“TESTING AND PERFORMANCE EVALUATION OF TRACTOR DRAWN SEED- CUM FERTILIZER DRILL FOR SOWING OF MINOR MILLET”

M. Tech. (Agril. Engg.) Thesis

by

Meena Kanwar

DEPARTMENT OF FARM MACHINERY AND POWER ENGINEERING
SWAMI VIVEKANANDA COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY
FACULTY OF AGRICULTURAL ENGINEERING
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“TESTING AND PERFORMANCE EVALUATION OF TRACTOR DRAWN SEED-CUM FERTILIZER DRILL FOR SOWING OF MINOR MILLET”

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Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.)

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Meena Kanwar

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CERTIFICATE – I

This is to certify that the thesis entitled "**Testing and Performance evaluation of Tractor Drawn Seed-Cum Fertilizer Drill for sowing of Minor Millet**" submitted in partial fulfillment of the requirements for the degree of **Master of Technology** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Meena Kanwar** under my/our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigations have been duly acknowledged by ~~him~~/her.

Date: 18/7/2015

Chairman

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman	(Dr. B. P. Mishra)	________
Member	(Dr. A. K. Dave)	________
Member	(Dr. Ajay Verma)	________
Member	(Dr. A.K. Pali)	________
Member	(Dr. S.P. Gupta)	________

CERTIFICATE - II

This is to certify that the thesis entitled **"Testing and Performance evaluation of Tractor Drawn Seed- Cum Fertilizer Drill for sowing of Minor Millet"** submitted by **Meena Kanwar** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of Master of Technology in the Department of Farm Machinery and Power Engineering has been approved by the external examiner and Student's Advisory Committee after oral examination..

Signature External Examiner
(Name Dr Atul K Shrivastava

Date:

Major Advisor ____________________

Head of the Department/Section ____________________

Faculty Dean ____________________

Approved/Not approved

Director of Instructions ____________________

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(Meena Kanwar)

Department of Farm Machinery and Power Engineering,
Faculty of Agricultural Engineering
I.G.K.V., Raipur (C.G.)

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations	Description	Abbreviations	Description
Agril. -	Agricultural	IS -	Indian Standards
AMA -	Agricultural Mechanization in Asia, Africa and Latin America	ISAE	Indian Society of Agricultural Engineering
ANOVA -	Analysis of Variance	J. -	Journal
ASAE -	American Society of Agricultural Engineers	kg -	Kilogram
BIS -	Bureau of Indian Standards	kW -	Kilowatt
°C -	Degree centigrade	m -	Meter
CAD -	Computer Aided Design	m^2 -	Square meter
CIAE -	Central Institute of Agricultural Engineering	m/s -	meter per Second
cm -	Centimeter	min -	Minute
cm^2 -	Centimeter square	mha -	million hectare
d.b. -	Dry basis	mm -	Millimeter
dia -	Diameter	MS -	Mild Steel
etc. -	Et-cetra	No. -	Number
et al -	Etlii and others	N -	Newton
Engg. -	Engineering	% -	Per cent
Fig. -	Figure	q -	Quintal
h -	Hour	rpm -	Revolution per minute
h/day	- Hour per day	Rs. -	Rupees
ha -	Hectare	sec -	Second
hp	Horse power	Sr. -	Serial
IARI	Indian Agricultural Research Institute	S.S. -	Sum of square
ICAR	Indian Council of Agricultural Research	Viz. -	Namely
i.e. -	That is	wb. -	Wet basis
IGKV -	Indira Gandhi Krishi Vishwa Vidyalaya		
IRRI	International Rice Research Institute		

THESIS ABSTRACT

a) Title of the Thesis: Testing and Performance Evaluation of Tractor Drawn Seed-Cum Fertilizer Drill for sowing of Minor Millet

b) Full Name of the Student: Meena Kaṇwar

c) Major Subject: Farm Machinery and Power Engineering

d) Name and Address of the: Major Advisor
Dr. B.P. Mishra
Professor.& Head,
Department of Farm Machinery and Power Engineering.
Faculty of Agricultural Engineering,
IGKV, Raipur

e) Degree to be Awarded: Master of Technology in Agricultural Engineering

Signature of the student

Signature of Major Advisor
Date: 18/7/2015

Signature of Head of the Department

ABSTRACT

A seed cum fertilizer drill was used for sowing of Ragi and Kodo at SVCAET, IGKV, Raipur .The seed rate of Ragi and Kodo was kept at 5 kg/ha and 8-10kg/ha respectively . The seeds was sown by filling the seeds of respective crop in the required section of seed hopper in Ragi and Kodo, the row to row spacing was 30 cm. Exposure scale 4 and 5 selected with metering roller 4 for Ragi and Kodo. Metering roller 5 exposure scale 3 gives nearest value for desired fertilizer ~~seed~~ rate. The effective field capacity for Ragi and kodo of the machine was found to be 0.45 ha/h

and 0.51 ha/h with field efficiency 77 and 82. The cost of operation was Rs.580 per hr and energy requirement was 1859 MJ/ha for sowing. Different treatments were used for sowing kodo and Ragi by seed drills including different seed and DAP ratios. Treatment T-7 yielded maximum production of kodo over others mixture ratios. T-7 treatment was Seed: DAP ratio of (2:1). This ratio gave maximum kodo yield (0.93 tonne / ha) of kodo. It may be due to better and early fertilization of crop, as seed and fertilizer placed together. Treatment T-7 yielded maximum over others mixture ratios for Ragi also. T-7 treatment was Ragi Seed:DAP ratio of (1:1). This ratio gave maximum Ragi yield (2.9 tonne/ha). It may be due to better and early fertilization of crop, because seed and fertilizer placed together. In broadcasting method Grain yield was obtained for Ragi was significantly higher than kodo, which was recorded as 0.63(tonne/ha) and for kodo 0.31(tonne/ha) respectively. Straw yield obtained from kodo was significantly higher than Ragi i.e. 0.43(tonne/ha) and 0.41(tonne/ha) respectively. This is due to the fact that the machine has greater coverage width and least amount of overlapping due to shovels,which increases efficiency of the machine.

सारांश

थीसिस शीर्षक	कोदो व रागी की बुवाई हेतु टैक्टर चालित सीड कम फर्टिलाजर ड्रिल का परीझण व प्रर्दशन
छात्र का नाम	मीना कंवर
पमुख विषय	प्रक्षेत्र यंत्रण एंव शक्ति अभियात्रिकी
प्रमुख सलाहकार	डॉ बी पी मिश्रा प्राघ्यापक एवं विभागाघ्यक्ष. एस. वी सी .ए. इ. टी.एवं अनुसंघान केन्द्र इं.गा. कृ विश्वविघालय रायपुर
डिग्री प्रदान की जाऐगी	मास्टर ऑफ टेक्नालोजी कृषि अभियांत्रिकी

छात्रा का हस्ताक्षर

प्रमुख सलाहकार का हस्ताक्षर

दिनाक 18/7/2015

विभागाघ्यक्ष का हस्ताक्षर

सारांश

रागी व कोदो की सीड कम फर्टिलाजर ड्रील के द्वारा बुवाई एस. वी सी .ए. इ. टी. आइ . जी. के .वी . फार्म मे की गई बीज की दर रागी व कोदे दोनो के लिए 5 कि. गा. पर हेक्टेयर रखी गई। बीजो की बुवाई सीड हापर के आवशयक भाग के द्वारा जोदी मे कमानुसार की गई पंक्ति से पंक्ति की दूरी 30 से .मी. रर्खी गई चुनित मिटरिंग रोलर 4 मे प्रर्दशन स्केल 4 व 5 रागी के लिए व मिटरिंग रोलर 5 व प्रर्दशन स्केल 3 ने कोदे के लिए आवशयक सीड फर्टिलाजर दर दिया। मशीन की प्रभावी क्षेत्र झमता 0.45 हेक्टेयर पर घंटा व 0.51 हेक्टेयर पर घंटा व क्षेत्र दक्षता 77 प्रतिशत व 82 प्रतिशत रागी व कोदा के लिए कमानुसार पाई गई। कार्य लागत रू 580 प्रत्येक घंटे की दर से तधा उर्जा की आवशयकता 1859 मेगा जूल पर हेक्टेयर बुवाई के लिए पाई गई। विभिन्न प्रकार के उपचार अलग-अलग सीड व डी ए. पी. अनुपात को लेकर बुवाई की गई, जिसमे टी-7 मे सबसे ज्यादा का उत्पादन हुआ अन्य की तुलना मे उपचार टी-7 मे सीड व फर्टिलाजर का अनुपात 2 : 1 लिया गया अनुपात मे सबसे ज्यादा (0 .91 टन पर हेक्टेयर) कोदे का उत्पादन हुआ, यह फसल के अच्छे व जल्दी फर्टिलाजेशन की वजह से हो सकता है क्योकि सीड व फर्टिलाजर को एक साध हाला गया। उपचार टी 7 ने सबसे ज्यादा उत्पादन दिया। रागी के लिए भी. रागी के टी-7 उपचार मे रागी सीड व डी ए. पी. का अनुपात 1 :1 लिया। इस अनुपात मे रागी का सर्वाधिक उत्पादन 2 .9 टन पर हेक्टेयर पाया गया। ये भी फसल के अच्छे व जल्दी फर्टिलाजेशन के कारण सकता है! क्योकि बीज व फर्टिलाजर को एक साध डाला गया। प्रसारण विधि के द्वारा रागी का उत्पादन उल्लेखनीय दंग से रागी के लिए अधिक आया कोदे की तुलना मे जो कि 0.63 टन पर हेक्टेयर व 0.31 टन पर हेक्टेयर रागी व कोदे के लिए अभिलिक्षित किया गया . कोदे से पाप्त भूसा उपज रागी से पाप्त भूसा उपज से अधिक घा जो कि कमानुसार 0.43 टन पर हेक्टेयर व 0.41 टन पर हेक्टेयर पाया गया यह सब इसलिए आया क्योकि मशीन की अधिक क्षेत्र चाडाइै धी तधा सबसे कम ओवरलैपिग शावेल की वजह से धी जिसने मशीन की दक्षता बदा दी .

अधिक आया कोदेा की तुलना मे जो कि 0.63 टन पर क्टेयर रागी व कोदेा के लिए अभिलेखित किया गया . कोदेा से पाप्त भूसा उपज रागी से पाप्त भूसा उपज से अधिक घा जो कि क्रमानुसार 0.43 टन पर हेक्टेयर व 0.41 टन पर हक्टेयर पाया गया य सब इसलिए आ क्योकि मशीन का अधिक क्षेत्र चौड़ाई थी तधा सबसे कम ओवरलैपिग भाावेल की वजह से थी जिसने मशीन की दक्षता बदा दी .

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CHAPTER-I
INTRODUCTION

Minor Millets or small millets are unlike to major millets (Maize , Jowar & Bajra). It may be defined as millets cultivated for their small grains which are borne on short, slender grassy plants. In other words they refer to a group of small seeded cereal crops. The most important minor millet cultivated in India are Finger Millet (*Ragi*), Proso Millet, Barnyard Millet, Italian Millet, Kodo Millet little Millet ,job's tears and teff.

The term 'Minor millets' refers to a group of small-seeded cereal crops

Minor Millet can be grown even in poor soil and climatic conditions. They have short growing season and can be very well fitted into multiple cropping systems both under irrigated as well as dry framing conditions. They can provide nutritious grain and fodder in a short span of time .Their long storability under ordinary conditions has made them "famine reserves", this aspect is very important as Indian agriculture suffers from vagaries of the monsoon.

Minor millets have a capacity for wide adaption .They can withstand a certain degree of soil acidity and alkalinity, stress due to moisture and temperature and variation in soils from heavy to sandy and infertile .They are grown from the extreme southern tip of India at sea level to the temperate north Himalayan areas up to an altitude of 3000 metres with consequent variation in photoperiod from short to long days.

Grain like sorghum and pearl millet crops, not only form a staple food for the farming community but also provide substantial quantities of palatable fodder for cattle. Small millet grains are nutritionally rich. Dietary surveys carried out by the National Institute of Nutrition, Hyderabad, Proceedings of the (First International Small Millets Workshop Bangalore, India, October 29-November 2) indicated that these grains are particularly low in phytic acid and rich in iron and calcium, and concluded that the small millet grains are nutritionally rich.

Finger millet also known as *Ragi* in India .it is an annual plant widely grown as a cereal in the arid areas of Africa and Asia. *Ragi* is originally native to the Ethiopian Highlands and was introduced into India approximately 4000 years ago (Hulse *et al*., 1980)

The grain of finger millet is globular to oval, and has a diameter that ranges from 1.0 to 1.5 mm. India is world's lagers producers of millets having production of 10,000 MT in 2010-2011. Chhattisgarh is also major producing state of millet specially the Baster region having production of 64 MT in 2011-12. (Source Wikipedia.org/wiki/millet).

Finger millets are generally grown in higher rainfall areas (600-1200mm) and are one of the better crops for acidic soil. It matures within 100 to 130 days (Hulse *et al.,* 1980). It is very adaptable to higher elevations and grown in the Himalaya up to 2,300 meters in elevation (Sheetharam *et al*., 2002). Ragi contains 7.7 % protein, 1.5 % fat, 2.6 % minerals, 3.6 % fiber, 72.6 % carbohydrate and its 100 g of seeds contains 350 mg of calcium, 283 g of phosphorus, 3.9 mg of iron (Hulse *et al*., 1980).

Kodo millets is the coarest among the food grains and also remarkable drought resistant. In India, it is grown mostly in Andhra Pradesh , Tamil Nadu , Karnataka , Uttar Pradesh and Maharastra as rainfed crop. It occupies the land longer than any other dryland grain crop. The crop is of minor importance and only small areas are cultivated.

Kodo requires warm and dry climate it is highly drought tolerant hence can be grown in areas of scarce and erratic rainfall it is generally grown in areas receiving 40-50 cm rainfall annually.

Broadcasting finger millets seeds is the most common practice in rainfed areas. But it is always better to sow finger millets in lines instead of broadcast. Line sowing ensure better germination, reduces seed requirement and facilitates intercultural operation as compared to broadcast method of sowing. Drill or place the seed 3-4 deep and cover. It with soil .In areas with adequate moisture, *Ragi* can be grown by the method of transplantation. Higher yields are obtained in case of transplanted crop as compared to died seeded crop.

In India and so in Chhattisgarh cultivation of different crops is influenced greatly by soil type, climate and amount of rainfall. During *Kharif* season, time available for final seedbed preparation and sowing

Millets are amazing in their nutrition content. Each of the millets is three to five times nutritionally superior to the widely promoted rice and wheat in terms of proteins, minerals and vitamins (Table A -2).

Therefore these crops produce an extraordinary food system that can secure India’s food, health and economy in future .That’s why it should not be known as the coarse cereals and may be renamed as Nutri-cereals. However its productivity is poor in Chhattisgarh which need to be enhanced by suitable engineering intervention.

At present in Chhattisgarh region the sowing of millets seed is performed by manual labour; it requires lot of human energy and time. Therefore mechanization is a very important issue in development of this tribal crop. The labour availability is scarce during the sowing period in *Kharif* and *Rabi* season. The cost of production is also high due to the manual labour. On the other hand in the operation, drudgery is highly involved. The production and productivity of the finger millet is low because every seed is not proper germinate in broadcasting and manual method, So it is felt that if this operation is performed by machine it will save time, energy and production cost. Keeping above points in mind, a study was carried out with these following objectives.

1. Study of physical properties of minor millets and mixture.
2. Selection of suitable mixture, seed-mixture ratio, and seed metering mechanisms for line sowing of minor millets.
3. Testing and evaluation of tractor drawn seed-cum-fertilizer drills for sowing of minor millets with different mixture ratios under laboratory and field condition.
4. Economic evaluation of seeding methods.

CHAPTER-II
REVIEW OF LITERATURE

Sowing operations are the most important operations for any crop production system. These operations consume considerable amount of energy and time. Timely and proper performance of these operations is essential to achieve higher crop productivity. Farmers adopt different methods of tillage involving many types of implements to obtain proper field condition for seed sowing. Sowing requires proper attention to place the seed in proper soil environment for germination.

In this chapter attempt has been made to review the work related to physical properties of Minor Millet , tillage , seed metering device, seed rate and sowing operations.

2.1 Physical properties of Minor Millet

Mandhyan *et al.* (1987) studied physical properties *of kodo (Paspalum Scrobiculatum* L.), *kutki (Panicum miliaceus* L.), and *sawan (Panicum miliare* L.). They reported that the average geometric mean diameter *of kodo* (1.82 mm) is higher than that of *sawan* (1.59 mm) and *kutki* (1.07 mm). The sphericity of *kutki* (0.93) is observed to be highest among the three minor millets and *kodo* has the least sphericity value. The length breadth ratio is highest in *sawan* (1.07)
indicating that *sawan* grain is the most slender of all. Thousand grain mass is the highest in *kodo* (4.89 g) followed by *sawan* (4.03 g) and *kutki* (2.00 g), but specific gravity is the highest in *kutki* (1.35). The bulk density of *kutki* (0.72 g/ml) is the highest followed by *kodo* (0.57 g/ml). The angle of repose of *kodo* (28° 50') was observed to be the highest followed by *sawan* (24° 25') and *kutki* (20° 21').

Dutta *et al.* (1988) reported that 1000 grain weight of gram (0.173 kg) is linearly related to its moisture content (10.9 %, db) and increases with increase in the moisture content. The sphericity and roundness of the grain are 73.5 and 69.7 per cent, respectively. If the root is ignored, the sphericity and roundness are found to be above 80 per cent. The shape of the grain is very close to prolate spheroid with its short axis as minor axis. The bulk and kernel densities linearly decrease with increase in the moisture content in the range of 9.64 to 31.0 per cent. The porosity increases linearly with moisture content. They further reported that the static coefficient of friction of the material increases with moisture content. The dynamic or emptying angle of repose increases (25.5° to 30.4°) with increase in moisture content (8.62 to 17.6 %, db) of the grain.

Visvanathan *et al*. (1990) summarized the findings that the angle of repose for sorghum, pearl millet, finger millet, *Kodo* millet, foxtail millet and little millet increased linearly with the increase of moisture content (10 to 30 %, wb) and the bulk density decreased linearly for all the grains.

Sharma and Mandhyan (1992) studied four varieties of *Kodo* to determine engineering properties. The slenderness ratio was varied from 1.01 to 1.05, the geometric mean diameter varied between 1.73 and 1.89 mm and the sphericity was varied from 0.88 to 0.90. They further observed that the angle of repose varied from 0.44 to 0.51 radians. Thousand kernel weight ranged from 4.60 to 5.10 g and the specific gravity was observed to be in the range of 1.08 to1.22.

Physico-chemical properties of pearl millet and small millets were studied by Hadimani and Malleshi (1993) and reported that the thousand kernel mass and volume of the millets ranged from 2.3 to 7.1 g and 1.4 to 5.1 ml, respectively, while their densities ranged from 1.37 to 1.64 g/ml. Thousand kernel mass and volume of milled grains ranged from 1.9 to 5.8 g and 1.3 to 3.8 ml, respectively. As expected, the density of milled grains ranged from 1.40 to 1.80 g/ml, which was higher than whole grains.

Deshpande *et al.* (1993) reported the moisture dependence physical properties of soybean. In the moisture range of 8.7 to 25.0 per cent (db), the length of grain increased from 6.32 to 6.75 mm, the width from 5.23 to 5.55 mm, the thickness from 3.99 to 4.45 mm. the geometric mean diameter from 5.09 to 5.51 mm, the sphericity from 0.806 to 0.816, the surface area from 0.813 to 0.952 cm , the volume of grain from 0.091 to 0.113 cm , and thousand grain mass from 0.110 to 0.127 kg. Kernel density decreased from 1216 to 1124 kg/m , bulk density from 735 to 708 kg/m^3 and porosity from 0.40 to 0.37. They further reported that soybean grain expands more along its thickness in comparison with the other two principal axes with increase in moisture content.

Jain and Bal (1997) studied three varieties of pearl millet seed, consisting of two hybrids GHB-30 and Bajra 28-15, and one Babapuri (traditional) variety. The average principal dimensions were 3.0. 1.9 and 1.75 mm for hybrid and 3.4, 2.2 and 2.0 mm for Babapuri variety of the pearl millet grain. Mean size based on surface area of the grain was 1.73 mm for hybrid varieties and 2.08 mm for Babapuri variety. It was also reported that the shape of the grain was confirmed to be cono-spherical. The sphericity was 0.94 and the shape factor of the grain was 1.07 for GHB-30, 1.01 for Bajra 28-15 and 1.06 for the Babapuri varieties, respectively. The surface area and the volume of a single pearl millet grain were 12.5 mm and 3.8 mm for hybrid varieties and 16.4 mm 5.8 mm"1 for Babapuri varieties, respectively. The bulk and grain densities were 850 and 1600 kg/m3, respectively, which are significantly higher than other cereal grains. Pearl millet exhibited low values of coefficient of friction of 0.25 and angle of repose of 23 to 25°. Porosity of the grain varied between 45 and 49 per cent.

Singh *at el*(2009).have studied The geometric mean diameter, sphericity, grain surface area, 1000 grain mass, true density (toluene displacement method), terminal velocity, dynamic angle of repose, coefficient of internal friction, coefficient of static friction at different surfaces (sun mica, canvas and mild steel surfaces), specific deformation and rupture energy of the grain were found to increase 12.21%, 4.79%, 30.47%, 30.75%, 6.74%, 32.99%, 127.05%, 60%, 18.57%, 34–67%, 69.2% and 88.87% respectively at increase of moisture content from 0.065 to 0.265 kg kg_1 dry matter. However, true density (proximate composition method), bulk density, interstices and rupture force of grain was found to be decrease 8.64%, 20.1%, 86.49% and 21.17% respectively at increase of moisture content. Similar trend was observed for barnyard kernel also. True density (toluene displacement method) was found lower as compared to true density (proximate composition method) at all experimental moisture range indicated that the presence of void space inside the grain and kernel.

Swami and Swami. (2010) Physical properties of finger millet have studied .Physical and mechanical properties of finger millet (*Eleusine coracana*) are necessary for the design of equipment to handle, transport, process and store the crop. The physical properties have been evaluated as a function of grain moisture content varying from 13 to 48% (db). In this moisture range, true density increased from 1120 to 1130 kg/m3; the bulk density increased from 709 to 775 kg/m3. The porosity of the finger millet grain was found to increase from 13.00 to 41.72%. The geometric mean diameter increased linearly 1.608 to 1.822 mm. The sphericity of the finger millet grains were in the range of 0.960 to 0.987 for the grain moisture content varying from 13 to 48% (db). The surface area and the surface volume were in the range of 9.00 to 10.2 mm2 and the surface volume was 2.8 to 3.2 mm2 and found to increase with the increase in moisture content of the grains.

Ramappa *et al.* (2011), The present investigation was carried out to study the physical properties of two varieties of *Ragi* (GPU-28 and L-15). The average sizes of grain sample taken for the study were 1.7 and 1.63 mm for GPU-28 and L-15 *Ragi* varieties, respectively. 1000 grains weight was 3.39 g for GPU-28 as compared to 3.27 g for L-15 *Ragi*. There was not much difference in specific gravity between the two varieties. The bulk densities of 733.6 and 731.67 kg/m3 were recorded for GPU-28 *Ragi* L-15 varieties of *Ragi*, respectively. Angle of repose and angle of friction for GPU-28 variety *Ragi* were 170-58’ and 300-58’, respectively. For L-15 *Ragi*, the angle of repose was 170-31’ and the angle of friction 300-22’. The grain samples contained a moisture content of 9.61 and 9.58 per cent for the varieties GPU-28 and L-15 *Ragi*, respectively. The colour of GPU-28 was very attractive with red brown, while that of L-15 was brown on dark brown. The colour also plays an important role as for as consumer’s acceptance is concerned. It was noted that, the GPU-28 was bold in size (1.70 mm) while the L-15 was smaller (1.63 mm). Of the factors investigated, the seed size and bulk density showed linear relationship with milling yield.

2.2 Seed Metering Mechanism

Kirschmann (1966) have studied on Feeding Mechanism for seed Apparatus for evenly distributing seed from a seed or grain hopper of a planting machine comprising a plurality of guide cups disposed under spaced apart discharge apertures in the bottom of the seed hopper, the guide cups being contoured to house rotatably supported metering wheels and cooperating therewith to form outwardly converging seed metering passages through which seeds are conveyed by transverse pockets formed in the periphery of the metering wheels. The metering wheels are mounted on a drive shaft which is adjustable relative to curved bottom portions of the guide cups, whereby the size of the seed metering passageway between the periphery of the metering wheels and said curved bottom portions may be varied to accommodate different sizes of seeds.

Short and Huber (1970) designed, fabricated and tested in laboratory for a planetary motion device. Test showed that the per cent of theoretical drop was almost independent of operating speed. Orifice velocity was a critical factor in picking up one seed at a time. In one of the better tests, the nozzles, delivering seeds at rates from 1to 6 seeds per sec. had one seed attached 80 per cent of the time and two seeds attached 20 per cent of time.

Wiedemann & cross (1979).Rangland development using semicircular seed box and augar agitator seed metering concept .A rangeland seeder featuring a semicircular seedbox and auger agitator mounted to heavy-duty frame has proven reliable and durable under rough rangeland conditions. The experimental seeder reduces the variability in metering fluffy seed due to the improvement in design. Satisfactory metering of slick seed was accomplished with a commercial, cup-feed mechanism. Flexing, runner openers prepared and placed seed in a furrow without undue mechanical breakage while traversing logs, stumps and other debris left after rootplowing. The features of the experimental seeder increase the potential for seeding brush-infested rangeland because of improved reliability and less need for costly clean-up of brush debris.

Searcy and Roth (1982) developed a microcomputer controlled metering system for accurately space-germinated seeds. The microcomputer detected seed presence with photoelectric devices and drove the metering mechanism with stepping motors. The system was tested on a planter evaluation stand for metering speed and spacing accuracy. They found that the seed-gel mixture with the lowest errors rate was a ratio of seed/2mL of gel. For all seed- gel mixtures, percentage of metering errors sharply increased after a metering rate of seed/s. below 2 seed/s the percentage errors generally ranged from 10 to 23 with no real pattern by seed ratio. In no instance was the metering error than 10 per cent.

Kumar *et al.* (1986) designed and developed animal drawn cultivator with seeding attachment having seed metering mechanism of fluted roller type. The capacity of M.S. seed box was 25 kg. Seed tubes were of polythene material having 2 cm diameter. The seed drops were 149,114, 76 and 36 kg/ha at full, 3nd 1/4 exposed length of the fluted roller respectively with average breakage of seeds for 1.8 per cent.

Shafii and Holmes (1990) investigated that metering of seeds by an air- jet flowing through a conical. Pressure distribution and forces exerted on the ball were measured for different cone configuration, orifice diameters, and cone ball clearances. Cone angle of 90°developed the highest retaining force. Two mathematical models were derived for the prediction of pressure distribution and forces on the ball. Model derived from stagnation point flow and boundary-layer theory accurately predicted the pressures and forces on the ball for the 1.59 mm orifice over the range of coneball clearance yielding high retaining forces.

Shearer and Holmes (1991) developed and tested a precision seed-metering device consisting of a submerged turbulent air-jet. Form testing, metering accuracy was found to be sensitive to nozzle supply pressures. Over the range of rotational speeds of 30 to 50 rpm, the metering device should be operated at nozzle supply pressures (gage) of 25 to 40 kpa (3.6 to 5.8 psi) for corn and 20 to 25 kPa (2.9 and 3.6 psi) for soybeans.

Gupta and Totak (1992) designed and developed 8-row tractor operated direct paddy seeder with inter row spacing of 25 cm for rice. For metering of seeds fluted rollers of 70 mm diameter with width of 140 mm having 12 flutes were used. They stated that the diameter of driving wheel was determined from the seed to seed spacing.

$$\boldsymbol{Dg/\ Dr = Dd/Df}$$

Where, Dg = Diameter of ground drive wheel

Dr = Diameter of metering roller

Dd = Diameter of hill dropping

Df = Distance between consecutive flute

Jesudass *et. al.* (1996) reported that sow dry paddy in dry tilled soil, a simple bullock-drawn seed drill 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 the agitator disc. The germination of paddy seed drill was 49 per cent, 33 per cent higher than that of manual broadcasting and mechanical broadcasting

Karayel *et al.* (2005) have conducted Due to the individual volumes of fluted wheel metering systems each holding more than one seed, seed drills provide random seed distribution. A prerequisite for the improvement of seed spacing is the fast and reliable evaluation of distribution accuracy in laboratory tests. A high-speed camera system for evaluating seed spacing uniformity and velocity of fall of seeds is described. The performance of the high-speed camera system in terms of seed spacing evaluation was compared with a sticky belt test stand, used as a reference. Identical seed patterns were evaluated applying both methods simultaneously using wheat and soybean seeds. The speed of the metering rollers of the seed drill was set at 10, 20, 30 and 40 rpm and that of the seed drill at a simulated travelling speed of 1 m/s. In general, the high-speed camera system worked well in obtaining the seed spacing and velocity of fall of seeds. In all the tests with the wheat and soybean seeds, the high-speed camera system did not miss any seed.

Ghosal and Pradhan. (2013) conducted an experiment of a low cost manually operated multi crop seed drill with suitable dimensions of cup, in cup feed metering mechanism for a particular crop. The drill has been developed and evaluated in the field condition to study its seed pattern characteristics and economic viability for small and marginal farmers in the state of Odisha. The seed drill developed was evaluated with the prevailing green gram variety ‘PDM-54’ in the Central farm of OUAT, Bhubaneswar in the year 2008. From the experiments it was found that the dimensions of cup i.e. 6 mm x 2.89 mm was found to be best and was used successfully up to a peripheral speed of 18.84 m/min. considering seed rate deviation, seed distribution and seed damage. The actual field capacity of the seed drill was 0.063 ha/h with a field efficiency of 78.75 per cent and there was a net savings of Rs. 1780.00 per hectare for green gram in comparison to the local traditional practice. This seed drill was costing of Rs. 1850 and total operating cost of Rs. 13.85 per hour may solve the problem of line sowing of seeds particularly for the small and marginal farmers to enhance production and productivity as a whole.

2.3 Performance of existing seed drill:

Nave and Paulsen (1979) compared five different models of seed metering devices for accuracy of the space between planted seeds and mechanical damage to the seeds. They concluded that there was no significant difference between metering systems for seed breakage and seed germination. They also found that the fluted roller meter had the maximum fluctuation for seed spacing.

Senapati *et al.*(1988) compared the performance of six grain drills for energy requirement, uniformity of seed distribution, and crop yield. They found that the implement factory seed cum fertilizer grain drill had the best overall performance coefficient.

Shukla *et al.* (1987) developed a rotary blade till attachment for direct sowing operation operated by a tractor of 35 h.p. and above germination count and the yield of wheat after maize or paddy and maize after wheat as sown by the developed machine was comparable to the conventional tillage and sowing practices. Saving in time fuel and production costs were 4.33 to 11.32 h/ha, 50.79 to 70.03 per cent and 2.68 to 14.0 per cent respectively.

Griepentrog (1998) state that quality of horizontal and vertical distribution of seeds is influenced by row spacing, sowing depth, soil conditions, seeders design, seed density, and operator skill. The mean spacing (*X*), the standard deviation of the spacing between plants (SD), and the coefficient of variation (CV) are commonly used for describing seed spacing uniformity. The mean spacing is influenced by seed or plant density and longitudinal distribution. For common grain drills, a CV of 20% is an acceptable accuracy achieved by mechanical and pneumatic machines when they are performing well.

Panning *et al.* (2000) evaluated sugar beet planting performance for a precision planter designed for shallow planting of small seeds, a general purpose planter designed for row crops, and a vacuum metering general purpose planter designed for row crops that was equipped with three seed tube designs. In their field study, the most uniform seed spacing for each planter configuration occurred at the lowest speed, which was 3.2 km/h. For all planter configurations, the seed spacing uniformity decreased as the forward speed increased from 3.2 to 8.0 km/h. Seed spacing uniformity determined in laboratory tests was greater than, or equal to, seed spacing uniformity determined in field tests

Karayel and Ozmerzi (2002) stated that the best sowing uniformity, the most uniform sowing depth, and maximum emergence percentage occurred when a precision seeders was used after preparing the soil with a mouldboard plough, disc harrow, and roller.

2.4 Sowing and seed

Ojediran *et al.*(2009) have studied on Two varieties of Pearl millet seeds (*Penisetum glaucum*) (Ex-Borno and SOSAT C88) were obtained from the Lake Chad Research Institute, Maiduguri-Nigeria and reconditioned to moisture contents ranging from 10% - 20% w.b. The reconditioned seeds were then evaluated for dimensions, sphericity, bulk density, solid density, porosity, thousand seed mass, angle of repose and static coefficient of friction on five structural surfaces. Within the range of moistures analyzed.

Singh and Singh (2009) have conducted a field experiment on different method of sowing and application of herbicides on the yield of pearl millet. The experiment was conducted during *kharif* seasons of 2002 and 2003 under rainfed condition. Study revealed that line sowing of pearl millet at 45 cm apart produced significantly maximum grain yield (11.96 and 10.98 q/ha) in comparison to broad cast sowing during both the years. However, grain yield with line sowing at 45 cm apart and closer line sowing at 30 cm was remained at par. Among the weed control measures, the application of atrazine @ 0.5 kg a.i./ha as pre emergence along with one hand weeding at 30 days after sowing gave significantly maximum grain yield (12.81 and 11.27 q/ha) than that of unweeded check and other treatment including in the study except one hand weeding at 25 days after sowing.

Pradhan *et al.* (2010) studies on “traditional techniques of harvesting and processing of small millet in tribal reign of Baster” reported on studies the basic problem in kodo millet is the milling for the grains ,milling drudgery associated with upper husk sticking endosperm tightly the reduces the efficiency of grain recovery from each spikelet .indigenous mill jatta is made out of well mixture of soil & straw that helps it to check deflocculating while working, which is used by turning the upper plate .time of milling for whole process required nearly half day of mill 20-30 kg of *Kodo* millet seed with grain recovery of 40 or ± 5% according to expert person.

De Koff and Robbins (2012) carried study on PLS and calibrating seed drill for seeding rate of native warm season grasses . They reported that it is important to determine the amount of seed we need to apply per acre to get the correct amount of Pure Live Seed (PLS) planted. As most of these seeds do not have a 100% germination rate and contain some inert material, a calculation must be performed to determine the PLS for your seed. Some seed bag tags already contain this information. If not, simply multiply the % germination by the % purity and divide by 100 to get the PLS percentage. To determine the rate you must apply for a specific PLS rate, you divide the recommended PLS seeding rate by the PLS percentage of your seed and multiply by 100.

2.5 Seed cum fertilizer drill

Sharma *el al.* (1983) designed and developed a single row seed cum fertilizer drill with frame of 40 x 40 x 3 mm mild steel angle iron. A 30 cm diameter lugged wheel was made from 30 x 5 mm mild steel flat with 25 mm long lugs welded on it. The rectangular boxes, one for seed and other for fertilizer (5 kg capacity) were fabricated from 20-gauge mild steel sheet. Separate fluted roller assemblies were provided to ensure uniform dropping of both seed and fertilizer on the front side of the frame, arrangement for hitching the machine with the wooden beam was provided.

Tondon *el al.* (1984) reported that the speed ratio of ground drive wheel to seed metering shaft was 2 to 2.5:1 and that to fertilizer shaft was 3:1.

Senapati *et al.* (1988) tested six seed drills for upland rice and found that 2-row seed-cum-fertilizer-drill had the highest performance index (3.3), seed distribution efficiency (81 per cent) and desired number of plants per row (28). The 3- row drill showed higher friction in the metering device.

Devnani (1991) suggested the box capacity for animal drawn seed drill should be 10-16 liters. He stated that fluted roller mechanism was suitable for all types of seed, which would control seed rate properly. He reported that the inclination of the seed delivery tube from vertical was kept smaller than 20 degree.

He found that draft for each of shoe type furrow openers was 20 kg for light soil and 30-35 kg for heavy soils.

Varshney *et al.* (1991) desiged and developed power tiller operated seed cum fertilizer drill with chain and sprocket power transmission system. They reported that fluted roller for metering of seed and adjustable opening for fertilizer gave better results for placement of seed and fertilizer.

Iqbal *et al.* (1994) reported that draft requirement of tillage implements has a great influence in design of tillage implements and deciding suitable tractor size and also concluded that draft of implement increases with increase in depth of ploughing.

2.6 Design of seed-cum-fertilizer drill

Behera *et al.* (1995) stated that Naveen seed cum fertilizer drill of CIAE, Bhopal gave the best performance in terms of highest return of Rs. 4693.75/ha, benefit cost ratio of 1.35 and seed distribution efficiency of 91.38 per cent compared to five other seed cum fertilizer drills tested. Further they found that the overall performance index was highest (0.88) in case of Naveen seed cum fertilizer drill. They recommended that Naveen seed cum fertilizer drill might be used for sowing of wheat, gram, soybean and sunflower besides rice by changing the exposed length of the fluted roller with minor adjustments.

Quasim and Verma (1995) studied on the performance of different line sowing implement on loam clay soil and stated that Indira seed drill. Nari and Datari are suitable for line sowing of paddy in the C.G. Indira seed drill covers 0.8 - 1.0 ha/day with draft required was 25-30 kg. It covered more area and low draft as compared to other seed drill. Indira seed drill and Datari was found to be 67.50 and 67.30 germination per cent respectively. The germination per cent was more as compare to CIAE seed drill (41.61 per cent).

2.7 Millet

According to Wadikar *et al*. (2007) with the change in scenario of utilization of processed products and awareness of the consumers about the health benefits ,Ragi has gained importance because of its functional components ,such as slow digestible starch and resistant starch.

Ayyangar (1932) reported that in some areas, such as southern Karnataka, the fodder is highly valued for feeding cattle and other ruminants, and it makes a good supplement to the income from the grain .Beside its uses as a cereal grain and/or fodder ragi is often grown because of its high reproducibility ranging between 200 and 500 fold .Thus , a little seed goes a long way in reproducing the crop .A second very highly resistant to storage insect pests ,even without any special care or attention .it is reputed to remain in good condition even when stored as long as fifty years.

Rao and Muralikrishna(2001) reported that traditionally ragi is processed either by malting or fermentation .Malting of ragi improves its digestibility, sensory and nutritional quality as well as pronounced effect in the lower in the anti nutrients.

According to Dulby and Tsai (1976) there are various benefits of malting such as vitamins –c is elaborated , phosphorus availability is increased and lysine and tryptophan are synthesized.

2.8 Seed rate

Bhattachajee (1978) reported that increase in panicle number as seed rate increased was offset by a decrease in panicle length and grain weight per panicle. Castin and Moody (1989) reported that there was an increase in grain yield in the untreated check plots but not in the weeded plots as a result of an increased seeding rate.

Sharma and Singh (1995) suggested that the use of higher seed rate or uprooting of 70-90 rice plants m^{-2} did not affect the grain yield of direct seeded crop adversely.

Phuong *et al.* (2005)found that with treatment consisted of four seeding methods; conventional and modified broadcast seeding, drill seeding with east – west and north south row orientations three seeding rates :40,80 and 160 kg seed ha^{-1} As well as two weed control levels : weed control with herbicide and no weed control .among the seeding methods drill seeding with east –west row orientation had the lowest rice grain yield loss caused by weeds(38% in the wet and 20% in the dry season), whereas the highest losses because of weeds were observed with conventional broadcast seeding (59% in wet and 27% in the dry season).

Gill *et al*. (2007) also supported that, contrary to effective tillers, the panicle length ,grains panicle^{-1} and 1000 grains weight gave the highest values at lower seed rates (50 kg ha $^{-1}$) which were significantly higher than 100 and 150 kg ha^{-1} respectively.

Yadav *et al*. (2007) observed that crop stand establishment was higher in direct –drilled compacted plots with 50 kg seed ha^{-1}

Walia *et al.* (2009),find out optimum seed rate and weed management practices in irrigated direct dry –seeded rice .A seed rate of 37.5to 45 kg/ha depending upon varieties was found optimum for successful cultivation of direct seeded rice(DSR)

Bhagirath and Johnson (2009) reported the relation of seeding rates (15-125kg ha^{-1}) of hybrid and inbred varieties to crop and weed growth in aerobic rice. Plant densities, tillers and biomass of rice increased linearly with increased in seeding rates under both weedy and weed free environments .weed biomass decreased linearly with increasing seeding rates 15 to 125 kg ha^{-1}. On the basis of these results, seeding rates greater than 80 kg ha^{-1} are advisable where there are risks of severe weed competition.

CHAPTER-III
METHODS AND MATERIALS

3.1 General

This chapter deals with the materials and methods employed for finding out physical property of minor millets, selection of suitable mixture for seeding, testing and evaluation of automatic seed cum fertilizer drill. It also includes suitable measurement techniques for recording various parameters related to performance evaluation. Testing and evaluation of seed cum fertilizer drill system have been described in this chapter. The machine was tested under lab and field conditions at farm of Faculty of Agricultural Engineering, IGKV Raipur during Kharif 2013-15. The testing of seed-cum-fertilizer drill with Minor Millets carried out as per Indian standard test codes.

It also includes suitable measurement techniques, adopted for recording of various parameters for testing of the machine.

The testing of seed-cum-fertilizer drill consisted of several steps and would require basic information about the following: -

- Crops, physical properties of seed.
- Soil and climatic condition.
- Sources of power available.
- Labour requirements during seeding.

3.2 Location

The testing was carried out during Kharif seasons of 2013-2015 at the research farm of Faulty of Agriculture Engineering, Raipur (C.G). The FAE farm is situated on national highway no. 6 in eastern part of Raipur city and located between $20^0$4’ North latitude and $81^0$39’ East longitude with an altitude of 293 m above mean sea level.

3.3 Climatic condition

The experimental site, Raipur comes under the seventh agro climatic region of India *i.e.* Eastern plateau and hills which is termed as sub-humid with hot summer and cold winter. The source of rainfall is south-western monsoon. It receives an average annual rainfall of 1326 mm (based on 80 years mean), mostly

(85%) concentrated during the period of June to September. A few showers are expected during winters and occasionally during summer months. May is the hottest and December is the coolest month of the year. The weekly maximum temperature raised up to 45.8°C during summer and minimum temperature reaches as low as to 8°C during winter season. The relative humidity is high from June to October and wind velocity is high from May to August with its peak in June-July months.

3.4 Physical Properties of Minor Millet

Physical properties of *Ragi* and *Kodo* seed such as moisture content , thousand seed mass, size and shape, spherisity , bulk density, porosity and angle of repose were determined using standard technique. In order to study the effect of moisture content on different physical properties of *Ragi* and *Kodo*, the moisture content of the sample was varied. All the above determinations were carried out in different moisture conditions. The seeds were then stored in a multilayered polythlene packages and stored in a cool and dry place. The nomenclatures used to describe the various physical properties are as follows:

The moisture content was determined using the ASAE standard method (ASAE, 1993) by drying.

Plate 3.1 : Digital micrometer screw gauge used for seed dimensions

3.4.1 Diameter of the seed

The measurement of diameter of the *ragi* and *kodo* seeds was done with the help of screw gauge (Plate-1) having the least count of 0.001 mm. Randomly 50 seeds were selected from each lot for the determination of diameter.

3.4.2 Spherisity

Dimensions like length, breadth and thickness of 20 grains were measured. The shape of the grains was expressed in terms of its spherisity and calculated as:

$$Sphericity = \frac{Geometric\ mean\ diameter}{Major\ diameter}$$

$$= \frac{abc)^{1/3}}{a}$$

in which, geometric mean diameter or size = $(abc)^{1/3}$ mm

Where,

a = longest intercept, mm

b = longest intercept normal to 'a', mm

c = longest intercept normal to 'a' and 'b', mm

3.4.3 Thousand seed weight

The thousand seed weight was determined by selecting 1000 seeds randomly with the help of an electronic balance with the accuracy 0.001 g , the process repeated three time and averaged was taken.

3.4.4 Bulk density

Bulk density was determined by filling a measuring cylinder of 100ml with grains by pouring it from a certain height, striking off the top level and then weighing the contents on a balance. The ratio of weight of the sample and volume occupied by it is expressed as the bulk density, g/m^3.

Bulk density (ρb) $= \frac{Weight\ of\ grians}{Volume\ occupied\ by\ grains}$ g/m^3

3.4.5 Porosity

Porosity is the percentage of volume of voids in the test sample at given moisture contents (Jain and Bal , 1997) Porosity is a property of the grain , which depends on its bulk density (Dutta et al . 1988) Porosity was calculated as ratio of difference in the grain and bulk density to grain density and expressed in percentage ((Jain and Bal , 1997) .

Porosity, % $= \frac{(1-Bulk\ density)}{True\ density}\ x\ 100$

3.4.6 Moisture content

Moisture content was determined by the method described by Raghuramulu *et al.* (1983). Ten 10 g of the material was weighed into a weighed moisture box and dried in an oven at 100 to 105 °C and cooled in a desiccators. The process of heating and cooling was repeated till a constant weight was achieved.

$$\text{Moisture. \%} = \frac{(\textbf{Initial Weight} - \textbf{Final Weight})}{\textbf{Weight of the sample}} \times 100$$

3.4.7 Angle of repose

Measurement of emptying Angle of repose and filing Angle of repose was done for emptying angle of repose a box of 150x 150 x150 mm dimension was taken. The box was filled with *Ragi* and *Kodo* seeds up to the top. The box was open on one side .this open was closed temporarily with the help of a card board and the box was filled with seed. Then the cardboard easy removed slowly ,the grains fall down in an angle .the height of fall of the seed was noted.

For filling angle of repose three iron discs of diameter 150, 225 , and 300 mm were taken . The seed were poured on to the discs till the heap form a cone the height of the heap formed was noted. Let it be H . Angle of repose was calculated as follows:

$$\text{Angle of repose} = \tan^{-1}\left(\frac{2H}{B}\right)$$

Where

H = height of the cone, m

B = base of the cone, m

3.5 Constructional details of seed cum fertilizer drill

As shown in plate 3.1. It consists of frame, ground wheel, transmission system (gear system), hopper, seed metering device , furrow opener, speed ratio . The details of specification of Seed cum fertilizer drill given in Appendix-.B

3.5.1 Details of construction of seed cum fertilizer drill

Automatic-seed-cum fertilizer drill consists of following parts:

1. Frame
2. Tines
3. Tine supporting braces
4. Furrow openers

5. Seed box
6. Cup feed roller type seed metering device
7. Seed tubes
8. Power transmission system
9. Three point hitching system.

Plate 3.2 : Automatic seed cum fertilizer drill

3.5.2 Considerations for suitable seed cum fertilizer drill :

Beside following requirements, it should be capable to sow small seed at desired seed rate.

- Low cost machine so that small farmers can afford it.
- Suitability for *Ragi* and *Kodo* crops.
- Simplicity' in construction.
- Ease of operation and adjustment.
- Uniform placement of seed.
- Arrangement for adjusting seed rate.
- Arrangement for uniform placement of required quantity of fertilizer.
- Suitable depth control mechanism.
- The machine is easy to operate

3.5.3 Working principle of seed cum fertilizer drill

Seed drill is a machine for placing the seeds in a continuous flow in furrows at uniform rate and at controlled depth with or without the arrangement of covering them with soil. seed drill ,fitted with fertilizer dropping attachment ,distribute the fertilizer uniformly on the ground it is called seed cum fertilizer drill. Such a drill has a large seed box which is divided length wise into two compartment, one for seeds and another for fertilizers.

3.6 Testing of seed cum fertilizer drill

A new seed cum fertilizer drill procured by the Agril. Engg., Raipur without manual test reports etc. thus to generate data and introduction of machine testing was planned with different crop before taking to the farmers field. In testing IS: 6316: 1993-test Code For cereal sowing machine was adopted

3.6.1 Laboratory Test

Automatic seed-cum-fertilizer drill was tested and evaluated for sowing of *Ragi* and *Kodo* with different seed mixture under controlled lab condition at Faculty of Agricultural Engineering, IGKV Raipur. The tests conducted as per BIS test code for sowing equipment- seed cum fertilizer drill (IS 6316:1993).The seeds were firstly lab tested for physical properties and then seed drill was evaluated in laboratory. For the selection of the metering mechanism, calibration was done with all of the 7 types of roller with different combination of seed box exposure length starting from 1 cm to 10 cm. The suitable combination of metering cups for *Ragi* and *Kodo* was tested by sand bed method.

An artificial levelled bed of 25 cm depth from fine sand and of a length of 5 m and the width 2.5 m was prepared. Allow the drill to travel over this bed with furrow openers or seed tubes lowered as near to the top surface of the bed as possible. Observed the number of seeds dropped and the average distance between two seeds for each metre of bed length. Repeated this procedure three times.

During laboratory testing following work carried out.

1. Calibration of seed and fertilizer metering
2. Effect of quantity of seed in hopper on seed rate
3. Mechanical damage to seed by metering mechanism**.**

3.6.2 Calibration of seed-cum-fertilizer drill.

It was calibrated in the laboratory for metering desired quantity of seed and fertilizer. During test following parameters observed.

A. The working width (W) of machine was calculated as follows

$$W = M \times S \qquad \text{----------(3.1)}$$

Where.

M = Number of furrow openers

S = The spacing between the openers, m

W = Working width, m

B. The circumference (C) of the ground driving wheel was measured.

$$C = \pi \times D \qquad \text{----------(3.2)}$$

Where,

D = Diameter of ground wheel (m)

C = Circumference of driving wheel (m)

C. Area covered in one revolution of wheel was calculated.

$$A = \pi \times D \times W \qquad \text{-----------(3.3)}$$

D. The calibration of seed drill is done by taking 20 revolution of the ground wheel. Therefore the area covered was calculated from the area covered in one revolution multiplied by 20 (No. of revolution).

E. Ground wheel drive was made free to rotate by jacking up the drill. One mark was put on the drive wheel and another mark on the body of the drill so that the revolution was counted correctly.

F. Hopper was filled with the seed and fertilizer in respective chamber of the hopper. Polythene bags were tied at the open end of the seed delivery tube.

G. The rate control adjustment for the seed and fertilizer was set for maximum drilling.

H. The drive wheel was rotated for 20 revolutions and the seed and fertilizer collected in the bags were weighed.

I. The seed rate was calculated by the following formula.

$$\text{Seed rate (kg/ha)} = \frac{\textbf{\textit{Weight of seed collected}}}{\textbf{\textit{Area covered}}} \quad \text{-----------(3.4)}$$

Above procedure was repeated by adjusting suitably the rate control till required seed rate of seed and fertilizer were obtained.

$$\text{Seed rate(kg/ha)} = \frac{1000 \times Ws \times M}{W \times \pi \times D \times n} \quad \text{------------(3.5)}$$

Where,

Ws = seed weight (g)

M = Number of furrow openers (IS-6316:1993)

W = working width (m)

D = Diameter of ground wheel

n = number of revolution of ground wheel

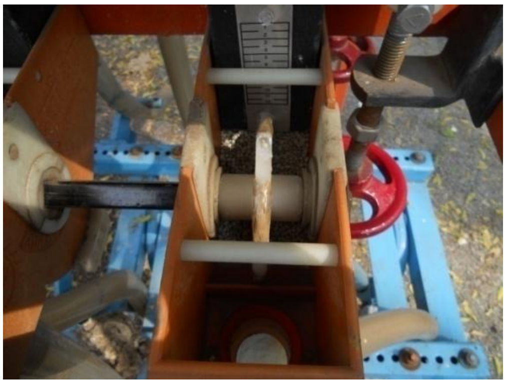


Plate 3.3 Calibration, seed and fertilizer placement uniformity test.

3.6.3 Effect of quantity of seed in hopper on seed rate

Seed and fertilizer box was completely filled by seed and the seed rate was checked. The process was repeated by filling the hopper for 3/4, *1/2*, *1/4* capacity and the corresponding seed rate (s) were measured for comparison. The data collected are given in Appendix.

3.6.4 Mechanical damage to the seed by metering mechanism

During calibration, the seeds were collected from furrow putting a bag below the furrow openers and visually broken seeds were counted. The broken seeds were weighed and percentage of damaged seeds were determined, using given formula.

3.7 Field test

For the seed bed preparation tillage operation was conducted with one pass of MB plough, one pass of cultivator and one pass of rotavator. Soil sample was collected before and after the tillage operation. After initial setup sowing was done with the help of seed cum fertilizer drill using Roller no.4 for both the seeds.. In first plot of *Ragi* seed were sown with different ratio with row to row spacing of 30 cm and plant to plant distance 8-10 cm. In second plot of *Kodo* seed were sown with different ratio with row to row spacing of 30 cm plant to plant distance 8-10 cm. For more accuracy and precision result three replication for each crop was taken. The seed drill was operated with the tractor in III low gear at an operating speed of 2.5 ± 0.3 km/h. The sowing with the modified seed drill is sown in Plate 3.6 and 3.7.The width of coverage achieved was 2.00 m due to making of space alternate row pairs of *Ragi* and same width is utilized to *Kodo*. The field performance was conducted in order to obtain actual data for overall machine performance, operating accuracy, work capacity , and field efficiency .

Following observations were recorded during the field tests.

i. Moisture content of the soil
ii. Bulk density of the soil
iii. Time lost in turning at head land, adjustment and refilling the hopper.
iv. Depth of placement of the seed.
v. Effective width of coverage.
vi. Total time of sowing operation.
vii. Uniformity of seed and fertilizer placement**.**

From above observations effective field capacity, field efficiency and draft were determined.

3.7.1 Experimental details

The experiment was laid out in Randomized Block Design with three replications. There were nine application of *Ragi* and *kodo* millets The layout plan of experiment was depicted in Layout No.1 and,2 Seeding operation and other Layout No. 3 and 4 for using broadcasting method of minor millets .

Table No. 3.1 : The details of the experiment are as below:

S. No.		Particulars Plot No	Specifications Area, m^2
1.	Tractor-Seeding	Plot No. 1	685
		Plot No. 2	603
	Broad-casting	Plot No.3	20
		Plot No. 4	20
2		Season of experiment	Kharif
3		Crop	*Ragi* , *Kodo*
4		Variety	GPU -28 , JK -439
5		Date of sowing	23 June 2014
6		Date of harvesting	10 Oct.-2014
7		Tilth	2xC + 1xRota + 1xS.f.d.

3.7.2 Moisture content

Moisture content (%) on dry basis of soil was measured by oven dry method. The soil samples from different locations within a plot were taken using core sampler 56 mm diameter and 95 mm in length and a soil auger. The collected soil samples from each location were weighed initially and then kept in an oven for 24 hours at 105°c for obtaining dry weight of soil and moisture content was calculated as follows:

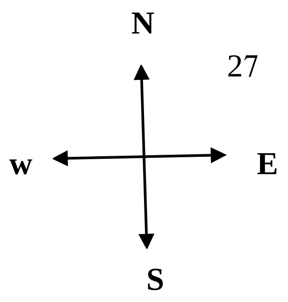
$$Mc_d\,(\%) = \frac{(W1 - W2)}{W2} \times 100 \qquad \text{---------(3.6)}$$

Where,

Mc_d = Moisture content of soil on dry weight basis,

W_1 = Weight of wet soil and

W_2 = Weight of dry soil



Field No. 2

27.40 m

22m

T_1		
T_2		
T_3		
●		
T_4		
T_5		
T_6		
●		
T_7		
T_8		
T_9		

Treatment : Kodo : mixture

T_1 – K-Sl (2:1)

T_2 - K-Sl (1:2)

T_3 - K-Sl (1:1)

T_4 - K-S (2:1)

T_5 - K-S (1:2)

T_6 - K-S (1:1)

T_7 - K-F (2:1)

T_8- K-F (1:2)

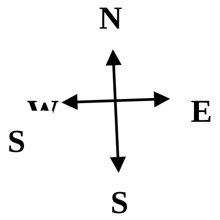
T_9- K-F (1:1)

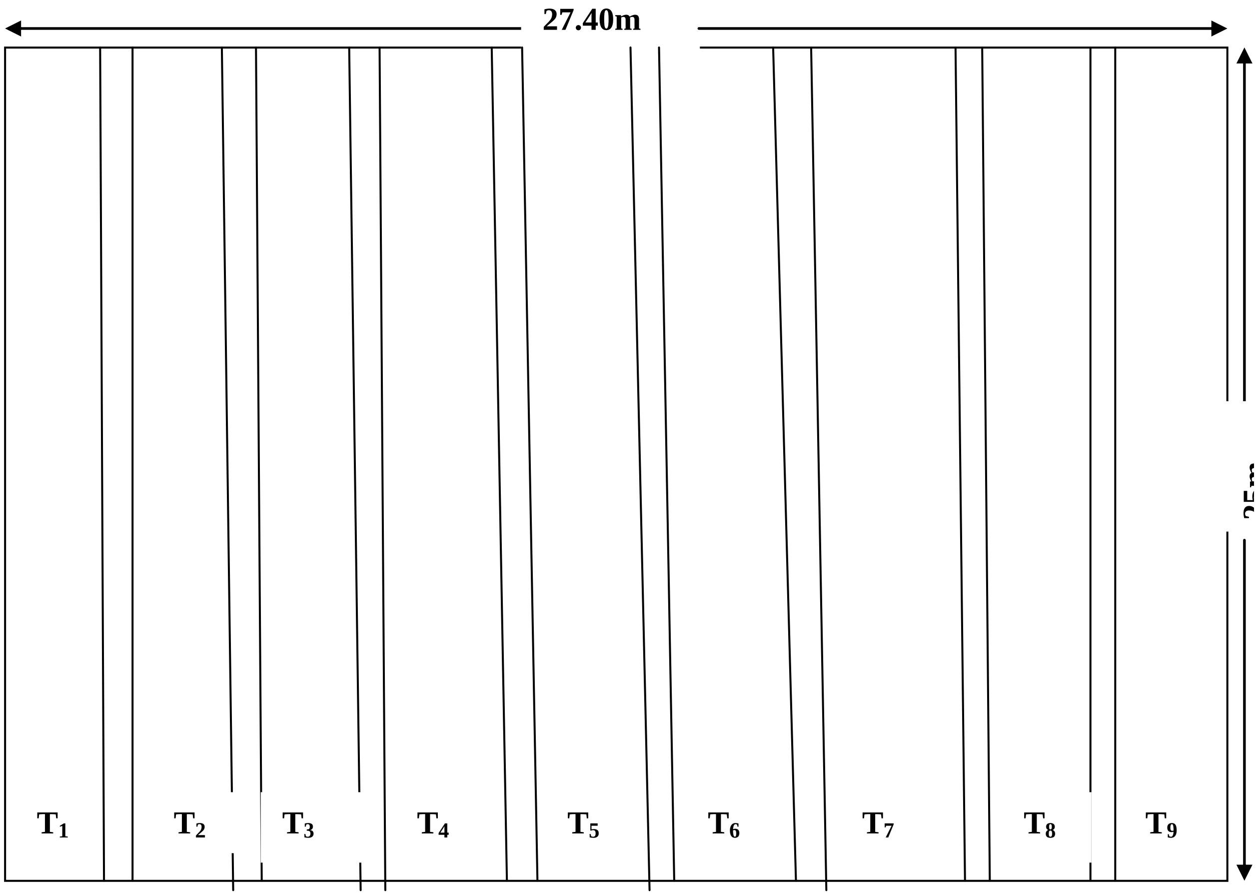
● – 0.5 m distance between two applications

Layout details

Design - RBD
Replication -3 (Three)
No. of treatment – 9 (nine)
Plot No. -2(two)
K –Kodo
Sl –Slurry
F-fertilizer

Field No. 1





Treatment : Ragi : mixture

T_1 – R-Sl (1:1)

T_2 - R-Sl (2:1)

T_3 - R-Sl (1:2)

T_4 - R-S (1:1)

T_5 - R-S (1:2)

T_6 - R-S (2:1)

T_7 - R-F (1:1)

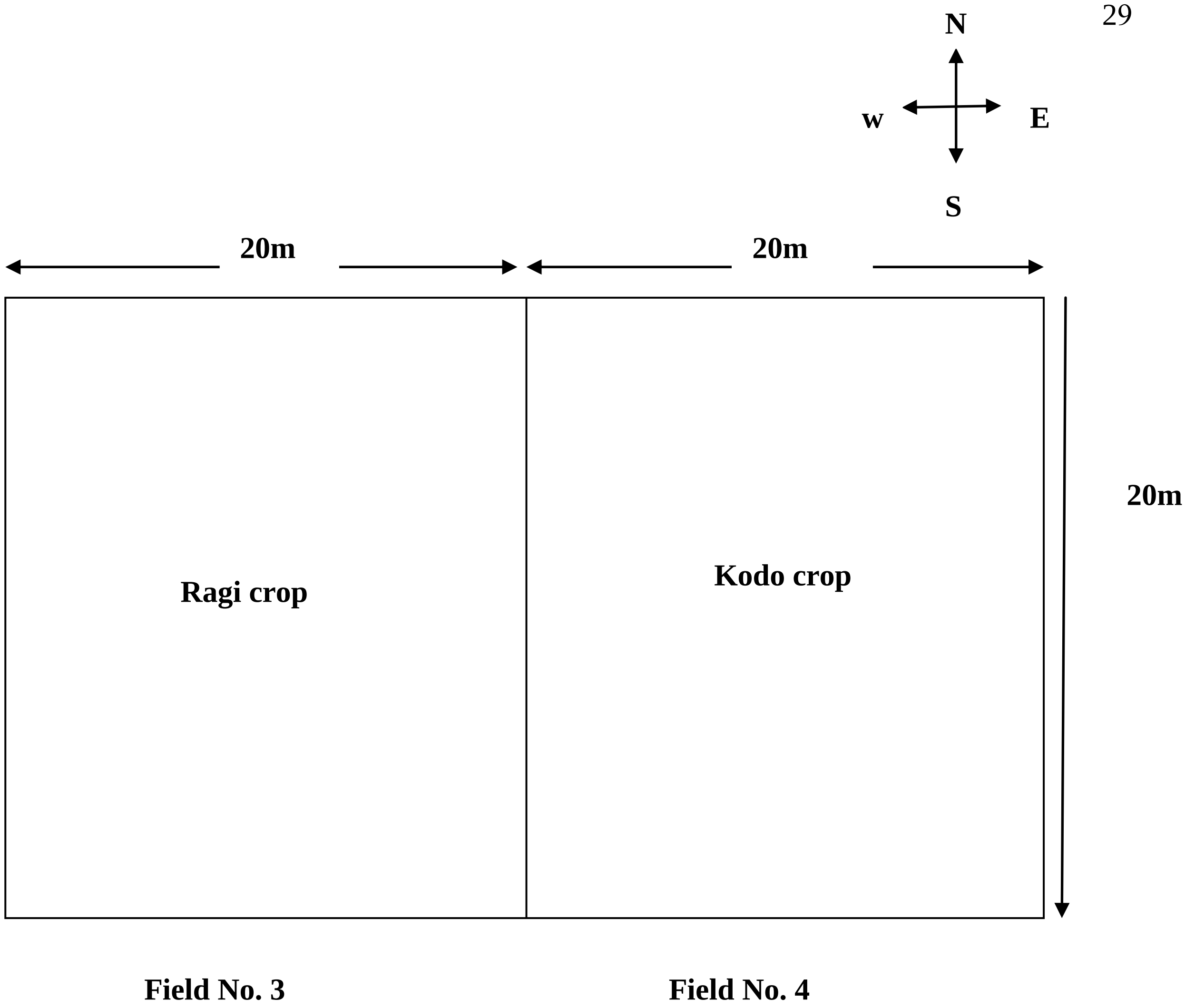
T^8- R-F (1:2)

T_9- R -F (2:1)

● – 0.5 m distance between two applications

Layout details

Design - RBD
Replication -3 (Three)
No. of treatment – 9 (nine)
Plot No. -1(One)
R –Ragi
Sl –Slurry
F-fertilizer



Broadcasting Method of minor millets

Plate 3.4 : Seed metering and dropping mechanism

The metering rollers specification were given in Table 3.2

Table 3.2 : Metering rollers specification

Metering unit roller number	Roller Thickness (mm)	Number of Grooves / roller
2	2.5	10
3	1.4	10
4	8	10
5	12	10
6	23	3
7	7	2

(A) Metering roller no.5

(B) Metering roller no. 4

Plate. 3.5 Selected metering rollers for testing of Ragi and Kodo

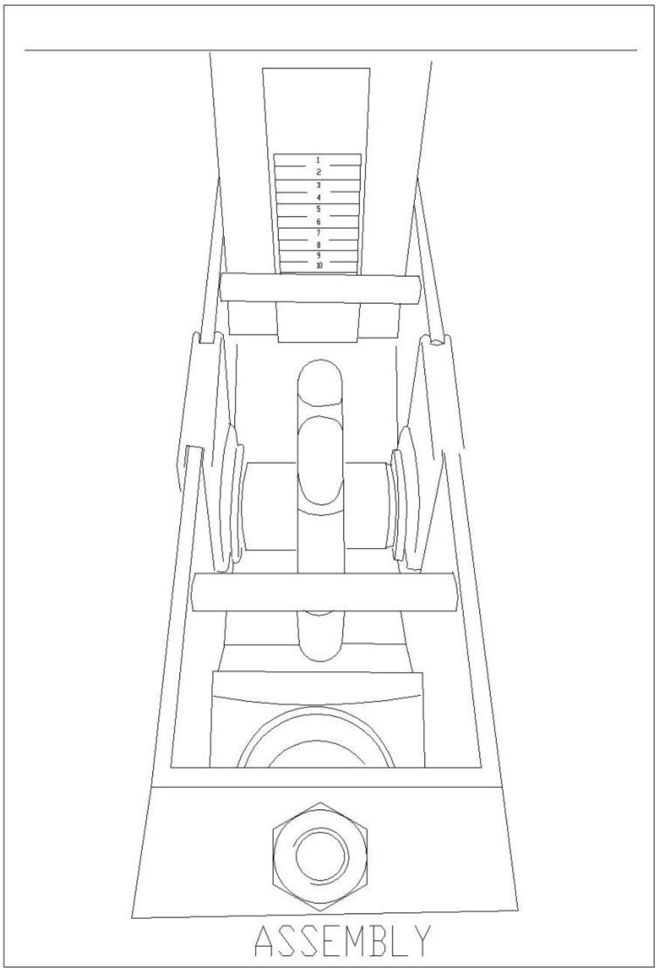


Fig No. 3.1 Autocad design of seed metering mechanism

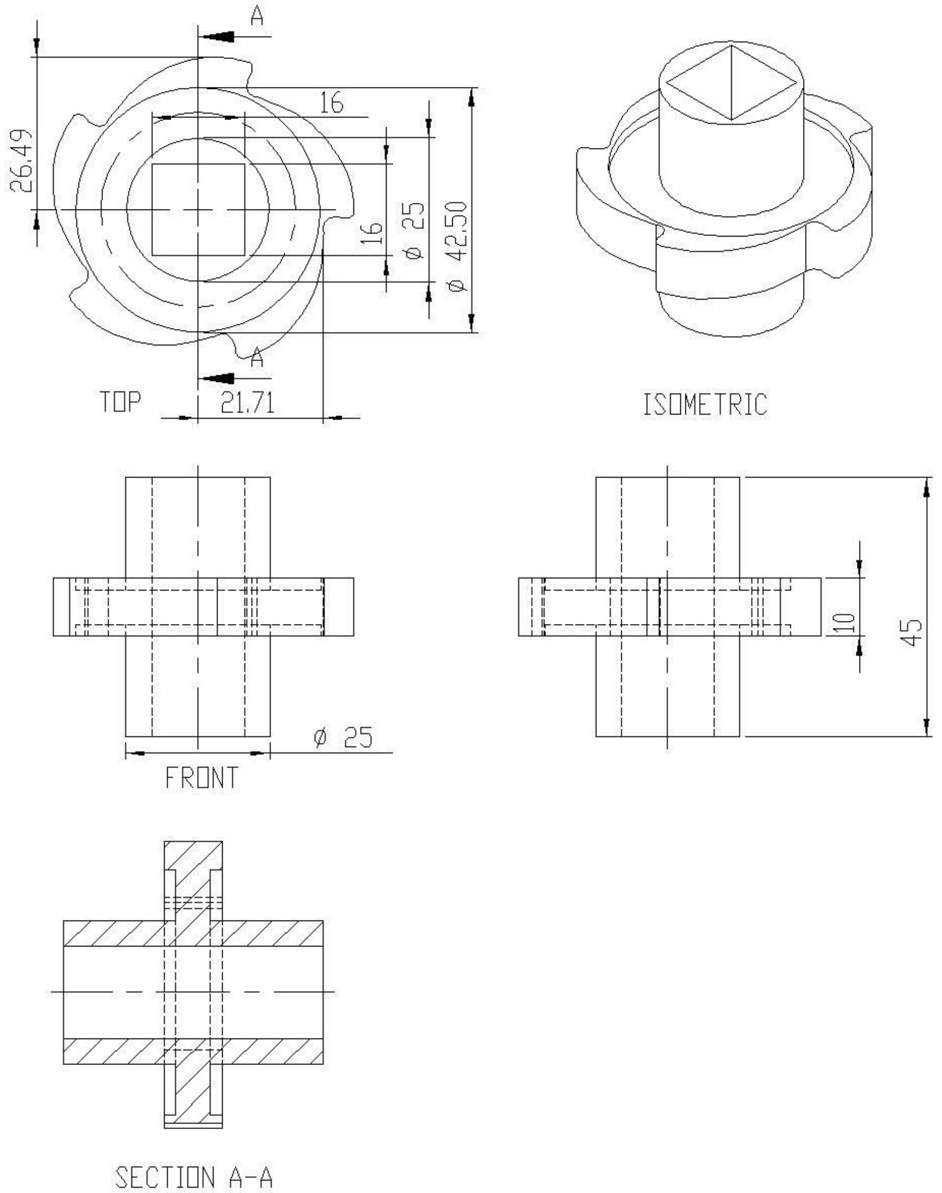


Fig No. 3.2 Autocad design of roller

Table 3.3 : Specification of Automatic seed-cum-fertilizer drill

S. No.	Particulars	Specification
1	Overall dimension	
	Length (mm)	2200
	Width ,(mm)	660
	Height ,(mm)	1360
2	Depth of sowing (cm)	15
3	Row to Row spacing (mm)	30
4	Working width(mm)	2100, adjustable
5	No. of tines	8
6	Types of metering device	Cup feed metering
7	Ground wheel diameter(mm)	500
8	Type of furrow openers	Shovel type
9	Fertilizer Metering Mechanism	Cup feed Mechanism
10	Power transmission	Chain and sprocket

Table 3.4 : Detail of material of construction of seed-cum-fertilizer drill

S. No.	**Name of part**	**Material**	**Section or size**
1	Hopper	M S Sheet	Trapezoidal
2	Metering Unit	Fiber /plastic	Round with cups, 20 mm
3	Frame	M S Angle and Flat	10 mm
4	Furrow opener	M.S. Cast steel	Shovel type, 2 mm x 10 mm
5	Seed / fertilizer pipe	Plastic	1500 length ,45 outer dia , 2 mm thickness
6	Transmission gears	Cast Iron	12 teeth, 15 mm pitch spacing
7	Ground wheel	M S rods	Circular 12 lugs, dia 500 mm
8	Feed shaft	M S sheet	Rectangular 4 x 4 mm, 2000 mm length

Plate 3.6: Marking in field and sowing process

Plate No 3.7 : Find out moisture content using core cutter

3.7.3 Bulk density

Bulk density of the soil is the oven dry mass per unit volume of the soil. The bulk density of soil was measured by core sampler. The core sample of soil of known volume was collected and weighed. The bulk density was calculated by using formula

$$6 = \frac{\mathbf{mass}}{\mathbf{volume}}$$

Where,

BD = 6 = Bulk density of soil, g/cm^2

M = Oven dry mass of soil contained in core sampler, g

V = Volume of core sampler, cm^3

3.7.4 Speed of operation

The tractor has four forward and one reverse gear, looking to the suitable crop and field condition the machine was operated in first gear and working speed was calculated from the time required for the seed cum fertilizer drill to travel a selected distance of m in the field.

Speed (km/h) = 3.6 x distance travel (m/sec)

3.7.5 Measurement of time lost in turning

The automatic-seed-cum fertilizer drill was operated length wise from one end to other. Time required to travel and turning at headland was measured. The time loss in h/ha was also calculated.

3.7.6 Width and depth of operation

The depth of sowing was measured at different locations with the help of depth scale by putting a tip of depth scale in ploughed sole and average was taken, the width of operation was calculated by dividing the total width of field by the number of passes.

3.7.7 Measurement of wheel slip

To calculate the wheel slip the tractor was operated at implement with load and without load condition. A mark on tractor drive wheel with coloured tapes and the distance the tractor moves forward is measured , 10 revolutions under no load (A) and on the same surface and with the same number of revolutions with load (B), wheel slip was calculated as follows :

$$\text{Wheel slip (\%)} = \frac{B - A}{A} \times 100$$

Where

A = No. of revolutions of drive wheel for a given distance under no load.

B= No. of revolutions of drive wheel for the same distance at load**.**

3.8 Field capacity and field efficiency of the machine

Theoretical field capacity and effective field capacity were determined on the basis of area covered per unit time.

3.8.1 Theoretical field capacity

It is the rate of field coverage that would be obtained if machine was performing its function 100 % of the time at the rated speed and always covering 100 % of its rated width. (IS: 11531 - 1985).

$$TFC = W \times \boldsymbol{S/10}$$

Where,

TFC = Theoretical field capacity, ha/h

S = Speed of operation, km/h

W = Theoretical width of implement, m

3.8.2 Effective field capacity

It is the actual average rate of coverage of area by the machine, based upon the total field time. The machine was operated with a fixed speed (maximum possible) for continuous field work for a fixed time and the area covered during the period was measured to determine the average output per hour. (IS: 11531 - 1985)

$$EFC = \frac{\mathbf{A}}{\mathbf{T}}$$

Where,

EFC = Effective field capacity, ha/h

A = Actual area covered, ha

T = Total time required to cover the area, h

3.8.3 field efficiency

The term field efficiency is used to describe the efficiency of the machine in operation. It is ratio of effective field capacity to the theoretical field capacity and expressed in percent. (IS: 11531 - 1985)

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

3.9 Seed and fertilizer placement uniformity

To conduct the uniformity twenty for fertilizer and seed placement operate the drill in the field under the same good seed bed conditions and with average depth setting of the furrow openers. Cover 100 m of row length and carefully remove the soil without disturbing the seed and the fertilizer at several spots (a minimum of 5) in each row. Measure the depth of the seed and fertilizer below the soil surface and the vertical spacing of the fertilizer with respect to the seed. The test was conducted with selected metering roller with optimum exposure scale opening.

3.10 Agronomical parameters

3.10.1 Fertilizer application

The recommended dose of fertilizers for *Ragi* (50:40:20 N: P_2O_5: K kg ha^{-1}) and *Kodo* (40:20:20 N: P_2O_5: K Kg ha^{-1}), was supplemented as basal dose in the form of urea, diammonium phosphate and muniate of potash.

3.10.2 Intercultivation and weeding

One hoeing and a hand weeding were carried out at 25 and 35 days after sowing, to keep the plots free from weeds.

3.10.3 Harvesting and threshing

The crops were harvested at dates . Firstly all the border plants were cut close to ground level and kept separately and then plants from net plot area were cut at the base close to ground level. The plants were heaped and left for drying (2- 4 days). The dried plants were threshed with experimental plot thresher. After threshing the produce was winnowed, cleaned and weighed. The grain and stover yield per net plot area were recorded separately and used to work out yield per hectare. plants from net plot area were harvested for recording yield, *Ragi* on 10 oct. and Kodo was harvested on 10 oct. .

3.11 Collection of experimental data

Five plants from each plot were selected randomly and tagged for recording various growth and yield components, for growth and yield analysis. Destructive sampling was done at different growth stages like 30, 60'DAS and at harvest.

3.11.1 Plant height (cm)

The plant height of five randomly selected plants was measured. The measurement was made from base of plant to the tip of longest leaf at 30 DAS and from base of plant to the base of the panicle at 60 DAS.

3.11.2 Number of tillers (ear head) per meter row length

Number of productive ear heads (effective tillers) per meter row length in net plot area was recorded at the time of harvest .Number of grains per ear head Ten ear heads were randomly selected for recording the number of grains per ear head. These ear heads were threshed separately and number of grains per ear head recorded.

3.12 Grain and straw yield

The grain yield data was obtained by harvesting the crop manually from 1 m² areas which were earmarked for data collection in the test field. The crop was threshed and cleaned manually, and the grain so obtained was weighed to determine the crop yield. Total five replications were taken from treatment to work out the average grain yield on per hectare basis. To determine the straw yield, the total dry biological yield was noted and the clean grain weight was subtracted. The straw yield was expressed in kg/ha.

3.13 Harvest index (HI)

From the yield of grain and biomass, the harvest index was calculated by using the formula suggested by Donald (1962).

$$\text{HI} = \frac{Grainyield\ \ (Kgha{-}1)}{Totalbiomass\ \ (Kgha{-}1)} \quad \text{or} \quad \frac{Economicyield\ \ (Kgha{-}1)}{Biologicalyield\ \ (Kgha{-}1)}$$

3. 14 Cost of Operation

The objective of estimating cost of farm machinery operation is to serve as a basis for planning and management. The cost of operation under each treatment was estimated as per IS: 1979:9164. The cost of using farm machinery consists of expenses for ownership and operation, and overhead charges. It may also include a margin for profit. Ownership costs are independent of use and are often called as fixed cost. Cost for operations vary directly with use and are referred as variable cost.

3.14.1 Fixed cost

3.14.1.1 Depreciation

This cost reflects the reduction in value of a machine with use (wear) and time (obsolescence). While actual depreciation would depend on the sale price of the machine after its use, on the basis of different computational methods depreciation can be estimated by straight-line method as given below –

$$D = \frac{P - S}{L \times H}$$

Where,

D = Depreciation cost, average per year,

P = Purchase price of the machine,

S = Residual value of the machine, and

L = Useful life of the machine in years

H = Working hour per year

The depreciation cost per hour can be estimated by dividing D by the number of hours the machine is expected to be utilized in a year. Residual value if the machines may be taken as 10 percent of the purchase price.

3.14.1.2 Interest

An annual charge of interest was calculated taking 12 percent of average purchase price as basis. Average purchase price was calculated using the formula given below.

$$A = \frac{P + S}{2} + \frac{i}{H}$$

Where,

A = Average purchase price,Rs/h

P = Purchase price of the machine, Rs,

S = Residual value of the machine.Rs,

H = Annual Working hour

I = Interestrate , %

3.14.1.3 Insurance, taxes and shelter

Insurance and taxes were estimated taking 1.5% of average purchase price of machine into consideration.

Total fixed cost is sum of A ,B , and C .

3.14.2 Variable Cost

3.14.2.1 Fuel

The actual fuel consumption in each treatment was observed and estimation was done accordingly. These are one of the main parameters which were considered while comparing performance of the machines. The fuel consumption has direct effect on the cost economics of the machine or tillage technique. The fuel consumption was measured using, Top fill Method‟ (RNAM, 1983). The fuel tank of the tractor was filled at its full capacity. The tractor along with the machines for respective treatments at constant speed was run. After completing the passes, fuel was refilled in the tank up to the original level. The quantity of refilled fuel was measured by measuring cylinder and time required for the completion of passes we noted down .Both observation were used for computation of fuel consumption and time requirement for treatment.

3.14.2.2 Oil

The cost of engine oils and lubricants was estimated as 3% of fuel consumption cost.

3.14.2.3. Repair and maintenance

The IS: 9164-1979 indicates that the percentage of accumulated repair cost of seed cum fertilizer drill is 100.3% for a usable life of 8 year. Hence, the repair and maintenance cost of seed cum fertilizer drill used in the experiment was estimated taking it to be 8% per year.

3.14.2.4 Wages and Labour charges

The cost of labour was estimated taking the prevailing rate of Rs. 25/h.

3.15 Energy analysis

Energy input and output in wheat was calculated from sowing to harvest of all treatments. It was calculated in Mega Joule MJ ha^{-1} with the reference value prescribed by Mittal *et al.* (1985). Standard values taken for energy estimation are given in the appendix D.

Energy use efficiency and output- input ratio were calculated by using the formula:

$$\text{Energy output - input ratio} = \frac{Energy\ \ output\ \ (MJ/ha{-}1)}{Energy\ \ input\ (MJ/ha{-}1)}$$

$$\text{Specific Energy (MJ ha}^{-1}\text{)} = \frac{Energy\ \ input\ \ (MJ/ha{-}1)}{Energy\ \ output\ (MJ/ha{-}1)}$$

3.16 Economics

The operational cost for tillage and sowing operations for all treatments was estimated .the details of fixed and variables inputs are discussed in results section . Economic analysis of all treatments related to tillage and sowing was done with standard procedure, and given in Appendix.

3.17 Broadcasting method

The seeding by machine was compared and evaluated with the traditional broadcasting method. The Broadcasting is the process of random scattering of seeds on the surface of seed beds .it can be done manually or mechanically both ways. When broadcasting is done manually uniformity of seed depends upon skill of the man. Soon after broadcasting the seeds are covered by planking or some other . usually higher seed rate is applied in this system.

CHAPTER-IV
RESULTS AND DISCUSSION

This chapter deals with the results obtained in the study and experimentation. In order to fulfil the objectives of the project work, the study was carried out to determine the physical properties of minor millets (*Kodo and Ragi*). Laboratory and field experiments were conducted for and testing of selected Farm King seed cum fertilizer drill with different mixture ratios (Seed and mixing materials) in the laboratory as well as in the field. The performance of this machine was evaluated with traditional practice, considering required seed rate, field capacity, field efficiency, cost of operation and energy requirement etc. Testing of Farm King Automatic seed cum fertilizer drill for selecting of suitable cell type roller and suitable mixture was carried out at the research Farm of Faculty of Agricultural Engineering . I.G.K.V., Raipur during year 2013 and 2014.

4.1 Physical properties of *Kodo* and *Ragi*

To study the physical properties of minor millets, the popular varieties of Kodo and Ragi were selected as discussed in Chapter –III. Among the physical properties i.e. Moisture content , Bulk Density, Porosity, Sphericity, Angle of repose , Seed size (Equivalent diameter) and test 1000 test weight were observed and result are reported in Table 4-1 . For *Kodo* and *Ragi* respectively. The results of different parameters of the physical properties of *kodo and Ragi* grain are discussed under following heads.

4.1.1 Moisture content

The physical properties of *Kodo* and *Ragi* in moisture content of seeds. Physical properties were observed and determined with seed moisture content on dry basis and mean of results are presented in Table 4.1. The physical properties were measured at average moisture content of 13.46 % and 13.05 % for Kodo and Ragi respectively.

Table 4.1 : Physical properties of *Kodo* and *Ragi* .

Parameters	*Kodo*	*Ragi*
Moisture content, % (db)	13.46	13.05
Bulk density, g/ cc	0.66	0.64
Porosity, %	37.70	29.46
Angle of repose, degree ^{0}	25.56	17.56
Sphericity	0.91	0.95
Equivalent diameter,(size) mm	1.89	1.61
Seed test weight,000 grain mass, g	5.55	3.62

4.1.2 Bulk density

The bulk density of *Kodo* and *Ragi* seeds is an important parameter for designing of box capacity and for optimizes the seed rate of the crop. Three replications were made for each sample for more accuracy. Table 4.1 shows that the Bulk density of Kodo (0.66 g/cc) is little more than Ragi (0.64 g/cc).

4.1.3 Porosity

The Porosity for *kodo and Ragi* seeds are shown in the result Table 4.1 , which shows that the porosity of Kodo (37.7 %) is more than Ragi (29.46 %).

4.1.4 Angle of repose

The Angle of repose affect flow of seed from the hopper and tube, therefore it was measured for both type of seeds. The angle of repose of *kodo and Ragi* seeds are shown in Table 4.1.The angle of repose of *Kodo* seed was more (25.56 ^{0}) than *Ragi* (17.56 ^{0}).

4.1.5 Sphericity

The Sphericity for *kodo and Ragi* seeds were calculated as discussed in chapter III and mean value is given in Table 4.1. shows the physical properties of seeds.

4.1.6 Equivalent diameter

The seed –size is determined in terms of Equivalent Diameter (ED) or the geometric mean diameter. The ED of *kodo and Ragi seeds* calculated as shown in (Appendix- C **).** The table shows that the equivalent diameter of the *kodo and Ragi* seed is 1.89 mm and 1.61 mm respectively (Table 4.1).

4.1.7 Thousand-grain mass

Kodo and *Ragi* seeds are very small in size and mass. The 1000 grain weight is an important parameter which affects the seed rate, so it is very necessary to calculate the 1000 grain weight for precision sowing. The thousand test weight of *Kodo* and *Ragi* was found to be 5.55 g and 3.62 g (Table 4.1).

4.2 Physical properties of soil of test- field

4.2.1 Moisture content and bulk density of soil

Moisture content (%) on dry basis of soil was measured by oven dry method. Three soil samples were taken randomly at 5.0, 10 and 15 cm depth from surface of soil using core samplers of 8.8 cm diameter and 18 cm height.

Table 4.2 : Moisture content and bulk density of soil(Field no.1)

S. No.	**Depth, cm**	**Moisture content, %(db)**	**Bulk of density, g/cm^3**	
			Before operation	After operation
1	5.0	15.24	1.20	1.15
2	10.0	15.76	1.39	1.32
3	15.0	17.12	1.58	1.50

The moisture content at 5.0, 10.0 and 15.0 cm depth was found to be 15.24, 15.76 and 17.12 % on the dry basis respectively. Bulk density of soil was measured by core sampler. Bulk density of soil (before operation) was found to be 1.20 g/cm3, 1.39 g/cm3 and 1.58 g/cm3 and after operation was found to be 1.15 g/cm3, 1.32 g/cm3, 1.50 g/cm3 at respective depth of 5, 10 and 15 cm.

Table 4.3 : Moisture content and bulk density of soil (Field no.2)

S. No.	**Depth, cm**	**Moisture content, %(db)**	**Bulk of density, g/cm^3**	
			Before operation	After operation
1	5.0	15.00	1.11	1.07
2	10.0	15.10	1.17	1.11
3	15.0	16.99	1.46	1.40

The moisture content at 5.0, 10.0 and 15.0 cm depth was found to be 15.00, 15.10 and 16.99 % on the dry basis respectively. Bulk density of soil was measured by core sampler. Bulk density of soil (before operation) was found to be

1.11 g/cm3, 1.17 g/cm3 and 1.46 g/cm3 and after operation was found to be 1.07 g/cm3, 1.11 g/cm3, 1.40 g/cm3 at respective depth of 5, 10 and 15 cm.

4.3 Laboratory test of seed cum fertilizer drill

4.3.1 Calibration of seed cum fertilizer drill

The tractor drawn automatic seed drill was calibrated in the laboratory for desired seed rate by using the different size rollers, different exposure length of metering scale and different hopper filling. The available metering rollers number (2, 3, 4, 5, 6,and 7) were selected for to study the suitability for fine seed.

4.3.2 Selection of metering roller

Roller number 5, 6 and 7 gave non-uniform seed delivery of *Kodo* and *Ragi* and also the seed rate was high with these rollers. Considering the desired seed rate the Roller number 4 was found suitable for *Kodo* and *Ragi* seed and Roller no. 5 were found suitable for fertilizer . As descried under chapter-III the .So calibration was done with all the rollers for all the two crops and selected rollers 4 and 5, were found suitable. For *Kodo* and *Ragi* roller 4 were used and. Table G-3 and Table G-4 shows the calibration results of *Kodo* and *Ragi* crop with metering roller 4. Metering scale from 4 to 12 gives the uniform seed delivery rate. The recommended seed rate for *Kodo* seed was in a range of 8-10 kg/ha . Ragi in a range 5 kg/ha. For metering roller 4 scale exposure gives nearest value of seed rate in range 8-10 kg/ha for Kodo and for Ragi metering roller 4 exposure scale 4 gives nearest value of seed rate 5 kg/ha.

4.3.3 Laboratory test

4.3.3.1 Calibration

The seed cum fertilizer drill machine was calibrated in the laboratory for the desired seed rate by adjusting the exposed length of the flutes.

4.3.3.2 Effect of hopper filling on seed delivery rate:

Table G-1 and Table G-2 indicates the seed rate of *Ragi* and *Kodo* for different exposure scale varied with the hopper filling (Full, 3/4th , half and 1/4). It was observed that all the sample collected for same exposure scale were nearly same and there was very little deviation among the sample i.e (<2.0). The CV was also very less about in range of (0.85-1.38) and (9.18- 63.18) on average. For *kodo* seeds and for *Ragi* seeds was very little deviation among the sample i.e (<2.0). The CV was also very less about in range of (0.88-2.07) and (17.64- 45.17) on average.

4.3.3.3 Effect on seed delivery between rows

Table G-3 indicates the variation in seed rate of *Ragi* among the rows (Furrow opners). It was observed that the entire samples collected for same exposure scale were nearly same and there was little deviation among the sample i.e (3.30-3.31). The CV was about (95.45-96.19) in range. Exposure scale 4 is best suited for the recommended seed of *Ragi* crop (average 5 kg/ha).

Table G-4 indicates the variation in seed rate of *Kodo* among the rows (Furrow opners). It was observed that the entire samples collected for same exposure scale were nearly same and there was little deviation among the sample i.e (5.40-5.43). The CV was about (77.60-79.20) in range. Exposure scale 5 is best suited for the recommended seed of *Kodo* crop (average 10 kg/ha).

Table G-5 indicates the variation in dropping rate of fertilizer among the rows (Furrow opners). It was observed that the entire samples collected for same exposure scale were nearly same and there was little deviation among the sample i.e (7.92-7.94). The CV was about (74.89-85.55) in range. Exposure scale 3 is best suited for the recommended seed of Fertilizer crop (average 10 kg/ha).

`4.3.4 Mechanical damage to seed by metering mechanism

Visual observations for mechanical damage due to metering mechanism were recorded and it was found that there was no visual damage to the seeds of *Ragi,* and *Kodo.* However the internal damage of seeds was measured by sowing of seeds in steel trays and found that the seed damage for Ragi and kodo was not significant at neligible level of significance. The results are shown in Table 4.4

Table 4.4 : Mechanical damage to seeds by seed cum fertilizer drill

S. No.	Crop	Weight of broken seeds, g	Total weight of sample, g	Broken seeds, %
1	Ragi	1.2	1000	0.12
2	Kodo	1.4	1000	0.14

Seed collected in 10 revolutions

4.3.5 Selection of metering unit for fertilizer

The seed drill was calibrated with all available fertilizer metering rollers and the optimum application rate (10 kg/ha) was found with roller number 5 at exposure scale 3. Table 4.9. indicates the fertilizer application rate of *Ragi* and *Kodo* among the rows (Furrow openers). It was observed that the entire samples collected for same exposure scale were nearly same and there was little deviation among the rows i.e (7.92-7.94). The CV was about in the range of (74.89-85.55). (Exposure scale 3 is best suited for the recommended fertilizer application rate of *Ragi* and *Kodo* (average 10 kg/ha).

4.4 Field preparation before sowing

4.4.1 Primary and secondary tillage operations

The primary tillage operation was performed with the use of cultivator and secondary operation with rotavator. The field performance results of tractor drawn cultivator and tractor drawn rotavator were presented in Appendix- M and Appendix – N After the operations field was divided equally to operate the seed cum fertilizer drill three times in a row and for three replications were made for each trial.

4.5 Field performance results of Seed cum fertilizer drill

The actual seed rate found on field condition for the Ragi and Kodo were shown in Table 4.5. Metering roller 4 for *Ragi* , and *Kodo* was used for sowing. The exposure length of scale was fixed at number 4 for both crop to conduct the experiment. The seed rate was found near to the recommended seed rate for sowing . At recommended exposure scale number 4 the seed delivery rate of *Ragi* with roller number 4, *Kodo* with roller number 4

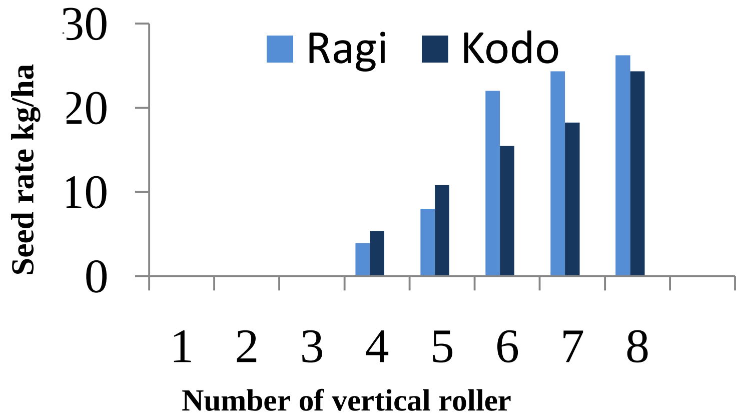


Fig 4.3- Seed rate at different roller

4.5.1 Speed of operation of seed cum fertilizer drill

The speed of operation was calculated from the time required by the machine to travel the distance of 25 m. and 27.40m The average speed of operation of automatic seed drill was found to be 2.80 km/ h and2.90 km/h. The calculation of speed of operation was given in Appendix-K.

4.5.2 Wheel slippage

The wheel slippage of operation was calculated from the time required by the machine to travel the distance of 25m and 27.40 m. The average wheel slippage was found 8.2 and 7.9 per cent. The calculation of speed of operation was given in Appendix -J

Table 4.5 : Field Performance results of seed cum fertilizer drill for Ragi and Kodo crop.

Sr. No.	Particulars	Ragi	Kodo
1	Actual area covered, m^2	685.0	602.8
2	Effective working width, m	2.00	2.00
3	Mean operating time min	14.5	14.5
4	Time lost in Turning, min	3.7	2.7
5	Actual area covered, ha	0.0685	0.06028
6	Traveling speed, km/h	2.5	2.5
7	Theoretical field capacity, ha/h	0.62	0.62
8	Effective field capacity, ha/h	0.51	0.51
9	Field efficiency, %	77	77
10	Wheel slip of tractor, %	8.2	7.9
11	Fuel consumption, lit/h	4.5	4.5
12	Cost of operation, Rs/h	580.9	580.9
13	Energy requirement, MJ/ha	1290	1290

The data showed in Table 4.5 that the effective field capacity of the seed cum fertilizer drill for *Ragi and Kodo* was 0.51 ha/h with field efficiency 77 % . This is due to the fact that the machine has greater coverage width and least amount of overlapping due to shovels, which increases efficiency of the machine. The field efficiency basically depends up on the size, shape, of the field, method of operation and operator. The cost of operation was Rs 580.9 per ha and energy requirement for *Ragi* and *Kodo* is same1290 MJ/ha for sowing seeding operation.Result for Ragi and Kodo at per machine performance is same .

4.6 Agronomical Parameters

4.6.1 Plant height

Table H-1 represents the plant height of *Ragi*.The plant height of wheat was observed to be 11.0, 29.0, 52.9, 82.4, and 96.5 cm at 15, 30, 60, and 90 days respectively. Treatment T_9 (*Ragi* : Fertilizer) ratio for plant heights is better of other treatment. Table H-2 The plant height of *kodo* was observed to be 11.5,25.9,45.9,89.5 and 92.3 cm at 15, 30, 60 and 90 days respectively**.** Treatment T*1* (*Kodo* : slurry) ratio for plant heights is better of other treatment

4.6.2 Effect of different millets : mixture ratio on yield component

Table I-1 represents the the yield *Ragi* : mixture ratio T_7(ragi : Frtilizer) respectively. The tillers/branch, no of ear/silique, weight of ears/silique, no of seeds/silique, weight of 1000seeds/100 gm to be 2.4, 2.3, 8.0 ,2712, 3.6 respectively show the best of other treatment

Table I-2 represents the yield *Kodo* : mixture T_7 (kodo : fertilizer) ratio respectively at the tillers/branch, no of ear/silique, weight of ears/silique, no of seeds/silique, weight of 1000seeds/100 gm to be 5.3,4.3 , 9.5, 1120, 6.67

4.7 Grain and Straw Yield

Table 4.6 shows the yield of *Kodo* grain and straw. Treatment T_7 yielded maximum over others mixture ratios. T_7 treatment is Seed : DAP ratio of (2:1). This ratio gave maximum grain yield (0.93 tonne / ha) . It may be due to better and early fertilization of crop, as seed and fertilizer placed together.

Table 4.6 : Grain and Straw yields as influenced by different *Kodo* - mixture ratio.

Treatment	Biomass Yield (tonne ha^{-1})	Grain Yield (tonne ha^{-1})	Straw Yield (tonne ha^{-1})	Harvest index (%)
T_1	1.06	0.38	0.68	35.84
T_2	0.2	0.08	0.12	40.00
T_3	2.01	0.77	1.24	38.30
T_4	1.06	0.38	0.68	35.84
T_5	2.27	0.85	1.42	37.44
T_6	2.01	0.77	1.24	38.30
T_7	2.48	0.93	1.55	37.5
T_8	2.27	0.85	1.42	37.44
T_9	2.01	0.77	1.24	38.30

This effect is not satisfied becauce wehter condition is affected *kodo* crop as a result kodo crop yield is affected and gaven a low yield

4.8 Biomass yield and Harvest Index

The Table 4.6 also indicates the Biomass yield and Harvest Index of *Kodo* crop. Maximum biomass yield was found with Seed –DAP ratio of 2:1 , that is T_7 (2.48 t/ha) followed by T_8 and T_5 (both yielded 2.27 t/ha).

Similarly Table 4.7 shows the yield of *Ragi* grain and straw. Treatment T_7 yielded maximum over others mixture ratios. T_7 treatment is *Ragi* Seed : DAP ratio of (1 : 1). This ratio gave maximum grain yield (2.9 tonne / ha) followed by T9 (2.8 tonne /ha). It may be due to better and early fertilization of crop, as seed and fertilizer placed together.

Table 4.7 : Grain and Straw yield as influenced by different *Ragi*-mixture ratio

Treatment	Biomass Yield (tonne ha^{-1})	Grain Yield (tonne ha^{-1})	Straw Yield (tonne ha^{-1})	Harvest index (%)
T_1	3.7	2.1	1.6	56.75
T2	4.1	2.4	1.7	58.53
T3	4.3	2.5	1.8	58.13
T4	3.4	2.0	1.4	58.82
T5	4.2	2.5	1.7	59.52
T6	4.1	2.4	1.7	58.53
T7	4.8	2.9	1.9	60.41
T8	4.1	2.6	1.5	63.41
T9	4.6	2.8	1.8	60.86

4.9 Plant Height of *Ragi* and *Kodo* under broadcasting seeding

Table O-1 represents the plant height of *Ragi* and *kodo* crop at different growth stages. The plant height of *Ragi* was observed to be 10.2, 15.7, 41.1 62.2 and 89.5 cm at 15, 30, 60, and 90 days respectively. Whereas the plant height of *kodo* was observed to be 10.5, 20.1,38.9,67.6 ,90.1 cm at 15, 30, 60 and 90 days respectively. Height of both crop were found almost similar. The height of both the crop may be considered as dwarf (< 1.0 m).

4.10 Yield Attributes of *Kodo* and *Ragi*

The yield attributes of *Kodo* and *Ragi* crop under broadcasting method was observed and reported in Table O-2.

Table O-2 represents the yield *Ragi* respectively. The tillers/branch, no of ear/silique, weight of ears/silique, no of seeds/silique, weight of 1000seeds/100 gm to be 2.4, 2.1, 4.0, 1050 ,3.87 respectively show the best of other treatment represents the yield *Kodo* respectively at the tillers/branch, no of ear/silique, weight of ears/silique, no of seeds/silique, weight of 1000seeds/100 gm to be 1.8 ,1.6 ,3.7 ,571 , 5.50

Table 4.8 :Yields as influenced by crop at broadcasting method

Crop	Biomass Yield (tonne ha^{-1})	Grain Yield (tonne ha^{-1})	Straw Yield (tonne ha^{-1})	Harvest index(%)
Ragi	1.04	0.63	0.41	60.57
Kodo	0.74	0.31	0.43	41.89

Table 4. 10 represents Grain yield has obtained *Ragi* was significantly higher than *kodo* from sowing by *Ragi* crop represent that total grain yield recorded 0.63 (tonne/ha)and *kodo* crop represent that total grain yield recorded 0.31 (tonne/ha)

Straw yield has obtained *Ragi* was significantly higher than *kodo* from sowing by *Ragi* crop represent that total straw yield recorded is 0.41 (tonne/ha)and *kodo* crop represent that total straw yield recorded 0.43(tonne/ha)

4.11 Energy cost of cultivation of sowing of millets

Results depicted through Table 4.20 revealed that the total input energy MJ/ ha7430.23 and 4517.23 MJ/ha in which highest energy was consumed in fertilizer application operation 3630 MJ/ha because it included seed energy otherwise tillage operation which consume 1810 MJ/ha ha^{-1} followed by sowing operation 956 MJ/ha^{-1} ,threshing 406 MJ/ha^{-1} and harvesting 314 MJ/ha^{-1}, weeding operation 314 MJ/ha^{-} and the lowest energy consumption was recorded in harvesting and weeding because operation was done by manually in the crop production. The total energy output was recorded

4.11.1 Energy Ratio and Specific Energy Requirement

The energy available from grain and straw represents the energy output where as energy consumed in various operations represents energy input. The energy from grain, straw, tillage operations, tillage to threshing operations, and total direct and indirect energy including seed, fertilizer and energy output-input ratios are presented in Appendix -P of seeding operation (*Kodo* and *Ragi* crop) and the highest energy output-input ratio was obtained in T_7 treatment Ragi Seed :

DAP ratio of (1 : 1). This ratio gave maximum 0.084 . Kodo T_7 treatment is Seed : DAP ratio of (2:1). gave 0.067 and also the specific energy required having value 0.045 and 0.038 MJ/kg.

In Appendix –P Table P-3 show Energy Ratio and Specific Energy the broadcasting method for *Kodo* and *Ragi* crop the Energy Ratio is 0.026 and 0.021 and Energy Ratio is 0.013 and 0.1

Table 4.9 : Energy use pattern in cultivation of *Millets by* seeding operation

S. No.	Operation	Method	Energy Input, MJ/ha	
			Ragi	Kodo
1	Tillage	Cultivator x2 Rotavator x1	1810	1810
2	Sowing	Seed-Cum Fertilizer Drill	1350	1290
3	Fertilizer application	Seed Cum Fertilizer Drill	3613.88	717
4	Weeding	Manual	314	314
5	Harvesting	Manual	314	314
6	Threshing	Thresher	431.35	431.35
	Total		**7838.23**	**4876.23**

Table 4.10 : Energy use pattern in cultivation of *Millets by* broadcasting method

S. No.	Operation	Method	Energy Input, MJ/ha	
			Ragi	Kodo
1	Tillage	Cultivator x2 Rotavator x1	1810	1810
2	Sowing	manual	11.87	11.87
3	Fertilizer application	Manual	3611.92	720.92
4	Seed	Manual	73.5	147
5	Spraying	Manual	66.37	66.37
4	Weeding	Manual	314	314
5	Harvesting	Manual	276.32	276.32
6	Threshing	M annual	406.23	406.23
	Total		**6570.19**	**3752.71**

4.12. Economic analysis of the seed drill

The economic analysis of sowing has been done to identify that would suit to farmers and to arrive at a decision for providing policy support for accelerating the technology for its wide scale adaptation

4.12.1 Operation cost for tillage and sowing

The data related to operation cost for sowing by seed drill were obtained for as shown in Appendix-.Q The operating cost of tractor was calculated 580 per hour, whereas The Cost for tillage and sowing operations in sowing of kharif crop were calculated Rs.1859.36 per hectare

CHAPTER-I
SUMMARY AND CONCULSIONS

Traditional method of sowing of *Kodo* and *Ragi* seeds is performed by manual labours. The labour availability is scare during the sowing period in Kharif season. The cost of production is increased due to the manual labour and drudgery is also involved. So it is felt that if this operation is performed by machine it will save time, energy and production cost. A seed cum fertilizer drill with cup feed metering mechanism was converted for sowing of *Ragi* and *Kodo* Different type of seed flow from each cup was achieved by dividing the seed hopper in different sections and filling the required seed in respective sections by dividing the seed box in to compartments. The seed rate of *Ragi* and *Kodo* was kept at 5 kg/ha and 8-10 kg/ha respectively. In *Ragi* and *Kodo,* the row to row spacing was 30 cm .

The tests conducted as per BIS test code for sowing equipment- seed cum fertilizer drill (IS 6316:1993). The metering roller was selected and calibrated with suitable combination of seed box exposure scale. The performance results shows that the use of seed cum fertilizer drill is beneficial to sow .

The required seed rate for *Ragi* and *Kodo* was found in the range 4.92 kg/ha and 11kg/ha. Roller number 4 were found suitable for the *Ragi* and *Kodo*. For *Ragi* at exposure scale number 4 and for *Kodo* metering exposure scale 5 were found suitable.

- ❖ For *Ragi* metering roller 4 scale exposure 4 gives nearest value of seed rate 4.92 kg/ha
- ❖ For *Kodo* metering roller 4 scale exposure 5 gives nearest value of seed rate 5 kg/ha .

The hopper filling has very little effect on seed delivery for all three crops. *Kodo* crop has shown higher seed rate variation at exposure scale 11 and 12.

The mechanical seed damage for *Ragi* and *Kodo* was found 0.12 %,and 0.14 % respectively.

Exposure scale 5 is best suited for the recommended fertilizer application rate of *Ragi* and *Kodo* (average 10 kg/ha).

The effective field capacity of seed cum fertilizer drill for *Ragi* and *Kodo* was found to be 0.51 ha/h with field efficiency of 77 % .

The cost of operation of seed cum fertilizer drill was Rs 580 per ha and energy requirement was 1290 MJ/ha for sowing seeding crops.

Total input energy of seeding opertion for *Ragi* 7771 MJ ha^{-1} and for *Kodo* 4814 MJ ha^{-1} in which highest energy was consumed in fertilizer operation 3613.88 MJ/ha, because it included fertilizer energy otherwise tillage operation which consume 1810 MJ/ ha.

Total input energy of broadcasting method for *Ragi* 6216 MJ ha^{-1} and for *Kodo* 3319 MJ ha^{-1} in which highest energy was consumed in fertilizer operation 3613.88 MJ/ha

Treatment T_7 yielded maximum over others mixture ratios. T_7 treatment is Ragi Seed : DAP ratio of (1 : 1). This ratio gave maximum grain yield (2.9 tonne / ha) followed by T_9 (2.8 tonne /ha). It may be due to better and early fertilization of crop, as seed and fertilizer placed together.

The yield of *Kodo* grain and straw. Treatment T_7 yielded maximum over others mixture ratios. T_7 treatment is Seed : DAP ratio of (2:1). This ratio gave maximum grain yield (0.93 tonne/ha). It may be due to better and early fertilization of crop, as seed and fertilizer placed together.

Suggestions for future work

1. The machine should be modified for roller grooves system.
2. The design of seed delivery pipe should be improved for continues seed delivery.
3. The design of shovel need to be developed and can be replaced with inverted T type furrow opener to improve the sowing operation.
4. The seed cum fertilizer drill to be tested for longer period under different soil and field conditions to assess its suitability.
5. Leveller plate can also be attached with the machine.

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APPENDIX-A

Table: A.-1 : Area and production of small millets in different states (2010)

Sr. No	State	Area ('000ha)	Production (MT)	Yield (kg/ha)
1	Andhra Pradesh	0298	129	432
2	Bihar	0084	052	610
3	Gujarat	0066	027	416
4	Karnataka	0233	093	401
5	Maharashtra	0177	099	558
6	Madhya Pradesh	1306	313	240
7	Orissa	0107	060	563
8	Tamil Nadu	0235	188	801
9	Uttar Pradesh	0223	164	735
10	Chhattisgarh	0248	64	240
	All India	2869	1181	411

(Source-Eands.dacnet.nic/Normal_Estimatel/---/small%20millets.xls)

Table: A.2- : Minerals of finger and *Kodo* millets

Nutrients	P Mg/100g	K Mg/100g	Na Mg/100g	Mg Mg/100g	Co Ppm	Cu Ppm	Mn Ppm	Zn Ppm
Finger millet	0.24	0.43	0.02	0.11	0.10	0.3	7.5	15
Kodo millet	0.32	0.17	0.01	0.13	0.05	0.2	-	-

(Source- www. eolss.net/ebooks/Sample%20Chapters/C10/E5-02-01-04.pdf)

APPENDIX-B

Table B-1 : Specification of seed cum fertilizer drill

S. No.	Particulars	Specification
1.	Overall dimension	
	Length (mm)	2200
	Width (mm)	60
	Height (mm)	1360
2.	Depth of sowing (cm)	15
3.	Row to Row spacing (cm)	30
4.	Working width (mm)	2100, adjustable
5.	No. of tines	8
6.	Types of metering device	Cup feed Mechanism
7.	Ground wheel diameter (mm)	500
8.	Type of tines	Shovel-type
9	Fertilizer Metering	Cup feed Mechanism

APPENDIX - C

Table C -1 : Seed size of *Kodo*

S. No.	Length (mm)	Width (mm)	Thickness (mm)	ED (mm)
1	2.094	2.090	1.456	6.37
2	2.175	2.098	1.543	7.04
3	2.337	2.044	1.488	7.10
4	2.397	2.040	1.468	7.17
5	2.393	2.050	1.490	7.30
Average	2.266	2 .075	1.470	6.996

Table C - 2 : Seed size of *Ragi*

S. No.	Length (mm)	Width (mm)	Thickness (mm)	ED (mm)
1	1.712	1.620	1.587	4.17
2	1.766	1.623	1.507	4.31
3	1.784	1.620	1.501	4.33
4	1.827	1.632	1.531	4.56
5	1.785	1.667	1.597	4.75
Average	1.774	1.632	1.5446	4.424

APPENDIX - D

Table D -1 : Moisture content and bulk density of soil(Field no.1)

S. No.	Depth, cm	Moisture content, %(db)	Bulk of density, g/cm
1	5.0	15.24	1.46
2	10.0	15.76	1.51
3	15.0	17.12	1.49

Table D - 2 : Moisture content and bulk density of soil (Field no.2)

S. No.	Depth, cm	Moisture content, %(db)	Bulk of density, g/cm
1	5.0	15.00	1.40
2	10.0	15.10	1.45
3	15.0	16.99	1.46

APPENDIX -E

1. Condition of field

    a) Area and shape of test field

    b) Type of soil

    c) Moisture content. – field no. 1 - 16.04 % db

    field no. 2 - 15.69 %db

    d) Bulk density, – field no. 1 - 1.48 g/cm^3

    field no. 2 - 1.43 g/cm^3

2. condition of seed and fertilizer

    a) Name and variety

    Ragi : GPU -28

    Kodo : JK-439

    Fertilizer : DAP(Basal type)

    b) shape and size

    1. *Ragi*

        Length 1.77 mm

        Width 1.63 mm

        Thickness 1.544 mm

    2. *Kodo*

        Length 2.26 mm

        Width 2.07mm

        Thickness 1.47mm

c) Weight of 1000 seeds :

Ragi : 3.656 g

Kodo : 6.078 g

3. Condition of machine and operator :

    a) Source of power : Tractor Drawn

    b) Adjustments of working parts of machine

    (i) Adjustments for seed and fertilizer rate :

    Ragi : 5 kg/ha

    Kodo : 8-10 kg/ha

    (ii) Adjustments of furrow opener for depth of sowing : 15 cm

    (iii) Adjustments for row to row spacing : 30 cm

APPENDIX – F

Table F -1 : Brief specification of instruments used during field study

1. Core cutter

Length : 185 mm

Height : 450 mm

Width : 90 mm

Diameter of cylinder : 50 mm (Inner diameter)

56 mm (Outer diameter)

Length of cylinder : 86 mm

Frame : Conduit pipe 25 mm in diameter

Handle : Conduit pipe 20 mm in diameter

2 .Electric oven

The electric oven was used to find out moisture content of soil samples. The temperature of electric oven ranges from 0 to 2000^{0}C.

APPENDIX – G

Table G-1 : Seed rate of *kodo* under different exposure- scale and seed box- filling condition.

Scale exposure no.	**Seed rate (kg/ha) under varied box filling**				**Mean**	**SD**	**CV**
	100%	75%	50%	25%			
1					--	--	--
2					--	--	--
3					--	--	--
4	2.75	1.95	1.86	1.05	1.90	1.20	63.18
5	4.44	2.45	2.2	2.1	3.27	1.65	50.60
6	5.39	3.75	3.49	3.43	4.01	1.38	34.51
7	5.81	4.62	4.61	4.31	4.83	1.06	21.92
8	7.01	5.70	5.55	5.51	5.94	1.06	17.84
9	8.02	6.77	6.65	6.31	6.93	1.20	17.42
10	8.92	7.66	7.4	7.04	7.75	1.32	17.14
11	9.52	8.46	8.35	8.31	8.66	0.85	9.87
12	10.30	9.67	9.15	9.06	9.54	0.87	9.18

* not drop a seed

Table G-2 : Seed rate of *Ragi* under different exposure- scale and seed box- filling condition.

Scale exposure no.	**Seed rate (kg/ha)) under varied box filling**				**Mean**	**SD**	**CV**
	100%	**75%**	**50%**	**25%**			
1					--	--	--
2					--	--	--
3					--	--	--
4	2.41	1.86	1.76	1.16	1.79	0.88	49.17
5	2.84	2.56	2.41	2.21	2.52	0.44	17.64
6	3.86	3.37	3.02	2.90	3.28	0.67	20.64
7	4.79	4.08	3.92	3.44	4.05	0.95	23.52
8	5.74	4.99	4.61	4.02	4.84	1.21	25.12
9	6.97	6.04	5.33	4.90	5.81	1.46	25.19
10	7.67	7.08	6.04	5.50	6.57	1.53	23.34
11	8.35	8.28	7.00	6.21	7.46	1.51	20.28
12	9.98	9.44	7.95	7.04	8.60	2.07	24.16

* not drop a seed

Table G-3 : Seed rate (kg/ha) of *Ragi* seed with different exposure scale under different furrow openers with selected metering roller no. 4. In 20 revolution of Ground wheel

Scale exposure no	Seed rate (kg/ha)/furrow opener							
	F1	F2	F3	F4	F5	F6	F7	F8
1								
2								
3								
4	0.49	0.48	0.47	0.49	0.49	0.47	0.48	0.49
5	1	0.99	0.99	1	1	0.99	0.99	1
6	2.75	2.72	2.7	2.75	2.75	2.7	2.72	2.75
7	3.04	3.02	3	3.04	3.04	3	3.02	3.04
8	3.28	3.24	3.2	3.28	3.28	3.2	3.24	3.28
9	3.9	3.85	3.83	3.9	3.9	3.83	3.85	3.9
10	4.23	4.2	4.22	4.23	4.23	4.2	4.22	4.23
11	4.79	4.75	4.77	4.79	4.79	4.77	4.75	4.79
12	5.17	5.15	5.16	5.17	5.17	5.15	5.16	5.17
Mean	3.18	3.15	3.14	3.18	3.18	3.14	3.15	3.18
S.D	3.30	3.30	3.31	3.30	3.30	3.30	3.30	3.30
C.V	96.19	95.55	94.95	96.19	96.19	95.05	95.45	96.19

Table G-4 : Seed rate (kg/ha) of *Kodo* seed with different exposure scale under different furrow openers at selected metering roller no. 4. In 20 revolution of Ground wheel

Scale exposure no	Seed rate (kg/ha)/furrow opener							
	F1	F2	F3	F4	F5	F6	F7	F8
1								
2								
3								
4	0.67	0.66	0.66	0.67	0.67	0.65	0.66	0.67
5	1.34	1.35	1.33	1.35	1.35	1.35	1.34	1.35
6	2.28	2.56	2.56	2.58	2.58	2.55	2.56	2.58
7	3.87	3.02	3.01	3.04	3.04	3.02	3.02	3.04
8	4.05	4.02	4.03	4.05	4.05	4.02	4.03	4.05
9	5	5.03	5.02	5	5	5	5.02	5
10	6.08	6.05	6.07	6.08	6.08	6.05	6.07	6.08
11	7.03	7	7	7.01	7.03	7.05	7.01	7.05
12	8.34	8.30	8.34	8.34	8.32	8.34	8.32	8.34
Mean	4.29	4.22	4.22	4.23	4.23	4.22	4.22	4.24
S.D	5.42	5.40	5.43	5.42	5.40	5.43	5.41	5.42
C.V	79.20	78.13	77.78	78.09	78.30	77.66	78.01	78.17

Table G-5 : Dropping rate (kg/ha) of fertilizer (DAP) with different exposure scale under different furrow openers at selected metering roller no. 5.

Scale exposure no	Furrow opener							
	F1	F2	F3	F4	F5	F6	F7	F8
1								
2								
3	1.40	1.38	1.39	1.40	1.40	1.39	1.38	1.40
4	2.61	2.6	2.6	2.61	2.61	2.6	2.6	2.61
5	3.34	3.33	3.32	3.34	3.34	3.32	3.32	3.34
6	4.69	4.68	4.67	4.69	4.69	4.68	4.67	4.69
7	6.24	6.23	6.23	6.24	6.24	6.22	6.25	6.24
8	7.25	7.24	7.23	7.25	7.25	7.24	7.22	7. 25
9	8.32	8.3	8.25	8.32	8.32	8.3	8.35	8.32
10	9.95	9.93	9.9	9.95	9.95	9.93	9.9	9.95
11	11.51	11.53	11.47	11.51	11.51	11.53	11.49	11.51
12	12.63	12.62	12.6	12.63	12.63	12.63	12.62	12.63
Mean	6.79	6.78	6.76	6.79	6.79	6.78	6.78	10.60
S.D.	7.94	7.94	7.92	7.94	7.94	7.94	7.94	7.94
C.V	85.55	85.35	85.35	85.55	85.55	85.35	85.30	74.89

*   = not for drop condition

Table G-6 : Mixture ratio 1: 1   *Ragi* (1): slurry (1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	0.91	0.90	0.89	0.91	0.91	0.89	0.90	0.91
5	1.58	1.56	1.57	1.58	1.58	1.56	1.57	1.58
6	2.26	2.25	2.24	2.26	2.26	2.24	2.25	2.26
7	3.022	3.01	3.00	3.02	3.02	3.00	3.03	3.02
8	4.10	4.08	4.09	4.10	4.10	4.08	4.09	4.10
9	5.03	5.01	5.00	5.03	5.03	5.00	5.05	5.03
10	6.13	6.11	6.10	6.13	6.13	6.12	6.10	6.13
11	7. 24	7.22	7.23	7.24	7.24	7.22	7.23	7.24
12	8.15	8.14	8.13	8.15	8.15	8.13	8.14	8.15

Table G-7 : Mixture ratio 1:1 *Kodo* (1): slurry(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	0.82	0.81	0.80	0.82	0.82	0.80	0.81	0.82
6	1.77	1.76	1.75	1.77	1.77	1.76	1.75	1.77
7	2.62	2.61	2.61	2.62	2.62	2.60	2.61	2.62
8	3.22	3.23	3.25	3.22	3.22	3.25	3.20	3.22
9	4.68	4.66	4.67	4.68	4.68	4.67	4.66	4.68
10	5.69	5.68	5.70	5.69	5.69	5.70	5.68	5.69
11	6.72	6.70	6.75	6.72	6.72	6.75	6.70	6.72
12	7.73	7.70	7.75	7.73	7.73	7.75	7.70	7.73

Table G-8 : Mixture ratio 1:2 *Kodo* (1) slurry(2)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	1.91	1.90	1.89	1.90	1.90	1.89	1.90	1.91
6	2.47	2.45	2.46	2.47	2.47	2.45	2.46	2.47
7	3.34	3.35	3.36	3.34	3.34	3.36	3.35	3.34
8	4.17	4.16	4.15	4.17	4.17	4.16	4.15	4.17
9	5.10	5.09	5.11	5.10	5.10	5.09	5.11	5.10
10	6.18	6.15	6.16	6.18	6.18	6.16	6.18	6.18
11	7.25	7.23	7.24	7.25	7.25	7.24	7.23	7.25
12	8.18	8.16	8.17	8.18	8.18	8.16	8.17	8.18

Table G-9 : Mixture ratio 1:2 *Ragi* (1): slurry(2)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	0.59	0.58	0.57	0.59	0.59	0.57	0.58	0.59
6	2.89	2.88	2.86	2.89	2.89	2.88	2.86	2.89
7	4.08	4.06	4.05	4.08	4.08	4.08	4.05	4.08
8	6.14	6.14	6.15	6.14	6.14	6.15	6.16	6.14
9	8.12	8.10	8.11	8.12	8.12	8.12	8.11	8.12
10	10.32	10.30	10.35	10.32	10.32	10.35	10.30	10.32
11	12.64	12.62	12.66	12.64	12.64	12.62	12.66	12.64
12	14.41	14.39	14.41	14.38	14.41	14.38	14.39	14.41

Table G-10 : Mixture ratio 1:1 *Ragi*(1) : sand(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	2.33	2.32	2.31	2.33	2.33	2.32	2.31	2.33
6	3.63	3.62	3.60	3.63	3.63	3.62	3.60	3.63
7	4.76	4.77	4.75	4.76	4.76	4.77	4.75	4.76
8	5.96	5.95	5.94	5.96	5.96	5.95	5.94	5.96
9	6.31	6.30	6.30	6.31	6.31	6.30	6.30	6.31
10	7.98	7.97	7.96	7.98	7.98	7.97	7.96	7.98
11	8.81	8.80	8.80	8.81	8.81	8.80	8.80	8.81
12	9.78	9.77	9.76	9.78	9.78	9.77	9.76	9.78

Table G-11 :Mixture ratio 2:1 *Ragi*(2): sand(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	1.94	1.92	1.95	1.94	1.94	1.95	1.92	1.94
6	3.93	3.90	3.90	3.93	3.93	3.90	3.92	3.93
7	5.60	5.58	5.59	5.60	5.60	5.58	5.57	5.60
8	7.13	7.12	7.15	7.13	7.13	7.12	7.15	7.13
9	9.23	9.22	9.22	9.23	9.23	9.21	9.22	9.23
10	11.1	11.02	11.03	11.01	11.01	11.01	11.03	11.00
11	13.31	13.29	13.29	13.31	13.31	13.29	13.28	13.31
12	15.10	15.08	15.07	15.10	15.10	15.08	15.07	15.09

Table G-12 :Mixture ratio 1:2 *Ragi*(1) : sand(2)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1	□	□	□	□	□	□	□	□
2	□	□	□	□	□	□	□	□
3	□	□	□	□	□	□	□	□
4	0.47	0.47	0.46	0.47	0.47	0.46	0.46	0.47
5	2.79	2.77	2.79	2.79	2.76	2.78	2.78	2.79
6	4.02	4.03	4.02	4.02	4.00	4.02	4.01	4.02
7	6.13	6.11	6.11	6.13	6.13	6.11	6.11	6.13
8	8.04	8.03	8.03	8.04	8.04	8.03	8.02	8.04
9	10.38	10.37	10.36	10.38	10.38	10.36	10.36	10.38
10	12.50	12.48	12.49	12.50	12.50	12.49	12.48	12.50
11	14.16	14.15	14.15	14.16	14.16	14.17	14.15	14.15
12	16.07	16.05	16.06	16.07	16.07	16.05	16.06	16.07

Table G-13 : Mixture ratio 1:2 *Kodo*(1): sand(2)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	0.82	0.80	0.81	0.82	0.82	0.81	0.80	0.82
6	1.85	1.84	1.84	1.85	1.85	1.84	1.83	1.85
7	2.87	2.85	2.86	2.87	2.87	2.86	2.85	2.87
8	3.88	3.87	3.86	3.88	3.88	3.87	3.86	3.88
9	4.29	4.27	4.28	4.29	4.29	4.28	4.27	4.29
10	5.10	5.08	5.07	5.10	5.10	5.07	5.08	5.10
11	6.22	6.20	6.19	6.22	6.22	6.19	6.20	6.22
12	7.42	7.41	7.41	7.42	7.42	7.43	7.41	7.42

Table G-14 : Mixture ratio 2:1 *Kodo*(2): slurry(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	2.01	2.00	1.99	2.01	2.01	2.00	1.99	2.01
6	3.63	3.62	3.60	3.63	3.63	3.62	3.60	3.63
7	4.96	4.95	4.97	4.96	4.96	4.95	4.95	4.96
8	5.60	5.58	5.57	5.60	5.60	5.58	5.57	5.60
9	6.98	6.96	6.97	6.98	6.98	6.97	6.96	6.98
10	7.25	7.23	7.20	7.25	7.25	7.20	7.23	7.25
11	8.04	8.00	8.03	8.04	8.04	8.03	8.02	8.04
12	9.21	9.20	9.20	9.21	9.21	9.19	9.20	9.21

Table G-15 : Mixture ratio 2:1 *Ragi*(2) : slurry(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	0.89	0.87	0.88	0.89	0.89	0.87	0.88	0.89
5	1.98	1.99	1.97	1.98	1.98	1.98	1.97	1.98
6	2.87	2.88	2.85	2.87	2.87	2.87	2.86	2.87
7	3.34	3.33	3.32	3.34	3.34	3.32	3.33	3.34
8	4.94	4.93	4.92	4.94	4.94	4.92	4.93	4.94
9	5.34	5.33	5.33	5.34	5.34	5.33	5.32	5.33
10	6.13	6.11	6.13	6.13	6.13	6.11	6.12	6.13
11	7.27	7.25	7.25	7.27	7.27	7.26	7.25	7.27
12	8.68	8.66	8.65	8.68	8.68	8.66	8.65	8.68

Table G-16 : Mixture ratio 1:1 *Kodo*(1) : sand(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	1.05	1.04	1.03	1.05	1.05	1.04	1.03	1.05
6	2.12	2.11	2.10	2.12	2.12	2.11	2.10	2.12
7	3.49	3.47	3.48	3.49	3.49	3.47	3.48	3.49
8	4.54	4.53	4.55	4.54	4.54	4.53	4.55	4.54
9	5.64	5.65	5.63	5.64	5.64	5.65	5.63	5.64
10	6.89	6.88	6.86	6.89	6.89	6.87	6.88	6.89
11	7.91	7.90	7.92	7.91	7.91	7.90	7.92	7.91
12	8.22	8.20	8.21	8.22	8.22	8.21	8.20	8.22

Table G-17 : Mixture ratio 2:1 *Kodo*(2) : sand(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4								
5	0.63	0.64	0.62	0.63	0.63	0.64	0.62	0.63
6	2.59	2.57	2.55	2.59	2.59	2.55	2.57	2.59
7	4.02	4.00	4.02	4.02	4.02	4.00	4.02	4.02
8	6.11	6.09	6.10	6.11	6.11	6.10	6.09	6.11
9	8.04	8.02	8.01	8.04	8.04	8.01	8.01	8.04
10	10.22	10.20	10.21	10.21	10.22	10.21	10.20	10.22
11	12.05	12.04	12.03	12.05	12.05	12.03	12.04	12.05
12	14.58	14.57	14.56	14.58	14.58	14.56	14.57	14.58

Table G-18 : Mixture ratio 1:1 *Kodo*(1) : Fertilizer(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.00	0.99	0.99	1.00	1.00	0.99	0.99	1.00
5	2.75	2.72	2.70	2.75	2.75	2.70	2.72	2.75
6	3.04	3.02	3.00	3.04	3.04	3.00	3.02	3.04
7	3.28	3.24	3.20	3.28	3.28	3.20	3.24	3.28
8	3.90	3.85	3.83	3.90	3.90	3.83	3.85	3.90
9	4.23	4.20	4.22	4.23	4.23	4.20	4.22	4.23
10	4.79	4.75	4.77	4.79	4.79	4.77	4.75	4.79
11	5.17	5.15	5.16	5.17	5.17	5.15	5.16	5.17
12	6.24	6.23	6.23	6.24	6.24	6.22	6.25	6.24

Table G-19 : Mixture ratio 2:1 *Kodo*(2) : Fertilizer(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.17	1.16	1.15	1.17	1.17	1.16	1.15	1.17
5	2.21	2.19	2.20	2.21	2.21	2.19	2.20	2.21
6	2.91	2.90	2.89	2.91	2.91	2.90	2.89	2.91
7	3.45	3.44	3.42	3.45	3.45	3.44	3.45	3.45
8	4.03	4.02	4.02	4.03	4.03	4.00	4.01	4.03
9	4.91	4.90	4.89	4.91	4.91	4.90	4.89	4.91
10	5.51	5.50	5.49	5.51	5.51	5.49	5.50	5.51
11	6.22	6.20	6.21	6.22	6.22	6.20	6.21	6.22
12	7.05	7.03	7.04	7.05	7.05	7.04	7.03	7.05

Table G-20 : Mixture ratio 1:2 *Kodo*(1) : Fertilizer(2)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	2.61	2.60	2.60	2.61	2.61	2.60	2.60	2.61
5	3.34	3.33	3.32	3.34	3.34	3.32	3.32	3.34
6	4.69	4.68	4.67	4.69	4.69	4.68	4.67	4.69
7	6.24	6.23	6.23	6.24	6.24	6.22	6.25	6.24
8	7.25	7.24	7.23	7.25	7.25	7.24	7.22	7. 25
9	8.32	8.30	8.25	8.32	8.32	8.30	8.35	8.32
10	9.95	9.93	9.90	9.95	9.95	9.93	9.90	9.95
11	11.51	11.53	11.47	11.51	11.51	11.53	11.49	11.51
12	12.63	12.62	12.60	12.63	12.63	12.63	12.62	12.63

Table G-21 : Mixture ratio 1:2 *Ragi*(1) : Fertilizer(2)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.77	1.76	1.75	1.77	1.77	1.76	1.75	1.77
5	2.10	2.10	2.10	2.10	2.10	2.11	2.10	2.10
6	3.45	3.42	3.43	3.45	3.45	3.43	3.42	3.45
7	4.62	4.61	4.60	4.62	4.62	4.60	4.61	4.62
8	5.52	5.50	5.51	5.52	5.52	5.50	5.51	5.52
9	6.66	6.65	6.64	6.66	6.66	6.64	6.64	6.66
10	7.05	7.04	7.03	7.05	7.05	7.03	7.02	7.05
11	8.36	8.35	8.35	8.36	8.36	8.35	8.34	8.36
12	9.68	9.67	9.66	9.68	9.68	9.67	9.66	9.68

Table G-22 : Mixture ratio 2:1 *Ragi*(2) : Fertilizer(1)

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.91	1.90	1.89	1.90	1.90	1.89	1.90	1.91
5	2.84	2.82	2.83	2.84	2.84	2.83	2.83	2.84
6	3.87	3.86	3.85	3.87	3.87	3.85	3.86	3.87
7	4.09	4.08	4.07	4.09	4.09	4.07	4.08	4.09
8	5.00	4.98	4.99	5.00	5.00	4.99	4.98	5.00
9	6.05	6.03	6.04	6.05	6.05	6.04	6.03	6.05
10	7.09	7.07	7.08	7.09	7.09	7.08	7.07	7.09
11	8.36	8.35	8.34	8.36	8.36	8.34	8.35	8.36
12	9.45	9.43	9.44	9.45	9.44	945	9.43	9.45

Table G-23: Exposed lengths & hopper capacity in *Ragi* crop in 100% capacity

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	2.42	2.40	2.41	2.42	2.42	2.41	2.40	2.42
5	2.95	2.93	2.94	2.95	2.95	2.94	2.93	2.95
6	3.02	3.00	3.01	3.02	3.02	3.01	3.00	3.02
7	3.94	3.92	3.90	3.94	3.94	3.92	3.93	3.94
8	4.62	4.61	4.60	4.62	4.62	4.61	4.60	4.62
9	5.34	5.33	5.32	5.34	5.34	5.34	5.34	5.34
10	6.05	6.04	6.04	6.05	6.05	6.03	6.04	6.05
11	7.01	7.00	7.00	7.01	7.01	7.00	7.00	7.01
12	7.96	7.94	7.95	7.96	7.96	7.94	7.95	7.96

Table G-24 : Exposed lengths and hopper capacity is *Ragi* crop in 25% capacity

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.17	1.16	1.15	1.17	1.17	1.16	1.15	1.17
5	2.21	2.19	2.20	2.21	2.21	2.19	2.20	2.21
6	2.91	2.90	2.89	2.91	2.91	2.90	2.89	2.91
7	3.45	3.44	3.42	3.45	3.45	3.44	3.45	3.45
8	4.03	4.02	4.02	4.03	4.03	4.00	4.01	4.03
9	4.91	4.90	4.89	4.91	4.91	4.90	4.89	4.91
10	5.51	5.50	5.49	5.51	5.51	5.49	5.50	5.51
11	6.22	6.20	6.21	6.22	6.22	6.20	6.21	6.22
12	7.05	7.03	7.04	7.05	7.05	7.04	7.03	7.05

Table G-25 :Exposed lengths and hopper capacity is *Ragi* crop in 75% capacity

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.86	1.86	1.87	1.87	1.87	1.87	1.86	1.87
5	2.84	2.82	2.83	2.84	2.84	2.83	2.83	2.84
6	3.87	3.86	3.85	3.87	3.87	3.85	3.86	3.87
7	4.09	4.08	4.07	4.09	4.09	4.07	4.08	4.09
8	5.00	4.98	4.99	5.00	5.00	4.99	4.98	5.00
9	6.05	6.03	6.04	6.05	6.05	6.04	6.03	6.05
10	7.09	7.07	7.08	7.09	7.09	7.08	7.07	7.09
11	8.36	8.35	8.34	8.36	8.36	8.34	8.35	8.36
12	9.45	9.43	9.44	9.45	9.44	945	9.43	9.45

Table G-26 : Exposed lengths and hopper capacity is *Ragi* crop in 50% capacity

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.77	1.76	1.75	1.77	1.77	1.76	1.75	1.77
5	2.56	2.55	2.55	2.56	2.56	2.55	2.55	2.56
6	3.38	3.37	3.36	3.38	3.38	3.37	3.36	3.38
7	4.80	4.79	4.78	4.80	4.80	4.79	4.78	4.80
8	5.74	5.75	5.74	5.74	5.74	5.75	5.74	5.74
9	6.98	6.97	6.97	6.98	6.98	6.97	6.97	6.98
10	7.68	7.67	7.65	7.68	7.68	7.67	7.65	7.68
11	8.29	8.27	8.28	8.29	8.29	8.27	8.28	8.29
12	9.99	9.98	9.97	9.99	9.99	9.98	9.97	9.99

Table G-27 : Exposed lengths and hopper capacity is *Kodo* crop in 100% capacity

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	2.61	2.60	2.59	2.60	2.61	2.60	2.59	2.61
5	3.87	3.85	3.86	3.87	3.87	3.87	3.88	3.87
6	4.76	4.75	4.74	4.76	4.76	4.77	4.78	4.76
7	5.65	5.64	5.63	5.65	5.65	5.64	5.64	5.65
8	6.88	6.87	6.86	6.88	6.88	6.86	6.87	6.88
9	7.89	7.87	7.88	7.89	7.89	7.87	7.88	7.89
10	8.78	8.76	8.77	8.78	8.78	8.76	8.77	8.78
11	9.32	9.31	9.32	9.32	9.32	9.30	9.31	9.32
12	10.07	10.06	10.05	10.07	10.07	10.05	10.06	10.07

Table G-28: Exposed lengths and hopper capacity is *Kodo* crop in 75% capacity

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.95	1.96	1.95	1.95	1.95	1.95	1.94	1.95
5	2.45	2.44	2.43	2.45	2.45	2.43	2.44	2.45
6	3.76	3.74	3.75	3.76	3.76	3.74	3.75	3.76
7	4.32	4.31	4.30	4.32	4.32	4.30	4.31	4.32
8	5.56	5.54	5.55	5.56	5.56	5.55	5.54	5.56
9	6.78	6.77	6.77	6.78	6.78	6.75	6.76	6.78
10	7.67	7.65	7.66	7.67	7.67	7.66	7.65	7.67
11	8.32	8.31	8.31	8.32	8.32	8.32	8.30	8.32
12	9.07	9.06	9.05	9.07	9.07	9.05	9.06	9.07

Table G-29 : Exposed lengths and hopper capacity is *Kodo* crop in 50% capacity

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.87	1.85	1.86	1.87	1.87	1.86	1.85	1.87
5	2.20	2.19	2.19	2.20	2.20	2.20	2.21	2.20
6	3.51	3.50	3.40	3.51	3.51	3.49	3.50	3.51
7	4.63	4.62	4.61	4.63	4.63	4.61	4.62	4.63
8	5.71	5.70	5.70	5.71	5.71	5.70	5.69	5.71
9	6.32	6.32	6.31	6.32	6.32	6.31	6.31	6.32
10	7.50	7.49	7.49	7.50	7.50	7.49	7.49	7.50
11	8.47	8.45	8.46	8.47	8.47	8.46	8.45	8.47
12	9.16	9.15	9.14	9.16	9.16	9.15	9.14	9.16

Table G-30 : Exposed lengths and hopper capacity is *Kodo* crop in 25% capacity

Metering scale Setting	Weight of seed rate in kg/ha from furrow openers no.							
	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8
1								
2								
3								
4	1.05	1.04	1.03	1.05	1.05	1.03	1.04	1.05
5	2.10	2.10	2.10	2.10	2.10	2.11	2.10	2.10
6	3.45	3.42	3.43	3.45	3.45	3.43	3.42	3.45
7	4.62	4.61	4.60	4.62	4.62	4.60	4.61	4.62
8	5.52	5.50	5.51	5.52	5.52	5.50	5.51	5.52
9	6.66	6.65	6.64	6.66	6.66	6.64	6.64	6.66
10	7.05	7.04	7.03	7.05	7.05	7.03	7.02	7.05
11	8.36	8.35	8.35	8.36	8.36	8.35	8.34	8.36
12	9.68	9.67	9.66	9.68	9.68	9.67	9.66	9.68

APPENDIX - H

Table H-1 : Effect of different seed mixture ratio on plant height (cm), of *Ragi* at various growth stages.

Treatment	15 days	30 days	60 days	90days	At harvest
T1	10.2	13.7	43.7	74.3	84.4
T2	10.3	16.2	47.1	75.9	90.8
T3	10.2	15.7	46.3	75.1	90.1
T4	10.3	16.8	46.3	74.5	84.4
T5	10.5	18.5	48.7	75.1	89.2
T6	10.6	19.3	49.1	78.0	90.8
T7	10.5	18.6	47.1	75.1	89.0
T8	10.7	22.0	50.9	79.5	92.2
T9	11.0	29.0	52.9	82.4	96.5

Table H-2 : Effect of different seed mixture ratio on plant height (cm), *Kodo* at various growth stages.

Crop	15 days	30 days	60 days	90days	At harvest
T1	11.5	25.9	45.9	89.5	92.3
T2	10.5	20.5	40.6	69.8	84.7
T3	11.0	22.8	43.7	75.9	90.0
T4	10.9	26.3	50.7	78.0	92.6
T5	11.0	29.1	58.2	90.7	94.5
T6	10.0	22.4	47.6	89.3	94.0
T7	11.5	29.8	60.3	95.8	101.9
T8	10.7	27.0	50.9	90.2	96.0
T9	11.0	31.0	58.00	86.5	98.2

APPENDIX- I

Table I-1 : Effect of different Ragi : mixture ratio on yield component

Treatment	No. of tiller /Branches	No. of ears	Weight of ears(g)	No. of seeds ears	Weight of 1000/100 g seeds(gm)
T1	1.8	1.7	6.5	2193	3.5
T2	2.0	2.0	6.8	2312	3.1
T3	2.2	2.1	7.0	2507	3.3
T4	1.9	1.7	6.8	2250	3.6
T5	2.3	2.2	7.6	2652	3.4
T6	2.0	1.9	7.2	2312	3.1
T7	2.4	2.3	8.0	2712	3.6
T8	2.2	2.0	8.7	2507	3.2
T9	2.3	2.1	8.7	2652	3.4

Table I-2 : Effect of different Kodo : mixture ratio on yield component

Treatment	No. of tiller /Branches	No. of ears	Weight of ears(g)	No. of seeds ears	Weight of 1000/100 g seeds(gm)
T1	2.4	2.0	6.8	981	5.50
T2	0.3	0.1	7.2	869	4.82
T3	4.0	3.4	7.7	1010	5.93
T4	2.4	2.0	6.7	981	5.50
T5	4.4	3.8	8.8	1081	6.41
T6	4.0	3.4	7.5	1040	5.91
T7	5.3	4.3	9.5	1120	6.67
T8	4.4	3.8	9.0	1081	6.20
T9	4.0	3.4	8.4	1040	5.91

APPENDIX –J

Table J-1 : Tractor wheel slippage for Seed-cum-seed drill for field no.1

Sr. No.	Expected dist covered by tractor wheel at no load. (m)	Observed dist covered by tractor wheel at load (m)	Wheel slip %	Average %
1	25	23	8.1	8.2
2	25	23.2	8.3	
3	25	23.3	8.2	
4	25	23	8.0	
5	25	23.1	8.1	

Table J-2 :Tractor Tractor wheel slippage for Seed-cum-seed drill for field no.2

Sr. No.	Expected dist covered by tractor wheel at no load. (m)	Observed dist covered by tractor wheel at load (m)	Wheel slip %	Average %
1	27.40	25. 40	7.8	7.9
2	27.40	25.38	7.6	
3	27.40	25.39	7.9	
4	27.40	25.40	7.8	
5	27.40	25.38	7.6	

APPENDIX –K

Table K-1: Data pertaining to the field test of Automatic seed drill field no.1

Sr No.	Distance , m	Time , sec	Speed, km/h
1	25	30.0	2.81
2	25	30.49	2.80
3	25	30.51	2.81
4	25	30.50	2.79
5	25	30.49	2.80
Average	25		2.80

Table K-2: Data pertaining to the field test of Automatic seed drill field no.2

Sr No.	Distance ,m	Time , sec	Speed, km/h
1	27.40	35.0	2.90
2	27.40	34.50	2.88
3	27.40	34.56	2.90
4	27.40	35.03	2.90
5	27.40	34.50	2.88
Average	27.40		2.90

APPENDIX -L

Energy calculations

Human energy = Time required (h ha-1) × energy equivalent

life Useful hours working Annual (h/ha) required Time (kg) implement the of Weight

energy Implement □ □ □

Diesel energy = Amount of diesel consumed (l ha-1) × energy equivalent

Electric energy = Electric energy input × energy equivalent × working hours

Energy equivalents of energy sources

Particular	Units	Equivalent energy ,MJ
A. Input		
1 human labour	Man –hour	1.96
2 women	Woman- hour	1.57
3 diesels	Litre	56.31
4. Electricity	Kwh	11.93
Machinery	Kg	
a.Electric motor	Kg	64.80
b. Prime mover (self propelled)		68.40
c.Farm Machinery		62.70
d. Chemical fertilizer		
Nitrogen		60.60
P2o5		11.10
K20		6.70
B . output		
1 . main product(Grain)	Kg (dry mass)	14.70
2. main product(pulse)	Kg (dry mass)	14.70
3. main product(oilseed)	Kg (dry mass)	25.0
4. by product	Kg (dry mass)	12.50

APPENDIX-M

Table M -1 : Field performance results of tractor drawn cultivator

Sr. No.	Parameter	Value *Ragi*	Value *Kodo*
1	Actual area covered, m2	685	602
2	Effective working width ,m	2.00	2.00
3	Teverlling speed km/h	4.5	4.5
4	Thoertical field capacity ha/h	0.9	0.9
5	Field Efficiency ,%	76%	76%
6	Wheel slip of tractor ,%	8.2	8.2
7	Fuel consumption ,lit/h	4.08	4.08
8	Cost of operation , Rs/h	480	480
9	Energy Requirement , MJ/ha	1285	1285

APPENDIX-N

Table N-1: Field performance results of tractor drawn rotavator

Sr. No.	Particular	Specification For crop	
		Ragi	***Kodo***
1	Area and shape of field ,m^2	685	602
2	Last crop in the field		
3	Height of stubbles of last crop, cm	**8-10**	**8-10**
4	Depth of operation, mm	**15**	**15**
5	Soil moisture condition, % (wb)	**16-18**	**16-18**
6	Penetrometer profile, mm	**100**	**100**
7	Cone index, kg/cm2, before/after	**7.2-10.8/3.7-5.6**	**7.2-10.8/3.7-5.6**
8	MMD before/after operation, mm	**39.5/11.6**	**39.5/11.6**
9	Speed of operation, km/h	**1.8**	**1.8**
10	Fuel consumption, l/h	**4.2**	**4.2**
11	Field efficiency, %	**60**	**60**
12	Cost of operation Rs/h	**520**	**520**
13	Energy Requirement MJ / ha	**210**	**210**

APPENDIX-O

Table O-1 : Plant height (cm) of *Ragi* and *Kodo* under broadcasting method at various growth stages.

Crop	15 days	30 days	60 days	90 days	At harvest
Ragi	10.2	15.7	41.1	62.2	89.5
Kodo	10.5	20.1	38.9	67.6	90.1

Table N-2 : Yield Attributes of *Ragi* and *Kodo* under broadcasting method

Crop	No. of tillers/ branches	No. of ears/ plant	Weight of ear, gm	No. of seeds / ears	Weight of 1000 seeds (gm)
Ragi	2.4	2.1	4.0	1050	3.87
Kodo	1.8	1.6	3.7	571	5. 50

APPENDIX-P

Table no P-1 : Total output energy of *Ragi* and *Kodo* crop

Sr. No.	**treatment**	**Ragi crop(MJ/ha)**	**Kodo crop(MJ/ha)**
1	T1	50.87	14.08
2	T2	56.54	2.67
3	T3	53.81	26.81
4	T4	48.95	14.09
5	T5	59.25	30.24
6	T6	56.54	26.81
7	T7	66.38	33.04
8	T8	56.97	30.24
9	T9	63.66	26.81

Table no P-2 : Energy ratio and specific energy of the *Ragi* and *Kodo* crop

Sr. No.	Treatment	Ragi		Kodo	
		Energy ratio	specific energy	Energy ratio	specific energy
1	T1	6.49	3.73	2.85	12.99
2	T2	7.21	3.26	0.54	61.70
3	T3	6.86	3.40	5.43	6.41
4	T4	5.98	3.91	2.85	12.99
5	T5	7.55	3.13	6.12	5.80
6	T6	7.21	3.26	5.43	6.41
7	T7	8.46	2.70	6.69	5.30
8	T8	7.26	3.01	6.12	5.80
9	T9	8.12	2.79	5.43	6.41

Table no P-3 : Energy ratio and specific energy of the *Kodo* and *Ragi* crop for broadcasting method

Sr. no.	Crop	Grain product (MJ /ha)	Straw product (MJ/ha)	Total energy (MJ/ha)	Energy ratio	specific energy MJ/kg
1	Ragi	9261	5125	14386	2.13	10.71
2	Kodo	4557	5375	9932	2.64	12.10

APPENDIX-Q

Cost of operation

A) Cost of operation of tractor

Purchase cost (Rs) = 5, 00,000

Useful life (hrs) = 1000

Years = 10

Salvage value, (10 % of capital) = Rs 50,000 /-

1. Fixed cost (Rs/h)

Depreciation = $\frac{500000 - 50000}{10}$ = Rs 45000

Interest (12 % of initial investment)

= $\frac{500000 - 50000}{2} \times 0.12$ = 32,700

Insurance and taxes (@ 2 % of capital cost)

= 0.02 x 5, 00,000 = Rs 10000 /-

Housing cost (1.5 % of capital cost)

= 0.015 x 5, 00,000 = Rs 7500 /-

Total fixed cost = 45,000 +32,700 +7500 +7500

= Rs 95,200/-

Hours of use per year = 1000

Fixed cost of operation per hour = $\frac{95,200}{1000}$ = 95.2

2. Variable cost

Repair and maintenance cost (8 % of capital investment)

== $\frac{5,00,000 \times 8}{100 \times 1000}$ = Rs 40 /-

Fuel cost (Taking fuel consumption = 4.5 lit/h diesel @ Rs 63 per lit.)

Fuel cost (Rs/ha) = 3.5 x 63 =s Rs 283.5 /-

Lubricant cost (Taking 10 % of fuel cost.)

= 283.5 x 0.10 = Rs 28.35/-

Wages of driver/h (Wages @ Rs 200/day of 8 hours)

= $\frac{200}{8}$ = Rs25 /-

Total variable cost (Rs/h)

= 40+ 283.5 + 28.35+ 25

= Rs 376.85

Total operating cost (Rs/h)

= Fixed cost + Variable cost

= 95.2 + 376.8

= Rs 472.05/-

B. Cost of operation of tractor operated seed cum fertilizer drill

Initial cost = Rs 40200 /-

Useful life (hrs) = 100

Years = 10

Salvage value, (10 % of capital) = Rs 4020 /-

Depreciation = $\frac{40,200-4020}{10}$ =Rs 3618 /-

Interest (12 % of initial investment)

= $\frac{40,200+4020}{2}$ x 0.12 =Rs 2653 /-

Insurance and taxes (@ 2 % of capital cost)

= 0.02 x 40200 = Rs 804 /-

Housing cost (1.5 % of capital cost)

= 0.015 x 40200 = Rs 603 /-

Repair and maintenance (8 % of capital cost)

= 0.08 x 40200 = Rs 3216 /-

Total fixed cost = 3618 +2653.2 + 804 +630 + 3216

= Rs 10894.2/-

Hours of use per year = 100

Fixed cost of operation per hour = = Rs 108.21 100 10894

Cost of cultivation with tractor per hour (Rs/h)

= Cost of operation of tractor + Cost of cultivation

= 396.5 + 108.21

= Rs 580.992 /-

Cost of operation (Rs/ha) = $\frac{Cost\ of\ opertion\ \ Rs/h}{Actual\ \ field\ capacity\ \ ha/h}$

= $\frac{580.92}{0.58}$

= Rs 1001.71

RESUME

Name : Meena Kanwar

Date of birth : 24/08/1985

Present Address : W.R.S.Colony Q.No.214/6 Raipur,
Raipur (C.G.) 492009

Phone : 09009886186

E-Mail : Kanwarmeena024@gmail.com

Permanent Address : Vill.- Basin , Tah. Shakti
P.O.- Sandri, Dist. Janjgir Champa (C.G.)

Academic Qualification :

Degree	Year	Institution/University
High School	2001	M.P.Borad
Higher Secondary	2004	M.P.Borad
B.Tech. (Agril. Engg)	2012	JNKVV. Jabalpur
M.Tech. (Agril. Engg)	2015	IGKV Raipur

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Signature