line seeding in hills improves easy removal of weeds and wild rice, application of agro chemicals for weed control and for protecting rice crop against the incidence of frequent and large scale pests and diseases. In order to overcome the problems stated above and to mechanize and enhance production and productivity of wetland rice cultivation in traction poor soils, a precision paddy hill seeder attachment was developed for Yanji Make rice transplanter with following objectives:

1. To study the soil, seed, machine parameters related to power operated paddy hill seeder design and working.
2. To design and develop a power operated paddy hill seeder
3. To test and evaluate the performance of prototype paddy hill seeder.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1 Introduction

Precision seeding of crop is paramount importance to achieve reduced seed rate, good crop geometry, uniformity of seed placement and sound crop stand. The manual application of seed, without suitable machines fails to achieve the goals of proper seeding and decreased cost of cultivation. Design of a power operated paddy hill seeder needs optimization of different design parameters including crop, soil and machine. The review of previous research works related to hill seeder, influence of crop, machine and operational parameters on the design of seeders are presented under the following sub headings.

2.2 Direct seeding of Rice

Direct seeded crops require less labor and tend to mature faster than transplanted crops. In this method, plants are not subjected to stresses such as being pulled from the soil and re-establishing fine rootlets. However, they have more competition from weeds.

2.2.1 Broadcasting

Broadcast seeding is of particular use in establishing dense plant spacing. In comparison to traditional drill planting, broadcast seeding will require 10–20% more seed. It's simpler, faster, and easier than traditional row sowing. Broadcast seeding works best for plants that do not require singular spacing or that are more easily thinned later.

2.2.2 Line seeding

Line Sowing is a better method than broadcasting. Seeds are sown in the main field in lines. The spacing is 22.5 to 30 cm between lines and 8 to 10 cm within a line.

2.2.2.1 Manual line seeders

Islam *et al.* (1999) improved the performance of drum type seeder (BRRI) developed by IRRI for lowland paddy by incorporating a seed collector assembly to overcome the unwanted seed dropping at headlands which saved 5 to 7 kg ha^{-1}. The design features of eight rows seeder include 150 mm diameter cylindrical drum with 9 mm diameter seed metering holes and at an operating speed of 1.02 kmph.

Devnani (2002) developed a light weight, low cost, simple to operate four row rice drum seeder. The seeder consisted of 215 mm dia cylindrical drum having 17 numbers of rectangular seed metering holes of 10 x 20 mm. The operating speed was 1.2 km h^{-1}. The field capacity of developed seeder varied from 0.0198 ha h^{-1}. The average pull needed for operating the seeder was 78.48 N.

Tajuddin and Rajendran (2002) developed a low land rice seeder based on IRRI design. It consisted of two seed drums, two skids, a 600 mm diameter lugged ground wheel and a handle. The seeder is capable of sowing 6 rows at 200 mm spacing. The seed rate requirement was 50 kg ha^{-1}.

Singh *et al.* (2007) the drum seeder developed at CIAE Bhopal, India. The amount of pre-germinated seed required to fill the drum seeder is about 2.5 kg and of approximately 4.6 cm length. The drum seeder is 80 cm wide as per the ergonomic parameters suitable to the worker. Sinkage of the filled drum seeder in puddled fields reported is 4.6 cm. The seed rate reported for the seeder is 51.6 kg ha^{-1}.

Lacayanga *et al.* (2009) improved a manual rice hill seeder for wetland paddy by using stainless steel plate as the metering disc. The cell diameter was increased to 10 mm, a hollow square bar for the frame for improved stability, paddle wheel in replacement of the skids and an improved design of furrow opener. The improved 5 row hill seeder was tested under wet and dry field conditions. Results showed that the seeder performance under wetland condition were, effective field capacity of 0.62 ha day^{-1} , seed rate of 20-45 kg ha^{-1} , seeding efficiency of 93.3% and missed hills of 3.3%.

Kumar *et al.* (2017) was tested manually drawn eight row direct paddy drum seeder. The laboratory calibration was carried out with different combinations of drum fill level viz., full, half, quarter, and travel speed viz., 1 km/h, 1.5 km/h and 2 km/h. From the laboratory calibration test the combination of half drum fill level and 1 km/h speed were selected for field evaluation in puddled field. It was found from the study that, the theoretical field capacity was found 0.16 ha h^{-1}, while effective field capacity of the drum seeder was observed 0.131 ha h^{-1}. The field efficiency of the seeder was found 82.08%. The number of seeds dropped per hill was 5. The hill to hill spacing was 14.5 cm. The number of hills per square m was 30. The hill missing was 5.8 %. The cost of operation of drum seeding is Rs. 42.67 per hour and Rs. 341.36 per ha. Seed rate was nearly constant for initial 10 m distance travelled. For the next successive points i.e. up to 20 m distance travelled seed rate was observed increasing continuously during actual field operation.

2.2.2.2 Animal drawn line seeders

Singh *et al.* (1983) developed a six-row IRRI-Pant nagar bullock drawn paddy seeder which required 1443 man h/ha for all the agricultural operations whereas transplanting methods required 1682 man h/ha. The diameter, length and number of grooves of the roller were 7.5 cm, 7.0 cm and 8.0 cm respectively. The overall length, height, width and weight of the seeder were 73 cm, 100 cm 150 cm and 48 kg respectively. The seeder was operated at 2.0 km h^{-1} forward speed and the seed rate was reported 70-80 kg ha^{-1}. The observed yield was 7800 kg ha^{-1} for Jaya variety. The maturity of the crops was advanced 10 days compared to bullock drawn treatment.

Srivastava and Panwar (1991) developed a drill for sowing pre-germinated rice consisting of a hopper, metering unit, furrow openers, ground wheels, float and the basic frame with controls. Soil machine crop variables relevant to the design of each of the components were identified and evaluated. Three sprout lengths of 2, 4 and 6.5 mm with seed rate 45, 50 and 55 kg ha^{-1} were used in the field to see the effect on yield. It was observed that a sprout length of 2-5 mm found to be optimum for maximum plant population and grain yield. Experiments were conducted on light sandy loam soils and paddy variety 'Pusa 33' was used. Field performance specification were 11.2 kg draught, 0.08 hah^{-1} field capacity, 72.8% field efficiency, 52.4 kg ha^{-1} seed rate, 92% plant emergence and 2.32 t ha^{-1} crop yield.

Jesudass *et al.* (1996) A simple bullock-drawn seeder was developed with orifice flow seed metering device and runner type furrow opener. The performance of the orifice flow metering device was tested by varying the orifice diameter, agitator disc diameter clearance between bottom of agitator and top of the orifice plate and speed of agitator disc. The clearance between agitating rotor and metering plate of the seeder should be one mm or less for maximum discharge of seeds. The performance of the prototype was tested in black cotton soil in comparison with mechanical broadcaster and manual sowing. The germination of paddy in plot-sown using direct paddy seeder was 49%, 33% higher than that of manual broadcasting and mechanical broadcasting.

Ryu and Kim (1998) developed a roller type metering device for precision planting of rice to study the scattering of seeds in the hill dropping planters with a roller type metering device. The hill dropping performance of the new roller was compared with semi-circular groove when the planter was operated with a forward speed range of 0.22 to 0.83 m/s and the hill distance fixed as 0.15 m. A total of 300 seeds were sown over 50 hills. Scattering distance ratio (a ratio to the hill distance of the range over which 90% of the seeds in a hill are placed) of the new roller was 25 to 30 %, sufficient for the precision planting of rice while that of the old one was 76 to 115%, indicating a uniform distribution of seeds along the row.

Singh *et al.* (2012) modified a bullock drawn paddy seeder based on the manually operated seeder of IRRI design. It was found that the total man-hour requirement per hectare was 1443 in the case of bullock drawn paddy seeder. In the case of manual transplanting method, man-hour requirement was 1682. It was also found that there was no significant difference in the grain and straw yield for bullock drawn seeder and transplanted paddy. The cost of cultivation was minimum in the case of the seeder.

Patil and Dhande (2015) developed a bullock drawn dry paddy seed cum fertilizer drill for upland cultivation with a cup feed seed metering mechanism. The developed dry paddy seed cum fertilizer drill has worked satisfactorily in the field. The average theoretical field capacity, effective field capacity and field efficiency were 0.151 ha h^{-1}, 0.11 ha h^{-1} and 75.96% respectively.

2.2.2.3 Power operated line seeders

Gupta and Herwanto (1992) developed a power tiller drawn 8 row direct paddy seeder to overcome human stress and drudgery in transplanting operation. The seeder had a working width of 2 m. The seeder had individual hopper for each row with a six fluted seed metering roller and a double disc furrow-opener. Two lugged driving wheels rotate the metering rollers mounted over a common shaft. Each flute in a metering roller can pick up 3 to 5 paddy seeds and place them in a furrow through seed guide at a desired depth of 2 to 7 cm. The seeder was provided with a foot-operated clutch to disengage the metering mechanism and a canopy to protect the operator from direct sunlight. The field capacity of seeder was about 0.5 ha h^{-1} at a forward speed of 0.81 m/sec and field efficiency of 78%. The seed rate was 15 to 20 kg ha^{-1}. The damage observed due to metering mechanism was nil for soaked seeds and 3% for pre- germinated seeds.

Sahoo *et al.* (1994) developed a six row power tiller operated pre-germinated paddy seeder and results showed that the effective field capacity of the seeder was 0.168 and 0.114 ha h^{-1} for 99 and 253 mm hard pan depths respectively. The row to row spacing was 200 mm and hill to hill spacing was

99.5 mm with 3-5 seeds per hill. Cup type seed metering discs of 8 mm diameter and 6 mm depth were designed so as to pick up 3-5 seeds per hill. The capacity of the hopper was 40 kg. The cost of operation of the seeder was observed Rs. 173 per hectare. The seed rate was set at 75 to 85 kg ha^{-1} for three varieties, super fine, fine and coarse grain.

Sawamura, (1995) A team of Scientists under (JICA) Japan and Philippines Rice Research Institute, Philippines worked from 1994-98 on a project to develop a power tiller operated anaerobic type paddy seeder. A 12-row unit was developed. It was able to sow the seeds at 40-120 kg/ha with a field capacity of 3 to 5 ha day^{-1}. The successful design of seeder was developed and reported (Ryuji Otani, 1998).

Nishida Hatsuki, (1996) A tractor operated anaerobic seeder was developed in Japan. The direct anaerobic seeding machine consisted of a tractor mounted combination of rotavator and a seed drill. Thus it is a multipurpose type unit useful for rice-wheat cropping system. It is desired to prepare the wet seed bed with a rotavator of shallow type and drop the seeds in the furrow, the seeds are covered with soil. The machine can do rotavating and broadcasting of paddy seeds.

Luo X.W.*et al.* (2008) introduced a precision rice hill-drop drilling technology. In single pass, it creates a ridge, opens the furrow on the ridge and water furrow between the ridges, and sows pre-germinated rice seeds in the furrow simultaneously. The water applied in the furrow between the ridges provides water for the growth of the rice seedlings. It is only necessary moisten the furrow without the need to irrigate the entire field. This design reduces the evaporation and saves water. To meet the requirements of different rice varieties, planting seasons, and soil conditions in China, precision rice hill-drop drilling machine was made with different row spacing, including 20 cm, 25 cm, 30 cm and 50 cm. The hill spacing can be adjusted from 10 cm to 25 cm. The amount of sowing seeds per drop can be adjusted from 3 to 10 grains.

Guozhong *et al.* (2015) designed a novel precise pneumatic rice seed metering device with groups of sucking holes plate, by which 3-4 seeds could be synchronously sucked and synchronously dropped into the paddy field. Experiments were conducted to investigate the seeding precision and simulate the field emergence rates on the indoor seeding bed. Other experiment conditions included the vacuum degree of 2.60 kPa, the rotation speed of seed sucking plate of 30 r/min, three sucking holes with a diameter of 1.6 mm, and the seed layer thickness of 25 mm. The seeding results showed that, in condition of no more than 2 seeds per hill, the emergence probabilities under the two moisture contents were 11.82% and 11.95%, respectively, and in condition of 3-4 seeds per hill, the results were 64.81% and 65.84%, respectively. With 2-5 seeds per hill, the results were 92.08% and 92.60%, respectively. If the emergence probability was 80%, under the two moisture contents, the no seed per hill probabilities were 1.33% and 0.80% respectively; the probabilities with 3-4 seeds per hill were 56.13% and 56.40% respectively; the probabilities with 5 or more seeds per hill were 10.67% and 10.13% respectively; the probabilities with 2-5 seeds per hill were 87.60% and 88.13% respectively.

2.3 Transplanting of rice

Transplanting is commonly practiced as a method of weed control for wet and puddled paddy fields. It requires less seed but much more labor compared to direct seeding. Also, transplanted crops take longer to mature due to transplanting shock.

2.3.1 Animal and manual type rice transplanters

Satish Kumbhar. *et al.* (2017) are designed and developed a manually drawn rice transplanter. The cost is cheap than motor and hand cranked mechanical rice transplanter. The four bar mechanism gives the each operating and maintenance with less parts which reduces the weight. After further improvement, this two row paddy transplanter can be transplanter 0.2 to 0.3 hectare/day while manual hand transplanting gives 0.1 to 0.1.5 hectare/day for 8 hours of working in a day. The total cost which include material and fabrication cost of transplanter is Rs. 6000 and easy to operate.

2.4 Rice metering mechanisms

Different types of metering mechanisms are used in drills and planters for regulating and controlling the rate or number of seeds dropped per rotation of the mechanism to achieve recommended seed rate of the crop sown. The devices used for metering the seeds for distributing in lines in the field are of volume basis. The common devices are fluted roller, inclined plate, roller and disc cell types, hole and agitator types etc., which functions on volume basis. However, the pneumatic and electronic devices meters seeds on the basis of number of seeds fills or picked by the cells

2.4.1 Mechanical metering mechanisms

Grewal *et al.* (2015) conducted laboratory experiments on inclined plate seed metering unit having 18, 24 and 30 grooves. Performance was evaluated on the basis of missing index, multiple index and quality feed index. It was observed that the missing index was highest in case of 18 groove plate at speed of 2 km h^{-1}. It decreased with the decrease in forward speed and also with the increase in the number of grooves of the metering plate. Minimum missing index was observed for 30 groove plate at the speed of 1 km h^{-1}. Multiple index was highest at speed of 2 km h^{-1} for 30 groove plate . Minimum value of multiple index was 13.67% at speed of 2 km h^{-1} for 18 groove plate. As the forward speed was increased from 1 km h^{-1} to 2 km h^{-1}, multiple indexes decreased. Quality of feed index was best for 30 groove plate at a forward speed of 1.5 km h^{-1}. Based on the results of the laboratory evaluation, 30 groove seed metering plate and a forward speed of 1.5 km h^{-1} was selected for the field evaluation. Average field capacity of the machine was found to be 0.11ha h^{-1} and average fuel consumption of the tractor was 3.2 l/h. The average germination count after 28 days after planting was found to be

14.66 plants/m row lengths. The average onion bulb size, average bulb weight and average yield of onion bulbs were found to be 4.94 cm, 56.68 g and 334 q ha^{-1} respectively.

Wang Z.M.*et al.* (2010). developed a precision rice hill-drop drilling technology machine. In one single pass, it creates a ridge, opens the drilling furrow on the ridge and water furrow between the ridges, and sows rice seeds in the drilling furrow simultaneously based on the requirements of rice planting. The precision rice hill-drop drilling technology has applied in more than 26 provinces in China. The rice yield increased by more than 10%, 8%, 6% and 5%, compared with the manual broadcasting, manual seedling broadcasting, manual transplanting, and mechanical transplanting, respectively. The production cost can be saved more than 1500 Chinese Yuan per hectare compared with manual seed broadcasting, manual transplanting, and mechanical transplanting.

2.4.2 Pneumatic metering mechanisms

Sahoo and Srivastava (2008) evaluated the performance of a prototype planter to plant soaked okra seeds. The machine had a modular hopper and an inclined plate type metering unit. The power transmission to the metering unit was through a ground wheel by chain and sprocket system. The machine had a provision for varying row spacing and depth of seed placement. Based on the laboratory and field trial of machine it was concluded that the deviation of seed discharge among the rows from average for half hopper, three-fourth hopper and full hopper were within the range of 7% and was statistically insignificant. The maximum deviation of seed discharge for any of the row was 3.85 per cent. An average field capacity of 0.20 ha $h^{-1}$was observed for continuous operation of okra planter at an average speed of 2.27 km h^{-1}. The field efficiency and field machine index were found to be 66.5 and 77.38 per cent. Also there was a saving of 77 man hours per hectare and 76 per cent in cost of operation.

Singh *et al.* (2005) evaluated a tractor operated pneumatic planter for planting cotton, groundnut and mustard seeds in black soil using metering disc with 120 degrees entry cone angle on 2.5 mm seed hole for cotton, 120 degrees entry cone angle on 4.5 mm seed hole for groundnut and 90 degrees entry cone angle on 1.5 mm seed hole for mustard seed, respectively. . The entry cone angle of the hole was varied from 90 to 150^0, the speed varied from 0.29 to 0.69 m/s, and the vacuum pressure from 1 to 2.5 kPa. The metering system of the planter was set to place the seeds at 250mm spacing. They found that the variability in seeds/plant spacing for cottonseeds (25.07 and 29.82 cm), groundnut seeds (10.05 and 12.36 cm) and mustard seeds (10.91 and 13.58 cm) obtained in the laboratory and field conditions, respectively, could not be compared as the variability in field condition included variation in plant spacing due to vibration of machine and seed viability.

Maheshwari and Varma (2007) conducted experiment on performance evaluation of pneumatic planter for pea and concluded that the average seed rate of this planter was very low in comparison to seed drill. They found that the seed rate for pneumatic planter and seed drill was 60 kg ha^{-1} and 100 kg ha^{-1} respectively and the uniformity coefficient for pneumatic planter and seed drill were 90.8 and 82.28%, respectively. The average plant population was 20 plants per sq. m for pneumatic planter which was approximately 11% higher than plant population by seed drill.

Matin *et al.* (2008) evaluated a multi crop power tiller operated inclined plate planter developed by BARI. The number of cells in the seed metering plate is 10 and it is inclined at 30° to the vertical. The peripheral velocity of the plate is 0.15 ms^{-1}. They reported that the average field work rate capacity of the unit is 0.19 ha h^{-1}. The unit resulted in a saving of 32.8 and 79.2 per cent saving in cost and labour respectively over traditional practice. In addition 18 per cent yield increase was also observed in mechanical method.

2.4.3 Electronic metering mechanisms

Kocher *et al.* (1998) developed an opto-electronic seed spacing system that measured time intervals between seeds and detected front-to-back location of seed drop events relative to planter was used to rapidly determine planter seed spacing uniformity in the laboratory. The seed detection sensor for the opto-electronic system consisted of a rectangular photo gate with 24 photo-transistors receiving light beam from 24 LEDs opposite them. The system also included circuitry to interface the photo gate with a digital I/O board in a personal computer. The belt test stand system was operated at forward speed of 3.2 km per hour. The seed spacing's obtained with the opto-electronic system were compared with the same seed spacings obtained from the grease belt test

Karthikeyan (2004) developed an electronic seed monitoring system for planter. The system comprised of light emitting diodes and phototransistors as sensing elements, a detector circuit and a seed flow detector block. A four digit counter was made for counting the number of seeds flow through the seed tube. As an alternative, a unit with three LEDs and three phototransistor combinations was also developed. The sensor was tested in laboratory as well as field conditions

Meena (2005) developed an electronically assisted seed metering mechanism. Metering mechanism consisted of electronic circuit which regulated a stepper motor. The seed carried by belt in its cell was supported from below by a plate. Stepper motor was used to drive the belt. Stepper motor was driven through a control circuit. Proximity sensor was used on the ground wheel spacing along with a plate to achieve the desired spacing at which seeds are to be sown.

Singh and Mane (2011) developed an electronic metering mechanism with an attempt to make the drills/planters simpler without compromising precision in seed placement for okra seed by using cup type seed metering unit. It was observed that at 15cm target seed spacing, the observed seed spacing were, 15.3, 15.2 and 15.3 cm, respectively at forward speeds of 1.0, 1.5 and 1.85 kmh^{-1}

respectively. Similarly at 30 cm target seed spacing, the observed seed spacings were, 30.4, 30.8, 31 and 30.9 cm respectively at 1.0, 2.0, 2.5 and 2.75 kmh^{-1} forward speeds respectively. At 15 cm target spacing the number of seeds per meter length varied between 5 and 7 with average of 6 seeds for all levels of forward speeds. The observed quality feed, multiple and miss indexes were, 96.4, 0.4, 0.2 per cent. The average seed spacing was observed was 9.8 cm with a precision of 8.6. It was stated that the opto-electronic system can be used instead of a grease belt test stand to rapidly obtain quantitative evaluations of planter seed spacing uniformity in the laboratory.

Zhai *et al.* (2014) developed precision seed metering system for the conventional direct seeder. The control system comprised a Hall Effect sensor, a single chip microcomputer system, a motor control module, a stepper motor and display. Hall sensor measured the seeder's working speed and a single chip microcomputer system predicted the rotational speed of seed-metering device. Three forward speeds of 1.0, 1.5 and 2.0 m s^{-1} were selected for laboratory experiment. The results were compared between ground wheel drive and electronic controlled metering system. Results showed that the spacing and quality feed index values at 1 m s^{-1} forward belt speed were observed as 84.79 mm and 85.83% for ground wheel drive system while 87.75 mm and 95% for electronic control metering system. It was observed that the system could effectively reduce the influence of inhomogeneous sowing caused by the ground wheel's slipping. The system was found to be reliable by the experiment.

Kamgar *et al.* (2015) developed an electronic controlled seed metering unit designed for grain drill for direct seeding of wheat. It comprised of a variable-rate controlled direct current motor (DCM, model: D12-8001-45W) as seed metering shaft driver, two digital encoders for sensing the rotational speed of supplemental ground wheel, seed metering shaft and a control box to handle and process the data of the unit. The seeding rate was determined based on the calculated error signal and output signal of the digital encoder of the supplemental ground wheel. The microcontroller computer value which is in the form of PWM voltage and send it to amplify by a MOSFET. A field with four different levels of wheat stubble coverage (10%, 30%, 40% and 50%) was selected for evaluation of the fabricated seed metering unit. The dynamic tests were conducted to compare the performance of installed fabricated seed metering unit on the grain drill and equipped grain drill with common seed metering unit at three forward speeds of 4, 6 and 8 km h^{-1} for supplemental ground wheel. Results of the fabricated seed metering unit assessment demonstrated that an increase in forward speed of grain drill fabricated seed metering unit and stubble coverage did not significantly affect the seeding rate in the grain drill for supplemental ground wheel. Using the fabricated seed metering unit reduced the coefficient of variation (CV) by approximately percent. Results of field evaluation showed that mechatronics mechanism decreased multiple index also; higher percentage in quality of feed index was obtained for planter equipped with mechatronics mechanism and rubber tire. The new system decreased both miss index and precision index, which is desirable. It was stated that adopting mechatronics mechanism on row crop planters eliminates the need for planter calibration.

2.5 Problems and constraints in rice seeding and transplanting

No study was reported on mechanical seeder for direct seeding of rice with proper metering mechanism which can ensure reduced seed rates, missing hills and uniformity of crop spacing. Systematic study on design parameters is need of the hour. The hill seeder should be equipped with provisions to ensure precision seeding.

MATERIALS AND METHODS

CHAPTER III
MATERIALS AND METHODS

Design and development of a power operated paddy hill seeder was studied for crop, soil and machine parameters and for their inter-relationship. The machine was designed to different seed varieties in dry or soaked condition to place the seeds precisely at recommended uniform spacing. This study pertained to the parameters, components design, material and fabrication methods and testing and evaluation of the prototype was conducted in the laboratory as well as field. The materials and test methods including design procedures are discussed in this chapter.

3.1. Engineering properties

Engineering properties are the properties which are useful and necessary for the development of preccision seeder critical parts.

The engineering and physical properties of seeds i.e. size, shape, bulk density, angle of repose and thousand grain weight that affect the seed metering performance, were determined for designing of precision paddy hill seeder. The size parameter helped in designing cell length and depth to accommodate the number of grains in the cells of seed metering cell roller mechanism. The shape property described the cell fill efficiency of paddy grains from the roller surface. Bulk density and true density values helped in design of seed hopper size. Angle repose and coefficient of frictional property were determined to design the required slope of seed hopper for free flow of paddy grains from the hopper. Coefficient of static friction values as a measure of resistance was determined for selecting hopper material for uniform and free flow of paddy grains, while the 1000 grain weight was used to determine the number of grain required per meter area for a desired seed rate. The physical properties were determined as following.

3.1.1 Physical properties

3.1.1.1 Bulk density

Bulk density and True density values are used to design the seed hopper. Bulk density was determined using a cube of size 10x10x10 cm. The cube was filled with paddy grains without any compaction, and later on the seeds filling the cube were weighed. The bulk density was determined as the ratio of weight of the seeds and volume of cube following relationship

$$\text{Bulk density,} = \frac{Weight\ of\ paddy(g)}{Volume\ of\ container,(cm^3)}$$

Where,

W = weight of the paddy, g

V = Volume of the sample, cc

3.1.1.2 True density

The true or solid density defined as the ratio of a given mass of sample to its volume was determined by the water displacement method. Accordingly, a known weight (50g) of sample is poured into 100 cm^3 fractionally graduated cylinder containing water. The mass of displaced water was recorded and used in the following expression to determine the true volume. The true density of paddy was determined by taking five replications.

$$\text{True volume } (g/cm^3) = \frac{\text{Mass of displaced water,(g)}}{\text{Density of water,(g cm}^{-3})}$$

By knowing the mass of the paddy and the true volume, the true density was obtained as the ratio between the mass to its true volume.

$$\rho_t = \frac{M_a}{V_t}$$

38

Where,

ρ_t = true density of paddy, g cm^{-3}

M_a= Mass of paddy in air, g

V_t= True volume of paddy, cm^3

3.1.1.3 Porosity

The porosity of paddy grain/seeds can be determined by using data from bulk and true densities of the material. The porosity of paddy seed was determined using the relationship presented by Mohsenin (1986) as follows.

$$\text{Porosity} = \frac{1-(\text{Bulk Density}/\ \text{True Density})}{100}$$

3.1.1.4 Moisture content

The given sample was dried in electric oven at a temperature of 105 c for 24 hours and weighed by using a weighing balance at every 8 hours interval to obtain 3 different levels of moisture content. The moisture content of the sample in percent dry basis was determined by the following formula.

$$\text{Moisture content MC(\%)}= \frac{\text{Wi}-\text{Wd}}{\text{Wi}}(100)$$

Where,

Wi = Initial weight of the sample, g

Wd = Final weight of the sample, g

3.1.1.5 Size, Shape, Sphericity

The size and shape of paddy seeds were the two important factors that determined the shape and size of seed metering roller. Paddy seeds had a three dimensional shape which could be measured as the length, breadth and thickness and were categorized as short, medium and large. Geometric mean size of paddy grain affects the groove length and depth of rotor in seed metering roller. A sample of 10 seeds of each variety was taken and geometric mean was determined by the following relationship.

$$\text{Geometrical mean} = 3\sqrt{l \times b \times t}$$

Where,

l = length of paddy, mm

b = breadth of paddy, mm

t = thickness of paddy, mm

Sphericity(ɷ) affects the uniform free flow of paddy grains from the metering roller groove surface. In order to define the shape of seeds, sphericity (ɷ) was calculated by utilizing the values of physical dimensions of seed using the following relationship

$$\text{Sphericity}(ɷ) = \frac{3\sqrt{l \times b \times t}}{l}$$

Where,

l = length of paddy, mm

b = breadth of paddy, mm

t = thickness of paddy, mm

3.1.1.6 Weight of paddy

1000 paddy samples grains weight were determined by using an electronic balance having an accuracy of 0.01g. True weight of each grain was determined by using fallowing formula.

$$\text{Weight of each grain (g)} = \frac{\text{Total weight of the given samples(g)}}{\text{Given number of samples(no.)}}$$

3.2 Frictional properties

Frictional properties such as angle of repose and coefficient of friction of paddy seeds on selected surfaces were studied to understand the ease with which the paddy seeds move or slide over selected surfaces. This is necessary to identify the materials suitable for making planting equipment's containers or tanks. The methods adopted for estimating these properties are detailed below.

3.2.1 Angle of repose

The angle of repose is the angle between the base and the slope of the cone formed on a free vertical of the granular material to a horizontal plane. The angle of repose was measured by using a wooden frame full of paddy grain sample is placed on a tilting top drafting table. The table top is tilled the grain starts moving downwards over the inclined surface. The angle of inclination was measured, which is the angle of repose of the paddy grain sample.

3.2.2 Coefficient of friction

The experimental apparatus used in the studys consists of a friction fewer pulleys fitted on a frame. A bottomless container was placed on the test surface and filled with known quantity of paddy grain weights were added to the loading pan until the container being to slide. The mass of paddy and the added weights represent the normal force and frictional force, respectively. The coefficient of static friction was calculated by using the fallowing formula.

$$\text{Coefficient of friction, } \mu = \frac{\text{Frictional force (kg)}}{\text{Normal force (kg)}}$$

3.3 Design considerations of paddy hill seeder

For the development of power operated paddy hill seeder, the crop and machine parameters were studied. An efficient design of a metering mechanism for paddy seed was designed to meet the expected performance of a paddy hill seeder.

3.3.1 Crop parameters

The crop parameters play a vital role in the design of seeders/planters. The crop parameters considered for the design of metering mechanism of paddy hill seeder were.

i. Row to row spacing, m
ii. Plant to plant spacing, m
iii. Number of seeds per hill
iv. Seed rate

The seed rate of paddy for direct seeding (Dum seeder) is about 40 kg h^{-1} for a row spacing of 20 to 22.5 cm

(RASS, Tirupati and Narendra Haridas Tayade 2017)

3.4 Machine parameters

The performance of the seeder depends on the cell size, forward speed, transmission ratio and seed dropping height.

Hence, the following variables were selected for achieving precision in seeding of paddy seeds as evaluated through the set precision performance parameters.

i. Forward speed of operation (S)
i. Transmission ratio speed (T)
ii. Metering cell shape (C)

1. **Forward speed of operation (S)**

The performance of a machine depends upon the forward speed of operation which affects the precision parameters like spacing, quality feed index and seed damage. To determine the optimum forward speed, the evaluations for different performance parameters were carried at 1.5 and 1.8 km h^{-1}speed levels.

2. Cell shape

Considering the shape of two paddy varieties, two cell size of metering rollers viz., were fabricated for the study. The average seed cell dimensions were 9 mm and 12 mm was taken as equivalent diameter, 4 mm was taken as cell depth for design of cell of seed metering rollers. The cell configuration was same for all the designed paddy metering vertical cell type rollers.

3.5 Design and development of paddy hill seeder

A power operated prototype paddy hill seeder was developed based on the physical and mechanical property of paddy varieties. The prototype essentially consists of a main frame, seed metering unit, power transmission system, and seed tube opening and closing mechanism. The hill seeder was designed to plant eight rows at row spacing of 0.23 m covering a total width of 1.7 m.

3.5.1 Design of seed hopper

The seed hopper made of MS sheet. The length of box is given by

Length of the seed hopper box = 110 cm

Field capacity of the machine = 0.23 ha/h

Let us design a seed box for such a capacity, that it requires refilling of seeds after 2 hour.

Therefore,

Weight of seed to be used in 2 hour = Seed rate (kg ha^{-1}) × Area covered per h × time (h)

$$= 50 \times 0.23 \times 2$$

$$= 23 \text{ kg}$$

$$\text{Volume of seed hopper} = \frac{Weight\ of\ seed\ (Kg)}{Bulk\ density(kg\ \text{m}-3)}$$

$$= \frac{23}{580} = 0.04 \text{m}^3$$

Bulk density of paddy =580 kg m^{-3}

Now from the fig.3.1,

Volume of seed hopper (V) = $\frac{(a+b)}{2} \times h \times L$

Where,

a=Bottom width of the box

b=Top width of the box

h=Height of the box

From fig.3.1,

b=2l+a

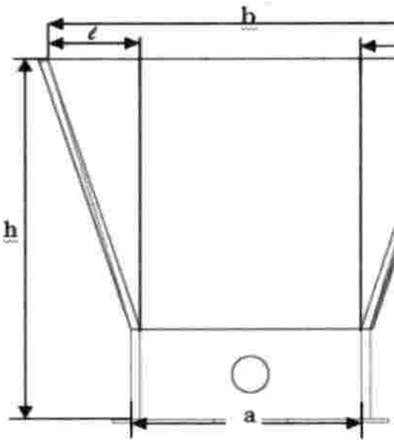


Fig.3.1 Cross sectional view of main seed hopper

Therefore, V= $\frac{(a+2l+a)}{2} \times h \times L$

$(V) = \frac{(2a+2l)}{2} \times h \times L$

Now from the fig.3.1, $\frac{h}{l} = \tan\theta$

So, l=cot θ

Now the above equation become, V= (a+h cotθ)$\times h \times L$

Where, $\theta = angle\ of\ repose, its\ considered\ as\ 39\ for\ paddy$

Assume the value of a=0.25m

Now, V=(0.25+h cot 42)×h×1.1

$0.04 = 0.275h + 1.35\ h^2$

$1.35\ h^2 + 0.275h - 0.04 = 0$

This quadratic equation is in the form of $Ah^2 + Bh + C = 0$

Where, A = 1.35, B = 0.275, C= -0.04

Now, we can solve for 'h' by using following formula

$$h = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$h = \frac{-0.275 \pm \sqrt{0.275^2 - 4 \times 1.35 \times -0.04}}{2 \times 1.35}$$

$$h = \frac{0.81}{2.7}$$

h=0.30m

The height of the box is 5 cm larger than the top width of the seed box for avoiding seed over flow.

So, b = 0.30 m

Design specifications of seed box are,

Length of box = 110 cm

Top width of the box = 25 cm

Bottom width of the box = 15 cm

Height of the box = 30 cm

Angle of repose = 39°

3.5.2 Design of secondary seed hopper

A secondary seed hopper was made to reduce the grain over burden over the metering mechanism. This box was developed based on the seed metering roller.

Design consideration of secondary seed hopper

1) The hopper should have especially of 250 g
2) The height of grain over the metering cell permits 2cm

Assumptions of secondary seed hopper

Length= 9 cm

Width= 4cm

Height = 7 cm

Volume of hopper $= L \times B \times H$

$= 9 \times 4 \times 7$

$= 180$ cc

Weight of grains $= \frac{volume}{density}$

$= 180/0.58 \times 0.8 = 248.5$ g

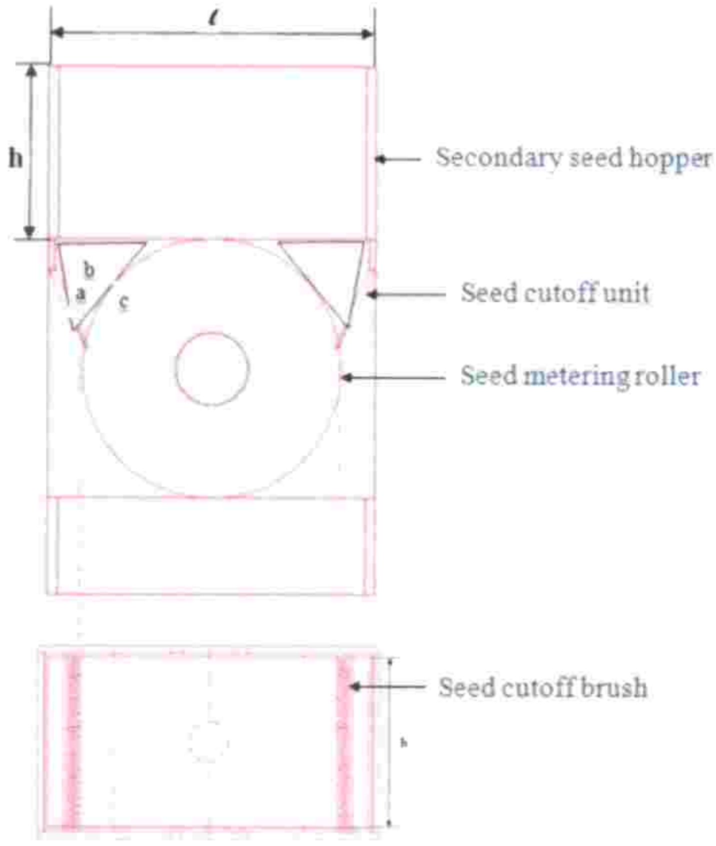


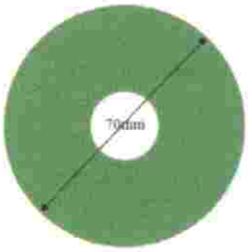
Fig.3.2 Cross sectional view of secondary seed box

46

3.5.3 Design of metering mechanism

For hill dropping paddy seeds, a roller type cell mechanism was selected. The roller cell was designed on the paddy dimensions. The 3 to 5 numbers of paddy seeds were to be picked by cell type roller per dropping cycle. The paddy grain size was determined as per section grain length 7.2 – 8.3 and thickness 2 – 2.3.

a. Top view

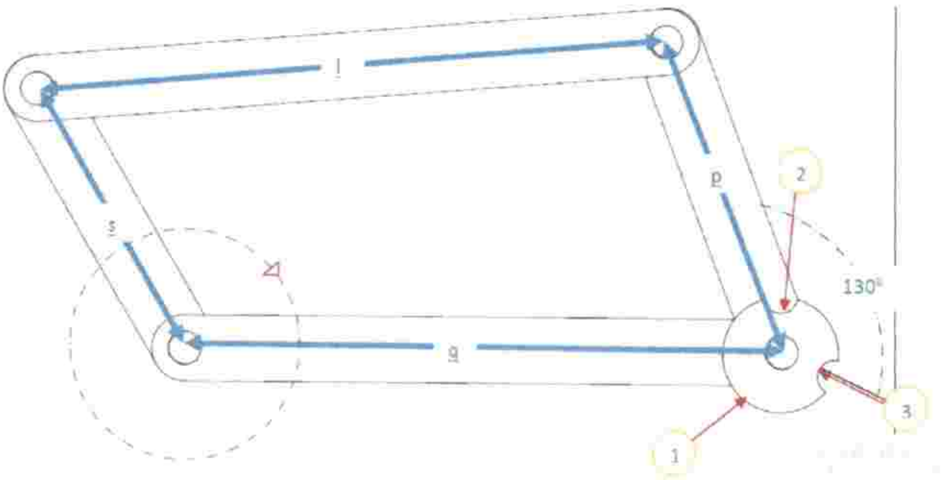


b. Isometric view **c. Side view**

Fig.3.3 Cross sectional view of seed metering roller (vertical cell type)

3.5.4 Design analysis of Crank Rocker metering mechanism

For better maintain of cell filling and distances between two hills a crank and rocker type mechanism was designed. After several analyses the bellowed design was selected for safe grain collecting and dropping. The links lengths ratio is selected based on the required safest angle.



$$S+l < p+q$$

Sl.No.	Description
1	**Seed metering roller**
2	**Seed pick up position**
3	**Seed dropping position**

Fig.3.4 crank rocker drive for seed metering mechanism

3.5.5 Design of transmission

3.5.5.1 Kinematics of gear and chain drive

N1 = Speed of the driver at input shaft in rpm

N2 = Speed of the driven at output shaft in rpm

N3 = Speed of the driver at output shaft (linked to seed hopper metering screw) in rpm

N4 = Speed of the driven at seed hopper metering screw shaft in rpm

N5 = Speed of the driver at output shaft (linked to seed metering shaft)

N6 = Speed of the driven at seed metering shaft in rpm

T1 = Number of teeth on the driver at input shaft

T2 = Number of teeth on the driven at output shaft

T3= Number of teeth on the driver at output shaft (seed hopper
Metering screw)

T4 = Number of teeth on the driven at seed hopper metering screw shaft

T5 = Number of teeth on the driver at output shaft (linked to seed
metering shaft)

T6 = Number of teeth on the driven at seed metering shaft

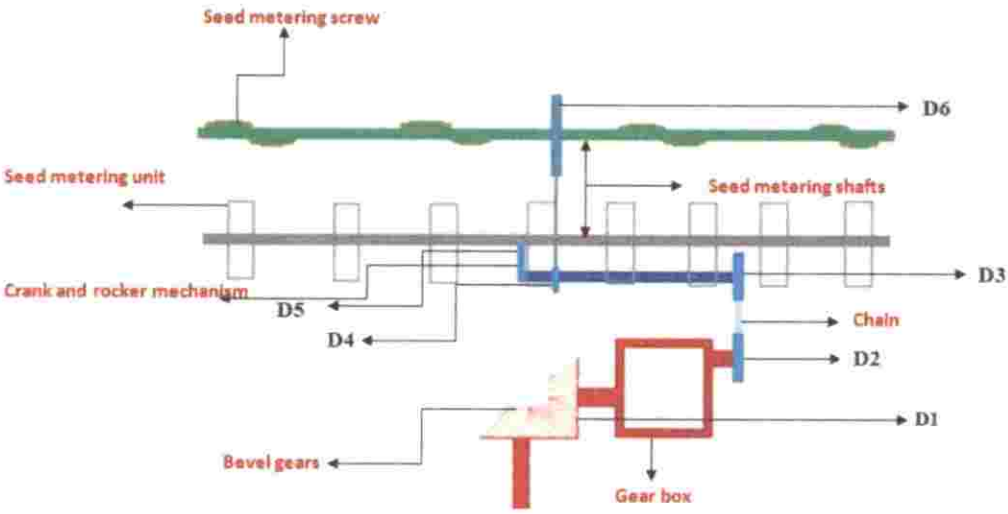
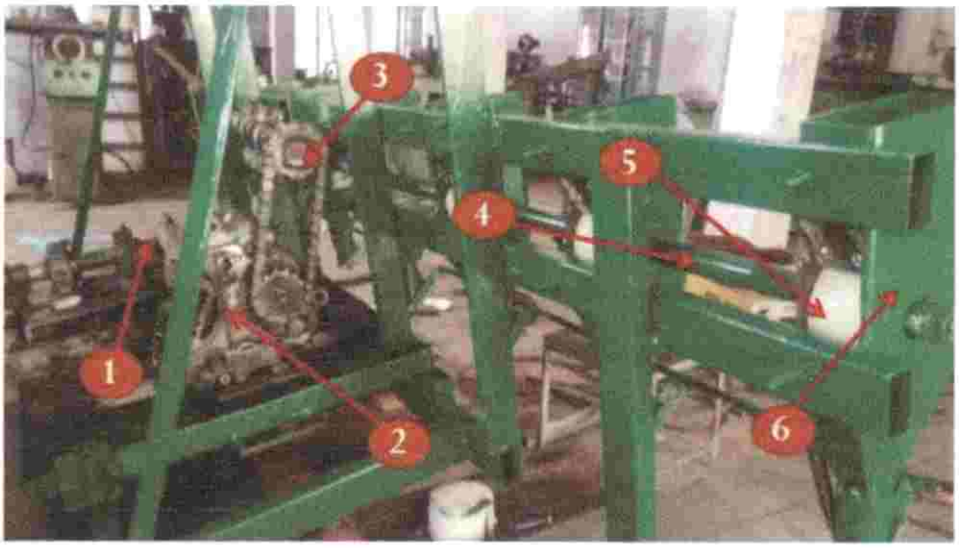


Fig.3.5 power transmission system



1	Bevel gear unit	4	Seed metering shaft
2	Variable speed gear box	5	Seed metering roller
3	Drive shaft for seed metering unit	6	Seed metering box (2^{nd} seed hopper)

Fig.3.5 power transmission system

A. At seed metering shaft

1. For 1:1.7 gear ratio (Low speed)

T_1=17, T_2=29

Velocity ratio,

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} = \frac{29}{17} = 1.7$$

Therefore,

$N_1 = 1.7\ N_2$

2. For 1:1.2 gear ratio (Medium speed)

T_1=21, T_2=26

Velocity ratio,

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} = \frac{26}{21} = 1.2$$

Therefore,

$N_1 = 1.2\ N_2$

3. For 1:1.2 gear ratio (High speed)

T_1=24, T_2=23

Velocity ratio,

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} = \frac{23}{14} = 0.95$$

Therefore,

$0.95\ N_1 = N_2$

4. At seed hopper metering screw

T_5=14, T_6=36

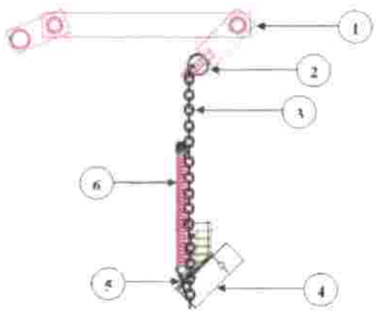
$$\frac{N_5}{N_6} = \frac{T_6}{T_5} = \frac{36}{14} = 3$$

Therefore,

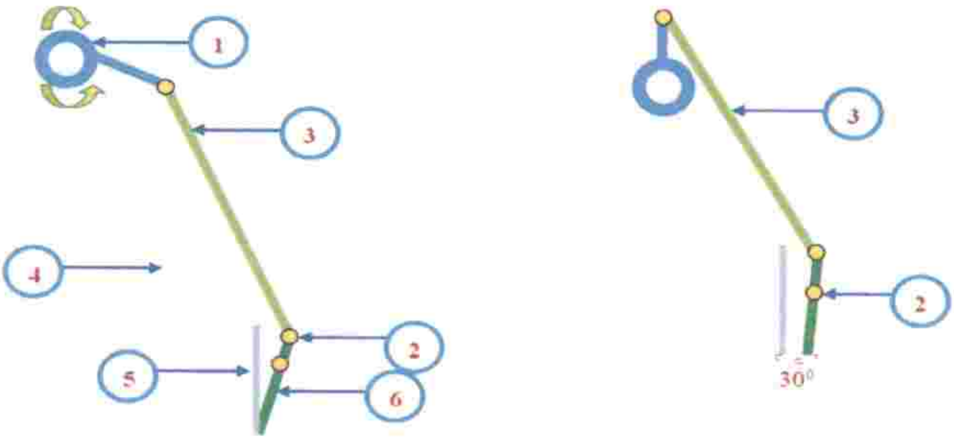
$N_5 = 3\ N_6$

3.5.6 Design of opening and closing mechanism

For paddy hill seeder, an opening and closing type mechanism was selected. The mechanism was designed based on the to and fro motion (rocking motion) of a seed metering shaft. This is designed on the aim to reduce the scattering of seeds and maintain the distance between the hills. This was dropped all the seeds without scattering. The developed opening and closing mechanism was shown in fig.3.6



No.	Description
1	Crank Rocker Mechanism
2	Seed metering shaft
3	Chain
4	Opening and closing Latch
5	Seed boot
6	Spring



No.	Description	No.	Description
1	Seed metering roller	4	Fixed link
2	Hinge points	5	Seed delivery tube
3	Lifter arm	6	Opening and closing latch

Fig.3.6 Opening and closing mechanism of seed tube for dropping seeds

3.6 Development of paddy hill seeder

A proto type of paddy hill seeder was developed with design dimensions determined. The constructional detail of the paddy hill seeder is presented below.

3.6.1 Constructional details of paddy hill seeder

The prototype hill seeder consisted of main frame, metering mechanisms, seed hoppers, power transmission system and seed dropping linkage. The different components of the hill seeder were designed for the structural strength for the dimensions using suitable raw materials.

3.6.1.1 Construction details of hopper

The seed hopper is constructed with MS sheet metal of thickness one mm. The seed hopper was made of four seed boxes, each box common for the two seed metering units. The hopper has a trapezoidal shape with rectangular bottom 1600 mm × 200 mm having a height of 350 mm and rectangular top 1600 mm × 350 mm. The recommended side slope of 40° is provided for the seed hopper, for gravity discharge for paddy seeds. In this case, a side slope of 39° to the horizontal was selected to ensure free flow of paddy seeds.

3.6.1.2 Seed tube

The seed tube of 25 mm diameter was selected to the seed hopper for the delivery chute to seed metering boxes. The height of tube was 200 mm and kept at an angle of 25^{O} to the vertical. The velocity of seed at the end of seed tube is reduced to low to minimize bouncing and thereby scattering of seeds.

3.6.2 Construction details of metering mechanism

3.6.2.1 Seed metering mechanism

A vertical cell type metering roller was designed and fabricated for paddy seeds. The seed metering disc was fabricated using 40 mm thickness and 70 mm diameter nylon roller having one semicircle shaped cell shown in Fig.3.3. The metering roller was mounted and rotated vertically.

The major dimensions of the oval shaped cell were 9 mm and 12 mm. The depth of the cell at the outer perfectly was 3 mm and increase to 4 mm towards the centre depth. A dual cell was made on the vertical roller the vertically mounted metering disc is rotated in a casing with a bottom chute to deliver the paddy seeds. The vertical cell metering roller was mounted on shaft of diameter 20 mm. the seeds from the main seed hopper was gravity assisted to fallow into the metering mechanism. The metering disc roller shaft was attached by the power from engine through the shafts, chain drives and gear box device with gravity feeding. The cut off was provided to prevent multiples and for excess seed removal from the cell.

3.6.2.2 Seed hopper metering mechanism

A screw type metering unit was fabricated for conveying seeds from main hopper to individual seed metering units. The seed hopper metering unit was fabricated using one mm thickness MS sheet and 30 mm outer diameter screw. The metering unit was mounted on a horizontal shaft of 18 mm diameter. The four metering screw were equally spaced along the shaft at a distance of 360 mm. The screw type metering unit is rotated in a hopper box with a bottom chute to deliver the seeds. The seed hopper metering unit is operated through suitable gears, sprocket and chain, drives.

3.6.3 Construction of power transmission of paddy hill seeder

The power is transmitted from the drive shaft of the self propelled unit to bevel gear unit through a universal coupling supported by pedestal bearing supports. The gear ratio for bevel gear unit is 1:1.3 as shown in Fig. 3.5. The output of the bevel gear unit is coupled to a gearbox input drive. The speed can be varied from low, medium and high speeds by selecting suitable gear ratio by shifting a gear shift lever. The output of the gear box is transmitted to a counter shaft through chain and sprocket drive. The counter shaft drives the crank of a crank rocker mechanism. The rocker shaft of the crank rocker mechanism drives the seed metering roller shaft on which the metering rollers are mounted are reciprocated to pick and drop the paddy seeds. The dropped seeds in each rocker stroke are collected at the seed tube gate and are dropped when actuated by four bar linkage connected to seed tube gate shutter. The alternate opening and closing of the seed tube facilitates in dropping the seeds downwards without much scatter.

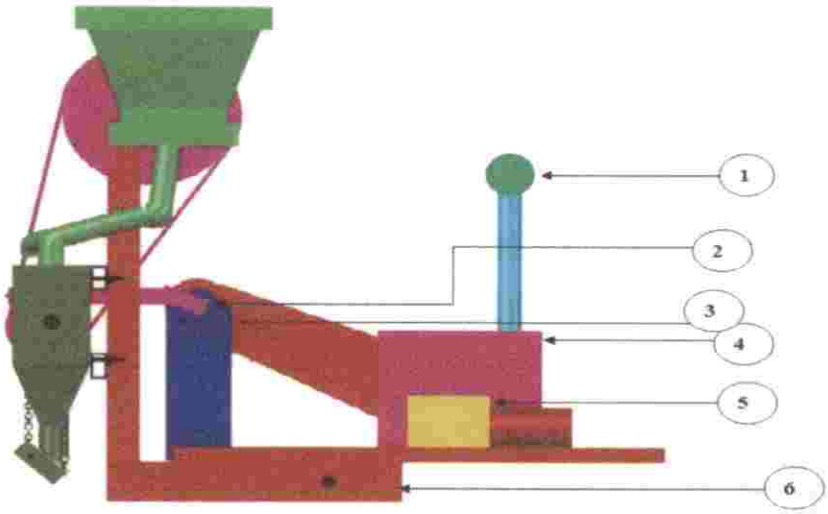
3.6.4 Construction of main frame and attachment

The main frame of the hill seeder that supports all other components of the paddy seeds. In this design, mild steel tube of 50 mm × 50 mm × 20 mm was used to give the required strength and rigidity, so that it can withstand all types of load during operation.

A connection between the frame and other component parts of the hill seeder was made using appropriate sizes of flat clamps, bolts and nuts. The design dimension of the frame was based on the design loads of components to be mounted on it.

3.7 Complete assemble of power operated paddy hill seeder

Power operated paddy hill seeder having has an overall dimension of 1900 mm, 160mm and 1500 mm with respect of length, width and height as shown in fig.3.7



No.	Description	No.	Description
1	**Gear shifting lever**	4	**Variable speed gear box**
2	**Flange blocks**	5	**Bevel gear box**
3	**Supporting frame for mechanism**	6	**Main frame**

Fig.3.7. Power operated paddy hill seeder (side view)

55

3.8 Testing of paddy hill seeder

3.8.1 Laboratory test

Laboratory tests were carried out for obtaining the correct seed rate and metering mechanism performance.

3.8.2 Calibration of unit

The developed prototype hill seeder was calibrated in the laboratory to observe the variation in different rows. The planter was jacked up so that the ground wheel of self propelled unit turns freely. A mark was made on the drive wheel and a corresponding mark at a convenient place on the body of the hill seeder to help in counting the revolutions of the ground wheel. The hopper was filled to three fourth to half of its capacity. The ground wheel rotated for 20 revolutions and a seed dropped from the metering unit was collected in the tray. The quantity of seeds collected was weighed. Calibration was done for two cell sizes, for three replications.

3.8.2.1 Mechanical damage of paddy seeds

Mechanical damage of the seeds will affect the germinated of sprout the seeds, so it is necessary to calculate the percentage of mechanical damage. For conducting this experiments injury free seeds were selected and used for the experiments. Take the weight of damaged seeds in two kg of the sample after the test and calculate the percentage of damaged seeds.

3.9 Test parameter

3.9.1 Statistical analysis for optimizing design values

The effects of selected levels of variables on the evaluation parameters were analyzed using statistical software. The experiment data were analyzed using completely randomized design. The statistical package (R software) was used to analyze the experimental data. This was done to obtain the necessary analysis of variance of the mean and interaction of the selected variables *viz.,* peripheral velocity of metering roller, forward speed and cell geometry as well as the dependent variables such as, spacing between hills, multiple index, missing index, seed rate and seed damage.

3.9.2 Design layout experiment for paddy planter

Sl. No.	Parameters	Variables	Levels	Values
i	Independent variables of study	Forward speed (S) kmph	S1 S2	1.5 1.8
		Transmission ratio speed (T) %	T1 T2 T3	1:0.95 1:1.2 1:1.7
		Cell shape (C) mm	C1 C2	9 12
ii	Performance parameters	Hill spacing, cm	HS	
		Quality feed index, %	QF	
		Multiple index, %	MU	
		Miss index, %	MI	
		Seed rate, kg	SR	

The following relationship was used for analysis.

Hill spacing	Missing index	Multiple index	Quality feed index	Seed rate	Seed damage
C1S1T1	C1S1T1	C1S1T1	C1S1T1	C1S1T1	C1S1T1
C1S1T2	C1S1T2	C1S1T2	C1S1T2	C1S1T2	C1S1T2
C1S1T3	C1S1T3	C1S1T3	C1S1T3	C1S1T3	C1S1T3
C2S1T1	C2S1T1	C2S1T1	C2S1T1	C2S1T1	C2S1T1
C2S1T2	C2S1T2	C2S1T2	C2S1T2	C2S1T2	C2S1T2
C2S1T3	C2S1T3	C2S1T3	C2S1T3	C2S1T3	C2S1T3
C1S2T1	C1S2T1	C1S2T1	C1S2T1	C1S2T1	C1S2T1
C1S2T2	C1S2T2	C1S2T2	C1S2T2	C1S2T2	C1S2T2
C1S2T3	C1S2T3	C1S2T3	C1S2T3	C1S2T3	C1S2T3
C2S2T1	C2S2T1	C2S2T1	C2S2T1	C2S2T1	C2S2T1

57

C2S2T2	C2S2T2	C2S2T2	C2S2T2	C2S2T2	C2S2T2
C2S2T3	C2S2T3	C2S2T3	C2S2T3	C2S2T3	C2S2T3

3.9.3 Optimization of variables for paddy planter

The selected levels of variables were optimized for achieving the optimum seeding efficiency reflected in terms of recommended seed spacing between seeds, quality feed index, multiple index, miss index.

3.10 Performance Evaluation of Paddy Hill Seeder

Performance evaluation was conducted for 12 combinations of forward speed, transmission ratio and cell size. Experimental design variables were the 2 levels forward speeds, 3 levels transmission ratios and 2 levels cell sizes. The performance was evaluated for following dependent parameters.

3.10.1 Missing index

Miss index (Imiss) is an indicator of how often the paddy seed skips the desired spacing. It is the percentage of spacing greater than 1.5 times the theoretical spacing S in mm.

$$\text{Imiss} = \frac{\text{n1}}{\text{N}}$$

Where,

n_1 = Number of spacing in the region > 1.5 S N = Total number of observations

3.10.2 Multiple index

The multiple indexes (Imult) are an indicator of more than one seed dropped within a desired spacing. It is the percentage of spacing that are less than or equal to half of the theoretical spacing S in mm.

$$\text{Imult} = \frac{\text{n2}}{\text{N}}$$

Where,

n_2 = Number of spacing in the region ≤ 0.5 S N = Total number of observations

3.10.3 Quality of feed index

The quality of feed index (I_{fq}) is the measure of how often the spacing is close to the theoretical spacing. It is the percentage of spacing that are more than half but not more than 1.5 times the theoretical spacing S in mm. The quality of feed index is mathematically expressed as follows.

$$I_{fq} = 100 - (Imiss + Imult)$$

Where,

Imiss - Miss index

Imult - Multiple index

3.11 Test procedure

Testing of power operated paddy hill seeder

The developed prototype of paddy hill seeder testing was conducted on a sand bed method. The tests were conducted at Kelappaji College of Agricultural Engineering and Technology, Thavanur campus. Shakthi Yanji Prime Mover was used as self propelled unit for field test. The following parameters were observed during the field test.

3.11.1 Missing

Numbers of hills in over a row length of 2 m was measured and missing hills values were recorded in the field at five different locations randomly to determine missing.

3.11.2 Number of seeds per hill

Number of seeds in each hill over a row length of 2 m was measured and the values were recorded in the field at five different locations randomly to determine number of seeds per hill.

3.11.3 Intra row spacing

The spacing between hills over a row length of 2 m was measured using a scale and the values were recorded. Spacing was measured in the field at five different locations randomly to determine spacing.

3.11.4 Row to row spacing

While conducting the field trials of the paddy hill seeder, the spacing between two adjacent rows (cm) was measured with the help of steel tape. The row to row spacing was measured in the field at five different locations randomly to determine row to row spacing.

3.11.5 Theoretical field capacity

It is the rate of field coverage that would be obtained if the machine were performing its function 100 per cent of the time at rated forward speed and always covered 100 per cent of its rated width.

Theoretical field capacity, ha $hr^{-1} = \frac{WS}{10}$

Where,

S = speed of machine in km/hr

W = rated width of the machine in meter

3.11.6 Effective field capacity

It is the actual rate of coverage of the field by the machine. It was calculated by the fallowing formula.

Effective field capacity, ha $hr^{-1} = \frac{A}{T_P + T_l}$

Where,

A = area covered in ha

TP = productive time, h

TL = Non-productive time, h

3.11.7 Field efficiency

This gives an indication of the time lost in the field and failure to utilize the full working width of the machine.

$$\text{Field efficiency, \%} = \frac{\text{Actual field capacity,ha/hr}}{\text{Theoritical field capacity,ha/hr}} \times 100$$

Field efficiency varies according to the shape and size of the field, the type and size of machine, the skill of the operator and other similar factors.

3.12 Cost Economics

3.12.1 Total cost of operation

The total cost of sowing was determined based on fixed cost and variable cost. The following variables were considered in determining the cost of operation.

A) Fixed cost

i) Depreciation

ii) Interest

iii) Insurance and taxes

iv) Shelter

B) Variable cost

i) Repair and maintenance

ii) Fuel

iii) labour

RESULTS AND DISCUSSIONS

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The physical and engineering properties of selected paddy varieties for determining design parameters of hill seeder for direct paddy seeding were determined. Interactive effect of selected levels of variables *viz.,* forward speed, seed metering mechanism and cell shape on cell fill efficiency, multiple index, miss index, hill spacing and seed rate was also determined. The experimental results were statistically analyzed and presented. (The optimization of the selected levels of variables for achieving best performance of hill seeder in terms of maximum value of cell fill efficiency, desired hill spacing and seed rate is also reported.)

4.1 Physical and engineering properties of paddy seed

The physical and engineering properties of paddy seeds evaluated for the design of paddy seeder were size, shape, angle of repose and bulk density and the observations related to paddy seed varieties are presented as following

4.1.1 Physical properties of dry paddy seed

4.1.1.1 Size and shape

The size and shape of selected paddy varieties were determined. The major, intermediate, and thickness dimensions of Uma and Jyothi varieties of dry paddy seeds were measured. The average dimensions of Uma and Jyothi varieties of dry paddy seeds are given in Table 4.1. The mean linear dimensions of randomly selected dry paddy seeds of Uma variety have a major axis (length) 7.62 ± 0.92 mm; intermediate axis (width) 3.15 ± 0.32 mm; minor axis (thickness) 2.98 ± 0.62 mm; equivalent diameter 4.17 ± 0.32 mm; geometric mean diameter 4.17 ± 0.32 mm; sphericity 0.552 ± 0.042 %; surface area 46.204 ± 0.053 mm^2; aspect ratio 0.425 ± 0.047.

Table 4.1 Physical dimensions of dry paddy seeds

Sl. No.	Dimensions	Uma	Jyothi
		Mean ± SD, mm	
1	Length (mm)	7.62±0.92	8.34±0.83
2	Width (mm)	3.15±0.32	3.02±0.36
3	Thickness (mm)	2.98±0.62	2.82±0.58
4	Equivalent diameter (mm)	4.17±0.32	4.14±0.29
5	Geometric mean diameter (mm)	4.17±0.27	4.14±0.25
6	Sphericity (%)	0.552±0.042	0.506±0.036
7	Surface area (mm^2)	46.204±0.053	47.053±0.055
8	Aspect ratio	0.425±0.047	0.372±0.051

Similarly, the mean linear dimensions of Jyothi variety have a major axis (length) 8.34±0.83 mm; intermediate axis (width) 3.02±0.36 mm; minor axis (thickness) 2.82±0.58 mm; equivalent diameter 4.14±0.29 mm; geometric mean diameter 4.14±0.29 mm; sphericity 0.506±0.036 %; surface area 47.053±0.055 mm^2; aspect ratio 0.372±0.051.

4.1.1.2 Bulk density

The bulk density of selected paddy variety was determined and presented Table4.2. The bulk density values of selected variety were found to be in the range of 557 to 565 kg m-3 with mean value of 560.25 kg m^{-3} was observed for Uma Variety. The bulk density range of 528 to 533 kg m^{-3} with a mean value of 530.18 kg m^{-3} was observed for Jyothi variety. The bulk density values are useful for calculating the volume of seed hopper for holding and metering paddy seeds.

4.1.1.3 True density

The true density of selected paddy variety was determined and presented Table4.2. The true density values of selected varieties were found to be in the range of 1155 to 1196 kg m-3 with mean value of 1185 kg m^{-3} was observed for Uma Variety. The true density range of 1070 to 1012 kg m^{-3} with a mean value of 1005 kg m^{-3} was observed for Jyothi variety. The lowest true density value of

1005 kg m^{-3} was observed for Jyothi variety under dry condition and highest 1185 kg m^{-3} for Uma.

Table 4.2 Bulk density and true density of dry paddy seeds

Sl. No	Paddy Varieties	Bulk density	True density
		Mean ±SD (kg m^{-3})	
1	Uma	560.24±4.05	1185±40.15
2	Jyothi	530.18±3.55	1005±38.65

4.1.1.4 Angle of repose

The Angle of repose of Uma and Jyothi varieties of dry paddy seeds were determined and results are given in Table 4.3. The angle of repose of Uma and Jyothi varieties were found to be 35.94^0 and 32.52^0 respectively.

Table 4.3 Angle of repose of dry paddy seeds

Sl. No.	Varieties	Angle of repose Mean ± SD (degree)
1	Uma	35.94^0±0.35
2	Jyothi	32.52^0±0.31

4.1.2 Physical properties of pre-germinated paddy seed

4.1.2.1 Moisture content

The moisture content of Uma and Jyothi varieties were found to be 46% and 42% respectively. The moisture content values are useful for calculating the volume of seed hopper for holding and metering paddy seeds.

4.1.2.2 Size

The size and shape of selected paddy varieties were determined. The major, intermediate, and thickness dimensions of Uma and Jyothi varieties of pre-germinated paddy seeds were measured. The length, width, thickness and mean diameter were determined. The average dimensions of Uma and Jyothi varieties of pre-germinated paddy seeds are given in Table 4.4. The mean linear dimensions of randomly selected pre-germinated paddy seeds of Uma variety have a major axis (length) 7.67±1.07 mm; intermediate axis (width) 3.19±0.23 mm; minor axis (thickness) 3.04±0.33 mm; equivalent diameter 4.20±0.28 mm; geometric mean diameter 4.20±0.28 mm; sphericity 0.546±0.042 %; surface area 46.997±0.053 mm^2; aspect ratio 0.416 ± 0.047. Similarly, the mean linear dimensions of randomly selected pre-germinated paddy seeds of Jyothi variety have a major axis (length) 8.35±1.16 mm; intermediate axis (width) 3.08±0.26 mm; minor axis (thickness) 2.86±0.44 mm; equivalent diameter 4.19±0.24 mm; geometric mean diameter 4.19±0.24 mm; sphericity 0.501±0.036 %; surface area 47.575±0.055 mm^2; aspect ratio 0.368±0.051.

Table 4.4 Physical dimensions of pre-germinated paddy seeds

Sl. No	Dimensions	Uma	Jyothi
		Mean ± SD, mm	
1	Length (mm)	7.67±1.07	8.35±1.16
2	Width (mm)	3.19±0.23	3.08±0.26
3	Thickness (mm)	3.04±0.33	2.86±0.44
4	Equivalent diameter (mm)	4.20±0.28	4.19±0.31
5	Geometric mean diameter (mm)	4.20±0.23	4.19±0.24
6	Sphericity (%)	0.546±0.042	0.501±0.036
7	Surface area (mm^2)	46.997±0.053	47.575±0.055
8	Aspect ratio	0.416±0.047	0.368±0.051

4.1.2.3 Bulk density

The bulk density of Uma and Jyothi varieties of pre-germinated paddy seeds were determined and results are given in Table 4.5. The bulk density of Uma and Jyothi varieties were found to be 583.34 kg m^{-3} and 552.11kg m^{-3} respectively. The hopper capacity of centrifugal broadcaster depends of upon bulk density of paddy seeds and also packing nature of pre-germinated paddy seeds.

4.1.2.4 True density

The true density of Uma and Jyothi varieties of pre-germinated paddy seeds were determined and results are given in Table 4.5. The true density of Uma and Jyothi varieties were found to be 1250 kg m^{-3} and 1020 kg m^{-3} respectively.

Table 4.5 Bulk density and true density of pre-germinated paddy seeds

Sl. No.	Varieties	Bulk density	True density
		Mean ±SD (kg m^{-3})	
1	Uma	583.34±3.02	1250±35.28
2	Jyothi	552.11±4.14	1095±32.13

4.1.2.6 Angle of repose

The angle of repose of Uma and Jyothi varieties of pre-germinated paddy seeds were determined as explained in section 3.1.1.5 and results are given in Table 4.6. The angle of repose of Uma and Jyothi varieties were found to be 38.94^0 and 36.52^0 respectively. The angle of repose of paddy seeds was determined to angle the sides of the trapezoidal hopper to facilitate free flow of seeds through the hopper bottom opening. This angle affects the free flow of paddy seeds through hopper.

Table 4.6 Angle of repose of pre-germinated paddy seeds

Sl. No	Varieties	Angle of repose (Mean ± SD, degree)
1	Uma	38.94±0.43
2	Jyothi	36.52±0.38

4.2 Design of power operated paddy hill seeder

4.2.1Design features and specifications

The paddy hill seeder was developed to suit rice crop and to work in various types of soil and their moisture conditions. Provisions were made to adjust hill to hill spacing. The hill to hill spacing was varied by changing the speed of metering roller through gears in a gear box. The general design specifications of the paddy hill seeder is given in Table 4.7

Table 4.7 design Specifications of paddy hill seeder

Sl. No.	Particulars	Values
1	Over all dimensions	
	Length × width ×height, mm	2500 x 2131 x 1300 mm
2	Specifications of prime mover	
	i. Make and model	VST SHAKTI YANJI 170F Single Cylinder Air Cooled Diesel
	ii. Power source, hp	05
3	Type of attachment	Mounted hill seeder
4	Number of rows	8
5	Row spacing, mm	238 mm
6	Plant spacing, mm	100 to 200 mm (Adjustable)
7	Nominal working width, mm	1900
9	Metering mechanism	
	i.Type of seed metering mechanism	Cell feed vertical roller type
	ii. source of power for driving metering mechanis	PTO
	iii. Number of seed metering disc	8
	iv. Diameter of metering disc, mm	70
10	Hoppers	
	a) Seed hopper	
	i. Shape	Trapezoidal section
	ii. Capacity, m^3	0.20
14	Weight of hill seeder, kg	60
15	Power transmission	
	i. The power from PTO to seed metering and hopper metering mechanisms	Gear box and chain sprocket to Crank Rocker linkage to metering disc shaft
	ii. Speed ratio	1:1.7, 1:23, 1:0.95

4.3 Effect of selected levels of variables on the precision (performance) parameters

A total number of 12 experiments with three replications were conducted in lab using sand bed method with selected levels of variables. The performance parameters, cell fill efficiency, multiple index, miss index, seed damage, spacing and seed rate were recorded for all the treatments of the investigation. The effects of selected levels of variables were evaluated for the performance parameters were analyzed and results presented.

4.3.1 Calibration tests

The paddy hill seeder was calibrated in the laboratory to determine the seed rate, mechanical damage of paddy seeds for a particular area. The calibration of paddy hill seeder was conducted to test and adjust the seeder to obtain desired seed rate. The calibrations test results are discussed in the following sections.

4.3.1.1 Calibration of paddy hill seeder for seed rate

The seed requirement per unit area was determined by calibrating the hill seeder in the laboratory. The paddy hill seeder was calibrated to determine the seed rate per hectare. The metering shaft was rotated for 100 revolutions and metered paddy seeds were collected from all the outlets and seed rate was calculated and the results are given in Table 4.8.

Table 4.8 Calibration results of paddy hill seeder

Sl. No.	Description		Value
1	Number of rows		8
2	Spacing between the rows , m		0.23
3	Number of revolutions of metering mechanism		100
4	Paddy seed collected, kg	C1	0.081
		C2	0.10

The recommended seed rate for direct sowing per hectare is 40 kg, as per (RASS, Tirupati and Narendra Haridas Tayade 2017). However, the developed power operated paddy hill seeder was calibrated to achieve a seed rate of 21.31 kg h^{-1} to 58.48 kg h^{-1} for different spacings are shown in table. 4.9

4.3.1.2 Mechanical damage of paddy seed

The paddy seeds were collected randomly during calibration and were observed for damaged ones from a 100 g quantity. The percentage of damaged seed was calculated. The mechanical damage of paddy might be due to higher forward speed of metering roller which leads to aggressive rubbing of paddy seed with metering cutoff within the metering mechanism chamber. Seed damage rate for different cell sizes, transmission speeds are shown in table. 4.9

Table 4.9 Effect of cell size, forward speed and transmission ratio on seed rate and seed damage rate

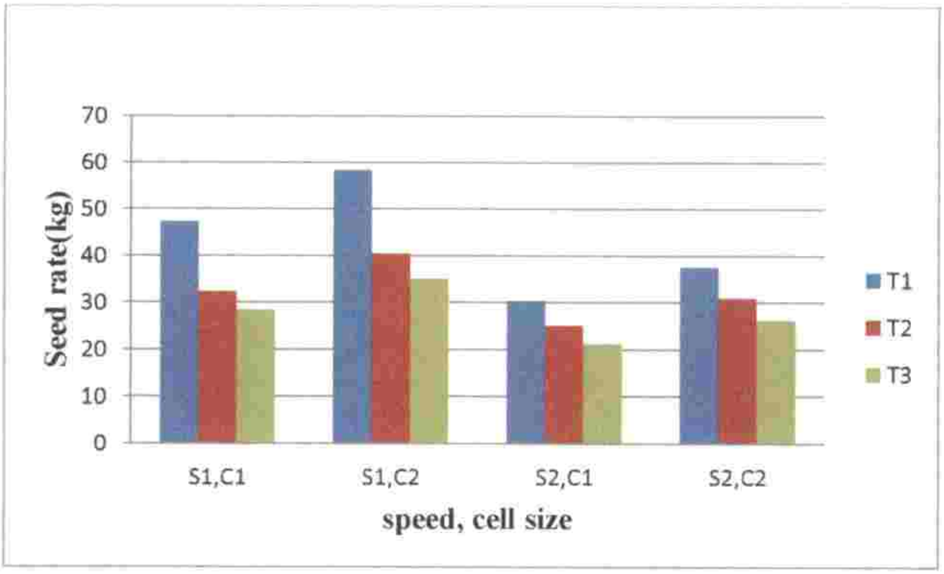
Cell shape	Forward speed (Km/h)	Seed rate (kg/ha)			Seed damaged rate (%)		
		T1	T2	T3	T1	T2	T3
C1	S1	47.37	32.38	28.42	6.9	5.2	4.0
C1	S2	30.34	25.08	21.31	6.9	5.2	4.0
C2	S1	58.48	40.49	35.09	6.5	4.1	2.69
C2	S2	37.6	30.96	26.32	6.5	4.1	2.69

4.3.1.1.1 Effect of forward speed, transmission ratio and cell size on seed rate

The mean values of seed rate at selected levels of variables viz., forward speed (S), transmission ratio (T) and cell shape (C) are presented Table 4.9. A seed rate of 21.31 $kgha^{-1}$ lowest seed rate was observed for C1 size cell at highest transmission ratio with high forward speed. A seed rate of 58.48 kg ha^{-1} highest seed rate was observed for C2 size cell at highest lowest transmission ratio with low forward speed as shown in table 4.9. The effect of forward speed, transmission ratio and cell size on seed rate is shown Fig. 4.1.

The analysis of variance (ANOVA) in Table 1 in Appendix III revealed that the forward speed, transmission ratio and cell size are significant at ($p < 0.01$). As forward speed, transmission speed and cell size increases there was significant increase on seed rate.

The results of DMRT indicated that speed S2, cell size C1 and Transmission ratio T3 produced the lowest seed rate and this was significantly low compared to other treatments transmission. Hence it may be concluded that operations of hill seeder at lower speeds (T2, T3) with lower cell size C1 and higher forward speed S2 decreases the seed rate.



S1=1.5 kmph S2=1.8 kmph T1= 1:0.95 T2= 1:1.2 T3= 1:1.7C1=9 mm C2=12 mm

Fig. 4.1 Effect of cell size forward speed and transmission ratio on seed rate

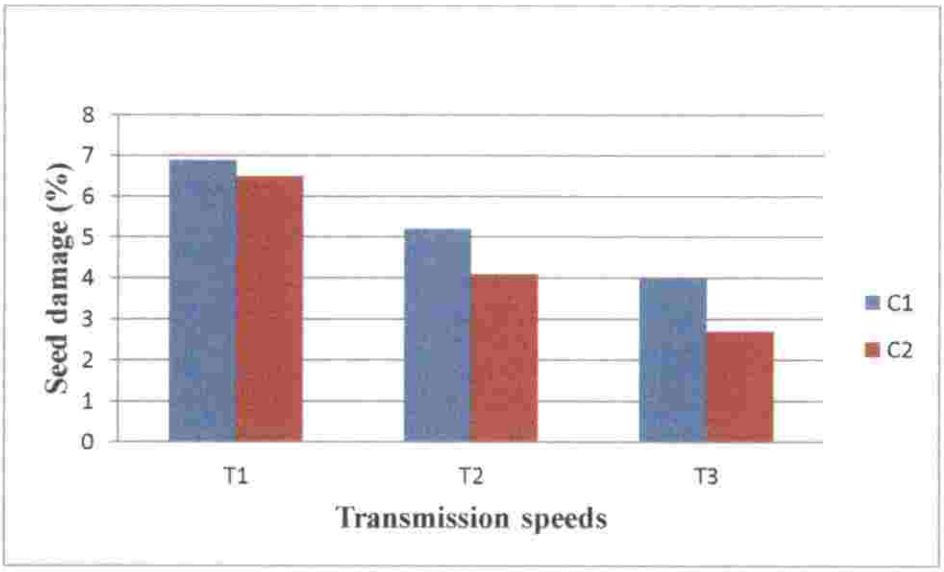
4.3.1.1.2 Effect of transmission ratio and cell size on seed damage

The mean values of seed damage at selected levels of variables viz., transmission ratio (T) and cell shape (C) were determined Table 4.9. The seed damage values observed for C1 were 6.9, 5.2 and 4.0 for transmission ratios T1, T2 and T3 respectively. The damage values observed for C2 were 6.5, 4.1 and

2.69 for transmission ratios T1, T2, T3 respectively. The lowest value of 2.69 % damage was observed at transmission ratio of T3 for C2.The Seed damage increased significantly with increase in transmission ratio and decreasing cell size as shown in fig.4.2

As shown in Table.2 of Appendix III, the seed damage was significant for various levels of the transmission ratio ($p<0.01$) and cell size ($p<0.01$). Average seed damage was not significantly affected by interaction of forward speed ($p>0.05$). As the transmission ratio and cell size decreases there was significant increase in seed damage.

The results of DMRT indicated that cell size C2 produced the lowest seed damage and this was significantly less compared to other C1. The change in seed damage obtained with respect to cell size and transmission ratio. Hence it may be concluded that operations of hill seeder at higher transmission speeds (T1, T2) with lower cell size C1 gave maximum seed damage compared to other combination of relations.



S1=1.5 kmph S2=1.8 kmph T1= 1:0.95 T2= 1:1.2 T3= 1:1.7C1=9 mm C2=12 mm

Fig. 4.2 Effect of cell size, forward speed and transmission ratio on damage

72

4.4 Performance evaluation of paddy hill seeder

The testing and evaluation of paddy hill seeder was conducted on a sand bed method. The testing of paddy hill seeder was conducted for a combination of forward speeds and transmission ratios of seed metering roller speeds for different cell sizes respectively. The test performance observations on seed count, missing seeds, multiple seed, and spacing between hills in rows were collected and computed for paddy.

The performance of the paddy hill seeder is given in Table 4.10. The results were analyzed statistically to determine the effect of cell size, forward speed and transmission ratio on the hill seeder performance indices for paddy sowing.

Table 4.10 Effect of forward speed and transmission ratio on performance of paddy hill seeder

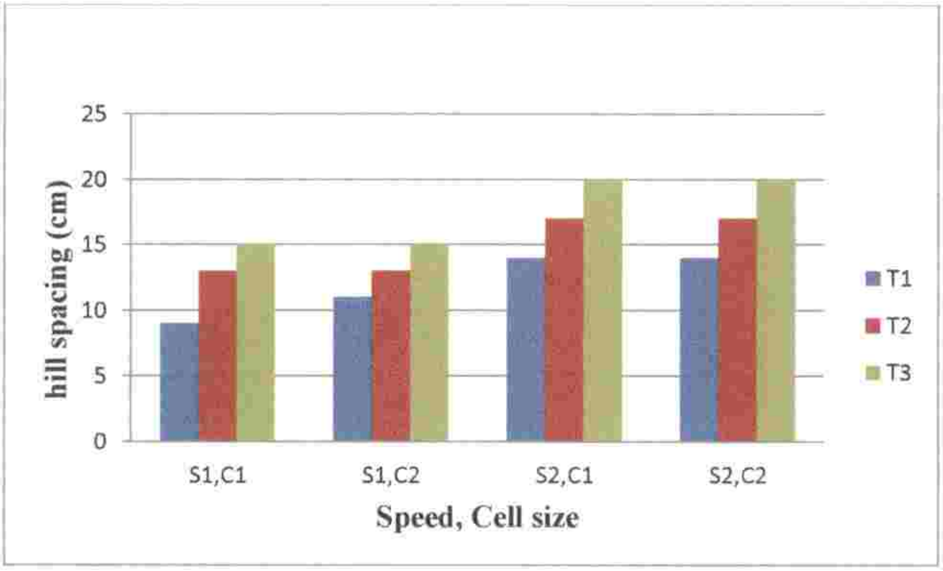
Sl.No.	Experiment runs	Mean hill spacing, cm	Missing index, %	Multiple index, %	Quality of feed index, %
1	$C_1S_1 T_1$	9	15.2	10.0	74.8
2	$C_1S_1 T_2$	13	12.1	8.1	79.8
3	$C_1S_1 T_3$	15	8.2	5.7	86.1
4	$C_1S_2 T_1$	14	15.2	9.0	75.8
5	$C_1S_2 T_2$	17	12.1	4.5	83.4
6	$C_1S_2 T_3$	20	8.2	3.2	88.6
7	$C_2S_1 T_1$	9	8.9	9.8	81.3
8	$C_2S_1T_2$	13	7.0	8.1	84.9
9	$C_2S_1 T_3$	15	5.6	5.2	89.2
10	$C_2S_2 T_1$	14	8.9	8.6	82.5
11	$C_2S_2T_2$	17	7.0	4.7	88.3
12	$C_2S_2 T_3$	20	5.6	3.3	91.1

4.4.1 Effect of forward speed and transmission ratio speed of metering roller on hill spacing for different cell size.

The seed spacing for both metering cells were in the range of 9-20 cm. The effect of forward speed and transmission ratios on hill spacing is presented in

73

Table 4.10. It is observed that the mean spacing between hills increased, with increase in forward speed and transmission ratio during testing. The mean spacing of hills for lowest transmission ratio (T_1) was in the range of 9 to 14 cm and for (T_2) it ranged from 13 to 17cm. However, for (T_3) it ranged from 15 to 20cm for two forward speeds (S_1 and S_2) respectively as given in Table 4.9. With decrease in speed of transmission from (T1) to (T3), the spacing between the hills increased.



S1=1.5 kmph S2=1.8 kmph T1= 1:0.95 T2= 1:1.2 T3= 1:1.7C1=9 mm C2=12 mm

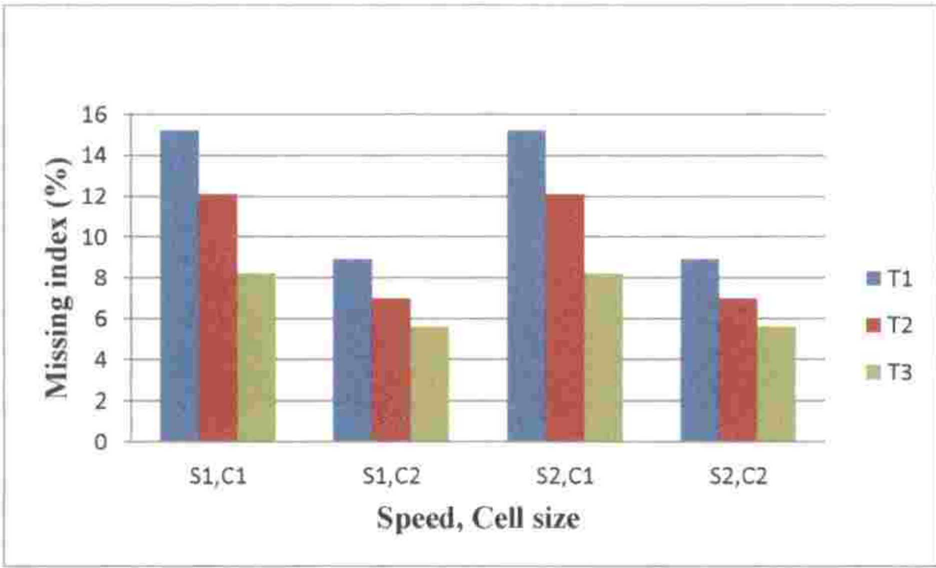
Fig. 4.3 Effect of forward speed and transmission ratio on hill spacing

As shown in Table 3 in Appendix III mean hill spacing was significant for various levels of the transmission ratio ($p<0.01$) and forward speed ($p<0.01$). Average mean hill spacing was not significantly affected by interaction of cell size ($p>0.05$). As the transmission ratio and forward speed increases there was significant increase in mean spacing of hills.

The results of DMRT indicated that cell size will not effected on the spacing. The change in spacing obtained with respect to speed and transmission ratio. Hence it may be concluded that operations of hill seeder at higher transmission speeds (T1, T2) with lower speed S1 gave maximum spacing comparatively other combinations.

4.4.2 Effect of forward speed and transmission ratio on missing index

The miss index values were in the range of 8.2-15.2%, and 5.6-8.9% for both metering cells C1 and C2 respectively Table 4.10. The lowest value of 5.6 % and highest value of 15.2% observed for C2 and C1 metering cells. It was observed that miss index increased with increase of transmission ratio and decreasing cell sizes for two forward speeds Fig 4.4. It may be at higher transmission ratio, the cell exposure time was less for filling of seed in cell from the hopper the effect of forward speed, and cell shape on miss index was presented (Fig. 4.4).



S1=1.5 kmph S2=1.8 kmph T1= 1:0.95 T2= 1:1.2 T3= 1:1.7C1=9 mm C2=12 mm

Fig. 4.4 Effect of forward speed, transmission ratio and cell size on missing index

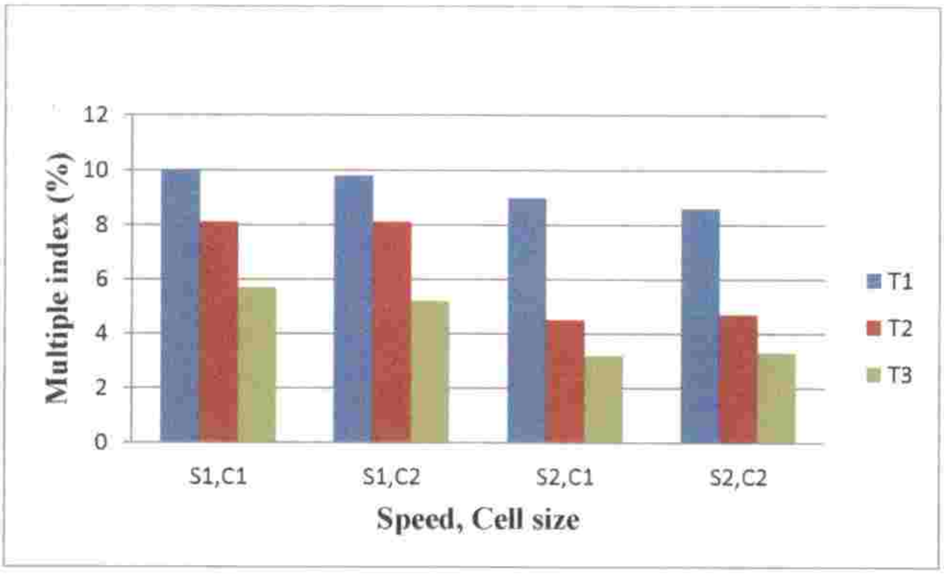
As shown in Table 4 in Appendix III the missing index was significant for various levels of the transmission ratio ($p<0.01$) and cell size ($p<0.01$). The missing index was not significantly affected by interaction of forward speed ($p>0.05$). As the transmission speed increased and cell size decreased there was significant increase in missing index.

The results of DMRT indicated that cell size C2 produced the lowest change in missing index and was significantly less compared to other C1. The change in missing index was obtained due to cell size and transmission ratio. Hence it may be concluded that operations of hill seeder at higher transmission speeds (T1, T2) with lower cell size C1 gave maximum missing index.

4.4.3 Effect of forward speed and transmission ratio on multiple indexes

The effect of forward speed and transmission ratio on multiple index for both cell sizes are discussed in this section

The mean values of multiple index at selected levels of variables viz., forward speed (S), transmission ratio (T) and cell shape (C) were determined. The range of multiple index observed was from 3.2-10.0%, and 3.3-9.8% for C1 and C2 cell sizes respectively for both forward speeds S1 and S2 as shown in Table 4.10. The lowest value of 3.2 % for C1 and highest value of 10 % were observed for rectangular metering roller of C2. The effect of forward speed, transmission ratio and cell shape on multiple index is shown Fig. 4.5.



S1=1.5 kmph S2=1.8 kmph T1= 1:0.95 T2= 1:1.2 T3= 1:1.7C1=9 mm C2=12 mm

Fig. 4.5 Effect of forward speed, transmission ratio and cell size on multiple index

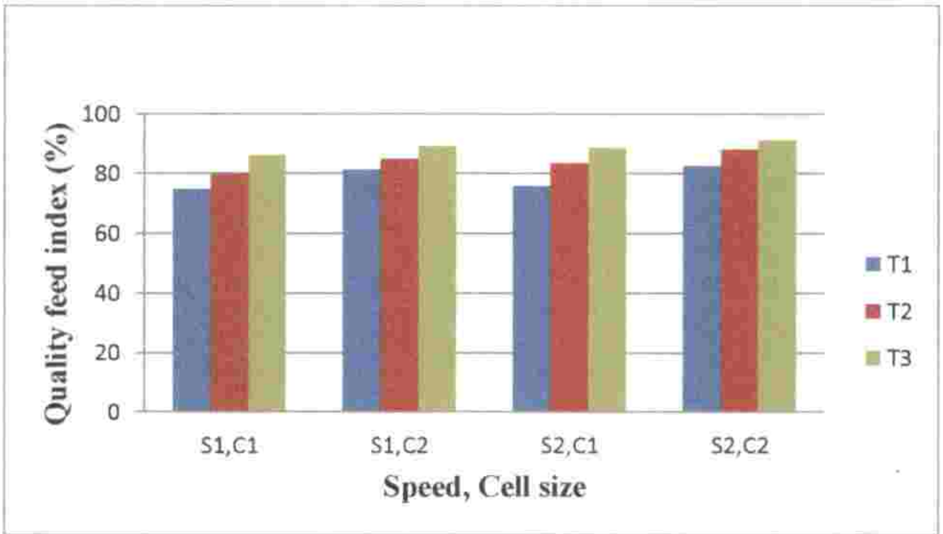
76

As shown in Table 5 in Appendix III, multiple index was significant for various levels of the transmission ratio ($p<0.01$) and forward speed ($p<0.01$). Average multiple index was not significantly affected by interaction of cell size ($p>0.05$). As the transmission speed and forward speed increases there was significant increase in multiple index.

The results of DMRT indicated that speed S2 produced the lowest change in missing index and this was significantly less compared to other S1. The change in multiple index obtained with respect to forward speed and transmission ratio. Hence it may be concluded that operations of hill seeder at higher transmission speeds (T1, T2) with lower forward speed S1.

4.4.4 Effect of forward speed and transmission ratio on quality of feed index

The mean values of quality feed index at selected levels of variables viz., forward speed (S), transmission ratio (T) and cell shape (M) were determined (Table 4.10). The mean quality feed index were in the range of 74.8-88.6%, and 81.3-91.1% for both metering cells C1 and C2 respectively. The highest quality feed index of 91.1% at a forward speed of 1.8 kmh^{-1} and highest transmission ratio was for C2 shape metering cell followed by 88.6% for C1 shape, respectively.



S1=1.5 kmph S2=1.8 kmph T1= 1:0.95 T2= 1:1.2 T3= 1:1.7C1=9 mm C2=12 mm

Fig. 4.6 Effect of forward speed and transmission ratio on quality feed index

The analysis of variance (ANOVA) in Table 6 in Appendix III revealed that the forward speed, transmission ratio and cell size are significant at ($p < 0.01$). As transmission ratio and cell size increases there was significant increase on quality of feed index.

The results of DMRT indicated that speed S2, cell size C2 and Transmission ratio T3 produced the highest Quality feed index and this was significantly high compared to other relations. Hence it may be concluded that operations of hill seeder at lower transmission speeds (T2, T3) with higher cell size increases the quality index.

4.5 Field capacity and field efficiency

The mean field capacity and efficiency of the paddy hill seeder were 0.26 ha h^{-1} at a forward speed of 1.8 km h^{-1} and 0.22 ha h^{-1} at a forward speed of 1.5 km h^{-1} with a field efficiency of 76% and 80% respectively. The detailed calculation procedure of field capacity and field efficiency of power operated paddy hill seeder given in Appendix III.

4.6 Cost of operation

The cost economics of paddy hill seeder was worked and given in appendix VII. Cost of planting by using power operated paddy hill seeder is Rs. 1490 h^{-1} and by manual method with drum seeder is Rs. 2550 h^{-1}.The cost and time saved over manual planting(drum seeder) was about 41.56% and 81 % .The cost of paddy hill seeder (Appendix V) was Rs.28573/-.

SUMMERY AND CONCLUSION

CHAPTER V

SUMMERY AND CONCLUSION

Agriculture plays a prominent role in the Indian economy. More than half of our population is directly or indirectly dependent on agricultural activities. Rice, one of the most important crops of India, occupies 24 per cent of gross cropped area of the country, i.e. 45 million ha under rice, in the world. Manual transplanting of rice is still the widely practiced rice establishment method which is very labour intensive i.e. 360 man-h/ha. Direct seeded rice (DSR) is becoming popular in India due to severe shortage of management of inputs, water and labour. At present, the area under DSR in India is about 23 per cent. Direct sowing through manual methods resulted in higher cost in weed and management of pests and incidence of diseases. Farmers have been using locally available seed drills for direct sowing which resulted in high seed rates, high missing hills and uneven crop, which resulted in yield reduction and increasing cost of cultivation. Sowing operation needs a high degree of precision to increase the efficiency of the inputs and reduce the losses. This necessitated the need for a power operated paddy hill seeder for direct seeding of rice. Therefore, this study was under taken to design and develop a power operated paddy hill seeder for direct seeding.

The paddy hill seeder was developed based on the agronomic sowing considerations, engineering and physical properties of paddy seeds. The paddy hill seeder components were designed based on the materials selected for the functional parts. The intra row spacing was varied by changing the gear to change speed ratio.

The direct seeded paddy hill seeder with Crank-Rocker drive for a seed metering mechanism was designed developed and tested in the laboratory. This resulted in superior seed filling of cells and dropping. The predominant paddy variety suitable for direct seeding viz., Uma and jyothi rice variety were selected for testing the metering mechanism. The physical and engineering properties of dry, one day soaked seeds were used for design of metering mechanisms. Vertical cell type roller mechanism was fabricated and used based on dimensions of paddy seeds. An opening and closing mechanism was designed and developed for maintaining hill dropping at a place without scattering of seeds. The developed power operated paddy hill seeder performed all sowing operations in a single pass.

The crop parameters *viz.,* row to row spacing of 0.23 m, hill to hill spacing of 0.09-0.20 m, 3 to 7 seeds per hill, seed rate of 21-58 kg ha^{-1} when metering mechanism calibrated for different hill spacings. The tests were conducted on sand bed to evaluate the seed metering mechanism performance with respect to spacing, seed rate, quality of feed index, multiple index, miss index, and seed damage at two different forward speeds (1.5 and 1.8 km h^{-1}), two cell sizes and three transmission speeds (1:1.7, 1:1.2 and 1:0.95). The missing index and multiple index were less for the different combinations of study parameters (speed 1.5 kmph, cell size 9 mm, Transmission ratio 1:1.7), (Speed 1.8 kmph, Cell size 9 mm, Transmission ratio 1:1.7) and (Speed 1.8 kmph, Cell size 12 mm, Transmission ratio 1:1.7). The quality feed index were 86.1, 88.6 and 91.1 respectively for above sequence of combinations of study parameters. The average field capacity of the paddy hill seeder was 0.22 ha h^{-1} and 0.26 ha h^{-1} with efficiency of 80.00% and 76.00 % for forward speeds of 1.5 and 1.8 kmph respectively. The cost of developed prototype mechanical hill seeder was Rs. 28573/

REFERENCES

REFERENCES

Anonymous.2014.Reports. Directorate of Economics and Statistics, Department of Agriculture and Corporation.

Devnani, R S. 2002. Direct seeding options, equipment developed and their performance on yield of rice crop. *Agricultural Mechanization in Asia Africa Latin America,*33(4): 27-33.

Grewal, R S. Khurana, R. Manes, G S. Dixit, A and Verma, A.2015 .Development and evaluation of tractor operated inclined plate metering device for onion seed planting. *Agricultural Engineering International: the CIGR Ejournal*, 17(2):31.

Gupta, C P.and Herwanto, T. 2006. Design and development of a direct paddy seeder.*Agricultural Mechanization in Asia, Africa and Latin America*, 23(1): 23-27.IS: 9164-1979: Guide for estimating cost of farm machinery operation.ISI, New Delhi.

Gupta, R.K., Ladha, J.K., Singh, S., Singh, R., Jat, M.L., Saharawat, Y., Singh, V.P., Singh, S.S., Singh, G., Sah, G. and Gathala, M., 2006. Production technology for direct seeded rice. *Rice Wheat Consortium Technical Bulletin*, *8*, p.16.

Guozhong, Z., Ying, Z., Xiwen, L., Zaiman, W., Qiang, Z. and Shasha, Z., 2015. Design and indoor simulated experiment of pneumatic rice seed metering device. *International Journal of Agricultural and Biological Engineering*, *8*(4), pp.10-18.

Islam, M D S. and Ahmad, D. 1999. Modification, Test and Evaluation of Manually Operated Drum Type Seeder for Lowland Paddy.*Pertanika J. Sci. & Technology,*7(2): 85-98.

Jesudass, D.M., Kumar, V.J.F and Balasubramanian, M (1996). Performance of bullock drawn upland direct paddy seeder. Agr. Mech. In Asia, Africa and Latin America, Vol.27 No.1, Page 21-24.

Kamgar, S. Noei-Khodabadi, F. andShafaei, S M. 2015.Design, development and field assessment of a controlled seed metering unit to be used in grain drills for direct seeding of wheat.*Information Processing in Agriculture*, 2(3-4):169- 176.

Karthikeyan, K. 2004. Development of an electronic seed monitoring system for planter.Unpublished M.Tech.Thesis, Department of Agricultural and Food Engineering.Indian Institute of Technology, Kharagpur, India.

Kaur, J. and Singh, A., 2017. Direct seeded rice: Prospects, probiems/constraints and researchable issues in India. *Current Agriculture Research Journal*, *5*(1), p.13.

Kumar, D., Singh, U.V., Kumar, J., Kumar, M. and Khan, K., 2017. Laboratory Test and Calibration of Direct Paddy Drum Seeder for Pre-Germinated Paddy Seeds. *Int. J. Curr. Microbiol. App. Sci*, *6*(9), pp.1037-1046.

Lacayanga, J E. Valdez, W G. Ines, R L. and Calderon, R P. 2009. Improved manual rice hill seeder for wetland paddy.*LUMINA*.20(1):1-13.

Luo, X.W., Jiang, E.C., Wang, Z.M., Tang, X.R., Li, J.H., & Chen, W.T. (2008). Precision rice hill-drop drilling machine. Transactions of the CSAE, 24(12), 52–56

Mahajan, G., Chauhan, B.S. and Gill, M.S., 2013. Dry-seeded rice culture in Punjab State of India: lessons learned from farmers. *Field Crops Research*, *144*, pp.89-99.

Maheshwari, T K. andVarma, M R. 2007. Performance study of pneumatic planter for pea.*Agricultural Engineering Today,*31(3&4):39-42.

Matin, M A.Roy, K C. andAmin, M N. 2008. Performance of BARI Developed Planter for Establishment of Maize. *Agricultural Engineering International: the CIGR Ejournal*, Manuscript PM 07 023. 10.

Meena, S. 2005. Design and development of an electronically assisted seed metering mechanism.Thesis, Department of Agricultural and Food Engineering.Indian Institute of Technology, Kharagpur, India.

Narendra, Haridas and Tayade. 2017. Assessment of drum seeder: An improved technology in rice production system. Department of Farm Machinery and Power. Krishi Vigyan Kendra, Dantewada, Chhattisgarh.

Nishida, H. (1996). The outline of activities conducted by Laboratory of Agricultural Machinery, Kyushu National Agricultural Experiment Station , AMA A&LA, Vol.27(1), pp.69.

Pandey, S. and Velasco, L., 2002. Economics of direct seeding in Asia: patterns of adoption and research priorities. In *Direct seeding: research strategies and opportunities* (pp. 3-14). International Rice Research Institute Los Baños, Philippines.

Patil, A S. and Dhande, K G. 2015.Development of bullock drawn dry paddy seed cum fertilizer drill.*International Journal of Sciences & Applied Research*, 2(3): 14-21.

Pathak, H., Tewari, A.N., Sankhyan, S., Dubey, D.S., Mina, U., Singh, V.K., Jain, N. and Bhatia, A., 2011. Direct-seeded rice: potential, performance and problems–A review. *Current Advances in Agricultural Sciences*, *3*(2), pp.77-88.

Ryu, H I. and Kim, K U. 1998.Design of roller type metering device for precision planting.*Transaction of ASAE.*,41(4): 923-930.

Sahoo, P K. and Srivastava, AP. 2008.Seed pattern characteristics of different metering systems for soaked okra seed. *Journal of Agricultural Engineering*, 45(1):1- 6.

Sawamura, Nobuyuki (1995). Development of a mechanical paddy seeder. Report of work at Phil Rice Research Institute, Maligaya Manos, Nueva Ecija, Philippines.

Singh, M K. Kumar, N. Verma, P and Garg, S K. 2012. Performance evaluation of mechanical planters for planting of chickpea and pigeonpea.*Journal of Food Legumes,*25(2): 131-134.

Singh SP, Gite LP, Agarwal N, Majumdar J (2007) Women friendly improved farm tools and equipments. CIAE Bhopal. India.

Singh, R C. Singh, G. and Saraswat, D C. 2005. Optimization of design and operational parameters of a pneumatic seed metering device for planting cotton seeds.*Biosyst. Eng.,*92 (4), 429-438.

Singh, R D. Singh, B. andSingh, K N. 1983. Evaluation of IRRI Pantnagar bullock- drawn, six row paddy seeder. *Agricultural Mechanization in Asia, Africa and Latin America*, 14(3):15-20.

Srivastava, A P. and Panwar, JS. 1991. Technology for seeding and planting of paddy.*Agricultural Science Progress*, 3:13-41.

Tajuddin, A. and Rajendran, P. 2002. Devices for inter-cropping green manure in wet seeded rice.*Agricultural Mechanisation in Asia, Africa and Latin America*, 33: 9-10.

Wang, Z. and Luo, X., 2010. Research of precision rice hill-drop drilling technology in China.

Zhai, J B. Xia, J F. Zhou, Y. and Zhang, S. 2014. Design and experimental study of the control system for precision seed metering device.*Int. J Agric. & Biol. Engg.,* 7(3): 13-18.

APPENDICES

APPENDIX I

A. Calculation of seed rate

Width of planter= 8× 0.238-20 = 1.90 m

Circumference of main drive wheel = π × 0.64 = 2.0m

Area covered per revolution = 1. 90× 2.0 = 3.8m²

$$\text{Number of revolution s per hectare} = \frac{10000}{3.8}$$

= 2632 revolutions

I. For forward speed S1 and cell size C1

Average seed collected for 100 revolutions of metering mechanism

= 0.081 kg

a) For 15 cm hill spacing

$$\text{Seed rate required for 2632 revolutions} = \frac{(2632 \times 200)}{15 \times 100} \times .081$$

Seed rate = 28.42 kg ha^{-1}

b) For 13 cm hill spacing

$$\text{Seed rate required for 2632 revolutions} = \frac{(2632 \times 200)}{15 \times 100} \times .081$$

Seed rate = 32.38 kg ha^{-1}

c) For 9 cm hill spacing

$$\text{Seed rate required for 2632 revolutions} = \frac{(2632 \times 200)}{15 \times 100} \times .081$$

Seed rate = 47.376 kg ha^{-1}

II. For forward speed S2 and cell size C1

a) For 20 cm hill spacing

$$\text{Seed rate required for 2632 revolutions} = \frac{(2632 \times 200)}{15 \times 100} \times .081$$

Seed rate = 21.31 kg ha^{-1}

b) **For 17 cm hill spacing**

$$\text{Seed rate required for 2632revolutions} = \frac{(2632 \times 200)}{15 \times 100} \times .081$$

Seed rate = 25.08 kg ha^{-1}

c) For 14 cm hill spacing

Seed rate required for 2632revolutions = $\frac{(2632 \times 200)}{15 \times 100} \times .081$

Seed rate = 30.45 kg ha^{-1}

I. For forward speed S1 and cell size C2

II. Average seed collected for 100 revolutions of metering mechanism

= 0.10 kg

a) For 15 cm hill spacing

Seed rate required for 2632revolutions = $\frac{(2632 \times 200)}{15 \times 100} \times .10$

Seed rate = 35.09 kg ha^{-1}

b) For 13 cm hill spacing

Seed rate required for 2632revolutions = $\frac{(2632 \times 200)}{15 \times 100} \times .10$

Seed rate = 40.49 kg ha^{-1}

c) **For 9 cm hill spacing**

Seed rate required for 2632revolutions = $\frac{(2632 \times 200)}{15 \times 100} \times .10$

Seed rate = 58.48 kg ha^{-1}

III. For forward speed S2 and cell size C2

a) For 20 cm hill spacing

Seed rate required for 2632revolutions = $\frac{(2632 \times 200)}{15 \times 100} \times .10$

Seed rate = 26.32 kg ha^{-1}

b) For 17 cm hill spacing

Seed rate required for 2632revolutions = $\frac{(2632 \times 200)}{15 \times 100} \times .10$

Seed rate = 30.96 kg ha^{-1}

c) For 9 cm hill spacing

Seed rate required for 2632revolutions = $\frac{(2632 \times 200)}{15 \times 100} \times .10$

Seed rate = 37.6 kg ha^{-1}

APPENDIX II

Field capacity and field efficiency

$$\text{Theoretical field capacity} = \frac{\text{Width of operation (m)} \times \text{Travel speed (km hr}^{-1})}{10}$$

$$\text{Effective field capacity ha hr}^{-1} = \frac{\text{Area covered ha}^{-1}}{\text{Productive time, hr} + \text{Non-productive time, hr}}$$

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

Where

Width of machine = 1.7 m

a) **For a forward speed of 1.8 km hr^{-1}**

$$\text{Theoretical field capacity} = \frac{1.9 \times 1.8}{10}$$

$$= 0.34 \text{ ha hr}^{-1}$$

$$\text{Effective field capacity ha hr}^{-1} = \frac{09 \times 30}{5.10 + 1.4} \times \frac{60}{10000}$$

$$= 0.26 \text{ ha hr}^{-1}$$

$$\text{Field efficiency} = \frac{0.26}{0.34} \times 100$$

$$= 76.46\%$$

b) **For a forward speed of 1.5 km hr^{-1}**

$$\text{Theoretical field capacity} = \frac{1.9 \times 1.5}{10}$$

$$= 0.28 \text{ ha hr}^{-1}$$

$$\text{Effective field capacity ha hr}^{-1} = \frac{09 \times 30}{6.0 + 1.2} \times \frac{60}{10000}$$

$$= 0.22 \text{ ha hr}^{-1}$$

$$\text{Field efficiency} = \frac{0.22}{0.28} \times 100$$

$$= 80.35\%$$

APPENDIX III

Analysis of variance for power operated paddy hill seeder (ANOVA)

Table 1 Analyses of variance of seed rate (ANOVA)

Source of variation	DF	SS	MS	F - value	Significance level
Speed	1	1293.6	1293.6	236.0	4.82e-16 **
Cell size	1	1223.4	1223.4	223.2	1.04e-15 **
Transmission ratio	2	1500.4	750.2	136.9	4.13e-16 **
Residuals	31	169.9	5.5		
Total	35	4187.3			

*Significant at 5% level **Significant at 1% level NS: Non-significant

Table 1.1 DMRT table for change in seed rate with respect to forward speed

Forward Speed	Seed rate
S1	46.15^{a}
S2	34.16^{b}

Table 1.2 DMRT table for change in seed rate with respect to cell size

Cell size	Seed rate
C1	34.32^{a}
C2	45.98^{b}

Table 1.3 DMRT table for change in seed rate with respect to transmission ratio

Transmission speed	Seed rate
T1	48.73[a]
T2	38.56[b]
T3	33.16[c]

Table 2 Analyses of variance of seed damage (ANOVA)

Source of variation	DF	SS	MS	F - value	Significance level
Speed	1	0.00	0.00	0.00	1
Cell size	1	7.91	7.91	146.4	2.82e-13 **
Transmission ratio	2	68.64	34.32	634.6	< 2e-16 **
Residuals	31	1.68	0.05		
Total	35	78.23			

*Significant at 5% level   **Significant at 1% level   NS: Non-significant

Table 2.1 DMRT table for change in seed damage rate with respect to cell size

Cell size	Seed damage
C1	5.34[a]
C2	4.43[b]

Table 2.2 DMRT table for change in seed damage rate with respect to transmission ratio

Transmission speed	Seed damage
T1	6.70^{a}
T2	4.65^{b}
T3	3.34^{c}

Table 3 Analyses of variance of average mean spacing of paddy hills

Source of variation	DF	SS	MS	F - value	Significance level
Speed	1	214.04	214.04	1001.5	<2e-16 **
Cell size	1	0.00	0.00	0.00	1^{NS}
Transmission ratio	2	241.73	120.87	565.5	<2e-16 **
Residuals	31	1239	34.40		
Total	35	1694.77			

*Significant at 5% level **Significant at 1% level NS: Non-significant

Table 3.1 DMRT table for change in spacing with respect to forward speed

Forward Speed	Spacing
S1	12.58^{a}
S2	17.46^{b}

Table 3.2 DMRT table for change in spacing with respect to transmission ratio

Forward Speed	Spacing
T1	17.98^{a}
T2	15.42^{b}
T3	11.67^{c}

Table 4 Analyses of variance of missing index of paddy seeds (ANOVA)

Source of variation	DF	SS	MS	F - value	Significance level
Speed	1	0.00	0.00	0.00	1^{NS}
Cell size	1	196.00	196.00	254.1	<2e-16 **
Transmission ratio	2	159.18	79.59	103.21	1.98e-14 **
Residuals	31	23.91	0.77		
Total	35	379.09			

***Significant at 5% level **Significant at 1% level NS: Non-significant**

Table 4.1 DMRT table for change in missing index with respect to cell size

Cell size	Missing index
C1	**11.83^{a}**
C2	7.16^{b}

Table 4.2 DMRT table for change in missing index with respect to transmission ratio

Transmission speed	Missing index
T1	**12.05[a]**
T2	9.55[b]
T3	6.90[c]

Table 5 Analyses of variance of multiple index of paddy seeds (ANOVA)

Source of variation	DF	SS	MS	F - value	Significance level
Speed	1	46.24	46.24	143.90	3.51e-13 **
Cell size	1	0.16	0.16	0.50	0.482
Transmission ratio	2	152.06	76.03	236.61	< 2e-16 **
Residuals	31	9.96	0.32		
Total	35	208.42			

***Significant at 5% level **Significant at 1% level NS: Non-significant**

Table 5.1 DMRT table for change in multiple index with respect to forward speed

Forward Speed	Multiple index
S1	**7.81[a]**
S2	5.55[b]

Table 5.2 DMRT table for change in multiple index with respect to transmission ratio

Transmission speed	Multiple index
T1	**9.35[a]**
T2	6.34[b]
T3	4.35[c]

Table 6 Analyses of variance of quality feed index of paddy seeds (ANOVA)

Source of variation	DF	SS	MS	F - value	Significance level
Speed	1	46.24	46.19	41.06	3.87e-07 **
Cell size	1	207.3	207.26	184.21	1.38e-14 **
Transmission ratio	2	619.6	309.79	275.24	< 2e-16 **
Residuals	31	34.9	1.13		
Total	35	908.06			

***Significant at 5% level **Significant at 1% level NS: Non-significant**

Table 6.1 DMRT table for change in quality feed index with respect to forward speed

Forward Speed	Quality feed index
S1	84.94[a]
S2	**82.68[b]**

Table 6.2 DMRT table for change in quality feed index with respect to cell size

Cell size	Quality feed index
C1	81.41[a]
C2	**86.21[b]**

Table 6.3 DMRT table for change in quality feed index with respect to transmission

Transmission speed	Quality feed index
T1	78.75[a]
T2	84.10[b]
T3	**88.75[c]**

APPENDIX IV

Estimation of cost of the machine

Sl. No.	Material	Qty, nos	Specification, mm	Length, m	Weight, kg m^{-2}	Total weight, kg	Cost, Rs.
I.	**Main frame**						
1.	MS rectangular pipe	1	35×15×3	7.42	69	14	970
2.	MS iron angle	1	50×50×5	2.25	72	5.85	421
3.	MS iron angle	1	25×25×2	9.2	72	18	1292
IV	**Rhizome and Compost boxes**						
1.	MS sheet (m^2)	1	20 gauge	1.8	-	-	1200
VI	**Round shafts**						
1.	GI round pipe	1	20	1.8	-	-	320
2.	SS round pipe	1	18	1.8	-	-	450
3.	MS Shaft	1	18	0.30	-	-	400
VII	**Metering mechanisms**						
1.	Metering rollers	8	70 (Dia.)	-	-	120	960
2.	MS rectangular pipe	8	95×45×3	0.26	-	100 each	800
3.	GI iron round pipe	8	25 (Dia)	0.06	-	-	100
IX	**Clamps**						
1.	MS Flat	2	18×50×5	.30	5.1	1.53	150
X	**Sprockets and bevel gears**						
1.	Sprocket	3	14 teeth	-	-	240 each	480
4.	Sprocket	1	36 teeth	-	-	-	800
5	Bevel gears	2	9,13 teeth	-	-	700+900	1600
4.	Spur gear box	1					6000
6.	Chain	1	12.77mm pitch	1.4	-	-	800
7.	Flange bearings	5	P204,208			360 each	1800
XI	**PVC Pipes**						

1.	PVC pipe	1	50 mm (Dia.)	1.6	-	-	600
XII	**Others**						
1.	Nut and bolts(kg)	10	-	-	-	-	1000
2.	Springs	8					80
2.	Welding rods	-	-	-	-	-	750
3.	Paint	-	-	-	-	-	800
	Total cost					**21773**	
		Fabrication				**6800**	
Total cost of planter						**28573**	

APPENDIX V

Cost of operation of paddy hill seeder

1. Prime mover

Cost of prime mover, C = Rs. 260000

Expected life, L = 08 years

Salvage value, S = 10% of C = Rs. 2600

Annual operating hours, H = 500 hrs

Annual interest or interest on Investment, I = 10%

i. Fixed cost

a) $$\text{Depreciation} = \frac{C - S}{L \times H}$$

Where,

C = Total prime mover

S = Salvage value 10% of C

H = Annual use in hours

$$\text{Depreciation} = \frac{260000 - 26000}{08 \times 400}$$

= Rs. 73 h^{-1}

b) $$\text{Interest} = \frac{C + S}{2} \times \frac{i}{H}$$

Where,

i = % rate of interest per year

$$\text{Interest} = \frac{260000 + 26000}{2 \times 400} \times \frac{10}{100}$$

=Rs. 35.75 h^{-1}

c) Housing cost (1% of the initial cost of prime mover)

$$= \frac{260000}{400} \times \frac{1}{100}$$

= Rs. 6.5 h^{-1}

100

d) Insurance and taxes (2% of the initial cost of prime mover)

$$= \frac{260000}{400} \times \frac{2}{100}$$

$= 13\ h^{-1}$

Total fixed cost = a + b+ c + d = Rs128.5h^{-1}

ii. Variable cost

a) Average diesel consumption = 1.2 lit h^{-1}

Fuel cost (1.2×Rs. 66.5 lit^{-1}) = Rs. 79.8 lit^{-1}

b) Lubrication cost (30% of fuel cost)

$$= 78.8 \times \frac{30}{100}$$

= Rs. 23.94 hr^{-1}

c) Repair and maintenance cost (10% of initial cost)

$$= \frac{260000}{400} \times \frac{10}{100}$$

= Rs. 6.5 hr^{-1}

d) Operator wages (Rs. 800 per day of 8 hours)

$$= \frac{800}{8} = 100\ h^{-1}$$

Total variable cost = a + b+ c + d = Rs. 180.69 h^{-1}

Total operating cost prime mover = Fixed cost + Variable cost

= 128 + 180.69

= Rs. 308.69 hr^{-1}

2. Paddy hill seeder

Cost of paddy hill seeder, C = Rs. 28573

Expected life, L = 06 years

Salvage value, S = 10% of C = Rs. 2500

Annual operating hours, H = 400 hrs

Annual interest, i = 10%

i. Fixed cost

a) $\text{Depreciation} = \frac{C - S}{L \times H}$

Where,

C = Total cost of machine

S = Salvage value 10% of C

H = Annual use in hours

$$\text{Depreciation} = \frac{28573 - 2857.3}{06 \times 400}$$

= Rs. 10.71 hr^{-1}

b) $\text{Interest} = \frac{C + S}{2} \times \frac{i}{H}$

Where,

i = % rate of interest per year

$$\text{Interest} = \frac{28573 + 2857.3}{2 \times 400} \times \frac{10}{100}$$

=Rs. 3.92 hr^{-1}

c) Housing cost (1% of the initial cost of tractor)

$$= \frac{28573}{400} \times \frac{1}{100}$$

= Rs. 0.71 hr^{-1}

Total fixed cost = a + b+ c = Rs. 15.34 hr^{-1}

102

ii. **Variable cost**

a) Repair and maintenance cost (5% of initial cost)

$$= \frac{28573}{400} \times \frac{5}{100}$$

$$= \text{Rs. } 3.57 \text{ hr}^{-1}$$

Total variable cost = Rs. 3.57 h^{-1}

Total operating hill seeder = Fixed cost + Variable cost

$$= 15.34 + 3.57$$

$$= \text{Rs. } 18.91 \text{ h}^{-1}$$

Total operating cost of power operated hill seeder = Prime mover + Seeder cost

$$= 308.69 + 18.91$$

$$= \text{Rs. } 327.6 \text{ h}^{-1}$$

Theoretical field capacity of hill seeder = 0.28

Actual field capacity of hill seeder = 0.22

Field efficiency of hill seeder = 80 %

Time required to cover 1 ha, h $= \frac{1}{AFC}$

$$= \frac{1}{0.22}$$

$$= 4.54 \text{ h ha}^{-1}$$

Cost of operation of paddy hill seeder = 4.54 × 327.6 = Rs. 1490 ha^{-1}

Cost of sowing by manually operated drum seeder

Labour requirement = 24 man hr ha^{-1}

Cost of planting Rs. 850 per labour $= \frac{24}{8} \times 850$

$= Rs.\ 2550\ ha^{-1}$

Cost saved over drum seeding $= 2550 - 1490$

$= 1060\ ha^{-1}$

Cost saved over drum seeding (%) $= \frac{1060}{2550} \times 100 = 41.56\%$

Time saved over manual seeding $= 24 - 4.54$

$= 19.46\ hr\ ha^{-1}$

Time saved over drum seeding (%) $= \frac{19.46}{24} \times 100 = 81\%$

3. Benefit-cost-ratio

Benefit cost per hectare = Cost of drum seeding- Cost of machine seeding

= Rs. 2550 – 1490

= Rs. 1060

Therefore,

$$\text{Benefit cost ratio} = \frac{\text{Benefit cost}}{\text{Cost of machine seeding}}$$

$$\text{Benefit cost ratio} = \frac{1060}{1490} = 0.71$$

ABSTRACT

105

DESIGN, DEVELOPMENT AND TESTING OF A POWER OPERATED PADDY HILL SEEDER

by

BANDI NAGESWAR

(2017-18-012)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

(Farm Machinery and Power Engineering)

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

DEPARTMENT OF FARM MACHINERY AND POWER ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND

TECHNOLOGY, TAVANUR - 679 573

KERALA, INDIA

2019

ABSTRACT

Rice (Oryza sativa L.) is important leading food crop and it is widely cultivated in India. The farmers are facing problems due to lack of labour, time, inputs cost and also due to drudgery in work. Nevertheless, mechanization in paddy cultivation can boost higher productivity and considerably reduce the cost of production. Therefore, the present study was undertaken to design and develop a power operated paddy hill seeder in paddy cultivation. The power operated paddy hill seeder was developed and tested based on the, engineering and physical properties of dry and pre-germinated paddy seeds.

The tests were conducted on sand bed to evaluate the seed metering mechanism performance with respect to spacing, seed rate, quality of feed index, multiple index, miss index, and seed damage at two different forward speeds (1.5 and 1.8 km h^{-1}), two cell sizes and three transmission speeds (1:1.7, 1:1.2 and 1:0.95). The mean hill to hill spacing was ranged from 0.09-0.20 m, 3 to 7 seeds per hill, seed rate of 21-58 kg ha^{-1}. The missing index and multiple indexe were less for the different combinations of study parameters (speed 1.5 kmph, cell size 9 mm, Transmission ratio 1:1.7), (Speed 1.8 kmph, Cell size 9 mm, Transmission ratio 1:1.7) and (Speed 1.8 kmph, Cell size 12 mm, Transmission ratio 1:1.7). The quality feed index were 86.1, 88.6 and 91.1 respectively for above sequence of combinations of study parameters. The average field capacity of the paddy hill seeder was 0.22 ha h^{-1} and 0.26 ha h^{-1} with efficiency of 80.00% and 76.00 % for forward speeds of 1.5 and 1.8 kmph respectively. Based on the performance evaluation results, it is concluded that the developed power operated paddy hill seeder is economical and efficient for direct sowing of paddy.