DESIGN AND DEVELOPMENT OF SINGLE ROW POWER WEEDER FOR RICE

M. Tech. (Agril. Engg.) Thesis

by

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DESIGN AND DEVELOPMENT OF SINGLE ROW POWER WEEDER FOR RICE

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Aditya Sirmour

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CERTIFICATE – I

This is to certify that the thesis entitled "**Design and development of single row power weeder for rice**" submitted in partial fulfilment of the requirements of the degree of **Master of Technology in Agricultural Engineering** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is a record of the bonafide research work carried out by **Er.Aditya Sirmour** under my guidance and supervision. The subject of the thesis has been approved by the Students Advisory Committee and the Director of Instruction

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.

Chairman

Date: 21/07/16

(Dr. Ajay Verma)

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

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CERTIFICATE – II

This is to certify that the thesis entitled "**Design and development of single row power weeder for rice**" submitted by **Er. Aditya Sirmour** to the Indira GandhiKrishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirements for the degree of **Master of Technology in Agricultural Engineering** in the Department of **Farm Machinery and Power Engineering** has been approved by the external examiner and Student's Advisory Committee after oral examination.

Date: 25/08/16

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Director of Instructions ______________________

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(Aditya Sirmour)

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LIST OF SYMBOLS

%	Percentage
^{O}C	Degree Celsium
Rs	Indian Rupees
a.i.	Active ingredient
Cc	Cubic centimetre
Db	Dry basis
Fed	Feddan (Egyptian unit for area)
Fig.	Figure
H	Hour
Ha	Hectare
ha/h	Hectare per hour
ha/day	Hectare per day
Hp	Horse Power
Kg	Kilogram
kg/h	Kilogram per hour
kg/ha	Kilogram per hectare
Km	Kilometer
km/h	Kilometer per hour
kN	Kilo Newton
L	Litre
l/h	Litre per hour
Mm	Millimeter
m^2	Meter square
MJ/ha	Mega Joule per hectare
m/sec	Meter per second
N	Namibian Dollar
No.	Number
US$	US Dollars
T	Ton
q/ha	Quintal per hectare

LIST OF ABBREVIATIONS

AICRP	All India Co-ordinated Research Project
ANOVA	Analysis of Variance
C.G.	Chhattisgarh
DAS	Day after sowing
et al	Et alibi
FAE	Faculty of Agricultural Engineering
IGKV	Indira Gandhi Krishi Vivshwavidyalaya
ICMR	Institute of Medical Research
viz.,	Namely

THESIS ABSTRACT

a) Title of the Thesis:	Design and development of single row power weeder for rice
b) Full Name of the Student:	Aditya Sirmour
c) Major Subject:	Farm Machinery and Power Engineering.
d) Name and Address of the Major Advisor :	Dr. Ajay Verma
e) Degree to be awarded:	Master of Technology in Agricultural Engineering

Signature of Major Advisor

Aditya

Signature of the Student

Date: 25/8/16

25/8

Signature of Head of the Department

ABSTRACT

Weed control is one of the most difficult tasks on an agricultural farm. Three methods of weed control are commonly known in agriculture. These are mechanical, chemical and biological control. Mechanical weed control is easily adopted by farmers once they get convinced of its advantages. Mechanical weed control not only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity. Weeding by mechanical devices reduces the cost of labour and also saves time.

Various types of mechanical weeders have been developed. In human operated weeders, muscle power is required and so it cannot be operated for long time. The traditional method of hand weeding is time consuming. In order to assess the possibility of mechanization of the weeding operation, the power operated single row active weeder are to be designed and developed in the workshop of Swami Vivekananda College of Agricultural Engineering and Technology and Research Station, Faculty of Agricultural Engineering, IGKV, Raipur. The

x

developed weeder should have the following features: 2.0 hp, 2-stroke petrol engine. It is compact light low weight equipment, self propelled with durable floating system. It is centrally driven with worm gear box for transmission. The working width of the developed machine could be adjusted between 140 mm to 250 mm. It is equipped with rotating blades with 176 rpm and is centrally driven. Due to compactness and low weight it is easily maneuverable. Different types of blades were designed (4 blade, 6 blade and 8 blade). The power transmission from the engine to the blade was done by means of a flexible shaft. The shaft dimensions were designed for the adequate strength by using standard formulae for torque and power transmission.

The developed power weeder was tested in the line sown paddy crop at different conditions and ergonomically evaluated. Highest working speed of operation was found as 0.69 m/sec by using 4 blades in power weeder followed by 0.61 m/sec on using of 6 blades at 15 DAS. The lowest fuel consumption was found in using of four blade in power weeder as 0.55 l/h while the maximum fuel consumption was found on using of 8 blades as 0.71 l/h. The maximum field capacity was found with 4 blade (0.054 ha/h) followed by 6 blade (0.048 ha/h) at 15 DAS. The weeding efficiency was observed as 88.62 % under single row active power weeder with using of 6 blade in a flange followed by 4 blade 82.92% at 35 DAS and 82.10% for ambika paddy weeder.

The cardiac cost involved in the operation of power paddy weeder was found out and the mean working heart rate value of the subject was 108 beats min-1. The energy expended during operation of a power paddy weeder was 19.50 kJ min^{-1}. The oxygen uptake in terms of VO2 max was 46% which was above the acceptable limit of 35% of VO2 max. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 3.0 and scaled as "light discomfort". More tillers have been produced after using this equipment and soil aeration and root growth was improved. It is comfortable to operate this machine. If only one worker is engaged for the weeding operation with this equipment, 7 min rest could be provided after operating the equipment continuously for the 30 min period.

शोध सारांश

शोध शीर्षक	धान के लिए एकल पंक्ति निराई मशीन की डिजाइन एंव निर्माण
छात्र का नाम	आदित्य सिरमौर
मुख्य विषय	कृषि यंत्र एवं शक्ति अभियांत्रिकी
मुख्य सलाहकार का नाम व पता	डॉ. अजय वर्मा
उपाधि का नाम	एम.टेक. (कृषि अभियांत्रिकी)

Aditya

मुख्य सलाहकार के हस्ताक्षर

छात्र का हस्ताक्षर

दिनांक 25/08/16

25/8

विभागाध्यक्ष के हस्ताक्षर

सारांश

खरपतवार नियंत्रण एक कृषि फार्म पर सबसे कठिन कार्यो मे से एक है। खरपतवार नियंत्रण के तीन तरीके आमतौर पर कृषि के क्षेत्र में जाना जाता है। यांत्रिकीय, रासायनिक और जैविक के द्वारा खरपतवार नियंत्रण करते है। यांत्रिकीय खरपतवार नियंत्रण आसानी से किसानों द्वारा अपनाई गई है क्योंकि इससे किसानों को अधिक लाभ प्राप्त होती है। यांत्रिक खरपतवार न केवल फसल पंक्तीयों के खरपतवार को उखाडता है साथ ही साथ मिट्टी की सतह को भी ठिला करता है और पानी की सेवन क्षमता को सुनिश्ति करता है। यांत्रिकीय उपकरणों के द्वारा निराई श्रम की लागत में कमि आती है और समय की भी बचत होती है।

विभिन्न प्रकार के यांत्रिक वीडर उपलब्ध है हाथ चलित वीडर में ज्यादा शक्ति लगने के कारण उससे ज्यादा देर कार्य नही किया जा सकता है। इन सब समस्याओं को देखते हुए एकल पंक्ति निराई मशीन धान के लिए स्वामी विवेकानंद कृषि अभियंत्रिकीय महाविधालय एंव अनुसंधान संस्थान रायपुर में बनाई गई है। बनाई गई वीडर में निम्न प्रकार की तकनीकि गुण – 2 हार्सपावर, 2 स्टोक पेटोल इंजन एंव इसकी वजन बहुत ही हल्का है। पानी में तैरने के लिए इसके निचे के हिस्से मे फलोट लगाई गई है। विकसीत मशीन की काम चौडाई 140 मिमी से 250 मिमी समायोजित किया गया है। यह 170 आरपीएम के साथ घूर्णन ब्लेड के साथ सुसज्जित है और केन्द्र संचालित है। ब्लेड के लिए इंजन से शक्ति स्थांतरित एक लचिले शाप्ट के माध्यम से होता है। शाप्ट के आकार के लिए मानक सुत्र का उपयोग करके प्रर्याप्त शक्ति में डिजाइन किया गया है। ब्लेड के विभिन्न प्रकार के डिजाइन किये गये थे– 4 ब्लेड, 6 ब्लेड, 8 ब्लेड,।

इंजन एंव इसकी वजन बहुत ही हल्का है। पानी में तैरने के लिए इसके निचे के हिस्से में फलोट लगाई गई है। विकसीत म ीन की काम चौडाई 140 मिमी से 250 मिमी समायोजित किया गया है। यह 170 आरपीएम के साथ घूर्णन ब्लेड के साथ सुसज्जित है और केन्द्र संचालित है। ब्लेड के लिए इंजन से भाक्ति स्थांतरित एक लचिले भााप्ट के माध्यम से होता है। भााप्ट के आकार के लिए मानक सुत्र का उपयोग करके प्रर्याप्त भाक्ति में डिजाइन किया गया है। ब्लेड के विभिन्न प्रकार के डिजाइन किये गये थे– 4 ब्लेड, 6 ब्लेड, 8 ब्लेड,।

विकसीत भाक्ति वीडर को अलग–अलग परिस्थितियों में लाइन बोया धान के फसल में परिक्षण किया गया। जिसके अनुसार उसकी अधिकतम गति 2.4 किमी प्रति घण्टा और औसत इंधन खपत 0.55 लीटर प्रति घण्टा ज्ञात की गई। इसकी औसत कार्य क्षमता 0.05 हेक्टेयर प्रति घण्टा और खरपतवार नियंत्रण दक्षता सबसे अधिक 6 ब्लेड 88.62 प्रति ात ज्ञात की गई। इस म ीन को एक व्यक्ति बिना किसी थकावट के 25 मीनट चंलाता है।

CHAPTER- I
INTRODUCTION

Weed control is one of the most difficult tasks in agriculture that accounts for a considerable share of the cost involved in agriculture production. Farmers generally expressed their concern for the effective weed control measures to arrest the growth and propagation of weeds. In Indian agriculture, it’s a very difficult task to weed out unwanted plants manually as well as using bullock operated equipments which may further lead to damage of main crops. More than 33 percent of the cost incurred in cultivation is diverted to weeding operations there by reducing the profit share of farmers. A weed is essentially any plant which grows where it is unwanted. A weed can be thought of as any plant growing in the wrong place at the wrong time and doing more harm than good (Parish, 1990). It is a plant that competes with crops for water, nutrients and light. This can reduce crop production. Some weeds have beneficial uses but not usually when they are growing among crops. Weeds decrease the value of land, particularly perennial weeds which tend to accumulate on long fallows; increase cost of cleaning and drying crops. Weeds waste excessive proportions of farmers’ time, thereby acting as a brake on development (Lavabre, 1991).

Weeding is an important but equally labour intensive agricultural unit operation. Today the agricultural sector requires non-chemical weed control that ensures food safety. Consumers demand high quality food products and pay special attention to food safety. Through the technical development of mechanisms for physical weed control, it might be possible to control weeds in a way that meets consumer and environmental demands.

In Chhattisgarh, rice occupies average of 3.6 million ha with the productivity of the state ranging between 1.2 to 1.6 t/ha depending upon the rainfall. The state is comprised with three agro-ecological zones i.e. Chhattisgarh plain, bastar plateau and northern hill region of surguja. These zones have huge variations in terms of soil topography, rainfall intensity and distribution, irrigation and adoption of agricultural production system and thus vary in the productivity of rice in these regions. In view of topographical structure prevailed in this part of the country, 20-30% of the rice is grown in low lying areas (Kanhar soil).

The rice is cultivated in different field situations from upland to extreme lowland. The area under upper midland is about 25 per cent of total rice area. The weed in upland rice comes up more easily and vigorously than in low land rice. The weed control in these conditions is complicated. Rainfed upland rice is grown in an area of 7.1 million hectare in India. A major portion of it 85 percent is an eastern states like Assam, Chhattisgarh, Madhya Pradesh, eastern UP ,West Bengal and Orissa. The remaining 15 percent is distributed in other states.

The crop weed competition is greater in direct seeded line sowing of rice because the crop and weed seeds germinate simultaneously and they start competing with each other for air, water, sunlight and nutrients. In this method of cultivation, it becomes difficult to keep the surface submerged throughout the crop growth period and hence it becomes favours for germination and growth of weeds.

In Chhattisgarh, women labours played a significant role in the rice cultivation (Marothia and Sharma 1985). They use a variety of hand tools and implements to perform various tasks in crop production process. The time has come when the tractor is also being operated by Indian women. Weeding is one of the most important field operations and consumes 15 per cent of total energy spent in crop production.

With the advent of mechanization and the adoption of high yielding varieties interest in mechanical weeders is seen among the farmers. Mechanical weed control reduces the drudgery involved in uprooting of the weeds. Moreover mechanical weeders besides killing the weeds loosen the soil between rows thus increasing air and water intake capacity. But this method of weed control has received much less scientific attention compared to the other methods. As a result traditional tools, implements and methods are still used by majority of the farmers for weed control.

1.1 Justification

The first distinction to define a mechanical weeder can be about the power source, so we may have manually or engine powered weeders. This feature has different implications:

1. It can influence the operational speed, i.e. an engine powered is usually

much faster than a manual one. The speed has and indirect effect over the pulverization of the soil. Engine powered implements pulverize it more than the manual ones. Though, pulverization of the soil is not the main function, because a weeder works at a shallow depth.

2. The engine-powered implements have a strong, direct impact over operational drudgery, saving its operator (or more than one) from an otherwise very tiring process, necessary when manual tools are involved. Even if not faster than the manual counterpart, saving on human labours is one of the critical features in adopting a powered machine.
3. It increases the relative importance of skills and competences in using the weeder. Power weeders are one step towards the standardization of practices, e.g. it has a fixed max rotational speed, fixed direction of movement, and it goes from one side of the field to another. Conversely, manual weeders still rely heavily on the characteristics of the operator(s), which cannot obviously be standardized. It is affecting speed, direction of movement, and the movement needed to operate a weeder, e.g. back and forth or constant push.

In single hand weeding the labour requirement is as high as 300 to 1200 man hr/ha. Availability of required number of labours during peak season of the year is a problem. Most of the farmers adopt hand weeding for control of weeds. Hand weeding has been found effective but it is expensive, laborious and time consuming, therefore the mechanical weed control is best. Most of the weeding equipments are indigenous developed and their dimensions and shapes are left to the skill and imagination of the local artisans. However in recent years, efforts were made to standardize these implements and to improve their design, incorporating ergonomic principal, which are expected to enhance the work output and workers efficiency, keeping in view her comfort and welfare.

Ergonomic dimensions corresponds best to the orientation of the designed hardware which are registered in different positions and postures that simulate the real working posture and positions in a conventional form. Hence to achieve the better efficiency, human comfort and safety, it is necessary to design the equipment keeping in view the operation capability and limitations.

1.2 Present Study

In Chhattisgarh, rice is grown by different methods, broadcasting, *biasi*, drilled or line sowing, *lehi* and transplanting depending upon the type of soil, topography of land, availability of water and labours. In order to increase the productivity of direct seeded rice in state, effort have been made through line sowing systems of cultivation, which not only maintain plant population but also offers additive advantages, such as intercultural operations, proper weed control and basal application of fertilizers.

The weed control operations are mainly done by three methods such as *biasi* operation, hand weeding and using of herbicides. In *biasi* operation, weeds are removed by using an indigenous plough after 35-40 DAS. By hand weeding, weeds are removed by hand which is more effective but it is expensive, labour intensive as well as time consuming. Nowadays herbicide usage is increasing. In view point of labour shortage circumstances; it is preferred as a quick and effective weed control method without damaging the rice plants. But, it has adverse effects on human health and environment.

In order to assess the possibility of mechanization of the weeding operation, the power operated single row active weeder are proposed to be designed and developed considering the optimum shape, size and location of cutting blades, evaluation of its performance with other weeding methods in field conditions, optimisation of dimensions of machine for better performance. The main objective is to design and fabrication of a power weeder, while minimum damages done to rice plants, cost effectiveness, easy manuvelling, low weight and fabrication by using freely available components and easy maintenance are main features of this design. Here comes the relevance of mechanised weeding, which is not a huge time consuming and significantly improves weeding efficiency as well as the quality of weeding.

The objective of the present study as:

1. To design and develop the single row active power weeder for rice.
2. To evaluate performance of developed machine.
3. Ergonomical evaluation of the developed machine.

CHAPTER-II
REVIEW OF LITERATURE

This chapter deals with the previous research work carried out by different researchers. The review of research information related to the present study has been arranged under the following headings.

2.1. General:

2.1.1 Weeds:

Weeds are nothing but those unwanted plants which are grow with the crop and they compete with the growing crop for light, nutrients and water. For the controlling of weed it is essential to know about the weeds for the experimental study to fulfil the purpose of design and development of women friendly weeder.

Smith(1964) stated that inter cultivation is an operation that required some kind of tool that stir the surface of the soil to a shallow depth in such a manner that young weeds could be destroyed and crop growth promoted. The primary objectives sought in cultivation of crop are:

1. Retain moisture by
    a. killing weeds
    b. loose mulching on surface
    c. Retaining rainfall
2. Develop plant food
3. Aerate the soil to allow oxygen to penetrate soil.
4. Promote activity of microorganism.

Agrawal and Singh (1968) listed the common weeds of agricultural land with their scientific and common names.

Biswas(1984) reviewed and reported about weeds in Bhopal region. Weeds classified in different ways as per their place of occurrence or habitat, duration of life cycle, plant family etc. As per the occurrence weeds may be classified in two broad group

1. Upland weeds
2. Aquatic weed

Upland weeds may further be classified as:

a) Weeds of agricultural land
b) Weeds of Pasteur land
c) Forests weeds
d) Weeds of wasteland etc.

The aquatic weeds may be classified as:

a) Fresh water weeds
b) Marine water weeds

As per the life cycle, weeds may be classified as:

a) Annual weeds
b) Biennial weeds
c) Perennial weeds

Devnani (1988) and Singh *et al.,* (1996) reported that the aim of inter cultivation is to provide best opportunity for the crop to established and grow vigorously, up to the time of harvest. The purpose of inter cultivation is to control the weed growth, improve the soil conditions by reducing evaporation from the soil surface, improve infiltration of rain or surface water, and to maintain ridges or beds on which the crop is grown. The control of weed is major objective as they compete with the crop for light, nutrient and water. Most of the work on weeding therefore emphasizes the need for timeliness of weeding operation. This underlines the need for farmers to have operation control over power and machinery. Since timeliness in weeding is virtually impossible to achieve if one is to rely on the traditional manually operated hand tools such as hand hoe, khurpi or khurpa and family labours.

2.1.2 Weed flora distribution:

Vega *et al*., (1985) recorded that Echinochloa crusgalli, Echinochloa colonum cyperus iria, commelina Benghalensis and Digtaria sauguinalis are the predominant weeds in rice fields.

Shelk *et al*., (1986) observed the weed flora in upland comprised of Acalypha indica, Binebra retroflexa, Corchonus aestuans, Digera arvensis, Cnodon dactylon, Alysicarpus regesus, Abutilon indicum and Cyperus rotundus.

Fischer *et al*., (1993) revelead that Eleusine indica, Echinochloa crus-galli, Echinochloa colonum, cyperus difformis, cyperus esculenthus, Cyperus iria and Eclipta alba were the main weed species present in direct seeded rice. Echinocloa crus galli and Eclipta alba were the major weeds which were widely distributed.

Huh *et al*., (1995) revealed that dominant weed species in dry seeded rice, in decending order of importance were linderia procumbens, cyperus difformis, cardemine, flexuosa, cyperus serotinus. The most dominant weeds present until the late stage of growth were cyperus difformis, Bidens frondosa and Digetaria ciliaris.

B.T.S.Moorthy (2004) Reported about the problem of weeds in upland rice and gives the weeds and their groups are:

1. Grasses.
2. Sedges.
3. Broad leaf weeds.

Further it gives the common species in above groups are:

Grasses: In grasses, Jungle rice or owned barnyard grass Echinochlora colona (L.) link; Common barnyard grass or small barnyard grass E.crus-galli (L.) Beauv; Goose grass Eleusine indica (L.) Gaerth; Bermuda grass cynodon dactylon(L.)Pers; Large crab grass Digitaria sang wina(L.);Crow foot grass Dactyloctenium aegyptium (L.) Wild; Yellow foxtail Setaria glauca Intermedia Roem and schult.

Sedges: Purple nut sedge Cyperus rotundus L; Rice sedge cyperus iria L.

Broad leaf weeds: Bristly starbur Acanthopermum hispidum DC; Spiny pig weed Amaranthus spinosus L; Goat weed Ageratum conyzoides L; Dog weed cleome viscosa L; white cock‟s comb Celosia argentea L; Euphorbia hirta L; Gripe weed phyllanthus niruri L; Day flower Commenlina benghalensis L; Wet land amaranth Alteranthera sessilis (L).

2.2. Timeliness in weeding

Duff and Oricno (1971) reported that the timing rather than the frequency of weeding was a major determinant of effective weed control for rice. Recommendations have been made for the first weeding to be done 2-3 weeks after sowing , followed by a second weeding three weeks later and if necessary a third one.

Igbeka (1984) indicated that the timing rather than the frequency of weeding was a major determinant of effective weed control for rice.

2.3. Loses due to weeds

Smith (1961) reported that the weed competition is a serious problem in almost all rainy seasons' crops causing the losses in yield ranging from 9 to 60 percent or more.

Grist (1976) has reported that the weeds affect the microclimate around the plants harbour diseases and pests, increases the cost of production, plug irrigation and drainage canals and lower the quantity and quality of crop and showed that the competition of one grass plant (Echinocloa crusgalli) per square foot reduced yield of rice by 25 percent.

Moorthy and Manna (1989) Weeds compete severely with upland rice for light, nutrients, moisture and space. The yield losses are colossal ranging from 50-97 per cent.

Tiwary and Singh (1989) recorded an increase in rice yield of 26.5 and 33.9 percent with the removal of grassy and broad leaf weeds.

Chandrakar and Chandrakar (1992) reported that the weeds compete severely for nutrients and depending upon the intensity of weed growth, deletion of nutrients may be up to 86.5kg N, 12.4kg P and 134.5 kg K per ha.

Moorthy (1996) reported that the percent yield losses due to weed competition for the first one month, two month and entire crop season were 23.7, 35.4 and 40.8 respectively.

Chauhan *et al.*, (2014) has reported that, in Asian countries, weedy rice, the unwanted plants of *Oryza sativa* competing with cultivated rice and these plants produce stained grains reduce rice yield from 16% to 74%.

2.4. Methods of weed control:

Weed control is the process of limiting weed infestation so that crops could be growth profitably and other activities of man conducted efficiently. Researchers with varied degree of success have tried many methods of weed control. Knowing the several of weed control and applying some of them systematically, based on the requirements and the situations, the problem of weeds in the agricultural farm may be kept under control.

Agrawal and Singh (1968) study the important methods of weed control.

Biswas (1984) gave the detailed account of various important weed control methods. The study describe the of methods weed control.

2.4.1 Chemical control of weed:

Chemical control of weeds is becoming popular day by day in the developing countries.

Singh and Reddy (1981) reported that the pre emergence of butaclor produced the grain yield equal to that of two hand weddings, which was maximum among all the other weed control treatments tested.

Fagade (1980) reported that the cost of herbicide application for weed control was half than that of hand weeding.

Singh *et al*., (1982) found that the highest net return was obtained with two weedings at 15 and 30 DAS of rice. When herbicide application was combined with one hand weeding, the highest net return was obtained with thiobencarb at 2 kg a.i./ha followed by butachlor at 2 kg a.i./ha and thiobencarb at 1.5 kg a.i./ha each combined with one hand weeding at 45 DAS.

Biswas (1984) though the advanced countries have mostly switched over to chemical control. The use of chemicals in for weed control has been quite low in India. However, a large number of herbicides are now available to control different types of weeds in rice crop. The reasons for limited use herbicides in India have been high cost herbicides, lack of knowledge on the available herbicides and their most of actions. Effective chemical control weed required different herbicides and management practices in various systems of rice cultivation. The work done on some of the important herbicides are presented herewith.

Ramamoorthy and Balasubramanian (1991) conducted a field experiment on a clay loam during the monsoon season to develop an economic integrated weed control method for upland direct seeded rice. The treatments comprised pre-emergence Pendimethlin (0.75 and 1.25 kg/ha), pre emergence Thiobencarb (1.0 and 1.5 kg/ha), hand weeding and mechanical weeding using a rotary weeder, alone and in combination. The major weeds were *Echinochloa colona* (E. colonum), *Eclipta prostrata* and *Cyperus rotundus*. Weed dry matter 80 days after sowing (DAS) was the lowest with the pendimethaline + hand weeding 30 DAS treatment (45.6 kg/ha), followed by thiobencarb + hand weeding 30 DAS treatment (58.2 kg/ha) and hand weeding 20, 35 and 50 DAS (75.0 kg). Net returns and grain yields were highest for the pendimethaline + hand weeding 30 DAS treatment (6539 Rs./ha and 4.6 t/ha respectively), followed by thiobencarb + hand weeding 30 DAS (Rs.61917 and 4.3 tonnes respectively) and thiobencarb + hand weeding 30 and 50 DAS (Rs.57057 and 4.2 t respectively).

2.4.2 Cultural methods of weed control

Hand weeding is very popular in rice and vegetable crops. In this method the weeds are uprooted by the hands.

Datta *et al.,* (1974) reported that the weeding is traditionally carried out with indigenous hand tools. These involve considerable time and labours.

Patel and Pandey (1983) reported that the hand weeding treatment was superior to chemical method of weed control in direct seeded up land rice.

Venugopal *et al.,* (1983) observed that weed competition was more under broadcast situation. Hand weeding gave the highest weed control efficiency (89.74%) and higher grain yield (63.55 qt/ha) compared to the herbicidal treatments.

Ghosh and Singh (1985) found that the hand weeding twice, one at 15 days and other at 30 days gave the highest weed control efficiency and the maximum grain yield.

2.4.3 Mechanical weed control

Biswas (1984) reported that the control of weeds is oldest far method of weed control though it received less scientific attention us compared to the other methods of weed control. The mechanical weed control methods are extensively used and shall be used in many developing countries including India because agricultural labours in these countries are cheap and easily available. Mechanical methods of weed control are simple and easily understood by farmers. The tools and implements for mechanical weed control are mostly manual and animal operated. Mechanical control of weeds involves use of weeders operated by human labours, animal drawn or tractor drawn weeders, self propelled weeders or power weeders.

Hand tools

Datta *et al* (1974) reported that the weeding is traditionally carried out with indigenous hand tools. These involve considerable time and labours.

Weeders

A mechanical device to remove the weeds from an agricultural land is known as weeder. A weeder may be manual or animal drawn and tractor mounted or power operated.

Considering the importance of the problem of weeding, the Regional Network for Agricultural Machinery (RNAM) of ECAP initiated a sub network activity on testing, evaluation and adoption of weeders during 1978. In the first workshop of RNAM in 1979. The available weeder in the participating countries namely India, Indonesia, Peoples Republic of Korea, Philippines, Shrilanka and Thailand were selected for testing and evaluation.

2.4.3.1 Types of weeders:

Biswas (1984) according to the power sources of weeder, they classified as follows :

1. Manual weeders
    a) Small tools or aids
    b) Chopping hoes
    c) Pull type hoes
    d) Push type weeder
    e) Push – pull weeder

2. Animal drawn weeders
    a) Hoes with triangular and straight blades
    b) Cultivators with shovels, sweeps and duck foot sweeps
    c) Animal drawn rotary weeders
    d) Hoes with rotary tines

3. Power operated weeders (self propelled weeders)

2.4.3.1.1 Manual weeders

These are various types of weeders which can be used for mechanical weeding in line sown rice. Manual and bullock mechanical weeder are friendly to environment, reduced time requirements, reduces human effort, manipulate the crop root zone reducing plant mortality, enhance root and shoot growth. The time saved by use of mechanical weeders may be utilized in better care and management of crop gaining higher yield. The mechanical weeders are also reported to be economical than chemicals and other methods Bhardwaj (2004).

Khan and Diesto (1987) reported that development of push type cono weeder which uproots and buries weeds in a single pass without requiring a back forth movement, specially suitable for rice. Manual weeding of rice in one hectare requires on an average of 120 man hrs. The cono weeder is about twice as for as to operate as that conventional rotary weeder.

Mishra and Vishwakarma (1992) have reported that the human labour output was increased by 8-10 times in weeding with developed Ambika paddy weeder. The weeder cuts the weed into small segments and incorporates those into the mud and facilitates recycle of the plant nutrients in the soil and improve the soil fertility.

Moorthy and Das (1992) conducted field trials in sandy loam soil and evaluated effectiveness of 2 types of manually operated implement (the rice wheel hoe and the finger weeder), used either once at 15 days after sowing or twice (15 and 30 days after sowing) and compared with hand weeding once at 15 days and twice at 15 and 30 days for weed control in rice. The rice wheel hoe used twice resulted in the 80% weed control and gave rice grain yield 1.65 t/ha and straw yields 3.54 t/ha. The finger weeder used twice resulted in the weed control 86.7% and grain yields 2.18 t/ha and the rice wheel hoe used twice resulted in straw yields 4.68 t/ha. All weed control treatments increased percentage weed control, grain yields and straw yields from un-weeded control values of 0, 0.18-0.64 t/h and 0.47-1.63 t/h, respectively to 26.7-86.7, 0.5-2.18 t/h and 2.03-4.68 t/h, respectively. The rice wheel hoe used twice resulted in the greatest benefit-cost ratio.

Tewari *et al.,* (1993) concluded that the overall performance of a straight flat blade was the best. The field efficiency was highest, physical damage to crop was the least and weed removal per unit area was the greatest. The average power required by push-pull weeder was 21.3 W.

Mishra *et al.,* (1993) conducted field experiments at ZARS, Ambikapur and found that the line sowing of Dhuria rice and weeding by Ambika paddy weeder gave higher yield and economic return compared to chemical weed control.

Sharma and Gogai (1996) observed that manually operated weeder used twice at 20 and 30 days after emergence controlled the weeds effectively and recorded low weeds.

Ramchandra and Gowda (1998) investigated the effect of different hand weeders for weeding. The weeders tested were *Varvari* (hand hoe), *Varvan cruddali*, long handle blade hoe. Weeding was carried out at 30 DAS and 45 DAS. The varvari was the best for uprooting weeds, but this was found labour intensive. It was concluded that among the long handled weeders, the wheel hoe was the best because it covered more area and loosened soil between rows.

Shiru (2011) reported that, a push-pull type of mechanical manual weeder was designed and fabricated. The weeder consists of main frame / handle, soil cutter (wedge), spikes, wheel bearing, bicycle chain and sprockets. It was quite simple, effective and the result is immediately observed. Tests result shows a weeding index (e) of 74.53%, efficiency of cutting blades 88% and field capacity of 0.02 ha/h. Small scale farmers can take advantage of the improved weeder to control weeds on their farms.

Muhammad and Attanda (2012) developed a hand push mechanical weeder that consists of two set of cone rotor blades, adjustable main frame and a float. The weeder, of effective field capacity of 0.357 ha/h has 64.87 N draft and overall width and depth of cut of 180 mm and 20mm respectively. With a single run of cut in between the rows on the field at a soil moisture content of 40.8%, the optimum weeding efficiency was 84.5% while weeding efficiency at 10.5% soil moisture content was 53.1%. Consequently, the highest plant damage of 8.33% was recorded at the 10.5% soil moisture content. 0.058 hp is the power required by a single person to push the prototype weeder.

Kumar *et al.* (2013) reported that, two types of manual weeder (cono-weeder and *Mandava* weeder) for shallow water conditions was selected and evaluated for different age group of workers (25 to 30, 30 to 35, and 35 to 40 years) at different day timings (T1 = 8.00 to 11.00 AM, T2 = 12.00 to 2.00 PM, and T3 = 4.00 to 6.00 PM). The weeding operations by different age group of workers at different working hours showed that the heart rates corresponding to cono-weeder and *Mandava* weeder was 154.54 beats/min and 140.17 beats/min, respectively. Oxygen consumption rate was 1.76 l/min and 1.47 l/min respectively. Working during 12:00 to 2:00 PM with both weeders developed maximum heart rate and oxygen consumption rate as compared to 8:00 to 11:00 AM and 4:00 to 6:00 PM. The study also reveals that, agricultural workers of 25 to 30 years age group developed maximum working heart rate and oxygen consumption rate during weeding operations, which were higher than the age groups of 30 to 35 years and 35 to 40 years.

Gongotchame *et al.* (2014) studied on participatory approaches to examine the suitability of six mechanical weeders (Ring hoe, Fixed-spike weeder, Curved-spike floating weeder, Twisted-spike floating weeder, Straight-spike weeder and 2-Row spike-and-blade weeder) and ranked and compared them in order of preference with weed management practices. The ring hoe had the highest rank with 97 % farmer‟s preference in the fields of non-ponded water and relatively.

2.4.3.1.2 Animal operated weeder

Yadav (1980) gave details of serrated blade for hoe and harrow, bullock drawn blade cum tine hoe for weeding and intercultural operations in dry land farming. The serrated blade of different size may be fitted in to the traditional blade hoe or blade harrow (bakhar). The serrated blades easily penetrate into the soil and help in moisture conservation.

Murthy *et al.*, (1996) evaluated the performance of a bullock drawn blade hoe for 3 different approach angles (120, 130 and 140 degrees) to determine the most effective angle with respect to implement draught, soil moisture conservation, weeding efficiency and crop (finger millet) yield under dry land conditions. The overall performance of the blade hoe was best with an approach angle of 140 degrees with respect to the formation of ridges and furrows, soil moisture conservation and yield but the draught was significantly higher (19.5 kg).

Biswas *et al.*, (1999) reported that the animal drawn weeder works between crop row spacing, the weeds left over along rows may be removed manually. The straight blades in traditional hoes tend to remove weeds up to the working width of the blades. However, due to clogging of the straight edges, the output is adversely affected. So there is need to study and use improved blades.

Balachand (2006) designed and developed an animal drawn weeder considering the functional requirements and its required strength to bear soil forces acting on it. The performance of Animal weeder having 3 types of blade *viz*. Straight blade, curved blade, and sweep blade was compared with the Ambika paddy weeder and Hand weeding. Weeding by Animal drawn weeder with sweep blade results higher field capacity (0.0759 ha/h), field efficiency (73.87%) and performance index (738.75) then the other two blades.

2.4.3.1.3 Power weeders:

Power weeeders are self propelled walking type machines used for weeding specially in lowland rice.

Zachariah (1967) has reported that tractive tillers are comparatively light in weight. They usually fitted with 4 to 7 hp air cooled petrol or kerosene engine is suitable for both wet and dry land farming.

A hand held mower was designed and fabricated at J.N.K.V.V., Jabalpur. In this model, a small petrol engine was mounted on a portable frame. The petrol engine was similar to the ones, which were used in sprayers and dusters. The knife blade of a 45 cm cutter bar was operated Anonymous (1979).A rotary mower was also designed for cutting grasses, bushes and other weeds with stem. The engine of 35 cc capable of developing 1.7 hp at 6000 rpm was used and a horizontal circular rotary blade was used for cutting.

Yatsuk, *et al*., (1982) has reported about use of miniature rototillers for soil working. Rototillers with small cutting width can also be used for light cultivation and weeding the space between the rows of some crops. Manual weeder with a flexible drive shaft and a portable engine earned on the shoulders is one of the types of miniature rototillers. The depth of soil working is regulated by the forward speed of the tiller : the lower the speed, the reater the depth of soil working. Miniature tillers are widely used in England, Japan and Italy. Pandey (1983) defined the mini power tiller as the smallest types of power tiller fitted with 2 to 4 hp petrol/ kerosene or diesel air cooled engine. It weighs from 60 to 100kg.

Md.Wali Ullah and Kofoed (1987) after testing found that both fuel consumption rate (L/h) and fuel consumption per ha (L/ha) are direct functions of the forward speed and depth of tillage.

Tewari (1987) developed a weeder cum herbicide applicating machine at the Agricultural Engineering department of IIT Kharagpur. It had a ground wheel made of MS tlats with 40 cm diameter having MS rod spokes, and a wheel guide extended rearwardly and fixed to a main platform made of angle iron having slots to attach different weeding blades. The unit could be used bothas a mechanical weeder and a herbicide applicator. To enable the machine work as a weeder it could be conveniently attached with various weeding range blades- flat inclined, flat inclined with serrated edges, four time double and the improved double blade. The applicator mechanism consisted of feed tank, dripping mechanism and applicating mechanism. The herbicides consumption was 100 to 200 L/ha. The mechanical weeder required 8 to 12 man- days /ha.

Singh (1988) used a portable frame and engine of knap sack power sprayer to transmit rotary motion to a serrated disc rotary blade. A flexible shaft was used as means of power transmission. Also an electric motor of 0.5 hp was used as prime mover for operating the same machine set. On testing the man-hour requirement of knapsack sprayer engine and electric motor operated slasher came 57 and 50 respectively. But after some time of operation flexible shaft had broken due to more jerks coming on it. He also developed a front mounted power tiller attached cutter blade to accomplish cutting in small time period. Bearings inside a hollow shaft were used to support a cutting blade rotating in horizontal plane and power transmission was done using a bevel gear set and V-belt. On testing it was found that only 16 man-hour are required to accomplish the cutting of one ha but power of the engine was underutilized thus making wastage of energy.

Tajuddin (1989) developed engine operated blade harrow for weeding. They observed weeding efficiency of the equipment at 15 degree, 25 degree and 35 degree blade angles, 200,300, 350 and 450 mm blade widths and 30, 40 and 50mm depth of operation. It was noticed that as the blade angle increased weeding efficiency is also increased. Draught of the blade harrow increased with increase in depth of operation. However the rate of the increase of the unit draught watt found to be decrease with increasing depth of operation.

Amir U. Khan (1990) reported that a three row mechanically powered weeder, originally developed at IRRI, has gained much popularity in Japan mostly because of the widespread fears of chemical pollution.

Gupta (1991) evaluated the performance of two rotary tynes, a spiral cutting edge and a straight cutting edge were studied in a soil bin. The study was conducted at four different rotor speeds with two modes of operations. The linear speed and working depth were kept constant at 1.33 km/h and 100 mm respectively. The performance criteria were specific energy requirement and puddling index. The result revealed that the spiral edge tyne gave about 9.31 percent higher performance index than the straight edge tyne under wet land condition.

Ambujam *et al.,* (1993) designed and developed a rotary rice weeder powered by a knapsack type, 1 kW engine. The machine had an operational depth of 70 mm with 80 percent weeding efficiency. The effective field capacity of the machine was 0.022 ha/h with a performance index of 587. The average fuel consumption of the machine was 0.86 L/h. The operational cost of the power weeder was Rs.502.717- compared to Rs.437.5/- for hand weeding.

Fanoll (1993) evaluated three models of shoulder-suspended, hand-guided rotaty power weeders in comparison with hand slashing of weeds. The power weeders were operated by 1.86; 1.49 and 1.12 kW gasoline engines. The field capacities of the machine were 12 to 131 % higher than the hand weeding processes. The carrying weights of these machines ranged from 5.4 to 10 kg with overall lengths, 1600 to 1700 mm . The engine characteristics were 2- stroke, single cylinder 50.2,35 and 27.2 cc displacements, flywheel, magneto- ignition; petrol operated 8:1 compression ratio and air cooled. Out of the three models tried, the 1.4kW machine had better performance in terms of both field capacity and weeding cost.

Rangasammy and Balasubramaniam (1993) developed a power weeder and performance was evaluated and compared with the performance of conventional method of manual weeding with hand hoe and using manually operated dry land weeder. The field capacity of weeder was 0.04 ha/h with weeding of 93 per cent for removing shallow rooted weeds. The performance index of weeder was 453.

Sahay *et al.,* (1996) developed a rotary grass/bush cutter. The machine used a 3 hp petrol start kerosene run engine and V-belt to drive a blade rotating in a horizontal plane. The developed machine performed well in lawns and fields having slopes upto 100 percent and grass/ bush thickness of 2 cm and height 1.5 m.

However bigger wheels were needed to support the chasis for coping up with the undulations of more than 30 cm depth and hikes.

Sahay (1997) tested a petrol run 35 cc engine driven manually operated bush cutter. This cutter could be held totally in both the hands. Its three blade star shaped knife used a solid shaft to transmit the power of the engine. This whole unit was set on a wheeled frame so that it could be operated in between two rows of a crop for cutting the weeds just above the ground surface. It had taken 22 man-hour per ha for cutting the grass with this machine. The limitation of this machine was that after 30 minutes time of operation the machine got overheated and required cooling for at least 10 minutes. Also due to hanging of the machine in the hands while operation, drudgery increased too much and it was required to get relieved for at least 10 minutes after operation of every 30 minutes.

Panwar (1999) designed and developed a lightweight, low horsepower engine operated weeder cum seeder for weeding of row crops and single row seeding of different crops. The machine was powered with 1.5 hp petrol start kerosene run engine. The common chasis was designed for reduced rolling resistance and adequate traction ability. The engine power was transmitted to 280 rnm ground wheel through a specially designed reduction gear box and chain and sprocket system. For weeding operation, three types of tools such as hoe blade, sweep and L-blade were attached at the rear of the machine. The weeding tool can be selected based on density of the weed and requirement of the operator. It is a walk behind type of machine with an average ground speed of 2.5 km//2. The field capacity of the machine ranged between 0.5 - 0.6 ha/day for 8 working hours per day. The average fuel consumption was observed in the range of300-350ml/h.

Viren M Victor and Ajay Verma (2003) designed and developed a power operated rotary weeder for wetland rice cultivation and fabricated at the faculty of agriculture engineering workshop, IGKVV, Raipur, India during 1999-2000 and tested in the experiment field. A 0.5-hp petrol driven engine was used for power weeder with a reduction gear box. The power transmission from engine to traction wheel and to the cutting unit was provided by means of a belt, pulley and chain sprocket. For cutting four L shaped standard blades were used on the hub, and and in turn fitted on rotary shaft. With 200mm spacing, the field capacity the machine varied between 0.04 to 0.06 ha/h with field efficiency of 71 per cent. The weeding efficiency of the machine was 90.5 per cent. The machine was simple, easy to fabricate by local artesian.

Tajuddin (2006) designed, developed and tested an engine operated weeder with 2.2 kW (3hp) petrol started kerosene run engine. The rated speed of 3300 rpm at load was reduced to 60 rev/min of ground wheel by belt – pulley and sprocket – chain mechanism. A sweep type weeding blade was designed for structural strength. The effective field capacity 0.10 ha/h, fuel consumption rate 0.60 to 0.75 l/h, depth of operation 37mm,35mm, 39mm, field efficiency 85.71, weeding efficiency 85.85% , initial cost of weeder 20,000 cost of operation 580/ ha were found.

Cloutier *et al*., (2007) stated that mechanical weed control is generally widespread and used by farmers who do not use herbicides and recommendations always come to control weed during the early crop stages because limited tractor and cultivator ground clearance and machine-plant contact may potentially damage the crop foliage at later growth stages**.**

Padole (2007) evaluated the comparison in field performance between rotary power weeder and bullock drawn blade hoe. Rotary power weeder comprises engine, gearbox, clutch, main frame, depth control wheel, V shaped sweep, cutter wheels, handle, controls and transportation wheels. It worked better than bullock drawn blade hoe in respect of working depth 5.67 cm (16.67% more),effective field capacity 0.14 ha/h (40% more), and field efficiency 90%, which is 34.11 % more than that of bullock drawn blade hoe. The cost of operation was found to be 798.46 compare to 894.87 per ha by bullock drawn blade hoe. Hence, it is more economical and effective than bullock drawn blade hoe as it saves 10.77% weeding cost; reduce plant damage up to 54.23%, and achieved weeding efficiency up to 92.76%.

Manuwa *et al.,* (2009) designed, fabricated and tested a petrol engine powered mechanical weeder for row crop at Federal University of Technology, Nigeria. The main component of weeder is 5 hp internal combustion petrol engine, transmission unit, three sets of weeding blades main frame and ground wheel. The length, width and height of weeder are 0.85, 0.32, 0.65m, respectively. The cutting blade width is 0.24 m which rotates at 800 rpm. The field test was conducted in moist soil condition, determined weeding efficiency as 95% with effective weeding capacity of 0.053 ha/h and fuel consumption of 0.7l/h. The production cost of weeder is US$ 285 in 2007.

Niyamapa and Chertkiattipol (2010) designed three prototype rotary blades to reduce the tilling torque, impact force and specific tilling energy, and tested in a laboratory soil bin with flat tilling surface. Experiments with the prototype rotary blades and Japanese C-shaped blade were carried out at forward speeds of 0.069 and 0.142 m.s-1 and at rotational speeds of 150, 218, 278 and 348 rpm (or 3.30, 4.79, 6.11 and 7.65 $m.s^{-1}$) by down-cut process in clay soil.

Nkakini *et al.* (2010) designed and fabricated a rotor-weeder powered with 1.4 hp petrol engine and compared the field performance with the traditional manual hand hoe. The weeder consists of main frame, handle, rotary blades, shaft, sprocket and chain, chassis, cutting depth hint rear cutting depth adjuster, wooden engine seating, engine and ground wheel. Theoretical field capacity of the rotor-weeder was 0.47 ha/h with an effective field capacity 0.34 ha/h which was approximately twenty times that of manual weeding. The performance index was 1,700 and fuel consumption was 3.2 l/day. Weeding efficiency of rotor weeder was 71% for removing shallow-rooted weeds.

Ratnaweera *et al.*, (2010) designed and fabricated a power weeder. The weeding ability was optimized by weeding three rows simultaneously. The double-action weeding drum was driven by a small 1.3 kW gasoline engine, which can enable removal of weeds, while facilitating the forward motion of the machine. In addition, the conical shaped weeding drums designed to loose-up soil without harming the rice. A novel row changing mechanism was helpful for operating the machine by single person without destroying rice. A helical shaped toothwas designed in the weeding drums to enhance the shearing effect for weeding while losing up the soil.

Zareiforoush *et al.*, (2010) presented a new theoretical approach to design main tillage components of rotary tillers. In designing the rotary tiller shaft, it was revealed that in addition to the torsional moment, the flexural moment was also effective on the system safety. It was also recognized that in designing a rotary tiller, blades are most subjected to fracture by incoming stresses. The optimal value of rotor diameter considering the values of maximum tangent force was about 39.4 mm.

Alizadeb (2011) studied field performance evaluation of four types of mechanical weeders, single row conical weeder (W1), two rows conical weeder (W2), rotary weeder (W3) and power weeder (W4) and was compared with hand weeding (W5) in rice. The results revealed that among the mechanical weeders, the highest weeding efficiency (84.33%) was obtained with W4 and the lowest value (72.80%) was measured with W3. The average of damaged plants in mechanical weeders was obtained as 3.83% compared to 0.13% in hand weeding. The weeding cost was reduced by 15.70, 38.51, 22.32 and 48.70% for W1, W2, W3 and W4, respectively as compared to W5.

Olaoye *et al.,* (2011) studied on the motion of weeding disc at any point on the surface of a rotary tiller. The weeder consists of 5 hp petrol engine, three pneumatic ground wheel, tool assembly, frame and handle. The performance of the weeder was investigated by considering the effects of four (4) weeding tools (Iron rod tine, Cable tine, Line yard tine and Plastic strand tine) and three (3) levels of weeding speeds (1804 rpm, 2435 rpm, 3506 rpm) on the weeding index, weeding efficiency and field capacity. The study resulted that for the forward speeds of 0.4 m/s to 0.5 m/s and engine speeds of 1804 rpm to 2261 rpm the weeding efficiency was 54.98% to 59.05% respectively.

Bin Ahmad (2012) suggested that to design an effective intra-row power operated weeder; the weeder should be targeted for different scale crops production and to achieve intra-row weed control efficiency of 80% or more. Also, the weeder should be able to control weeds with minimal crop plant damage with low bulky overall dimensions of the weeder.

Ojomo *et al.,* (2012) conducted a study on machine performance parameters by developing and evaluating a motorized weeding machine for the effect of moisture content (10%, 13% and 16%) and the type of cutting blades (Flat blade, spike tooth blade and curved blade) on the machine efficiency, quality performance efficiency, percentage of uprooted weeds and percentage of partially uprooted weeds. At 16% soil moisture content, the spike tooth blades gave the best machine efficiency by 94%, quality performance efficiency by 84%, percentage of uprooted weeds by 2.8% and least percentage of partially uprooted weeds by 1.8%.

Olaoye *et al.,* (2012) developed and evaluated a rotary power weeder to reduce the drudgery and ensure a comfortable posture of the operator during weeding and increases production with weeder components parts as frame, rotary hoe (disc), tines, power unit and transmission units. The results of field performance evaluation showed that, field capacity and weeding efficiency of the rotary power weeder were 0.0712 ha/h and 73% respectively. The cost of operation with this weeder was estimated as N 2,700 as against N 12,000 as manual weeding.

Thorat, D. *et al.,* (2013) was designed and developed for weeding of ridge planted crops. The main working components of the weeder were cutting blades and rotor shaft. Three types of blades (L-type, C-type and Flat-type) were selected having length, width and thickness of 100 mm, 25 mm and 6 mm, respectively, operating with a rotor shaft of 18 mm in diameter. C-type blades were most suitable at gang speed of 200 rpm and 15.26±0.96% (d.b) soil moisture content with weeding efficiency, plant damage, field capacity of 91.37%, 2.66%, and 0.086 ha.h-1, respectively. Time saving with ridge profile power weeder as compared to manual weeding was 92.97 per cent.

Kankal (2013) designed a self- propelled weeder on the basis of agronomic and machine parameters. The main features of prototype self- propelled weeder were, a 4 hp petrol start kerosene run engine, power transmission system, weeding blade (Sweep) and cage wheel. The rated engine speed 3600 rpm was reduced to 23 rpm of the cage wheel by using chain and sprocket mechanism in three steps.

Mahilang *et al.,* (2013) designed, developed and fabricated a power operated rotary weeder. The developed power weeder had a 1.4 hp petrol start/kerosene run engine as prime mover. The power was transmitted by means of belt, pulley from engine to traction wheel and to cutting units. For cutting, standard six L shaped blades were provided on the hub which in turn was fitted on rotary shaft. The weeding efficiency (91%), quality of work (14%), field efficiency (60%) and operational cost was found to be 808.42.

Hegazy *et al.*, (2014) developed a power weeder for maize crop with modified vertical blades which were mounted on a circular rotating element on its horizontal side; the motion was transferred to blades units by amended transmission system. The effect of weeder forward speeds, depth of operation, number of blades and soil moisture content on fuel consumption, plant damage, weeding index, effective field capacity, field efficiency, energy required per unit area and total cost were studied. Three levels of soil moisture content (7.73, 12.28 and 16.18%), two blades arrangements (two and four vertical blades for each unit), three weeder forward speeds (1.8, 2.1 and 2.4 km/h) and two depths of operation (from 0 to 20 and from 20 to 40 mm) was chosen. The results showed that, the minimum value of fuel consumption was 0.546 l/h and recorded by using two blades with 1.8 km/h weeder forward speed at depth of operation ranged from 0-20 mm and soil moisture content 16.18 %. The highest field efficiency was 89.88% by using two blades with 1.8 km /h weeder forward speed at depth of operation ranged from 0 to 20 mm and soil moisture content 16.18%. The minimum value of effective field capacity was 0.198 fed/h by using four blades, weeder forward speed 1.8 km/h, soil moisture content 7.73% and under depth of operation ranged from 20-40 mm. The lower value of total cost was 55.09 L.E /fed and was obtained by using two blades with 2.4 km/h weeder forward speed at depth of operation ranged from 0-20 mm and soil moisture content 16.18 %.

2.5. Ergonomic considerations:

Murrel (1979) stated that ergonomic is scientific study of the relationship between man and his working environment. The goal of ergonomic is to design the task so that its demand stays within the capacities of workers. Its object is to increase the the efficiencies of human activities by removing those features of design which are likely to cause inefficiencies or physical disability in the long term and thus to minimize the cost operation. He further stated that to achieve maximum efficiency a man machine system must be designed as whole.

Gite (1985) gives scientific study about ergonomic consideration. Ergonomic study gives the criteria for ergonomic design like design within the capability of human worker, use of proper posture of the operator for most efficient performance of the tool at a lesser fatigue, suitability of the tool for workers of varying age and body dimensions.

Gyanendra Singh (1989) study was carried out on the development of a wheel hoe weeder to improve its design and commercialize it through small scale manufacturers. This group manufacturers possessed limited fabrication facilities and thus improvement in the design of the weeder was made such that the same was adopted easily. Major modifications were made in the design of wheel, handle and cutting blade, considering human ergonomics.

David M. Fothergill *et al.,* (1992) the study was illustrated the effect of the hand object interface on the ability of a person to exert forces in different postures. Subjects performed one handed maximum pulling exertions on four different handle, placed 1.0 m and 1.75 above the ground. The strength manual exertion was significantly affected by handle type and handle placement. Analysis of variance also indicated a significant interaction between handle type and handle position.

Kumar and Divakar (1992) developed a weeder simulation test rig for push- pull and pull type weeders to simulate the weeding conditions since control of certain parameters viz soil moisture, weed population, depth of operation, force applied on weder handle in the field is difficult when observations are made for ergonomic studies with different subjects and weeders. In the test rig the pole shaft actuations as affected by the by the weeder, the soil manipulating force encountered, push-pull and reversible loading and quick return phenomenon are simulated. Two subjects were tested using the test rig of 0-6 kg loading conditions for four weeders and fatigue stree stabilization. During field operation of the weeder the drudgery initiation was observed to be at shorter interval of 12 minute for star, peg type weeders and fork hoe and 20 minute for hand hoe.

Yadav and Tewari (1996) an anthropometric survey of Indian farm workers from estern part of the country were conducted and these data could be used for design the agricultural machinery to develop ergonomic consciousness for the designers. Twenty nine body dimensions were measured for a sample of 134 farm workers in the age group 18 to 50 years. Data has been analyzed statistically and compared with those obtained for the farm workers of the other parts of the country viz northern, southern, central and western. The stature to weight ratio was found 3.02. Body dimensions were also compared with Americans, Germans and Japanese and variation was found at 5 per cent level of significance.

Yadav and Tewari (1996) reported that anthropometric data and ergonomic approach in design of frame equipment. An anthropometric survey of Indian farm workers from eastern part of the country was conducted and these data would be used for design of agriculture machinery to developed ergonomic consciousness for the designers. Twenty nine body dimensions were measured for a sample of 134 farm workers in the age group of 18 to 50 years. Data has been analyzed statistically and compared with those obtained for the farm workers of other part of country viz northern, southern, central and western. The mean stature of Indian workers was observed 162.1 cm while those for northern, southern, central and western regions where 168.5, 160.79, 162.0 and 164.4 cm respectively. The stature (cm) to weight (kg) ratio was found 3.02. The body dimensions were also compared with Americans, Germans and Japanese and variation was found at 5 per cent level of significant.

Rajvir Yadav (2000) survey about anthropometry of Indian female agricultural workers. The sample unorganized female workers involved in different agricultural activities the western part of India, were selected in order to gather information about body dimensions which are commonly used in ergonomic design. Earlier anthropometric survey carried out in the country were very few and specific to the male agricultural workers only. Therefore, 30 body dimensions necessary of the design of the equipment were identified and a sample study was conducted on 40 female farm workers in the age group of 18 to 50 years. Data has been analyzed statistically and compared with those obtained for the agricultural workers from other parts of the country.

Geetha S Philip and V K Tewari (2000) give the study on an anthropometry of Indian female agricultural workers and implication on tool design. With a view to generation anthropometric data based for women agricultural workers in southern region of India, an anthropometric survey was conducted. Different body dimensions of the subjects having direct implication on agricultural tool/ implement design were collected from 37 female workers during the survey. The data compared with that of the male worker of the region as well the data of females from other ethnic groups.

R. Remesan *et.al,* (2007) study revealed that both the weeders selected for the study has its own strengths and limitations. Rotary weeder can be recommended in the later stages of weed growth as the better weeding efficiency, more turning of the soil and uprooting of weeds overrules the higher cost of operation. Cono weeder performed the task with comparatively higher field capacity, better performance index in the early stages of weed infestation. The field performance analysis have shown that Weeding efficiency as 79 % and 72.5 % respectively for Rotary weeder compared to Cono weeder with damage factor of 7.06% and 4.55% respectively. It was found that a male subject took an average of 48.78 and 41 h/ha respectively for weeding operation with rotary and cono weeders; whereas the female subject took 80.65 and 76.33 h/ha respectively. The study also emphasised the variation of energy expenditure and overall discomfort associated with different weeding practices. Work Related Body Discomfort (WRBD) of farmers, associated with traditional hand weeding could be reduced to a considerable extent by switching over to these weeders. The energy cost analysis shown that weeding with these two tools viz. Cono weeder and Rotary weeder falls in “heavy” class of agricultural labour classification and hand weeding falls in “moderate” class for male labourers where as for female labourers these three weeding operations are in “moderate” class.

Bini sam (2016) was found out and the mean working heart rate of operator was 110 beats min-1. The operation was graded as “Moderately Heavy”. The work pulse of the power rice weeder is within the limit of continuous performance of 40 beats min-1. The oxygen uptake in terms of VO2 max was above the acceptable limit of 35% of VO2 max indicating that the three row power rice weeder was could not be operated continuously for 8 hours without frequent rest-pauses. It is suggested that two operators may be engaged in shift for a day long work with three row power rice weeder. The weeding index was found to be 88%. Area covered by the three row power rice weeder was 40 cent/hour while planting 30 cm rowpacing. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 4.0 and scaled as "More than Light discomfort".

CHAPTER - III
MATERIALS AND METHODS

This chapter’s deals with the design and testing of the developed single row power weeder for rice. The various factors involved in design were operation safety, light weight of machine, overcomes man power scarcity, saves time and cost, easiness in fabrication are taken into account for its design procedure. The operation and adjustment were made simple so that a village artesian can fabricate, repair the weeder and farmer can operate the weeder easily.

The materials and methods about the development and testing of power weeder are discussed in this chapter.

3.1 Experimental Site

The study was conducted in Swami Vivekananda College of Agricultural Engineering Technology and Research Station, Faculty of Agricultural Engineering, IGKV, Raipur (C) situated at 21⁰ 14’ 02” N latitude and 81⁰ 43’11” E longitude. The operational field meant for the study was selected from the demonstration / research field of the faculty.

3.1.1 Climate

Raipur has a tropical wet and dry climate, temperatures remain moderate throughout the year, except from March to June, which can be extremely hot. The temperature in April–May sometimes rises above 48 °C. These summer month also have dry and hot winds. In summers, the temperature can also go up to 50 °C. The city receives about 1,300 mm of rain, mostly in the monsoon season from late June to early October. Winters last from November to January and are mild (Anon., 2012).

3.2 Design consideration

A manually operated power weeder was designed for weeding of mechanical and manual transplanting of rice. From the design point of view- power source (engine), cutting blades shaft were the important components of single row power weeder for rice. A weeder has been built with interdependent purposes in mind; as to say, the script in it (Akrich, 1992) can have a plethora of different purposes. Such purposes can be seen as mechanisms, which may generate some others in a causal sequence, and/or being connected with others at the same logical level.

3.2.1 Power requirement

3.2.1.1 Assumption

Soil resistance has a considerable effect upon the power requirement of weeder. Also, width of cut and speed of operation influences power requirement of weeder. For calculating power requirement of the weeder, maximum soil resistance was taken as 0.5 kgf/cm^2. The speed of operation of the weeder was considered as 0.7 ms^{-1} to 1.0 ms^{-1}. Total width of coverage of cutting blades was in the range of 12 to 30 cm. The depth of operation was considered as 5 to 8 cm, transmission efficiency is 82%.

$$P_d = \frac{\text{SR x d x w x v}}{75} \text{ hp} \tag{3.1}$$

where,

SR = soil resistance, N/mm^2

d = depth of cut, cm

w = effective width of cut, cm

v = speed of operation, ms^{-1}

Hence, power requirement is estimated as

$$P_d = \frac{0.5 \text{ x } 8 \text{ x } 30 \text{ x } 1}{75} \text{hp} = 1.6 \text{ hp} = 1.26 \text{ kW} \tag{3.2}$$

3.2.1.2 Total power required

The total power required is estimated as 1.95 hp as follows

$$P_t = \frac{\text{Pd}}{\eta} = \frac{1.6}{0.82} = 1.95 \text{ hp } = 1.56 \text{ kW} \tag{3.3}$$

where,

Pd = Power required to dig the soil:

η = Transmission efficiency.

Thus, a prime mover of 1.49 kW (2 hp) was required for this weeder.

3.2.2 Worm and worm gear

For designing worm the lead angle (λ) can be calculated by using the equation:

$$\tan\lambda = \sqrt[3]{\frac{1}{\mathrm{Vr}}} \tag{3.4}$$

The velocity ratio (V_r) = $\frac{\mathrm{Nw}}{\mathrm{Ng}}$ = 34.09 (3.5)

Where,

Nw = speed of the worm, 6000 rpm

Ng = speed of the worm gear, 176 rpm

$\lambda = 17.14^0$

The centre distance between the two worm gears (x) is calculated by the pitch diameter of worm gear in the following expression:

D_g =m x Tg = 65.62 mm (3.6)

D_w= 3 x P_a=18.24 mm (3.7)

$$x = \frac{\mathrm{Dw+Dg}}{2} = \frac{18.24+65.62}{2} = 41.93 \text{ mm} \tag{3.8}$$

where,

D_w= pitch circle diameter of the worm, mm

D_g= pitch circle diameter of worm gear, mm

Then the normal lead is calculated by using the equation:

$$\frac{\mathrm{x}}{\mathrm{Ln}} = \frac{1}{2\pi}\left[\frac{1}{\sin\lambda} + \frac{\mathrm{Vr}}{\cos\lambda}\right] \tag{3.9}$$

$$\frac{\mathrm{x}}{\mathrm{Ln}} = 0.70689$$

L_n = 59.316 mm

The axial load (l) is calculated by equation:

$$l = \frac{Ln}{\cos\lambda} = 62.07 \text{ mm} \tag{3.10}$$

Module size (m) can be calculated as :

$$m = \frac{Pa}{\pi} = 1.93 \text{ mm}$$

where,

P_a = axial pitch, 6.08 mm

The face length (L_w) of the worm or threaded portion is calculated as:

$$L_w = P_a(4.5 + 0.02 + Tw) \qquad (3.11)$$

$$L_w = 39.64 \text{ mm}$$

Where,

T_w = number of threads on worm, (if V_r is in between 12 to 36 then Tw=2, R.S. Khurmi,2012)

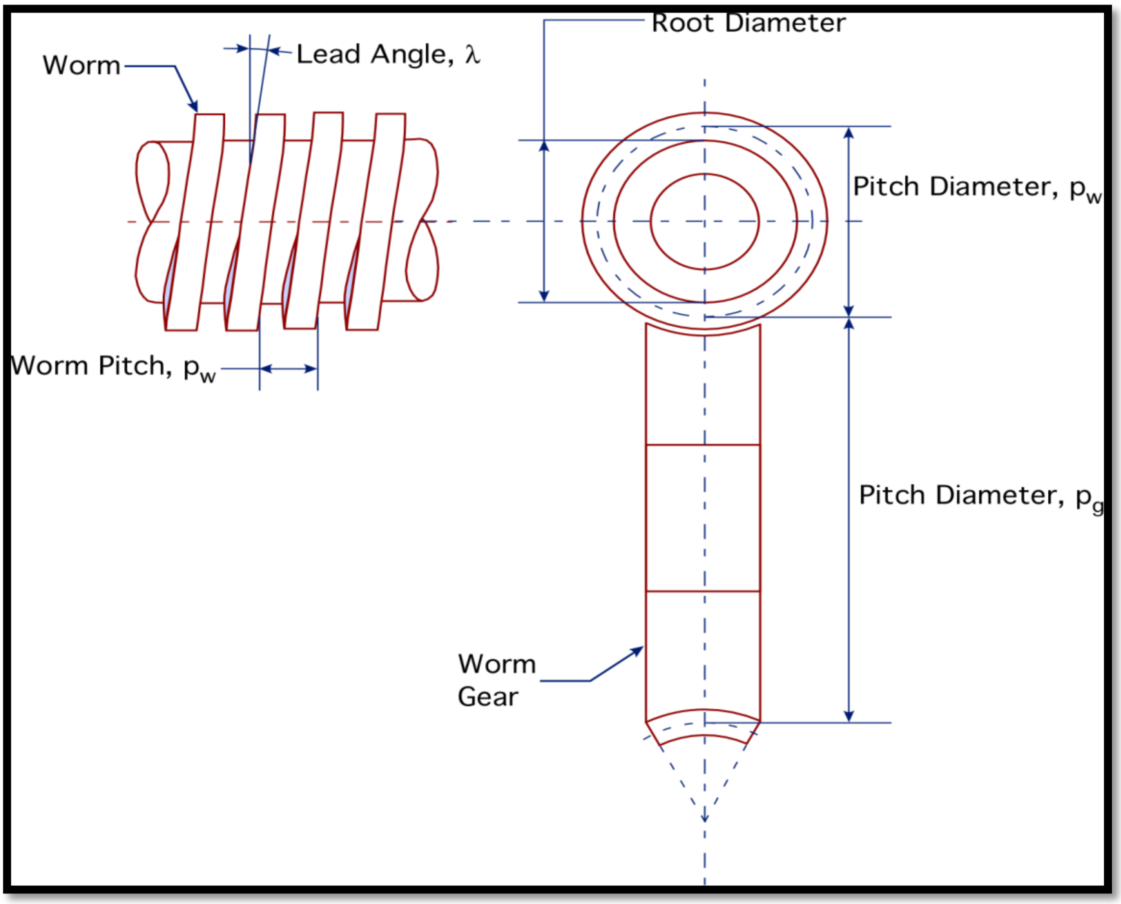

Fig. 3.1 Proportion of worm and worm gear

The following table shows the various proportions for worms in term of the axial pitch (P_a) in mm

Table 3.1 Proportion of worm

S.No.	Particulars	Value
1.	Normal pressure angle	14½°
2.	Pitch circle diameter for the worms integral with the shaft	2.35 P_a +10 = 24.288mm
3.	Pitch circle diameter for worms bored to fit over the shaft	2.4 P_a + 28 = 42.592mm
4.	Maximum bore of the shaft	P_a + 13.5 = 19.58 mm
5.	Hub diameter	1.66P_a +25 = 35.09 mm
6.	Depth of tooth	0.686 P_a = 4.17 mm
7.	Addendum	0.318 P_a = 1.93mm

Table 3.2 Proportions for worm gear

S.No.	Particulars	Value
1.	Normal pressure angle	14½°
2.	Outside diameter	D_g + 1.0135 P_a=71.78mm
3.	Throat diameter	$D_{g\,+}$ 0.636 P_a =69.49 mm
4.	Face width	2.38 P_a+6.5 =20.97mm
5.	Radius of face gear	0.882 P_a+14 =19.36mm
6.	Radius of gear rim	2.2 P_a +14 =27.38mm

Fig. 3.2 Power transmission system of worm and worm gear

3.2.3 Design of worm shaft

A shaft is a rotating machine element which is used to transmit the power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) setup within the shaft permits the power to be transferred machine or components linked up to the shaft.

3.2.3.1 Torque transmitted by the shaft

The torque transmitted through the shaft is worked out using the following formula (khurmi, R.S., 2012).

$$T = \frac{P \text{ x } 60 \text{ x } 10^3}{2 \text{ x } \pi \text{ x } N} \qquad (3.12)$$

where,

P = power, kW

T = torque transmitted by the shaft, Nm

N = revolutions per minute

Considering engine speed as 6000 rpm and engine power 1.49 kW we get torque as

$$T = \frac{1.49 \text{ x } 60 \text{ x } 10^3}{2 \text{ x } \pi \text{ x } 6000}$$

= 2.371 Nm

= 2371.40 Nmm

Thus the torque of 2.37 Nm was obtained.

3.2.3.2 Diameter of the flexible shaft

For designing the rotor shaft, the maximum tangential force which can be endured by the rotor should be considered. The maximum tangential force occurs at the minimum of blades tangential speed is calculated by the following (Bernacki *et al.*, 1972)

$$K_s = \frac{C_s \text{ x } 75 \text{ x } Ncx\ \eta_c x\ \eta_z}{u} \qquad (3.13)$$

$$K_s = \frac{1.5 \text{ x } 75 \text{ x } 0.9 \text{ x } 2 \text{ x } 0.8}{2.94} = 55.10 \text{ kg}$$

Where,

Ks = Maximum tangential force, kg,

Cs = Reliability factor (1.5 for non-rocky soils and 2 for rocky soils),

Nc = Power of engine, hp,

η_c = Traction efficiency for the forward rotation of rotor shaft as 0.9,

η_z = Coefficient of reservation of engine power (0.7-0.8),

u = Minimum tangential speed of blades

Tangential peripheral speed, u, can be calculated using the following equation:

$$u = \frac{2 \times \pi \times N \times R}{6000} \qquad (3.14)$$

$$u = \frac{2 \times \pi \times 176 \times 16}{6000} = 2.94\ ms^{-1}$$

Where,

N = Revolution of rotor, rpm, and

R = Radius of rotor, cm.

After substituting values for revolution of rotor shaft (176 rpm) and its radius as 16 cm in equation (3.14), tangential peripheral speed was obtained as 2.94 ms^{-1}.Using the tangential peripheral speed and other parameters in equation (1), the maximum tangential force was determined to be 55.10 kg.

The maximum moment on the rotor shaft (M_s) is calculated through the following:

$$M_s = Ks \times R \qquad (3.15)$$

M_s =55.10 x 16

M_s =881.6 kg-cm

In the above equation, R is the rotor radius (cm).

The yield stress of rotor made from rolled steel (AISI 302) was 520 MPa. The allowable stress on the rotor (τall) was calculated by the following equation (Mott, 1985):

$$\tau_{all} = \frac{0.577 \text{ x k x}\sigma_y}{f} \qquad (3.16)$$

$$= \frac{0.577\ x\ 0.75\ x\ 520}{1.5}$$

= 150.02 MPa =1530.6 kg.cm^{-2}

where,

τ_{all} = Allowable stress on rotor shaft, kg.cm^{-2},

k = Coefficient of stress concentration (0.75),

f = Coefficient of safety (1.5), and

σ_y = Yield stress, 520 MPa

By substituting above values in the following equation, rotor shaft diameter was calculated as:

$$D = \sqrt[3]{\frac{16 \times Ms}{\tau all \times \pi}}$$

$$D = \sqrt[3]{\frac{16 \times 881.6}{1530.6 \times \pi}}$$

D =14.3 mm

In order take into account fluctuating load during the operation, diameter of the rotor shaft was selected higher than the calculated value as 16 mm.

3.3 Design of cutting blades

Blades of the rotor are the components which directly interact with soil and as such have major impact on the operation of the weeders. The material used for manufacturing machines could be changed but this increases the associated costs significantly. The way of reducing the power requirement and to improve the life of machine is to improve geometry of blade. The interaction between soil and machines takes place at the blades; thus by improving their geometry the power required and the size of machine will reduce. The blade is designed & developed using the popular blades designs used in market available weeders as base. The finalized geometry not only reduces the power required but also decreases the cost of manufacture. The weight of machine is also reduced as smaller power source (engine) will be required to power the machine which will reduce the operating cost of the machine. In rotary weeders, blades are attached to a flange mounted on a rotating shaft usually by nuts & bolts. Commonly three types of blade geometries are used as blades for weeders and tillers namely, L-shaped blades, C-shaped blades and J-shaped blades. The C-shaped blades have greater curvature, so they are recommended for penetration in hard field and better performance in heavy and wet soils. The J-shaped blades are used for loosening, destroying the soil surface compaction and giving better ventilation to the soil, generally used for tilling hard and wet soils whereas L-shaped blades are the most common widely used for the fields with crop residue, removing weeds (Bernacki *et al.*, 1972 and Khodabakhshi *et al.*, 2013).

Different parameters used in the study and have been in consideration to give safe strength and bending values for manufactured blades during weeding operation. The calculation and assumptions are based on standard handbook of machine design were followed (Shigley *et a*l., 2004). Assumption was made as follows; Number of blades in one working set = 4; Length of blade = 11.3 cm; Width of blade = 4 cm. To calculate the design strength of blade; revolution per minute of rotor shaft (N) = 176 r.p.m; radius of engine output rotor (R) = 16 cm. Therefore, speed of engine output (u) will be determined above as 2.94 ms^{-1}.

For cutter blade design, number of blade, cutting width and thickness were important parameters. During cutting, blades would be subjected to shearing as well as bending stresses. Total working width of the weeder was 300 mm having rotor shaft of length of 250 mm. Total of 8 blades were provided with cutting width of 40 mm. Therefore, four blades were provided on each flange and two flanges were mounted on rotor shaft. The soil force acting on the blade (Ke) was calculated by the following equation:

$$K_e = \frac{Ks \text{ x } C_p}{i \text{ x } Z_e \text{ x } n_e} \tag{3.17}$$

$$K_e = \frac{55.10 \text{ x } 2}{2 \text{ x} 4 \text{ x } \frac{1}{4}} = 55.1 \text{ kg}$$

Where,

K_s = Maximum tangential force, kg,

C_p = Coefficient of tangential force as 0.8,

i = Number of flanges is 2,

Z_e = Number of blades on each side of the flanges is 4 and

n_e = Number of blades which act jointly on the soil by total number of blades .

By solving eqn. 3, the soil force acting on the blade (K_e) was determined as 55.1 kg.

The dimensions of the blades are given in Fig. 1. The values of be, he, S_s, S and S1 were equal to 0.2 cm, 2.0 cm, 4.0 cm, 8.0 cm and 1.0 cm respectively.

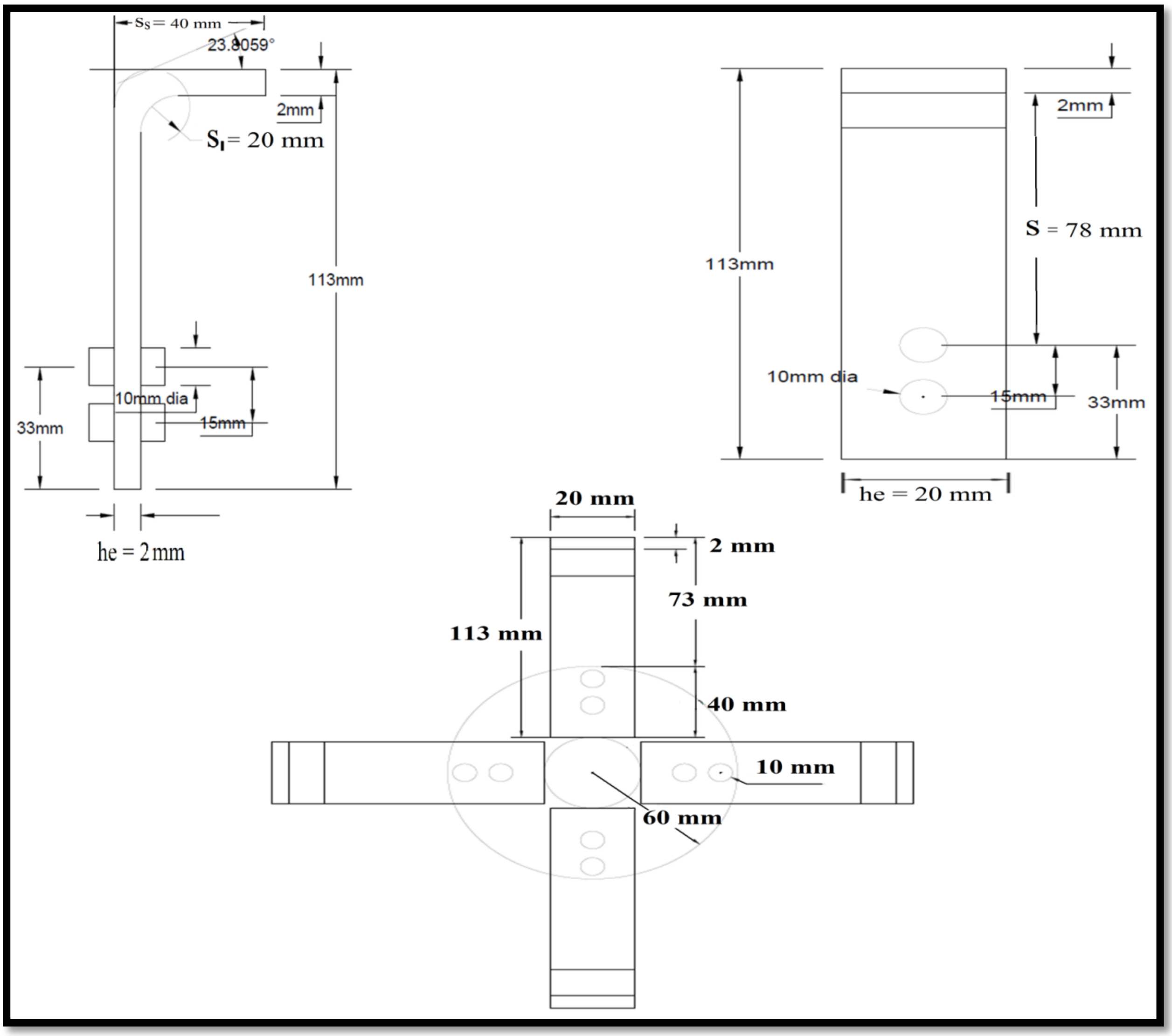

Fig. 3.3 Specification of blade

Considering the shape of the blades, the bending stress (σ_{zg}), shear stress (τ_{skt}), and equivalent stress (σ_{zt}) can be calculated by the following equations (Bernacki *et al.*, 1972):

$$\sigma_{zg} = \frac{6 \text{ x } K_e \text{ x } S}{b_e \text{ x } h_e^2} = \frac{6 \text{ x } 55.1 \text{ x } 8}{0.2 \text{ x } 4} = 3306 \text{ kgcm}^{-2} = 324.20 \text{ MPa}$$

$$\tau_{skt} = \frac{3 \text{ x } K_e \text{ x } S_1}{\left(\frac{h_e^1}{b_e} - 0.63\right) \text{ x } b_e^3} = \frac{3 \text{ x } 55.1 \text{ x } 1}{\left(\frac{2}{0.2} - 0.63\right) \text{ x } 0.2^3} = 2205.17 \text{ kgcm}^{-2}$$

$$= 216.25 \text{ MPa}$$

$$\sigma_{zt} = \sqrt{\sigma_{zg}^2 + 4\tau_{skt}^2} = \sqrt{3306^2 + (4 \; x \; 2205.17^2)} = 5511.87 \text{kgcm}^{-2}$$

$$= 540.52 \text{ MPa}$$

Where,

σ_{zg} = bending stress, MPa,

τ_{skt} = shear stress, MPa, and

σ_{zt} = equivalent stress, MPa.

The bending stress, shear stress and equivalent stress were determined as 324.20 MPa, 216.25 MPa and 540.52 MPa, respectively.

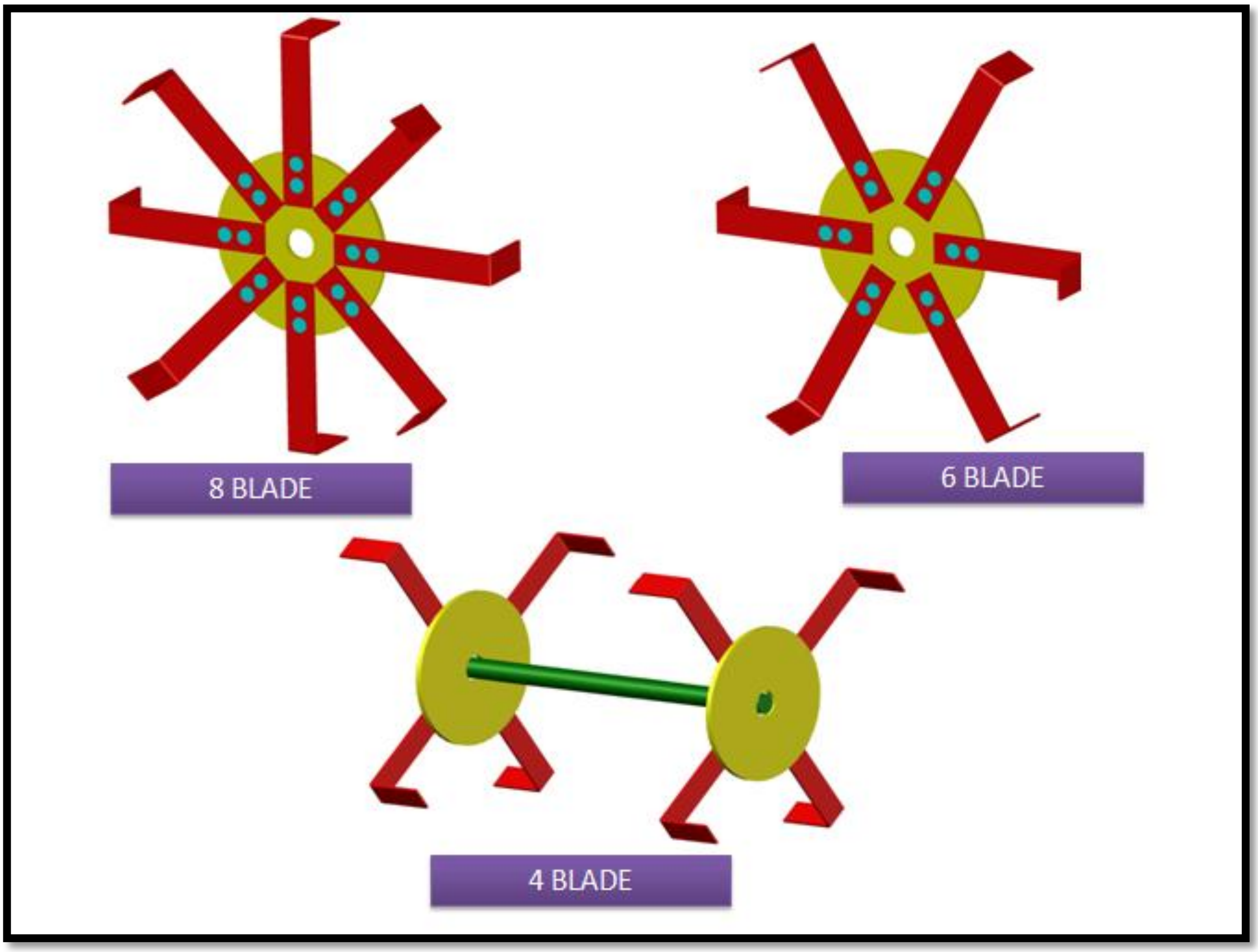

Fig. 3.4 3-D of developed blade

3.3.1 Determining the Blade Width (W)

Each blade must be capable to carry and throw the soil mass along the strip and it is possible only when the blade has enough width. It was assumed that most of the tilled soil mass is in the first half of the blade working depth and maximum working depth should be assumed 6 cm for power weeder so that the minimum blade width (W) can be determined using Eq. 3.18. The cutting angle (γ) is defined as angle between the blade plane and tangent to circumference.

$$W = \frac{H_h}{\sin\beta} \qquad (3.18)$$

and

$$\beta = 90° + \gamma - \alpha \qquad (3.19)$$

Where,

H_h=half of maximum working depth, m

α= angle of blade rotation from the horizontal, degree

β= angle of inclination of the blade from horizontal ,degree

γ= cutting angle, 23.8°

Inclination angle (β) was calculated from Eq. 3.19. To solve Eq.3.19, angle α was determined as:

$$\alpha = \sin^{-1}\left(\frac{\mathrm{H} - \mathrm{H_h} + \mathrm{R}}{\mathrm{R}}\right) = \sin^{-1}\left(\frac{3 - 6 + 16}{16}\right) = 54.34°$$

where,

H= maximum working depth

R= radius of rotor

The cutting angle γ was determined as 23.8°. By substituting above calculated values of angles γ and α in Eq. 3.19, inclination angle β was calculated as:

$$\beta = 90° + \gamma - \alpha = 90° + 23.8° - 54.34° = 59.46°$$

According to Eq. 3.18, the calculated minimum blade width W was 3.48cm.

3.3.2 Maximum expected Length of soil slice, L

$$\mathrm{L} = \frac{\mathrm{v \ x \ 2 \ x \ 3.14 \ x \ R}}{\mathrm{u \ x \ z}} \tag{3.20}$$

$$\mathrm{L} = \frac{0.70 \ \mathrm{x} \ 2 \ \mathrm{x} \ 3.14 \ \mathrm{x} \ 16}{2.94 \ \mathrm{x} \ 4}$$

L = 5.9 cm

Where,

v = forward speed, 0.65 m/sec

u= peripheral speed of rotor with radius R .

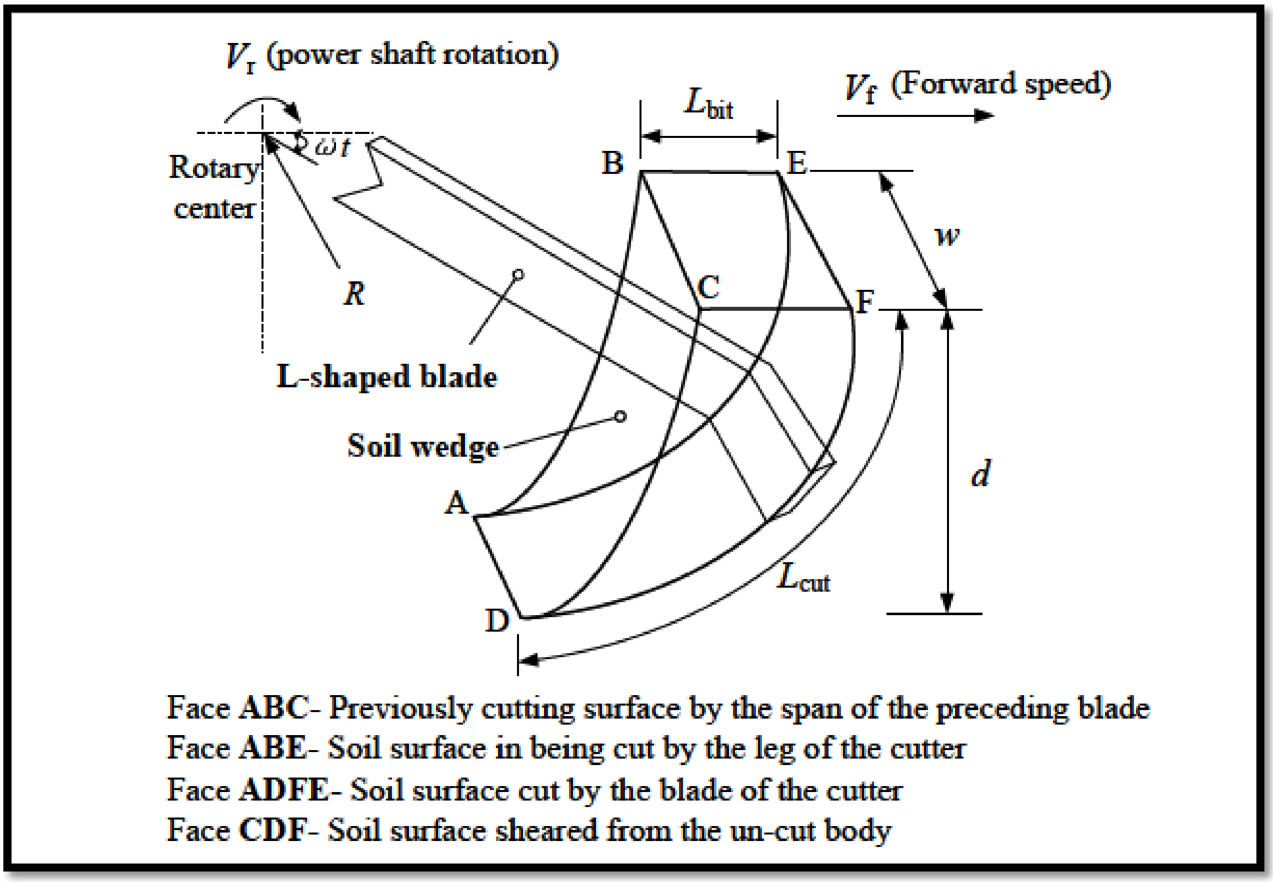

Fig. 3.5 Soil- tool interaction of L shaped blade

3.3.2.1 Maximum force required to cut the soil for each blade (P);

$$P = pA = 0.50 \text{ x } 2.2 \text{ x } 5.9 = 6.49 \text{ kg/each blade} \qquad (3.21)$$

Where;

p = Maximum specific resistance of soil = 0.50 kg/cm^2

A = Area to be disturbed,

A= a × length of soil slice; and

a = edge length of the blade, 2.2 cm.

l = length of blade, 11.3 cm

If we have maximum four blades but only one can cut and disturb the soil, and 3 sets in the power rotor, so the maximum force required to cut the soil by the weeder.

$\mathrm{P_{max}} = 6.49 \text{ x } 3 = 19.47 \text{ kg}$

Cutting force per unit length of blade

$$\mathrm{P_a} = \frac{\mathrm{P_{max}}}{\mathrm{l}} = \frac{19.47}{11.3} = 1.72 \text{ kgcm}^{-1}$$

Taking this as beam (cantilever) with uniformly distributed load, both maximum bending load and moment of inertia can be calculates as below:

$$\text{Maximum bending load} = \frac{\mathrm{P_a} \text{ x } \mathrm{l}^2}{2} = \frac{1.72 \text{ x } 11.3^2}{2} = 109.81 \text{ kgcm}$$

$$\text{Moment of inertia(I)} = \frac{1}{12} \text{ x } \mathrm{b_e} \text{ x } \mathrm{S_s^3} = \frac{1}{12} \text{ x } 0.2 \text{ x } 4^3 = 1.066 \text{ cm}^4$$

Where;

S_s is width of blade edge, 2 cm; and

b_e is maximum thickness of blade edge, 0.2 cm.

3.3.2.2 To check for bending;

$$\text{Deflection for cantilever beam} = \frac{\mathrm{P_{max}} \text{ x } \mathrm{l}^3}{3\mathrm{EI}} \tag{3.22}$$

Where;

E = 2.1 × 106 kg /cm^2 for mild steel.

The value will be:

$$\text{Deflection for cantilever beam} = \frac{19.47 \text{ x } 11.3^3}{3 \text{ x } 2.1\text{x } 10^6 \text{ x } 1.066} = 4.18 \text{ x } 10^{-3}$$

It is almost negligible and for safe design deflection should be < a/1200 ($4.18 \times 10^{-3} < 5 \times 10^{-3}$), so, it is safe. The manufactured sets of blades are shown in Fig. 3.6.

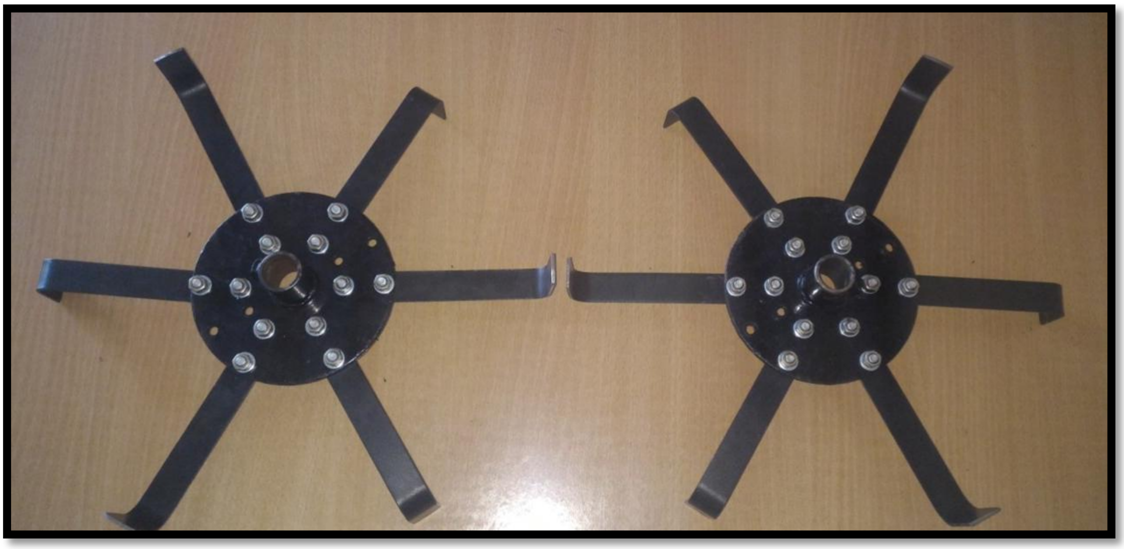

Fig. 3.6 Manufactured set of blade

3.3.2.3 Kinematics of rotary blade

The working tools of rotary machines execute a complex motion consisting of relative-rotary motion around the axis of the rotor with a peripheral speed of u and translatory with a travel velocity of v.

The power weeder designed on the principle of the rotary tiller. It is powered by a small I-C engine. The theory of operation on which the design of the weeder is based is presented as follows. Fig.1 is the sketch of a rotary hoe with a number of shares denoted as, A_1, A_2,..A_n. The sketch shows the mechanism of operation and various parameters of the soil slice. The radius of the rotor is R and depth of cut is denoted by a. Let V_m and ω be the forward speed of the implement and the angular velocity of the blade, respectively. So, as the implement moves forward a distance of $V_m t$, the blade rotates through an angle of ωt and the shares assume the positions $A_1'\ldots A_n'$. The coordinates of say A_1' referred to the x and y axes are given by

$$x = V_m t + R\cos\omega t \quad (3.23)$$

$$y = R(1 - \sin\omega t) \quad (3.24)$$

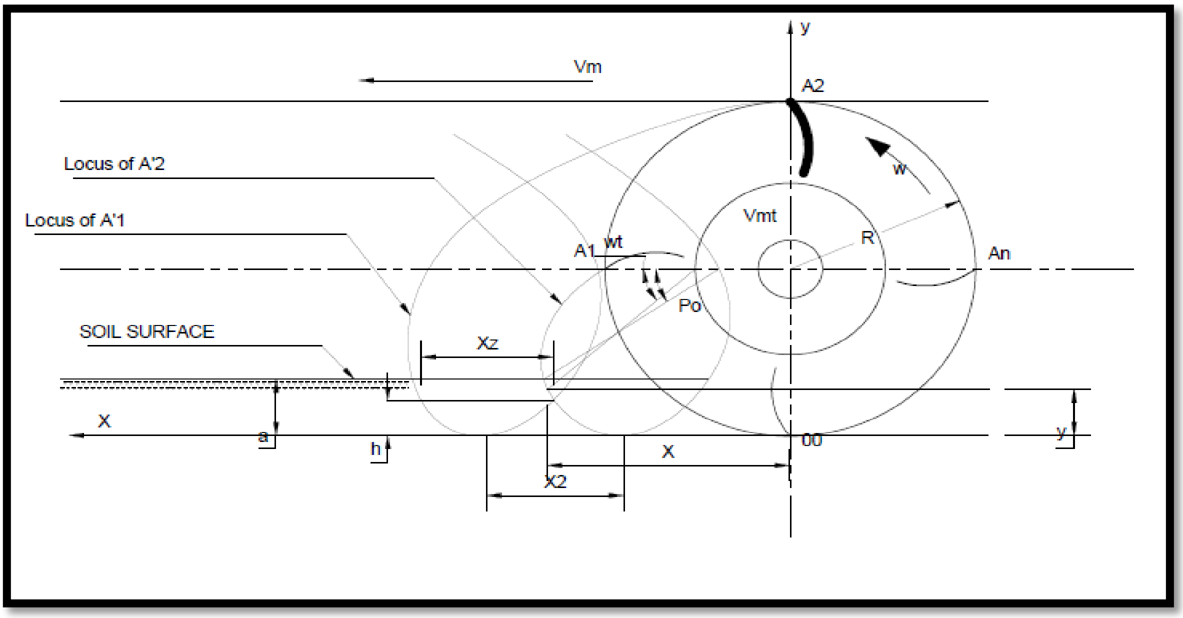

Fig. 3.7 Mechanism of operation of rotary weeder blade

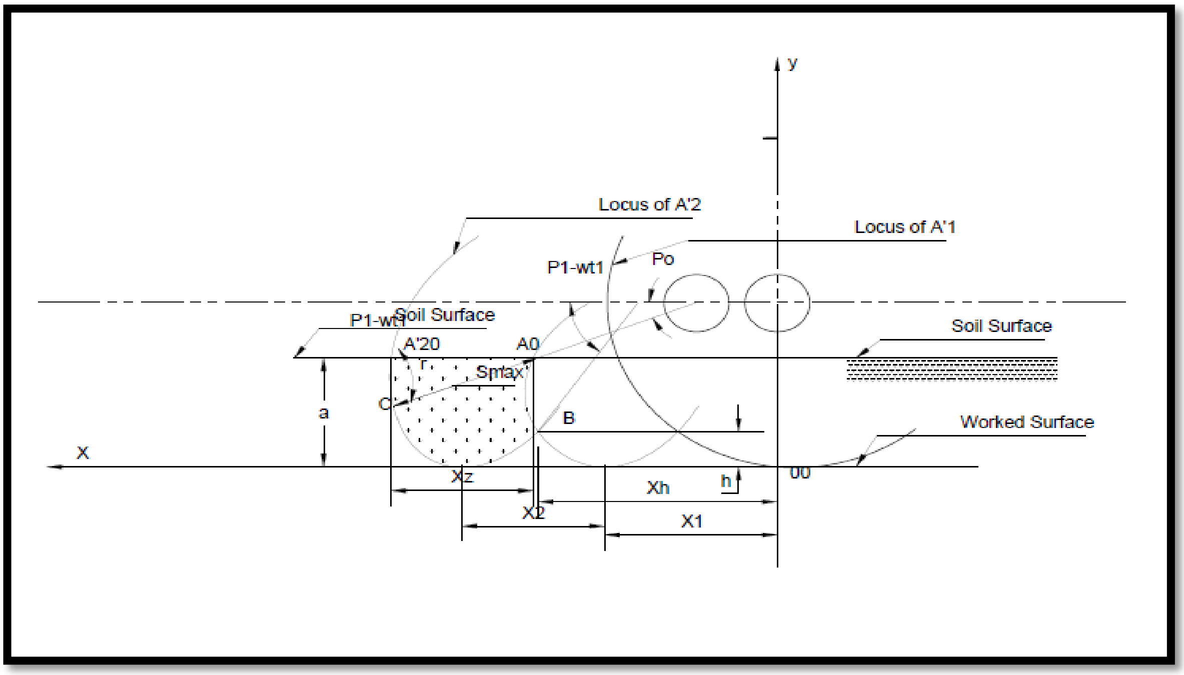

Fig. 3.8 Parameters of soil slice

3.3.3 Conditions for cutting off a soil slice:

The equations given in (1) describe the absolute motion of the share to trace the locus of A_1' over time as sketched in fig.1. Let $A_{1,0}$' denote the position of A_1 as it begins to cut through the soil. Denoting the depth of cut by a, the angle through which AI rotates to get to $A_{1,0}$' is given by ϕ_o which equals ωt_0 such that from equation, 1b),

$$\sin \emptyset_0 = 1 - \frac{a}{R} \tag{3.25}$$

As A_I starts to penetrate the soil at $A_{1,0}$' its direction of motion is vertically down. Afterwards, its motion will be opposite to the direction of implement forward travel as it cuts off a soil slice. This means that there is a point of inflexion in the locus traced by at A_1 at which the absolute velocities of the share in the x direction is zero and may be given by

$$\frac{dx}{dt} = \mathrm{V_m} - \mathrm{R}\,\omega \sin \emptyset_0 \tag{3.26}$$

and

$$\sin \emptyset_0 = \frac{\mathrm{V_m}}{\mathrm{R\omega}} = \frac{1}{\lambda} \tag{3.27}$$

which defines λ as,

$$\lambda = \frac{\mathrm{R\omega}}{\mathrm{V_m}} \tag{3.29}$$

From equation (3.28), λ may be given as

$$\lambda = {}^{R}\!/_{(R-a)} = {}^{1}\!/_{(1-m)}$$

where m is the ratio of a/R.

The above expressions gives the necessary condition for cutting off a soil slice. If the relative magnitudes of the peripheral velocity of the shares, V_m and the implement forward speed, V are such that dx/dt has the same direction as the implement travel after penetrating the soil, then the share withdraws from the soil without cutting off a soil slice. The different possible paths of a share through the soil for various values of λ are illustrated in fig.2 which shows that cutting off a soil slice is possible only when λ is greater than unity. Therefore, for any weeding to occur with a rotary weeder, the ratio Rw / V_m must be greater than unity.

Kinematics velocity (λ) at these forward and peripheral velocities was,

Kinematics velocity, $\lambda = \frac{u}{v} = \frac{2.94}{0.70} = 4.2$

3.3.4 Specific work method (SWM)

The specific work of rotary weeder is defined as the work carried on by rotary weeder at each rotation of L blades per the volume of broken soil, which could be calculated by the following equation (Bernacki *et al*, 1972):

$A = Ao + A_B$ kg-m/dm^3 (3.30)

Where: Ao and A_B are the static specific work and dynamic specific work of rotary tiller (kg-m/dm^3), respectively, which can be calculated throw the following equations (Bernacki *et al*, 1972):

A_O and A_B are obtained by using following relationship:

$A_O = 0.1Co\, k_o$ kg-m/dm^3

$A_b = 0.001a_u\, u^2$ kg-m/dm^3

$A_b = 0.001a_v\, v^2$ kg-m/dm^3

Where,

C_0 coefficient relative to the soil type,

k_o specific strength of soil (50 kg-m/dm^3) for very heavy soil

u is the tangential speed of the blades (m/s),

v is the forward speed (m/s), a_u and a_v are dynamical coefficients that are relative together throw the following equation

$a_v = a_u \lambda^2$ kg.s^2/m^4

where,

$$\lambda = \frac{u}{v}$$

Hendrick and Gill (1971) suggested the minimum value of 2.5 for λ. Matyashin (1968) reported that at the forward rotation of the rotary weeder shaft, the power consumption is decreased 10-15 %, in comparison with the shaft reverse rotation. Hence, in this design the forward rotation was considered for the rotary tiller shaft to reduce the power consumption and also utilization of the rotary weeder thrust force at the forward rotation. In designing the rotary weeder, the hard condition of the soil was considered. The values of C_o, K_o and au in very heavy soils are 2.25, 50 (kg/dm^3), and 400 (kg.s^2/m^4), respectively (Bernacki *et al*, 1972).

$$Ao = 0.1 \text{x } 2.25 \text{ x } 50 \text{ kg-m/dm}^3$$

$$= 11.25 \text{ kg-m/dm}^3$$

$$A_b = 0.001 a_u u^2 \text{ kg-m/dm}^3$$

$$= 0.001 \text{ x } 400 \text{ x} 1.44 \text{ kg-m/dm}^3$$

$$= 0.576 \text{ kg-m/dm}^3$$

$$A = A_o + A_b \text{ kg-m/dm}^3$$

$$= 11.25 + 0.576 \text{ kg-m/dm}^3$$

$$= 11.83 \text{ kg-m/dm}^3$$

In order to minimize the energy requirements for a given operation, the following suggestions could be made:-

1. Blade cutting width used, should be as small as possible.
2. Bite length should conform with tilth requirements.
3. Rotor speeds should be as slow as possible.

3.4 Description of Machine Components

Based on design values of different components, an engine operated rice weeder was fabricated in the workshop of the SV CAET, Faculty of Agricultural Engineering, IGKV, Raipur. A power source of 2 hp, 6000 rpm, two-stroke petrol engine was selected, which was capable of providing the required power. The technical specifications of the engine are shown in Table 3.3.

Table 3.3 Technical specifications of the machine

S.No.	**Specification**	**Value**
1	Number of cylinder	1
2	Engine maximum power at 6000 rpm	2 hp
3	Weeding width	140 mm to 250 mm
4	No. of Blades	4,6,8 as per field condition
5	Rotor speed	176 rpm
6	Weeding depth	3 - 8 cm
7	Power transmission	Light weight aluminium gear box
8	Fuel tank capacity	1.1 Lts
9	Fuel	Petrol mixed with lub.oil(1lts of petrol with 40 ml of oil)
10	Material of blade	Mild steel-L type blade
11	Overall dimension (LxWxH)	1345.8 x 573 x 1020 mm
12	Total weight	14.5 kg

The accompanying views and photographs show the general constructional features of the machine. The designed and developed rice power weeder is fabricated in the workshop of Swami Vivekananda College of Agricultural Engineering and Technology and Research Station, Faculty of Agricultural Engineering, IGKV, Raipur. The materials used for fabrication are mostly of mild steel. Each of the major components was designed, fabricated and then assembled properly.

3.4.1 Power unit

The power required for wetland rice inter-culture is about ½ to 1 hp per row (Olaye *et al.,* 2003). The engine to be used for design and development of power weeder therefore can cope with the draft requirement for one row. Hence, a single cylinder, 2- stroke petrol engine, recoil start of 43 cc (2 hp) with side valve and air cooled engine was used as a prime mover for the rice power weeder.

3.4.2 Transmission

A light weight aluminium gear box connected vertical with the engine. The power from the single central vertical rotor was transmitted to the rotor by means of worm and worm gear arrangement. The rotary wheels were rotated by the power transmission system of the engine. The bottom of the weeder is provided with the float. The forward speed of the machine with a speed ratio of 34:1 from engine to rotor shaft.

3.4.3 Floating mechanism

A particular subset of soil engaging components is the float system, which can be an addition or integrated into the design of the weeder. This component becomes relatively important when the weeder is thought to operate within particular crops or deep-water agriculture systems. In the case of rice cultivation, a float is needed for the machine not to sink in accordance with the different water levels into the soil. The floating mechanism is important part of the machine, as it helps the machine to float in muddy conditions without sinking. The floats reduce the ground reaction due to buoyancy effect. In the present study adjustable float made of plastic control the depth of shearing as required in different ground conditions. The width and the length of the frame for cutting tool were decided by considering the row to row space for crop and diameter of the rotor. As the row to row spacing was in the range of 15 to 24 cm, the width of the frame was kept as 130 mm and 200 mm was the length of the frame.

3.4.4 Rotary blades

In rotary weeders, blades are attached to a flange mounted on a rotating shaft usually by nuts & bolts. Commonly three types of blade geometries are used as blades for weeders and tillers namely, L-shaped blades, C-shaped blades and J-shaped blades. The C-shaped blades have greater curvature, so they are recommended for penetration in hard field and better performance in heavy and wet soils. The J-shaped blades are used for loosening, destroying the soil surface compaction and giving better ventilation to the soil, generally used for tilling hard and wet soils whereas L-shaped blades are the most common widely used for the fields with crop residue, removing weeds (Bernacki *et al.,* 1972 and Khodabakhshi *et al*., 2013).In this study, three units of rotary cutting blades were used for weeding operation. Each unit consist of four "L" shaped blades connected in orthogonally opposite direction on a rotary flange which is attached to the rotatory shaft by means of sleeved hub and nut – bolt system. The rotary cutting blades were made of MS flat 25×5 mm size, length of 11.3 cm. The MS flat are bending from one end to form "L" shape to satisfy the cutting length of 4 cm and fixed to rotary flange of 120 mm diameter by using nut and bolt of dia 10 mm. The cutting blades were circular rotating in the horizontal plane. The blades were connected to the rotating shaft with the help of nut, bolts and washer. Thus there was a provision to change the type of blade whenever required.

- 4 blade
- 6 blade
- 8 blade

Fig. 3.9 Different numbers of blade used

3.4.5 Handle

Handles are made of 20 mm MS rectangular frame of length 40 mm and width 18 mm with plastic grip fitted at the ends. The overall length of handle 1090 mm with two bends from point of attachment and have a height of 1020 mm from ground level. The length of handle cross bar is 570 mm and diameter of handle grip is 25 mm with a length of 105 mm. The handle is attached on main frame at the rear of the machine with help of four pieces of nut and bolts of having dia 10 mm. With help of handle, the machine can be steered. A throttle lever is provided on right side of the handle to control the engine speed (Varshney *et al.*, 2004).

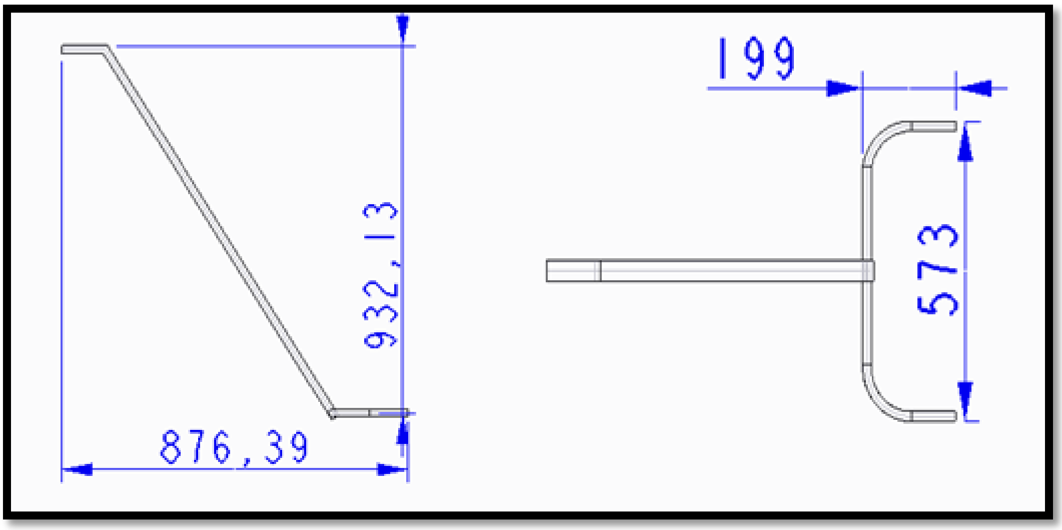

Fig 3.10 Design of handle

3.4.6 Mud flap

To avoid throwing of mud and stones towards operator and as a safety, a mud flap is provided covering the upper and rear side of the blades of the rotary cutting units. Upper side is made up of plastic sheet of length 490 mm and width 262 mm and the rear side is covered by rubber sheet of length 270 mm and width 190 mm. Both is connected and supported to the inner end of the handle by means of 10 mm diameter, 20 mm length nut and bolt with the help of MS flat of size of length 232 mm and width 20 mm.

3.4.7 Throttle lever

A hand operated throttle lever was provided for controlling the speed of the machine and is attached to right hand side of the handle. Fig. 3.9 shows the fabrication of power weeder in workshop, SVCAET & RS, FAE, Raipur.

3.4.8 Assembling of power weeder

After finalizing the dimensions of manufactured parts, assembling of all parts together was done and located in suitable frame, which carry the different units without baulking the performance of the engine and the weeder.

Fig. 3.11 Assembling of power weeder

3.4.9 Width of operation control arrangement

In addition to the above mentioned arrangements done for the weeder, a width of operation control device was used with the weeder; this arrangement makes the weeder working in a suitable width with minimum variation in the range of 14 cm upto 30 cm.

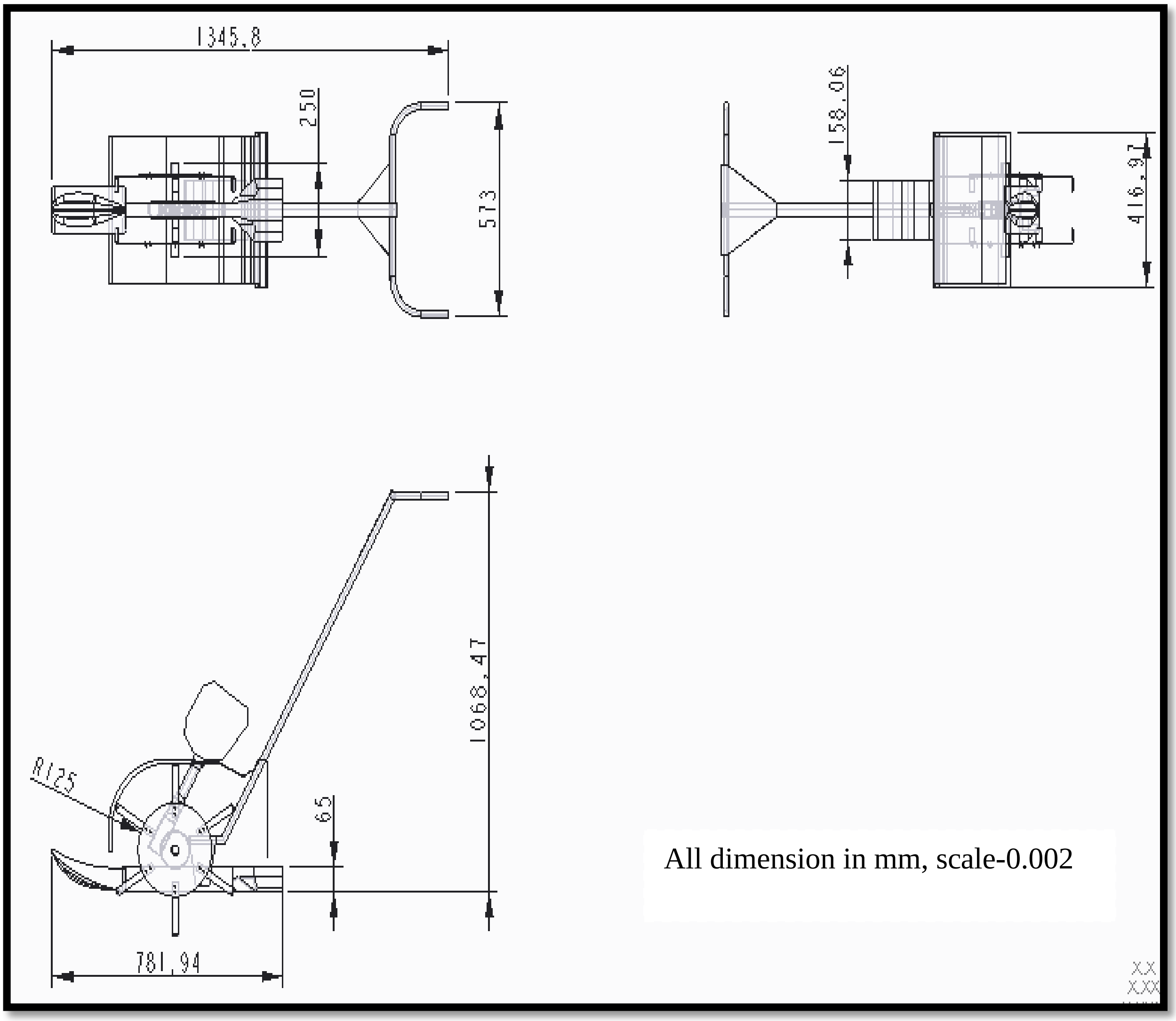

Fig. 3.12 2-D diagram of the developed machine

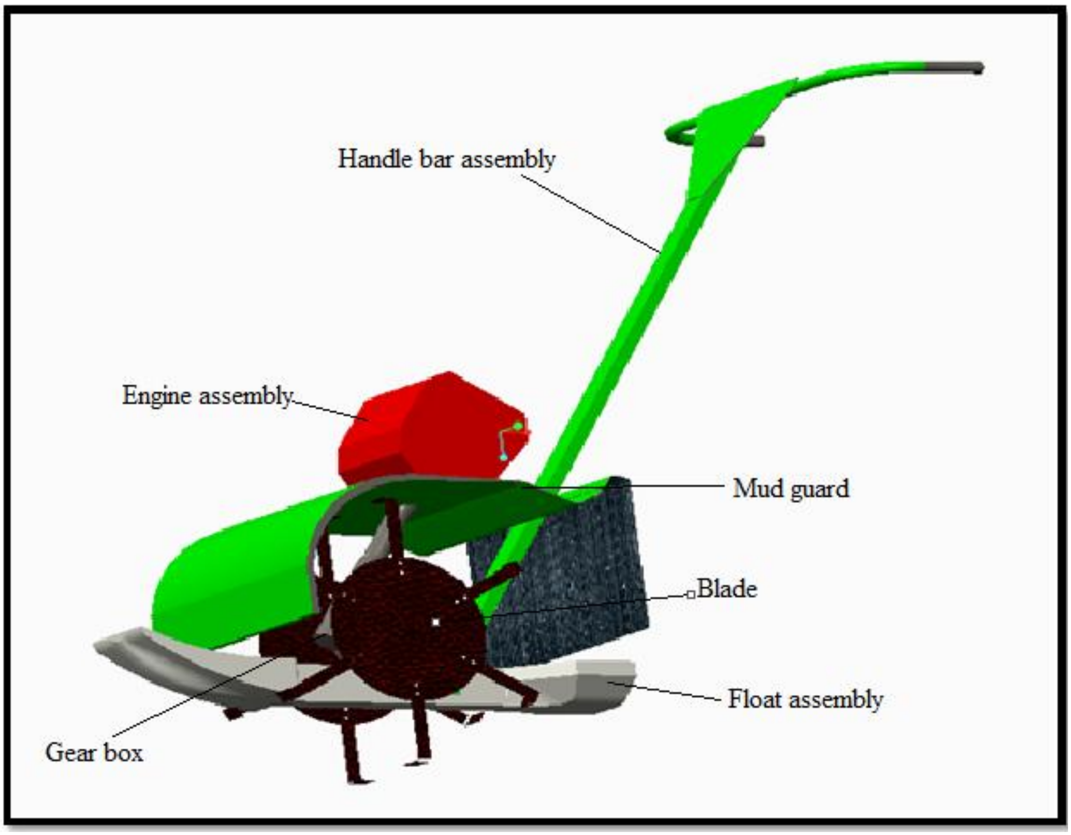

Fig.3.13 Developed machine

3.5 Experimental detail

The field experiment was conducted at different field conditions in IGKV research farm, Raipur. The selected plots were divided into four sub plots of 20 m x 20 m each, with a fairly regular, roughly rectangular or square shape. Three subplots were weeded by using a different blade arrangement in developed single row power weeder and one sub plot was weeded by ambika paddyweeder. Relevant observations of each treatment regarding field conditions of each were recorded before and after the weeding operation.

Power weeder with different numbers of blades and manual weeder (ambika paddy weeder) are selected as treatments:

(T1) Power weeder- 4 blades, all are at 90° to each other

(T2) Power weeder-6 blades, all are at 60° to each other

(T3) Power weeder-8 blades, all are at 45° to each other

(T4) Ambika paddy weeder

Both independent and dependent variables used in the study were as shown in Table 3.4.

Table 3.4 Variables taken for the study

Independent variables and their values	
Soil moisture content	26.26 %, 25.27 %, 21.42 %
Blades arrangement for each unit	Four, six and eight blades
Forward speed	1.5 to 2.6 km/hr.
Width of operation	14cm to 25 cm
Dependent Variables:	
Fuel consumption	Field efficiency
Plant damage	Effective field capacity
Weeding Index	Total cost

3.5.1 Testing and Performance Evaluation

Field testing was done by following the testing criteria and aspects mentioned by test codes. Testing of developed power weeder was tested as per IS: 1976:1976 test code and the following observations were recorded. Fig. 3.14 shows testing and performance evaluation of different treatments.

Fig. 3.14 Testing of gender friendly power weeder

3.5.1.2 Mechanical weeding -Power weeder

After completion of the development of power weeder the field experiment were conducted.to evaluate the performnce of the machine the following parameters has been considered. Weeder were operated across length and breadth of the field.

3.5.1.3 Mechanical weeding (manual operated)

Ambika paddy weeder was used for this operation. During operation, 5- 6 cm of standing water is maintained in the field. Then manually operated weeder is operated between the line sown rows of rice by pushing and pulling action of the weeder, weeds were cut and uprooted. Table.3.5 shows the specification of Ambika weeder .

Table 3.5 Specification of Ambika paddy weeder

Sl. No.	Particular		Specification
1	Over all dimension :	Length (mm)	1800
		Width (mm)	130
		Height (mm)	1200
2	Roller diameter	(mm)	160
3	Cutting width	(mm)	110
4	Cutting roller	(mm)	Contains 5 Numbers of blades
5	Handle width	(mm)	350
6	Soil cutting depth	(mm)	25 – 30
7	Weight	(kg)	3

Source: NAE, Annual Report, FAE, IGKV-2014-15

3.5.2 Operational parameters

3.5.2.1 Plant population

The total numbers of plants were counted in an area of one square meter by a quadrate of $1m^2$ from randomly chosen places in each plot, before and after every weeding operation to observe plant damage percentage.

3.5.2.2 Weed population

Weed population per square meter was recorded randomly from each plot with help of $1m^2$ quadrate, after 15 DAS, 25 DAS and 35 DAS. All the weeds present, in each plot were grouped under grasses, sedges and broad leaf weeds.

3.5.2.3 Bulk density of soil

The bulk density of soil was determined by core cutter method. The core sampler of the soil of known volume was collected and weighed. The soil bulk density was determined as:

Bulk density = mass of soil / volume of soil

$$\rho = \frac{M}{V} \tag{3.31}$$

Where,

ρ = Bulk density, g/cm^3

M = Mass of the soil, g

V = Volume of the soil, cm^3

3.5.2.4 Moisture content of soil

The moisture content of the soil was determined by oven drying method. In this, wet soil sample of known weight was kept in the thermostatically controlled oven at a temperature of 105° C for 24 hours. The dried soil is again weighed and the moisture content is determined as:

$$W = \frac{W_w - W_d}{W_w} \tag{3.32}$$

Where,

W = Moisture content, (% db)

W_w = weight of moist soil, g

W_d = weight of dry soil, g

3.5.2.5 Effective working depth

The depth of cut of the machine with different blades was measured in the field by measuring the depth of soil layer tilled by the blade in a row. The depth of the weeding was measured by measuring scale in different rows at different places. Average of five observations was taken as depth of weeding and expressed in cm.

3.5.2.6 Effective working width

The width of cut of the machine with different blades was measured in the field by observing the strip of soil and weeds cut in a row.

3.5.3 Machine performance and evaluation

The machine performance parameters such as weeding efficiency, plant damaged, effective field capacity, theoretical field capacity, field efficiency, and fuel consumption of power weeder were determined for the performance evaluation and are determined as follows.

3.5.3.1 Weeding efficiency

It is the ratio between the numbers of weeds removed by power weeder to the number of weeds present in a unit area and is expressed as a percentage. The samplings were done by quadrant method, by randomly selection of spots by a square quadrant of 1 square meter (Tajuddin, 2006).

$$\text{Weeding efficiency}(\%) = \frac{w_1 - w_2}{w_1} \qquad (3.33)$$

Where,

W_1 = Number of weeds counted per unit area before weeding operation

W_2 = Number of weeds counted in same unit area after weeding operation

3.5.3.2 Plant damaged

It is the ratio of the number of plants damaged after operation in a row to the number of plants present in that row before operation. It is expressed in percentage.

$$\text{plant damage}(\%) = \left(1 - \frac{q}{p}\right) x100 \qquad (3.34)$$

Where,

p = Number of plants in a 10 m row length of field before weeding.

q = Number of plants in a 10 m row length of field after weeding.

3.5.3.3 Effective field capacity

Effective field capacity is the actual average rate of coverage by the machine, based upon the total field time. It is a function of the rated width of the machine, the percentage of rated width actually utilized, speed of the travel and the amount of field time lost during the operation. Effective field capacity is usually expressed as hectare per hour (Kepner *et al.*, 1978).

$$\text{EFC} = \frac{A}{T_P + T_i} \qquad (3.35)$$

Where,

EFC = Effective field capacity, ha/h

A = Actual area covered, ha

T_p = Productive time, h

T_i = Non-productive time, h

3.5.3.4 Theoretical field efficiency

Theoretical field capacity of the machine is the rate of field coverage that would be obtained if the machine were performing its function 100% of the time at the rated forward speed and always covered 100% of its rated width. It is expressed as hectare per hour and determined as follows (Kepner *et al.*, 1978).

$$\mathrm{TFC} = \frac{\mathrm{w \ x \ s}}{10} \tag{3.36}$$

Where,

TFC = Theoretical field capacity, ha/h

w = Width of cut, m

s = Speed of operation, Km/h

3.5.3.5 Field efficiency

Field efficiency is the ratio of effective field capacity to the theoretical field capacity, expressed as percentage. It includes the effect of time lost in the field and of failure to utilize the full width of the machine.

$$\eta_e = \left(\frac{\mathrm{EFC}}{\mathrm{TFC}}\right) \mathrm{x} \ 100 \tag{3.37}$$

Where,

η_e = Field efficiency, %

EFC = Effective field capacity, ha/h

TFC = Theoretical field capacity, ha/h

3.5.3.6 Fuel consumption

The fuel consumption has direct effect the economics of the power weeder. It was measured by top fill method. The fuel tank was filled to full capacity before the testing at levelled surface. After completion of test operation, amount of fuel required to top fill again is the fuel consumption for the test duration. It was expressed in litre per hour.

Fig. 3.15 Feasibilty testing of power weeder

3.6 Ergonomics evaluation of the developed machine

3.6.1 Subjects

For ergonomic evaluation of weeders, four subjects were randomly selected from 49 agricultural workers in and around IGKV, Raipur. The workers were in the age group of 18-41 years. The entire sample of 49 subjects was divided into three age groups of 18-25, 26-33 and 34- 41 years and subjects from each age group were randomly selected for the study. Each subject was asked to operate the weeders for 20 min in a rice field having a row-to-row spacing of 25cm at IGKV, Raipur. The physiological characteristics of selected subjects are given in Table 3.6.

The ratio between height and weight of the subjects (H/W) could be extensively used to define and classify physique of the subjects. The physical work capacity is directly correlated with height and inversely with weight of the subjects. Hence in this study, the subjects for the field investigation of performance and ergonomic factors associated with weeding were selected on the basis of their height to weight ratio.

Body mass index, also called BMI, is a calculation of a correlation between a person's height and weight that categorizes him or her as underweight, of normal weight, overweight or obese, assuming a normal body composition. Underweight is considered a BMI of 18.4 or lower. A BMI of normal weight is any number between 18.5 and 24.9. The overweight range is between 25 and 29.9, with anything above that being considered obese.

Regardless of activity level, a minimum level of energy is required to sustain the body's everyday functions. Resting metabolism, the amount of calories needed to supply the body with the minimum level of energy, differs between individuals depending on variables such as age, weight, body composition and energy expenditure.

Body age is based on resting metabolism. Body age is calculated by using weight and body fat percentage to produce a guide to judge whether the body age is above or below the average for actual age. Body age varies according to Body composition and resting metabolism, even if height and weight is the same.

Table 3.6 Physiological characteristics of participants

Variable	S1	S2	S3	S4
Weight, kg	48.5	46	58.5	56
Age, year	29	33	26	22
Fat, %	22.6	19.2	14.8	26.2
RM, kcal	1180	1130	1454	1391
BMI	16.1	18.1	4.0	21.1
Body Age, year	19	30	22	28
Subcantaneous whole body, %	14.5	15.0	10.3	17.5
Subcantaneous trunk,%	12.0	13.2	8.8	15.3
Subcantaneous arms,%	21.3	21.0	16.2	26.2
Subcantaneous legs, %	21.1	18.5	15.2	32.1
Skeletal whole body,%	35.0	37.2	35.9	24.3
Skeletal trunk,%	27.6	26.1	30.5	39.2
Skeletal arms,%	42.0	40.1	40.8	41.2
Skeletal legs,%	52.2	50.5	53.0	49.4

3.6.2 Field layout experiments

The experiment was conducted in IGKV research farm feld in Raipur District, Chhattisgarh, India. The developed power rice weeder was put in proper test condition before conducting the tests. All the four subjects were equally trained in the operation of the power rice weeder. They were asked to report at the work site at 9:30 am and have a rest for 30 minutes before starting the trial. To minimize the effects of variation, the treatments were given in randomized order. All the subjects used similar type of clothing. The subjects were given information about the experimental requirements so as to enlist their full cooperation. The heart rate was measured and recorded using stethoscope for the entire work period. Each trial started with taking five minutes data for physiological responses of the subjects while resting on a chair under shade. They were then asked to operate the power rice weeder only for duration of periods till the subject was feel no fatigue and same procedure was repeated to replicate the trials for all the selected subjects.

3.6.3 Physiological response

3.6.3.1 Heart rate

The stethoscope was used to measure the average heart rate during the rest and working condition (beats/min).

$$\Delta \mathrm{HR} = \text{average working HR} - \text{average HR during rest} \qquad (3.38)$$

3.6.3.2 Oxygen consumption rate (l/min)

The oxygen consumption rate (amont of oxygen consumed by the whole body per unit time) was computed from the heart rate values of the operator and is given by the following equation(Singh *et al*.,2008).

Oxygen consumption rate (l/min) = 0.0114 x HR -0.68 (3.39)

Oxygen consumption rate (kJ)=Oxygen consumption rate x 0.93(1 LO_2=20.93kJ)

The physiological responses like heart rate and oxygen consumption rate (OCR) were measured. The Work load in term of OCR (OCR as % of $V0_2$ max) was determined. The energy expenditure rate (EER) was determined by multiplying the OCR Work with the calorific value of oxygen as 20.93 kJ/l (Nag and Dutt, 1980). The physiological response of workers was studied during the testing of the weeder. In this experiment the effect of the weeder on pulse rate and systolic and diastolic blood pressure was measured. The energy cost of the subjects thus obtained was graded as per the tentative classification of strains in different types of jobs given in ICMR report as shown in Table 3.7.

3.6.3.3 Assessment of postural discomfort

Assessment of postural discomfort included overall discomfort rating (ODR) and body part discomfort score (BPDS). The subjects were asked to report at the work site at 9:30 AM and have a rest for 30 minutes before starting the trial. After 30 minutes of resting, the subject was asked to operate the power rice weeder for duration of two hours. Sufficient rest period was given for each subject and the second trial should be started after the lunch.

Table 3.7 Tentative classification of strains (ICMR) in different types of jobs

Grading	Physiological response		
	Heart rate (bpm)	**Oxygen uptake, l/min**	**Energy expenditure, kcal/min**
Very light	<75	<0.35	<1.75
Light	75-100	0.35-0.70	1.75-3.5
Moderately heavy	100-125	0.70-1.05	3.5-5.25
Heavy	125-150	1.05-1.40	5.25-7.00
Very heavy	150-175	1.40-1.75	7.00-8.75
Extremely heavy	>175	>1.75	>8.75

3.6.3.4 Overall discomfort rating (ODR)

For the assessment of ODR, a 10 - point psychophysical rating scale (0 – no discomfort, 10 - extreme discomfort) was used which is an adoption of technique. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly (Fig.3.16). A movable pointer was provided on the scale to indicate the rating. At the ends of each trial subjects were asked to indicate their overall discomfort rating on the scale. The overall discomfort ratings given by each of the four subjects were added and averaged to get the mean rating.

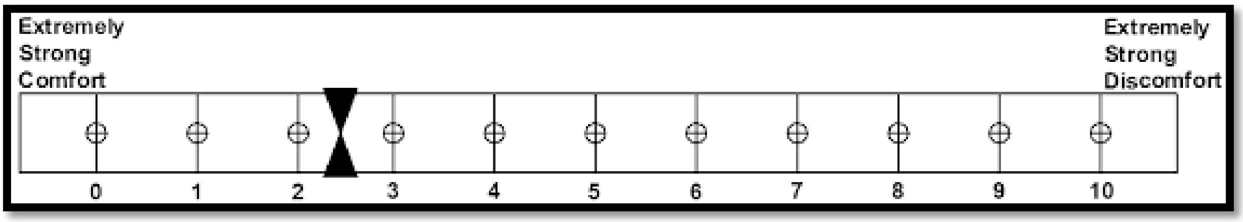

Fig. 3.16 Visual analogue discomfort scale for assessment of overall body discomfort

3.6.3.5 Body part discomfort score (BPDS)

To measure localized discomfort, technique was used. In this technique the subject's body is divided into 27 regions as shown in Fig.4.13. A body mapping similar to that of Fig.4.13 was made to have a real and meaningful rating of the perceived exertion of the subject. The subject was asked to mention all body parts with discomfort, starting with the worst and the second worst and so on until all parts have been mentioned. The subject was asked to fix the pin on the body part in the order of one pin for maximum pain, two pins for next maximum pain and so on. The body part discomfort score of each subject was the rating multiplied by the number of body parts corresponding to each category. The subjects were asked to locate the body parts with respect to degree of discomfort in the order as extremely heavy, very heavy, moderately heavy, heavy, light and very light. The scores given in that order were 6, 5, 4, 3, 2 and 1. The body part discomfort was determined by the following formula (Corlett and Bishop, 1976):

$$BPDS = S\ X_i \times S \qquad (3.40)$$

Where,

BPDS = Body parts discomfort score

X_i = Number of body parts

S = Discomfort score (6 to 1)

3.6.3.6 Acceptable workload (AWL)

3.6.3.6.1 Pulse rate

Pulse rate is a good index of physical as well as physiological load on the operator. The pulse rate was measured with the help of B. P. Monitor. The labours were allowed to relax for 10 min before commencement of operation. The pulse rate reading was taken by the B. P. Monitor of the operator before and after commencement of operation and in this way the pulse rate per minute was computed. The pulse rate is affected due to force required, working time and operator posture. Increased pulse rate also signifies muscular fatigue of subjects.

3.6.3.6.2 Blood pressure

Blood pressure is the pressure exerted by the blood on the walls of the blood vessels. The pressure of the blood in other vessels is lower than the arterial pressure. The peak pressure in the arteries during the cardiac cycle is the systolic pressure and the lower pressure (at the resting phase of the cardiac cycle) is the diastolic pressure.

Fig. 3.17 Instrument used for ergonomics evaluation of developed weeder

3.6.3.7 Work rest cycle

For every strenuous work in any field requires adequate rest to have an optimum work out put. Better performance results can be expected from both the operator and the worker only when proper attention is given for the work rest schedule for different operations. The actual rest time taken for each subject was found from the heart rate response curves of respective operations. The rest time was measured from the cease of the operation till the heart rate of the subject reaches resting level. The rest time taken was averaged to arrive at the mean value for three row power rice weeder. The rest pause to the subject was calculated using the following formula as given by:

$$R = \frac{T\,(E - A)}{E - B} \tag{3.41}$$

Where,

R = Resting time (min)

T = Total working time/day (min)

E = Energy expenditure during working task (kcal/min)

A = Average level of energy expenditure considered acceptable (kcal/min)

B = Energy expenditure during rest (kcal/min)

3.6.4 Instrument used

3.6.4.1 Body fat analyzer

Featuring a full body sensing technology that generates an accurate analysis of the visceral fat level, body fat, body weight, body fat percentage, skeletal muscle percentage and subcutaneous fat percentage, this battery operated fat analyzer comes with a step on analyser function. It is an ideal device for effective weight management since it displays body mass index to indicate the optimum levels of fat according to the dimensions of the body.

3.6.4.2 Blood pressure monitor

Blood pressure monitor was used to measure the blood pressure and pulse rate simply and quickly. It is a compact and fully automatic blood pressure monitor which works on the oscillometric principle to measure blood pressure and pulse rate without fuss.

3.7 Operational Cost

Cost of weeding operation performed for all treatments was worked out on the basis of the prevailing input and fabrication price of the implements, machinery and rental wages of operator and labours if required. The cost of operation of power weeder is divided into two heads known as fixed cost and operation cost, where fixed cost is independent of operational use while variable cost varies proportionally with the amount of use. (Kamboj *et al*., 2012).

The fixed cost includes depreciation, interest on the capital cost, shelter, insurance and taxes. Operation cost includes, fuel, lubricants, repair and maintenances cost, wages. Cost of weeding operation for power weeder was calculated in Rs./ha. Operation cost of the power weeder was calculated and given in Appendix –C.

3.7.1 Fixed cost

3.7.1.1 Depreciation

It was a measure of the amount by which value of the machine decreased with the passage of the time. According to the Kepner *et al.* (2005), the annual depreciation was calculated as follows:

$$D = \frac{C - S}{L \text{ X } H} \tag{3.42}$$

Where,

D = Depreciation per hour

C = Capital investments (Rs.)

S = Salvage value, 10% of capital investment (Rs.)

L = Life of machine in hours or years

3.7.1.2 Interest

Interest is calculated on the average investment of the machine taking into consideration the value of the machine in the first and last year. These are usually calculated on yearly basis. The annual interest on the investment can be calculated as (Kepner *et al.,* 1978).

$$I = \frac{C + S}{2} \text{ X } \frac{i}{H} \tag{3.43}$$

Where,

I = Interest per hour

i = 10 % per year

3.7.1.3 Taxes and insurance

Insurance charge is taken based on the actual payment to the insurance, it may be taken as 1% of the initial cost of the machine per year.

3.7.1.4 Housing

Housing cost is calculated on the basis of the prevailing rates of the locality, but roughly, the housing cost may be taken as 1 % of the initial cost of the machine per year.

3.7.2 Operation cost

3.7.2.1 Repair and maintenance cost

The repair and maintenance cost is a product of machine's cost price and repair and maintenance percentage factor (Kepner *et al.*, 2005 and Kamboj *et al.*,2012).

RM = 2.5 % × Purchase price or capital investment per year

3.7.2.2 Fuel cost

Fuel cost is calculated based on actual fuel consumption for the operation.

3.7.2.3 Lubricants

It can be determined depending upon the maintenance cost or depending upon the oil price or oil consumption. Average lubrication cost is taken as 1.5% of fuel cost in Rs. /h. (Kamboj *et al.,* 2012).

3.7.2.4 Wages of operator

Wages are calculated based on actual wages of workers per hour.

3.7.3 Total cost of weeding per hour

The total cost of weeding per hour of the developed power weeder can be calculated by summation of total fixed cost per hour with total variable cost per hour.

Total Cost/h = Fixed Cost per hour + variable Cost per hour

CHAPTER -IV
RESULTS AND DISCUSSION

This chapter deals with performance of the designed and developed power weeder for rice crop. The performance of the power weeder and corresponding recommendations are also described in this chapter. Field performance test was carried out in control condition as far as possible. The field performance results are shown and described in this chapter. The method of weed management practice such as, mechanical weeder (Ambika paddy weeder) is compared with power weeder for controlling weed. After satisfactory running of the machine with the different blades, the performance was evaluated in line sown rice field. The performance of the single row active power weeder and other different weed management practices are expressed in terms of weeding efficiency, plant damaged, field efficiency, fuel consumption, and cost of operation were calculated for 15, 25 and 35 days for transplantation.

In single row active power weeder, the power transmission mechanism (worm and worm gear arrangement), rotary cutting blades (“L” shaped), rotary shaft, handle, weeding width adjustments and other accessories such as mud flap and throttle system for engine speed control are the main developed parts of the available power weeder. The designed power weeder worked satisfactorily.

The front mounted, two flanges having cutting blades fulfilled the weeding process satisfactorily by cutting and uprooting weeds. The sharpened ends provided on the cutting blades helped to cut the soil and provided a minimum tillage in between the crop rows.

4.1 Operational parameters

4.1.1 Moisture content of soil

Eight soil samples were taken randomly from four replications on an interval of 15 DAS, 25 DAS and at 35 DAS from the soil surface. The average moisture content at 15 DAS is 26.26%, at 25 DAS is 25.27% and at 35 DAS is found as 21.42% on dry basis. Details observed data are represented in Table 4.1.

Table 4.1 Moisture content and Bulk density of soil sample

Sl.No.	Replication	Weight of moist soil (g)	Weight of dry mass (g)	Moisture content on dry Basis, %	Bulk density (g/cm^3)
1	At 15 DAS	221	175.03	26.26	1.20
2	At 25 DAS	160.38	128.02	25.27	1.25
3	At 35 DAS	221	182	21.42	1.40

4.1.2 Bulk density of soil sample

The soil samples were collected at depth levels of 20 cm before operation of weeder. The sample initially weighted before placing into an oven for 24 hours at 105 °C. After drying the weight of sample was again measured. The bulk density of soil at 15 DAS, 25 DAS and 35 DAS is found as 1.20 g/cm^3, 1.25 g/cm^3, 1.40 g/cm^3 respectively. Details observed data are represented in Table 4.1

4.2 Field performance test of power weeder

4.2.1 Operation speed

Operational speed of the machine with the different blades and on different crop/weed stage was determined. The statistically analysed results with mean operational speed of the power weeder are shown in Table 4.2. Highest working speed of operation was found as 0.69 m/sec by using 4 blades in power weeder followed by 0.61 m/sec on using of 6 blades at 15 DAS. Lowest operational speed was found on using 8 blades as 0.47 m/sec at 35 DAS. It was observed that there is no significant effect of different numbers of blades in operational speed at different stages of crop/ weeds. Details observed data are represented in Table 4.2.

Table 4.2 Effect of different blades of power weeder and ambika paddy weeder on working speed

Treatment	Actual working speed, m/sec		
	At 15 DAS	At 25 DAS	At 35 DAS
4 blade	0.69	0.66	0.66
6 blade	0.61	0.62	0.63
8 blade	0.51	0.50	0.47
Ambika paddy weeder	0.26	0.24	0.21
SEm±	0.01	0.01	0.01
CD at 5%	0.04	0.04	0.04
CV	6.01	5.72	6.19

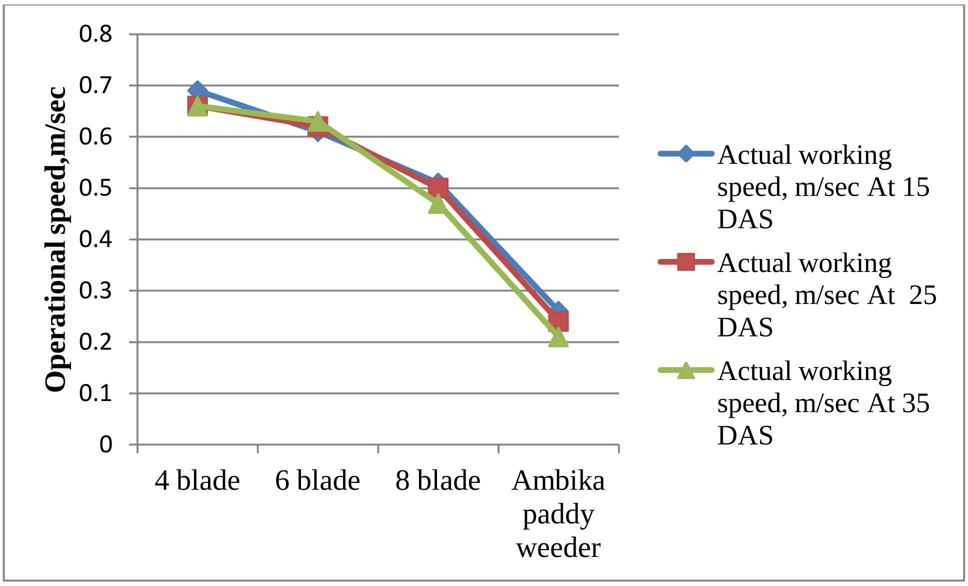

Fig. 4.1 Operational speed of power weeder with different blades and ambika paddy weeder

4.2.2 Fuel consumption

Fuel consumption of the power weeder was calculated by topping method. It was observed that the fuel consumption varied between 0.55 l/h to 0.71 /h. The lowest fuel consumption was found in using of four blade in power weeder as 0.55 l/h while the maximum fuel consumption was found on using of 8 blades as 0.71 l/h due to more depth of cut, clogging and more draft requirement. The data revealed that there is no significant effect of different numbers of blades in fuel consumption at different stages of crop/ weeds. At 25 DAS there is no significant effect on fuel consumption with different treatments. The details observed data are represented in Table 4.3.

Table 4.3 Effect of different blades of power weeder on fuel consumption

Treatment	**Fuel consumption, l/h**		
	At 15 DAS	**At 25 DAS**	**At 35 DAS**
4 blade	0.55	0.55	0.57
6 blade	0.59	0.60	0.61
8 blade	0.67	0.68	0.71
SEm±	0.01	0.03	0.02
CD at 5%	0.03	NS	0.06
CV	4.12	9.29	6.56

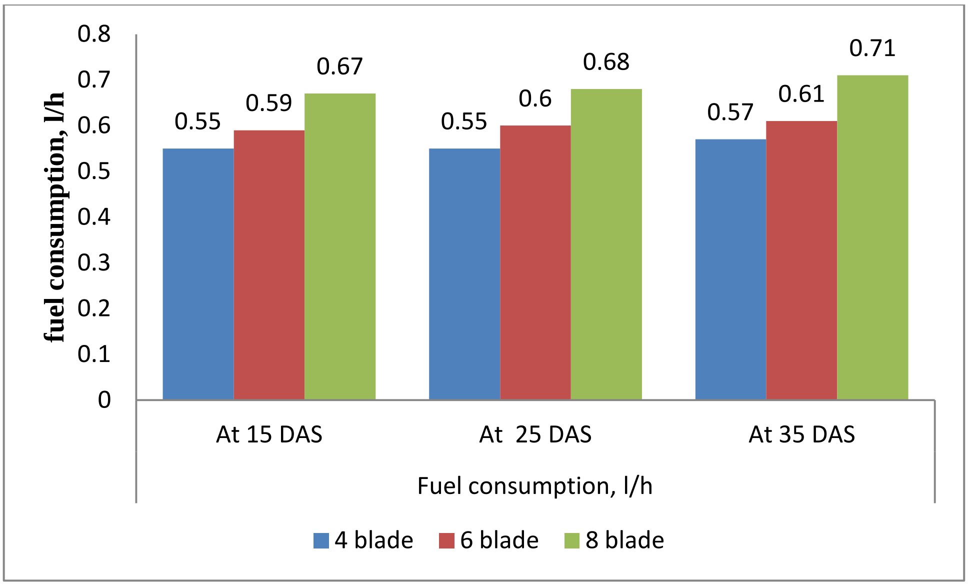

Fig. 4.2 Fuel consumption of power weeder with different blades

4.2.3 Actual working depth of cut

The statistically analysed result of actual working depth of cut is shown in Table 4.4. The data reveals that the maximum depth of cut was found with the 8 blade (6.86 cm at 15 DAS) followed by 6 blade as (4.74 cm at 35 DAS) which was statistically at par and lowest depth of operation was found with the 4 blade (3.84 cm at 15 DAS). The average working depth of ambika paddy weeder was found as 3.8 cm. It was observed that there is no significant effect of different numbers of blades in working depth at different stages of crop/ weeds. At 25 DAS there is no significant effect on different treatments. The details observed data of actual depth of cut are represented in Table 4.4.

Table.4.4 Effect of different blades of power weeder and ambika paddy weeder at different stages of crop/weeds on the actual working depth of cut (cm).

Treatment	Depth of cut, cm		
	At 15 DAS	At 25 DAS	At 35 DAS
4 blade	3.84	4.02	3.98
6 blade	4.72	4.72	4.74
8 blade	6.86	6.60	6.18
Ambika paddy weeder	2.8	2.4	1.9
SEm±	0.21	0.21	0.08
CD at 5%	0.65	NS	0.24
CV	10.54	9.23	4.21

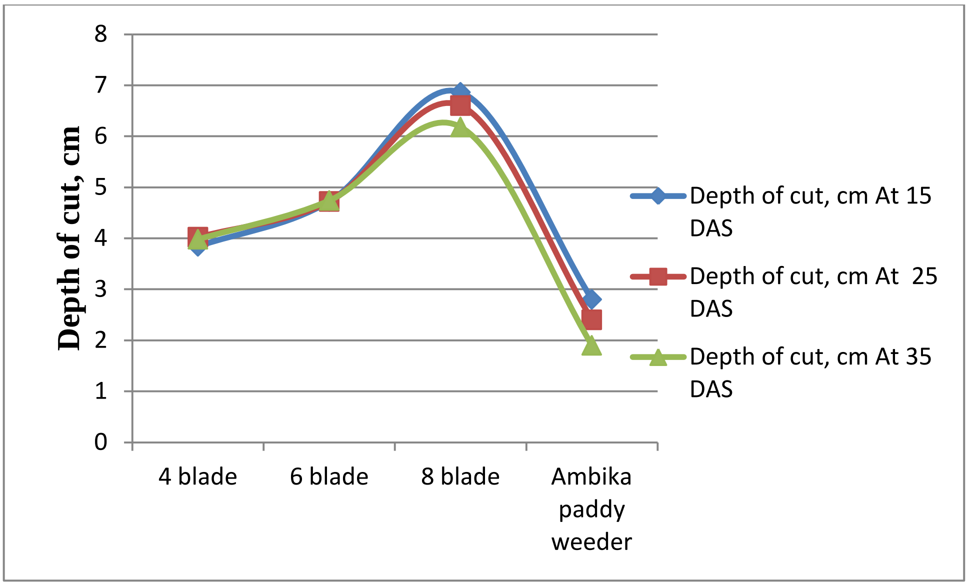

Fig. 4.3 Depth of cut of power weeder with different blades and ambika paddy weeder

4.2.4 Actual working width of cut

The width of cut of the machine with different blades was measured in the field by observing the strip of soil and weeds cut in a row. The width of cut of machine is adjustable from the 14 cm to 25 cm. So it should be set according to the row to row distance of plants. At 15 DAS it should be kept at 22 cm followed by 20 cm at 25 DAS and then at 35 DAS it should be reduced up to 18 cm due to increase in density of plant. The effective width of operation of ambika paady weeder was found as 12 cm.

4.2.5 Power requirement

Power requirement of the power weeder with the different blades and on different crop/ weed stages were determined. The statistically analysed result of the mean value of power requirement is shown in Table 4.5. The data revealed that power requirement at 15 DAS with 22 cm of width is maximum found in 8 blades as 0.51 hp followed by 0.42 hp in 6 blade and then 0.39 hp in 4 blades. Similarly at 25 DAS with operational width 20 cm the maximum power requirement was found as 0.50 hp again on 8 blade followed by 6 blades as 0.39 hp. At 35 DAS the least power requirement was found as 0.32 hp with 4 blades. The table indicates that there was no significant effect of rice crop/ weed stages on field efficiency.

Table.4.5 Effect of different blades of power weeder on power requirement

Treatment	Power requirement, hp		
	At 15 DAS	At 25 DAS	At 35 DAS
4 blade	0.39	0.36	0.32
6 blade	0.42	0.38	0.36
8 blade	0.51	0.44	0.35
SEm±	0.02	0.01	0.01
CD at 5%	0.05	0.04	0.02
CV	8.37	6.77	4.14

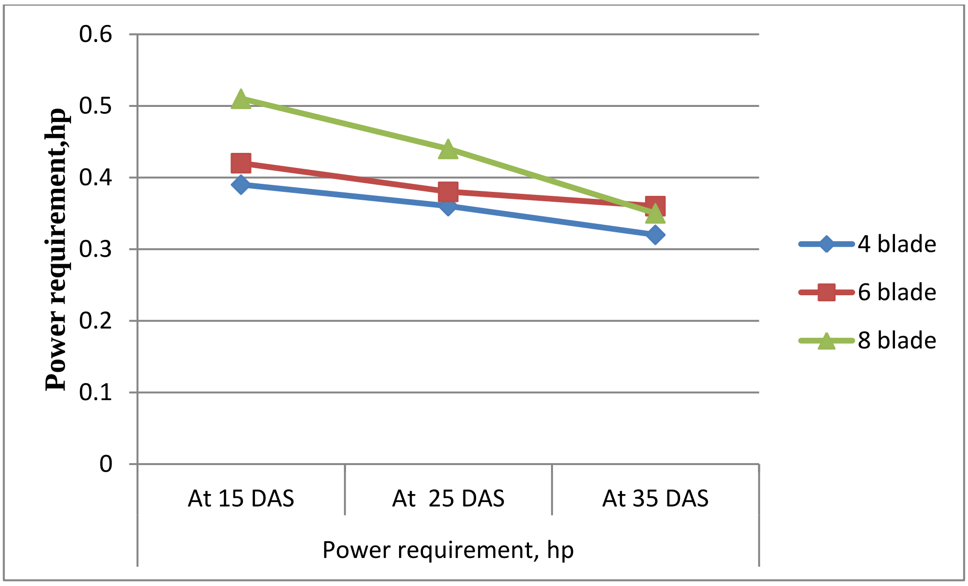

Fig. 4.4 Power requirement of power weeder with different blades

4.2.5 Actual field capacity

Actual field capacity of the machine with the different blades and on different crop/weed stage was determined. The statistically analysed results with mean actual field capacity are shown in Table 4.6. The data reveal that the maximum field capacity was found with 4 blade (0.054 ha/h) followed by 6 blade (0.048 ha/h) at 15 DAS, which was significantly higher than 8 blades at five percent level of significance. The crop/ weed stages have not shown any significant difference in the field capacity.

The highest field capacity in case of 4 blades was due to the comparatively less time required for the operation. The lowest field capacity (0.03 ha/h) at 35 DAS was determined in case of using of 8 blades. This may be attributed to the more time required for operation due to more depth of cutting. The field capacity for different weeding operations is delineated in Table. 4.6. The mean highest field capacity for ambika paddy weeder was determined as 0.011 ha/h. Details data are represented in Table 4.6.

Table.4.6 Effect of different blades of power weeder and ambika paddy weeder at different of crop/weeds on the actual field capacity (ha/h)

Treatment	**Actual field capacity, ha/h**		
	At 15 DAS	**At 25 DAS**	**At 35 DAS**
4 blade	0.05	0.05	0.04
6 blade	0.048	0.05	0.04
8 blade	0.04	0.04	0.03
Ambika paddy weeder	0.01	0.01	0.01
SEm±	0.001	0.001	0.001
CD at 5%	0.003	0.003	0.002
CV	5.325	6.111	5.259

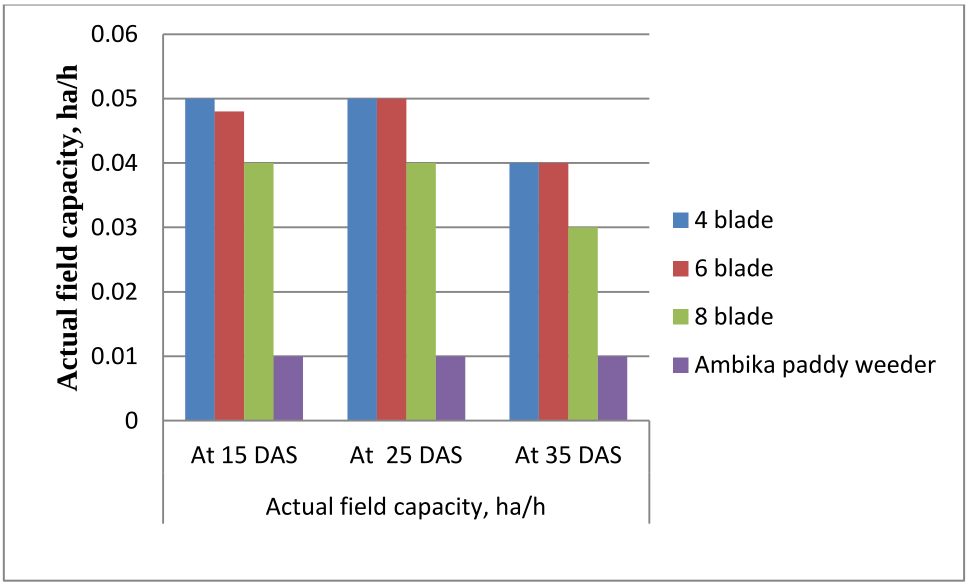

Fig.4.5 Actual field capacity of power weeder with different blades and ambika paddy weeder

4.2.6 Field efficiency

Field efficiency for different weeding operations for 15 DAS, 25 DAS and 35 DAS are depicted in Table 4.7. It reveals that, for 35 DAS, the weeding efficiency was observed as 61.47% under single row active power weeder with using of 4 blade in a flange and at same time field efficiency of ambika paddy weeder is found as 63.20%.

The field efficiency for 15 DAS, 25 DAS and 35 DAS was on average highest in power weeder with 4 blades. The statistically analysed data of field efficiency with its mean values and CDs are presented in Table 4.7. The data of the Table 4.7 reveal that the maximum field efficiency was recorded with the blade 4 blade (72.65 %) followed by the 6 blade (64.00%) at 15 DAS which were statistically at par at five percent level of significance. The field efficiency of the machine with the blade 8 blade was lowest (43.32%) at 25 DAS. The Table indicates that there was no significant effect of rice crop/ weed stages on field efficiency.

Table.4.7 Effect of different blades of power weeder and ambika paddy weeder at different stages of crop/weeds on field efficiency

Treatment	**Field efficiency, %**		
	At 15 DAS	**At 25 DAS**	**At 35 DAS**
4 blade	72.65	60.16	61.47
6 blade	64.00	65.60	57.95
8 blade	54.07	47.36	43.32
Ambika paddy weeder	67.15	66.16	63.20
SEm±	**1.05**	1.14	**0.96**
CD at 5%	**3.24**	3.52	**2.96**
CV	**3.64**	4.31	**3.81**

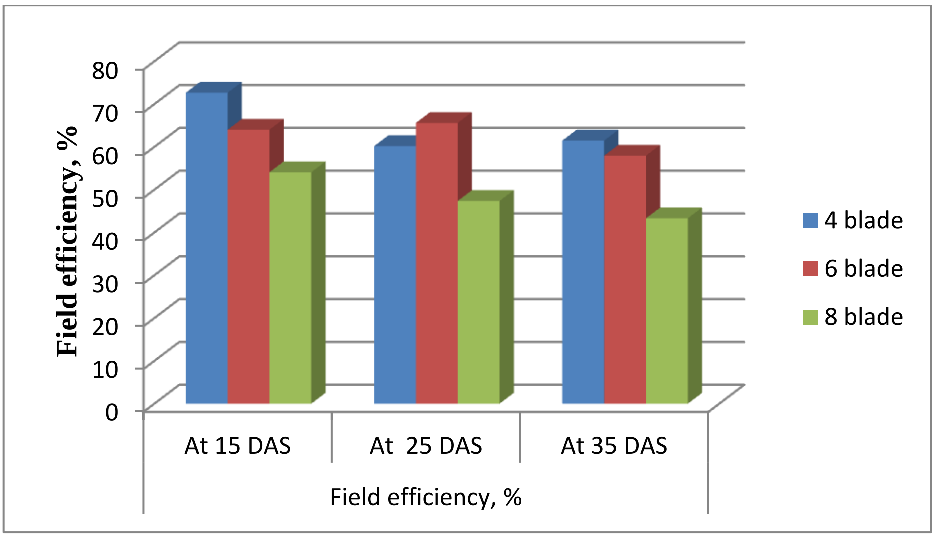

Fig 4.6 Field efficiency of power weeder with different blades and ambika paddy weeder

4.2.7 Weeding efficiency

Weeding efficiency for different weeding operations for 15 DAS, 25 DAS and 35 DAS are depicted in Table 4.8. It reveals that, for 35 DAS, the weeding efficiency was observed as 88.62 % under single row active power weeder with using of 6 blade in a flange and 82.10% for ambika paddy weeder.

The weeding efficiency for 25 DAS and 35 DAS was highest in power weeder with using of 6 blades. In case of Ambika paddy weeder and power weeder, weeding operation was done in between intra rows only and the weeds in inter rows were difficult to removed. For 25 DAS, for a high intensity weeds, Ambika paddy weeder showed difficulty to remove the fully matured weeds whereas the developed power weeder worked satisfactorily by cutting and removing the weeds as a result rice power weeder showed higher result as compared to the Ambika paddy weeder with 6 blades. In 35 DAS, the numbers of weeds were less as compared to the number of weeds in 25 DAS. This may be due to the influence of first weeding in 25 DAS.

Table.4.8 Effect of different blades of power weedcr and ambika paddy weeder at different stages of crop/weeds on weeding efficiency (%)

Treatment	Weeding efficiency, %		
	At 15 DAS	At 25 DAS	At 35 DAS
4 blade	80.42	81.97	82.92
6 blade	84.02	85.24	88.62
8 blade	82.72	85.04	87.45
Ambika paddy weeder	75.98	80.63	82.10
SEm±	0.873423	0.768221	1.553478
CD at 5%	2.691516	2.367327	NS
CV	2.417599	2.067103	4.0977

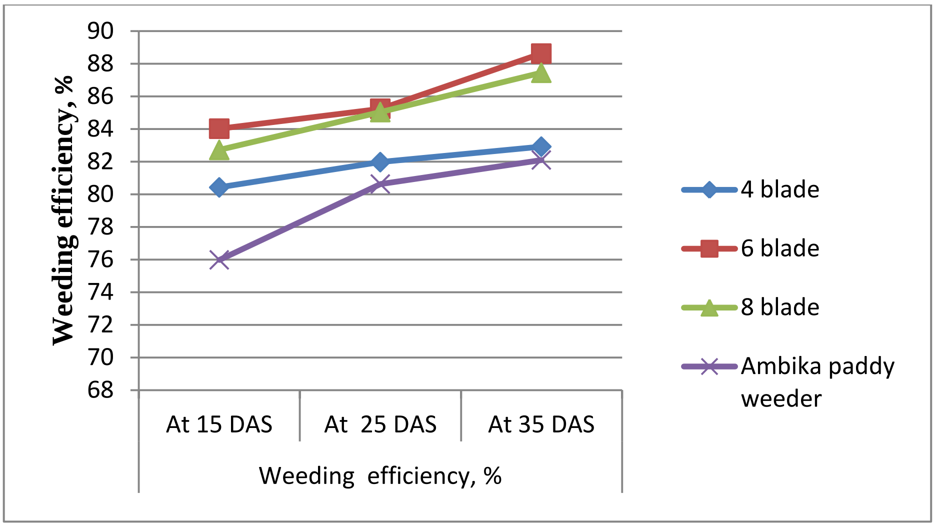

Fig.4.7 Weeding efficiency of power weeder with different blades and ambika paddy weeder

4.2.8 Plant Damaged

The plant damaged for different treatments are depicted in Table 4.9. It indicated that the maximum plant damaged for 15 DAS was observed as 5.66% under treatment with 8 blades power weeder followed by 2.02% for treatment with 6 blades. Table 4.9 shows the plant damaged for 25 DAS, again found highest with treatment under 8 blades among the remaining 4 blades or 6 blades. The plant damaged shown by ambika paddy weeder at 15 DAS is 1.19% followed by 1.39% at 25 DAS and 1.43% at 35 DAS. In case of power weeder and ambika paddy weeder, which is operated in intra rows, the rice plants which is grow out of line were damaged. While during operation by power weeder with 8 blades, the soil over topped on the crops and the number of plants buried in soil were large. This may be the reason for the highest result of 6.48 % plant damaged.

Table.4.9 Effect of different blades of power weedcr and ambika paddy weeder at different stages of crop/weeds on plant damaged (%)

Treatment	Plant damage, %		
	At 15 DAS	At 25 DAS	At 35 DAS
4 blade	1.32	1.85	2.03
6 blade	2.02	3.12	2.81
8 blade	5.66	4.74	6.48
Ambika paddy weeder	1.19	1.39	1.43
SEm±	0.902581	0.592344	0.631773
CD at 5%	NS	1.825351	1.946854

CV	79.19299	46.52341	44.34048

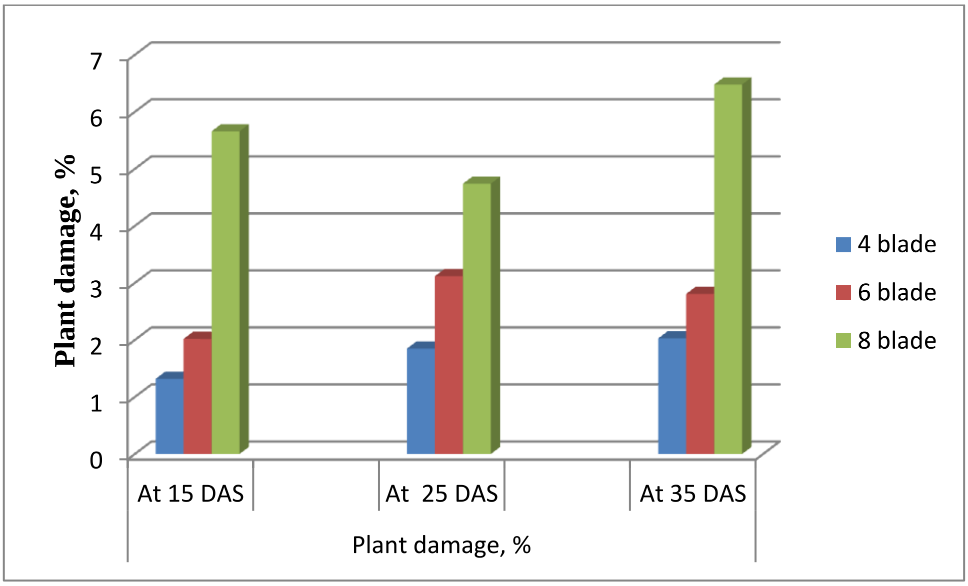

Fig.4.10 Plant damage per cent of power weeder with different blades and ambika paddy weeder

4.3 Ergonomics evaluation of developed machine

4.3.1 Anthropometric parameters of agriculture workers

The body dimensions of the subjects indicating the mean, standard deviation, 5th and 95th percentile values and minimum and maximum values for relevant anthropometric parameters of male and female agriculture workers, respectively. The mean age, stature and mass of male subjects were 29.8 year, 1649 mm and 51.2 kg respectively while the corresponding parameters for female subjects were 30.22year, 1505.5 mm and 46.33 kg. In general the male subjects were heavier and taller than female subjects. The mean lean body mass of male subject was also higher than female subjects. The details anthropometric data of female and male subjects are given in Appendix-C

Fig 4.11 Measurement of body dimension

4.3.2 Heart rate

Table 4.10 presents the data on various physiological responses of 20-41 year of age group during the power weeder operation before and after commencements of operation. Initially heart rate was different for each different groups ranging between 60 to 66 beats per min. For a particular workload the heart rate showed a sudden increase in starting periods of work and then established throughout the work. After the completion of the work, heart rate decreases drastically. Average heart rate of different age groups after the commencement of weeding operation was found as 109, 116, 111 and 114 beats /min. The detailed observed data of heart rate, of a particular subject with time duration shown in Table 4.10.

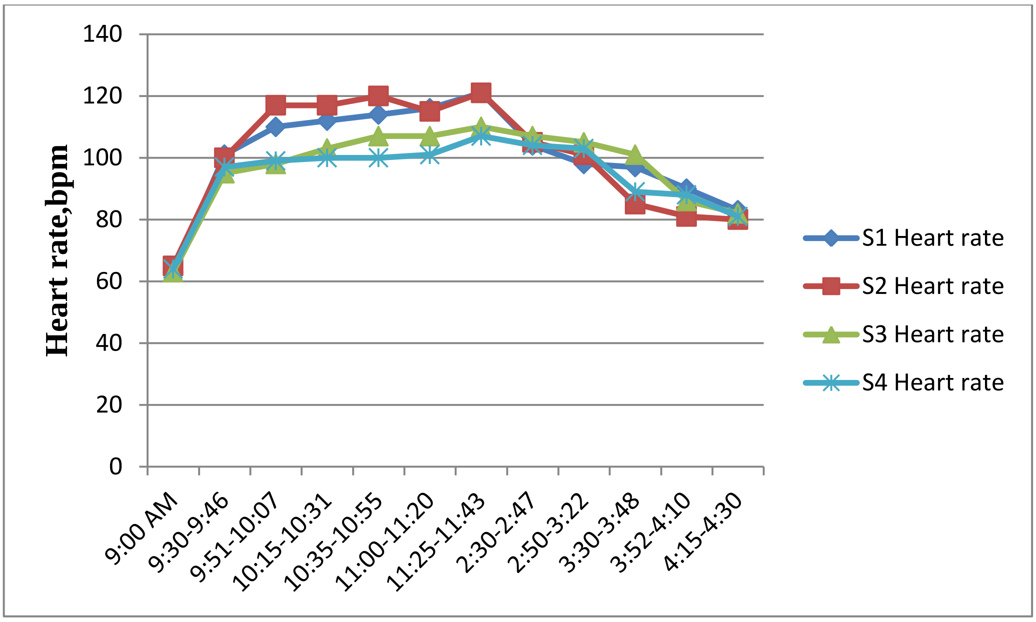

Fig 4.12 Variations of heart rate with time while operating power weeder

Table.4.10 Ergonomic aspect field observation data of power weeder

	Subject S1			Subject S2			Subject S3			Subject S4		
Time	**Heart rate**	**Pulse rate**	**B.P.**	**Heart rate**	**Pulse rate**	**B.P.**	**Heart rate**	**Pulse rate**	**B.P.**	**Heart rate**	**Pulse rate**	**B.P.**
9:00 AM	63	65	120/80	65	63	120/80	63	62	120/80	64	63	120/78
9:30-9:46	101	64	140/90	100	67	130/95	95	65	130/75	97	70	120/90
9:51-10:07	110	65	110/80	117	67	128/80	98	66	128/75	99	69	140/90
10:15-10:31	112	66	118/80	117	67	100/80	103	67	100/65	100	68	110/85
10:35-10:55	114	65	130/90	120	68	100/80	107	66	100/68	100	68	118/85
11:00-11:20	116	64	122/80	115	69	140/85	107	65	140/90	101	67	130/85
11:25-11:43	121	65	120/80	121	68	110/80	110	64	110/80	107	69	122/80
LUNCH												
2:00 PM	65	68	117/80	66	65	117/77	65	63	121/85	66	67	118/82
2:30-2:47	104	67	120/80	105	66	130/80	107	64	112/90	104	66	110/90
2:50-3:22	98	66	120/80	101	65	130/78	105	65	121/72	103	65	110/90
3:30-3:48	97	67	130/80	85	66	138/82	101	64	131/75	89	64	100/80
3:52-4:10	90	68	135/80	81	65	110/77	86	67	116/82	88	66	99/80
4:15-4:30	83	66	130/80	80	65	100/75	82	65	115/80	81	65	115/78

*Subject S1 and S2 are female body

*Subject S3 and S4 are male body

4.3.3 Oxygen consumption rate

Table 4.11 Energy expenditure during the work of power weeder

Subject	Power weeder					
	Max.avg. duration of work, min	Heart Rate (at work)	Pulse rate	VO_2 at work (l/min)	Blood Pressure	Energy Expenditure (kJ/min)
S1	22	109	71	0.56	128/86	11.78
S2	20.80	116	69.40	0.64	125/82	13.49
S3	21.80	111	69.40	0.59	114/80	12.25
S4	21.80	114	68.00	0.62	119/79	12.87
Average	21.6	112	69.45	0.60	122/82	12.60

4.3.4 Energy cost of operation

The average working heart rate of the operator was 109.55 beats min^{-1} and the corresponding value of oxygen consumption rate was 0.57 l min^{-1}. The corresponding energy expenditure was 12.60 kJ min^{-1}. Based on the mean energy expenditure, the operation was graded as "Moderately Heavy". In power rice weeder, the subjects can do the weeding in a standing posture (Fig.3.12). But in hand weeding the subjects were bending over work surfaces for targets which are too low. It may be suggested that pain rather than capacity may often be the limiting factor in such task situations. More tillers have been produced in the case of power rice weeder compared to ambika paddy weeder. It is more comfortable to operate power rice weeder. The rice weeder improves soil aeration and root growth. The disadvantages are starting torque is less and row to row distance should be correct.

4.3.5 Acceptable workload (AWL)

To ascertain whether the operations selected for the trails were within the acceptable workload (AWL), the oxygen uptake in terms of VO_2 max (%) was computed. Saha *et al.* (1979) reported that 35% of maximum oxygen uptake (also called maximum aerobic capacity or VO_2 max) can be taken as the acceptable work load (AWL) for Indian workers which is endorsed by Nag *et al.*, 1979 and Nag and Chatterjee, 1981. The oxygen uptake corresponding to the computed maximum heart rate in the calibration chart gives the maximum aerobic capacity (VO_2 max).

Each subject's maximum heart rate was estimated by the following relationship (Bridger, 1995).

Maximum heart rate (beats min^{-1}) = 200 - 0.65 x Age in years

The mean oxygen uptake in terms of maximum aerobic capacity was calculated and it was 45% and the value was above the acceptable limit of 35% of VO2 max indicating that the power rice weeder is could not be operated continuously for 8 hours without frequent rest-pauses.

4.3.6 Overall discomfort rating (ODR)

Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 3.0 and scaled as " Light discomfort" during weeding.(rameshan *et al.*,1987)

4.3.7 Body part discomfort score (BPDS)

The majority of discomfort was experienced in the left shoulder, right shoulder, left wrist, right wrist, left thigh and right thigh region for all the subjects during weeding and the body part discomfort score of subjects during weeding with power rice weeder was 24.12.

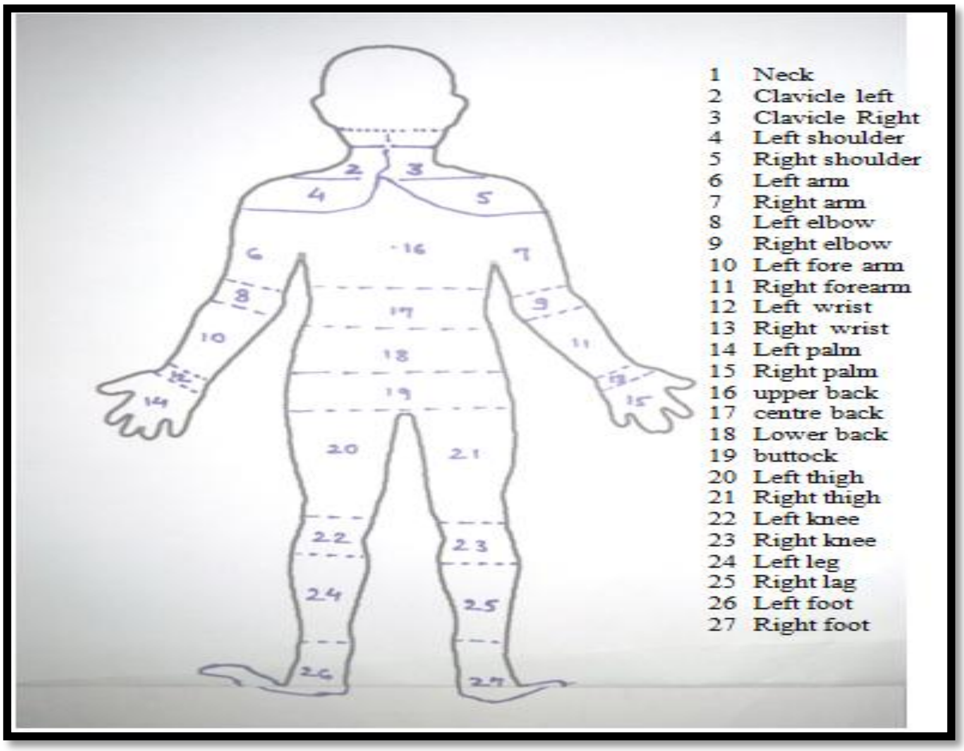

Fig.4.13 Regions for evaluating body part discomfort score

4.3.8 Work rest cycle

Rest pause was calculated, as all the subjects operated continuously for the 25 min period and it was found that 7 min rest could be provided to operator who was engaged in operating the equipment. The rest period calculated was also in agreement to the recovery heart rate of operator. If two operators are engaged with a machine in shift, it could be operated for day-long work.

CHAPTER-V

SUMMARY AND CONCLUSIONS

Weed control is one of the most difficult tasks in agriculture that accounts for a considerable share of the cost involved in agriculture production. Farmers generally expressed their concern for the effective weed control measures to arrest the growth and propagation of weeds. Lack of man power has been identified as one of the major problems for the sustainability of the rice industry. Hence transplanters and seeders were well developed as a step for mechanization. However, weeding method is still not well developed up to mechanization.

Mechanical weed control not only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity. Weeding by mechanical devices reduces the cost of labour and also saves time.

Power weeders are one step towards the standardization of practices, e.g. it has a fixed max rotational speed, fixed direction of movement, and it goes from one side of the field to another. Conversely, manual weeders still rely heavily on the characteristics of the operator(s), which cannot obviously be standardized. It is affecting speed, direction of movement, and the movement needed to operate a weeder, e.g. back and forth or constant push.

Looking to these problems and to give a new direction to the weeding operation an attempt was made to design, develop and test single row power weeder for rice.

Design and development of power weede would serve the purpose of minimum damages done to rice plants, cost effectiveness, easy manuvelling, low weight and fabrication by using freely available components and easy maintenance are main features of this design. Here comes the relevance of mechanised weeding, which is not a huge time consuming and significantly improves weeding efficiency as well as the quality of weeding.

The developed power weeder was tested at different field conditions and on the basis of those results obtained. Design parameters and their application in developing power weeder for rice to be established. Hence, the study was undertaken with the following objectives:

4. To design and develop the single row active power weeder for rice.
5. To evaluate performance of developed machine.
6. Ergonomical evaluation of the developed machine.

The testing was done in research field of SVCAET & RS, Faculty of Agricultural Engineering, I.G.K.V., and Raipur and statically data was analyzed. The testing was carried out to assess the technical and economic performance of the developed power weeder. It was tested on the basis of field capacity, field efficiency, weeding efficiency, performance index, energy consumption and cost of operation. This study revealed the meaningful findings, which may be developed further. Thus on the basis of the information observed during the study, the following conclusions could be drawn.

1. The performance of rice weeder was found excellently on wet condition.
2. The working width of the developed machine should be adjustable between 140 mm to 250 mm.
3. Using four blades with forward speed 2.48 km/h and depth of operation ranged from 3- 4.2 cm, with fuel consumption of 0.55 l/h, lower value of plant damage and low power required from engine to operate the weeder.
4. The minimum value of effective field capacity was 33.33 h/ha and was obtained by using eight blades, weeder forward speed 1.8 km/h, and maximum depth of operation was found 6.2 cm but due to more depth of cut, fuel consumption increases as 0.7 l/h.
5. The weeding efficiency found by using four blade, six blade and eight blade as 82.92%, 88.62% and 87.75% respectively at 35 DAS.
6. The operating cost of the rotary rice weeder was Rs.980/ha compared to Rs. 2300/ha for manual weeding
7. The saving in cost of weeding was 60% and saving in time was 65% compared to manual weeding.
8. The physiological cost was found out and the mean working heart rate of operator was 109 beats min^{-1}. The operation was graded as “moderately heavy”.

9. The oxygen uptake in terms of VO_2 max was above the acceptable limit of 35% of VO_2 max indicating that the power rice weeder was could not be operated continuously for 8 hours without frequent rest-pauses. It is suggested that two operators may be engaged in shift for a day long work with power rice weeder.

SUGGESTION FOR FUTURE WORK

1. Weeder is to be designed which can perform more than one operation using the same prime mover i.e. both for wet and dry land condition.
2. The developed power weeder needs further improvement in width adjustment.

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Appendix-A

RBD Calculations of field performance of power weeder

1. Speed of operation

Table A-1 Operation of speed of power weeder with different blade attachment and ambika paddy weeder at 15 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.00067	0.000167	0.1812	
Treatment	3	0.615335	0.205112	221.94	8.74
Error	12	0.01109	0.000924		
Total	19	0.627095			

Results	
SEm	0.013595
CD at 5%	0.041895
CV	6.013869

Table A-2 Operation of speed of power weeder with different blade attachment and ambika paddy weeder at 25 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.00153	0.000383	0.465	
Treatment	3	0.580855	0.193618	235.4	8.74
Error	12	0.00987	0.000823		
Total	19	0.592255			

Results	
SEm	0.012826
CD at 5%	0.039523
CV	5.718696

Table A-3 Operation of speed of power weeder with different blade attachment and ambika paddy weeder at 35 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.00512	0.00128	1.3964	
Treatment	3	0.666775	0.222258	242.46	8.74
Error	12	0.011	0.000917		
Total	19	0.682895			

Results	
SEm	0.01354
CD at	
5%	0.041725
CV	6.18519

2. Depth of cut

Table A-4 Effect of depth of cut of power weeder with different blades and ambika paddy weeder at 15 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	2.087	0.52175	2.3671	
Treatment	3	54.0775	18.02583	81.781	8.74
Error	12	2.645	0.220417		
Total	19	58.8095			

Results	
SEm	0.20996
CD at	
5%	0.647008
CV	10.5384

Table A-5 Effect of depth of cut of power weeder with different blades and ambika paddy weeder at 25 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	2.273	0.56825	2.6564	
Treatment	3	-26.342	-8.780667	-41.05	8.74
Error	12	2.567	0.213917		
Total	19	-21.502			

Results	
SEm	0.206841
CD at	
5%	NS
CV	9.231762

Table A-6 Effect of depth of cut of power weeder with different blades and ambika paddy weeder at 35 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.068	0.017	0.5484	
Treatment	3	49.1455	16.38183	528.45	8.74
Error	12	0.372	0.031		
Total	19	49.5855			

Results	
SEm	0.07874
CD at 5%	0.242643
CV	4.207125

3. **Field efficiency**

Table A-8 Effect of field efficiency with different blade attachment in powerweeder and ambika paddy weeder at 25 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	24.17152	6.04288	0.9258	
Treatment	3	913.6035	304.5345	46.655	8.74
Error	12	78.32832	6.52736		
Total	19	1016.103			

Results	
SEm	1.142573
CD at 5%	3.520919
CV	4.309507

Table A-9 Effect of field efficiency with different blade attachment in powerweeder and ambika paddy weeder at 35 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	80.66847	20.16712	4.3574	
Treatment	3	1226.398	408.7994	88.327	8.74
Error	12	55.53913	4.628261		
Total	19	1362.606			

Results	
SEm	0.962108
CD at 5%	2.964805
CV	3.808658

4. Fuel consumption

Table A-10 Effect of fuel consumption with different blade attachment in power weeder at 15 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.00816	0.00204	3.2903	
Treatment	2	0.03324	0.01662	26.806	8.74
Error	8	0.00496	0.00062		
Total	14	0.04636			

Results	
SEm	0.011136
CD at 5%	0.034315
CV	4.122483

Table A-11 Effect of fuel consumption with different blade attachment in power weeder at 25 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.006707	0.001677	0.4973	
Treatment	2	0.019893	0.009947	2.9501	8.74
Error	8	0.026973	0.003372		
Total	14	0.053573			

Results	
SEm	0.025968
CD at 5%	NS
CV	9.285616

Table A-12 Effect of fuel consumption with different blade attachment in power weeder at 35 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.005907	0.001477	0.8781	
Treatment	2	0.063613	0.031807	18.914	8.74
Error	8	0.013453	0.001682		
Total	14	0.082973			

Results	
SEm	0.018339
CD at 5%	0.056514
CV	6.564802

6. Plant damage

Table A-13 Effect of plant damage with different blade attachment in power weeder and ambika paddy weeder at 15 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	13.75813	3.439533	0.8444	
Treatment	3	66.45294	22.15098	5.4381	8.74
Error	12	48.87919	4.073266		
Total	19	129.0903			

Results	
SEm	0.902581
CD at 5%	NS
CV	79.19299

Table A-14 Effect of plant damage with different blade attachment in power weeder and ambika paddy weeder at 25 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	8.33387	2.083468	1.1876	
Treatment	3	56.53906	18.84635	10.743	8.74
Error	12	21.05229	1.754358		
Total	19	85.92522			

Results	
SEm	0.592344
CD at 5%	1.825351
CV	46.52341

Table A-15 Effect of plant damage with different blade attachment in power weeder and ambika paddy weeder at 35 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	9.59888	2.39972	1.2025	
Treatment	3	77.20976	25.73659	12.896	8.74
Error	12	23.94824	1.995687		
Total	19	110.7569			

Results	
SEm	0.631773
CD at 5%	1.946854
CV	44.34048

7. Power requirement

Table A-16 Effect of power requirement with different blade attachment in power weeder at 15 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.009493	0.002373	1.7537	
Treatment	2	0.044373	0.022187	16.394	8.74
Error	8	0.010827	0.001353		
Total	14	0.064693			

Results	
SEm	0.016452
CD at 5%	0.050698
CV	8.373523

Table A-17 Effect of power requirement with different blade attachment in power weeder at 25 DAS

at 20 DAS	SV	d.f.	SS	MS	F	F tab
	Replication	4	0.001373	0.000343	0.4813	
	Treatment	2	0.019693	0.009847	13.804	8.74
	Error	8	0.005707	0.000713		
	Total	14	0.026773			

Results	
SEm	0.011944
CD at 5%	0.036807
CV	6.767306

Table A-18 Effect of power requirement with different blade attachment in power weeder at 35 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	0.002933	0.000733	3.6975	
Treatment	2	0.00388	0.00194	9.7815	8.74
Error	8	0.001587	0.000198		
Total	14	0.0084			

Results	
SEm	0.006298
CD at 5%	0.019408
CV	4.142084

8. Weeding efficiency

Table A-19 Weeding efficiency with different blade attachment in power weeder andambika paddy weeder at 15 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	28.30328	7.07582	1.8551	
Treatment	3	187.0961	62.36537	16.35	8.74
Error	12	45.77208	3.81434		
Total	19	261.1715			

Results	
SEm	0.873423
CD at 5%	2.691516
CV	2.417599

Table A-20 Weeding efficiency with different blade attachment in power weeder andambika paddy weeder at 25 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	24.36618	6.091545	2.0644	
Treatment	3	123.8257	41.27523	13.988	8.74
Error	12	35.40978	2.950815		
Total	19	183.6017			

Results	
SEm	0.76822
CD at	
5%	2.36
CV	2.067

Table A-21 Weeding efficiency with different blade attachment in power weeder andambika paddy weeder at 35 DAS

SV	d.f.	SS	MS	F	F tab
Replication	4	10.01138	2.502845	0.2074	
Treatment	3	219.8049	73.2683	6.0721	8.74
Error	12	144.7976	12.06647		
Total	19	374.6139			

Results	
SEm	1.553478
CD at	
5%	NS
CV	4.0977

Appendix-B

Table B-1 Anthropometric data of female agriculture workers participated in study

Parameters	Mean	SD*	percentile		range	
			5th	95th	Min.	Max.
Age , years	30.22	6.35	34	51.2	28	35
Weight, kg	46.33	4.58	42	55	40	50
Stature, mm	1505.5	45.31	1460	1578	1460	1590
Acromial height, mm	1262	43.81	1208	1322	1200	1330
Vertical reach, mm	1935.5	70.20	1854	2026	1850	2030
Chest circumference, mm	846.11	138.45	692	1043	690	1120
Thigh circumference, mm	421.11	523.32	130	1338	110	1710
Buttock knee length, mm	510.67	50.48	452	586	440	604.6
Knee height, mm	437.67	147.61	215.6	509.6	46	516
Grip diameter, mm	44.67	2.28	42	48.24	42	48.4
Arm length, mm	816.11	64.11	764	928	760	960
Hand length, mm	178.22	13.55	166	198.8	166	210

Table B-2 Anthropometric data of male agriculture workers participated in study

Parameters	Mean	SD*	percentile		range	
			5th	95th	Min.	Max.
Age, years	29.8	9.5	90.1	45.5	18.0	65.0
Weight, kg	51.2	6.4	40.6	61.8	35.0	77.0
Stature, mm	1649	59	1552	1747	1424	1854
Acromial height, mm	1376	56	1284	1468	1102	1564
Vertical reach, mm	2045.2	74.1	1908	2514	1950	2060
Chest circumference, mm	440	39	373	500	310	575
Thigh circumference, mm	436	39	373	500	310	575
Buttock knee length, mm	465	5.3	417	515	56	531
Knee height, mm	456	31	415	492	52	526
Grip diameter, mm	48.65	3.2	44	50.56	42	50.26
Arm length, mm	850.23	60	780	956.35	780	1023
Hand length	200.20	13.56	170	200	164	250

Appendix-C

ESTIMATING THE COST OF POWER WEEDER

The initial cost of power weeder has been calculated by adding up the cost of individual components involved in the fabrication at the prevalent market price. These were then added to a reasonable percentage for fabrication cost and marginal profit of manufacturer.

The cost of power weeder is divided under the two heads know as fixed cost and variable cost.

Initial Cost of Machine

The initial cost of the power weeder was calculated on the basis of total materials used in fabrication and the cost of fabrication.

Cost of power weeder/ Capital Cost = Rs 19000/-

Economic Analysis

Following assumption was made for economic analysis of power weeder:

1. Expected life of weeder = 10 years
2. Annual use of weeder can be calculated as follows
3. Working hour (H) = 500 h/year, when working hour is 8 h/day(for two crops)
4. Salvage value (S)= 10% of initial cost
5. Rate of interest = 10% per annum
6. Labour required =01
7. Petrol cost = Rs.70/l (including 2T oil)
8. Fuel consumption = 0.62 l/h
9. Repair and maintainance = 5% of initial cost
10. Shelter, insurance and tax cost = 2% of initial cost

Fixed cost

1. **Depreciation (D)**

It is the cost of value of machine with the passage of time

$$\mathrm{D} = \frac{\mathrm{C-S}}{\mathrm{L\ X\ H}} = \frac{19000-1900}{10\ \mathrm{X}500} = \mathrm{Rs.}\,3.42/\ \mathrm{h}$$

Where,

D = Depriciation per hour

C = Capital investment

S= Salvage value, 10% of initial cost

H = Number of working hour per year

L = Life of machine in year

2. **Interest**

$$\mathrm{I} = \frac{19000 + 1900}{2} \text{x} \frac{0.10}{500} = \mathrm{Rs.}\, 2.09/\mathrm{h}$$

3. Shelter, insurance and tax cost
 2% of initial cost
 = Rs.380/year
 =Rs.0.76/h

 Total fixed cost =(Rs.3.42 + Rs.2.09 = Rs 0.76)/h = Rs.6.27/h

Variable cost

4. Fuel cost /h
 Fuel cost @ Rs70/l
 Fuel cost = Rs.70 x 0.55
 =Rs.38.5/h
5. Repair and maintainance @ 5% of initial cost
 = Rs 950/year
 =Rs 1.3/h
6. Labour charge = Rs.205/day = Rs 25.63/h

 Total variable cost = Rs.65.43/h

 Total cost of weeding = variable cost + fixed cost
 = Rs.65.43/h + Rs.6.27/h
 =Rs.71.7/h
 Average effective field capacity = 0.042 ha/h
 Cost of operation of weeder =Rs.71.7/0.05
 = Rs.1434 /ha

VITA

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