

**TECHNO ECONOMIC EVALUATION OF DIFFERENT
TYPES OF POWER WEEDER**

M. Tech. (Agril. Engg.) Thesis

by

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TYPES OF POWER WEEDER**

Thesis

**Submitted to the
Indira Gandhi Krishi Vishwavidyalaya, Raipur**

by

Jaya Dhruw

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FOR THE DEGREE OF**

Master of Technology

in

**Agricultural Engineering
(Farm Machinery and Power Engineering)**

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CERTIFICATE – I

This is to certify that the thesis entitled “**Techno economic evaluation of different types of power weeder**” submitted in partial fulfilment of requirements for 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 **Jaya Dhruw** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma or certificate course. All the assistance and help received during the course of the investigations have been duly acknowledged.

Date: 21/07/2022


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CERTIFICATE – II

This is to certify that the thesis entitled “**Techno economic evaluation of different types of power weeder**” submitted by **Jaya Dhruv** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfilment of the requirement 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 evaluator and Student’s Advisory Committee after oral examination.


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TABLE OF CONTENTS

Chapter	Title	Page no.
	ACKNOWLEDGEMENT	i
	TABLE OF CONTENTS	ii
	LIST OF TABLES	v
	LIST OF FIGURES	vii
	LIST OF NOTATIONS	ix
	LIST OF ABBREVIATIONS	x
	ABSTRACT	xvi
I	INTRODUCTION	1
II	REVIEW OF LITERATURE	5
	2.1 Weeds	5
	2.2 Mechanical and Physical Properties of Weeds	7
	2.3 Losses due to Weeds	8
	2.4 Weed Control Methods	9
	2.4.1 Chemical weed control method	9
	2.4.2 Cultural methods of weed control	10
	2.4.3 Mechanical weed control methods	10
	2.4.3.1 Manual weeders	11
	2.4.3.2 Animal drawn weeders	13
	2.4.3.3 Power operated weeder	14
	2.5 Cost and Economics Involved in Weed Management	23
	2.6 Concluding Remarks	25
III	MATERIALS AND METHODS	26
	3.1 Experimental Site	26
	3.1.1 Climate	26
	3.1.2 Experimental details	27
	3.1.2.1 Mustard	27

Chapter	Title	Page no.
	3.1.2.2 Cauliflower	28
	3.1.2.3 Cucumber	28
3.2	Details of Selected Power Weeders	29
	3.2.1 Power weeder 52 cc	29
	3.2.2 Power weeder 67 cc	31
	3.2.3 Sidepack brush cutter power weeder	33
	3.2.4 backpack brush cutter power weeder	35
	3.2.5 Solar power cum electric operated weeder	37
3.3	Experimental Design	39
3.4	Operational Parameters for Testing of Weeder	42
	3.4.1 Measurement techniques	42
	3.4.1.1 Moisture content of soil	42
	3.4.1.2 Bulk density of soil	43
	3.4.1.3 Plant population	44
	3.4.1.4 Weed population	44
	3.4.1.5 Effective working depth	45
	3.4.1.6 Effective working width	45
3.5	Machine Performance and Evaluation of Weeders	45
	3.5.1 Operating speed	45
	3.5.2 Weeding efficiency	46
	3.5.3 Plant damage	46
	3.5.4 Theoretical field capacity	47
	3.5.5 Effective field capacity	47
	3.5.6 Field efficiency	49
	3.5.7 Fuel consumption	49
	3.5.8 Performance index of weeder	49
3.6	Cost Analysis of Different Types of Power Weeder	50
	3.6.1 Operational cost	50
	3.6.1.1 Fixed cost of machine	50

Chapter	Title	Page no.
	3.6.1.2 Variable cost of machine	51
	3.7 Operational Energy Analysis of Weeders	52
IV	RESULT AND DISCUSSIONS	54
	4.1 Weed Studies	54
	4.1.1 Floristic composition of weeds	54
	4.1.2 Studies about prevailing weeding practices in selected crops	59
	4.2 Operational Parameters for Testing of Weeders	60
	4.2.1 Moisture content of soil	60
	4.2.2 Bulk density of soil	61
	4.2.3 Plant population	63
	4.2.4 Weed population	63
	4.2.5 Effective working depth	65
	4.2.6 Effective working width	66
	4.3 Machine Performance and Evaluation of Weeders	68
	4.3.1 Operating speed	68
	4.3.2 Fuel consumption	70
	4.3.3 Theoretical field capacity	72
	4.3.4 Effective field capacity	73
	4.3.5 Field efficiency	75
	4.3.6 Weeding efficiency	76
	4.3.7 Plant damage	78
	4.3.8 Performance index of weeder	79
	4.4 Operational Cost of Different Types of Power Weeder	81
	4.5 Operational Energy Analysis of Weeders	82
V	SUMMARY AND CONCLUSION	85
	REFERENCES	88
	APPENDIES	95
	Appendix-A	95
	Appendix-B	109
	Appendix-C	110
	RESUME	113

LIST OF TABLES

Table	Title	Page
3.1	Technical specification of power weeder 52 cc	30
3.2	Technical specification of power weeder 67 cc	32
3.3	Technical specification of sidepack brush cutter power weeder	34
3.4	Technical specification of backpack brush cutter power weeder	36
3.5	Technical specification of solar power cum electric operated weeder	38
3.6	Plan of experiments on test setup	40
3.7	Identification of treatments	40
3.8	Layout of experimental plot	41
3.9	Energy conversion coefficients	53
4.1	Weeds found in mustard	56
4.2	Weeds found in cauliflower	56
4.3	Weeds found in cucumber	57
4.4	Soil moisture percentage of mustard field	60
4.5	Soil moisture percentage of cauliflower field	60
4.6	Soil moisture percentage of cucumber field	61
4.7	Soil bulk density of mustard field	62
4.8	Soil bulk density of cauliflower field	62
4.9	Soil bulk density of cucumber field	62
4.10	Statistically analysed results with mean effective working depth (mm)	65
4.11	Statistically analysed results with mean effective working width (mm)	67
4.12	Statistically analysed results with mean operating speed and CDs values	69

Table	Title	Page
4.13	Statistically analysed data with mean fuel consumption (l/h) values	71
4.14	Statistically analysed results with mean theoretical field capacity (ha/h)	72
4.15	Statistically analysed results with mean effective field capacity (ha/h)	74
4.16	Statistically analysed results with mean field efficiency % of weeders	75
4.17	Statistically analysed results with mean weeding efficiency % of weeders	77
4.18	Statistically analysed results with mean plant damage per cent	78
4.19	Statistically analysed data with mean performance index of weeders	80
4.20	Fixed cost analysis of weeders	81
4.21	Variable cost analysis of weeders	81
4.22	Results of operational energy of weeders	83

LIST OF FIGURES

Figure	Title	Page
3.1	Mustard crop at weeding stage	27
3.2	Cauliflower field after weeding operation	28
3.3	Cucumber field after weeding operation	29
3.4	View of power weeder 52 cc	31
3.5	View of power weeder 67 cc	33
3.6	View of sidepack brush cutter power weeder	35
3.7	View of backpack brush cutter power weeder	37
3.8	View of solar cum electric operated weeder	39
3.9	Measurement of moisture content	43
3.10	Measurement of bulk density	44
3.11	Counting of weeds after weeding	45
3.12	Weeding operation:(a) power weeder 52 cc (b) power weeder 67 cc (c) sidepack brush cutter power weeder (d) backpack brush cutter power weeder (e) solar power cum electric operated weeder	48
4.1	Weed density in mustard crop	55
4.2	Weed density in cauliflower crop	55
4.3	Weed density in cucumber crop	55
4.4	Some common weeds found in all experimental sites	58
4.5	Variation of moisture content in different crop field	63
4.6	Variation of bulk density of soil in different crop field	63
4.7	Before and after weeding operation in mustard	64
4.8	Before and after weeding operation in cauliflower	64
4.9	Before and after weeding operation in cucumber	64
4.10	Variation of effective working depth of weeders in selected crop fields	66

Figure	Title	Page
4.11	Variation of effective working width of weeders in selected crop fields	68
4.12	Variation of operating speed in different crop fields	70
4.13	Variation of fuel consumption of weeders	71
4.14	Variation of theoretical field capacity of weeders in different crop fields	73
4.15	Variation of effective field capacity of weeders in different crop fields	74
4.16	Variation of field efficiency per cent of weeders	76
4.17	Variation of weeding efficiency (%) of weeders in different crop fields	77
4.18	Variation of plant damage (%) of weeders in different crop fields	79
4.19	Variation of performance index of weeders in different crop fields	80
4.20	Cost requirement of power weeder in Rs/ha	82
4.21	Energy requirement of different types of power weeder in MJ/ha	84

LIST OF NOTATIONS

Notation	Description
a.i.	active ingredient
cc	cubic centimeter
cm	centimeter
°	degree
°C	degree Celsius
g	gram
ha	hectare
hp	horse power
h	hour
kW	kiloWatt
Kg	Kilogram
l	litre
MJ	mega Joule
m	meter
mm	millimeter
-	minus
min.	minute
%	Percent
+	Plus
Rpm	Rotation per minute
₹	Rupees

LIST OF ABBREVIATIONS

Abbreviation	Full name
AICRP	All India Coordinated Research Project
Avg.	Average
BLDC	Brushless direct current motor
C.G.	Chhattisgarh
DAS	Day after sowing
<i>et al.</i>	Et alibi
FAE	Faculty of Agricultural Engineering
Fig.	Figure
FMPE	Farm Machinery and Power Engineering
ICAR	Indian Council of Agricultural Research
i.e.	That is
IGKV	Indira Gandhi Krishi Vishwavidyalaya
IWM	Integrated Weed Management
OUAT	Odisha University of Agriculture and Technology
SPD	Split Plot design
TFC	Theoretical field capacity
<i>viz.</i>	Namely

THESIS ABSTRACT

Title of the Thesis : Techno Economic Evaluation of
Different Types of Power Weeder

Full Name of the Student : Jaya Dhruw

Major Subject: Farm Machinery and Power
Engineering

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Degree to be awarded : Master of Technology in Agricultural
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Signature of Major Advisor

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Signature of the Student



Signature of Head of the Department

ABSTRACT

Weeds are unwanted plants that impede the use of land and water resources, negatively impacting crop production. Weed plants compete with crop plants for soil nutrients, moisture, light, and space, reducing production and increasing farm maintenance costs. Weeds are the primary cause of significant yield reduction issues. Weeding operations are a viable solution for removing unwanted plants in crop production. Weed control is one of the most critical aspects of modern agriculture. Many weed control methods (mechanical, chemical, cultural, biological) have been tried with varying degrees of success. When compared to other methods, cultural and biological methods take a long time to control weeds. In chemical methods,

weedicide application is generally expensive and harmful to both the environment and human health, so mechanical weeding is preferred among other methods of weeding. Furthermore, mechanical weeding loosens the soil surface by producing soil mulch, resulting in improved aeration and moisture conservation. It is critical to develop chemical-free agricultural products to ensure food security and long-term agricultural development. Among the different methods of weed control, mechanical method provides high quality food products and ensured food safety. Delays and negligence in weeding operations reduce crop yield. The majority of farmer control weeds with hand tools such as sickle, khurpi, and so on. The timely weeding is important for a good yield, this can only be accomplished by using mechanical power weeders, which perform simultaneous weeding and can reduce the time spent on weeding and drudgery involved in manual weeding.

The appropriate mechanisation technology is required to reduce drudgery, improve operational timeliness, and reduce weeding costs for small farmers so as to lessen the use of chemical and manual weed removal methods. The power weeder helps to remove weeds with less effort. It is appropriate for larger area infestations. Hence, a study was done to examine the performance of different types of power weeder viz., power weeder 52 cc (W1), power weeder 67 cc (W2), sidepack brush cutter power weeder (W3), backpack brush cutter power weeder (W4) and solar power cum electric operated (W5) weeder, which were evaluated for weeding in selected crop fields i.e., mustard, cauliflower and cucumber. The results revealed that among the power weeders, the highest weeding efficiency (88.6 %) was obtained with W5 at mustard crop and the lowest value (73.8 %) was obtained with W1 in cauliflower crop. The mean average plant damage percent of power weeders W1, W2, W3, W4 and W5 were found to be 1.33 %, 1.43 %, 1.33 %, 1.55 %, and 1.58 %, respectively. The highest plant damage was obtained in W5 and lowest was seen in weeder W1 and W3. The weeder W5 had the highest effective field capacity of 0.042 ha/h, while weeder W1 had the lowest effective field capacity of 0.030 ha/h. The field efficiency of weeders in three different crop fields was found to be highest in weeder W3 (85 %) and lowest in weeder W1 (79.3 %). The performance index of solar power cum electric operated weeders was found to be the highest (357), while


the power weeder 67 cc had the lowest value (95). The total operational cost (Rs/ha) of power weeder W1, W2, W3, W4 and W5 are estimated as 2744.1 Rs/ha, 2611.3 Rs/ha, 2513.9 Rs/ha, 2450.8 Rs/ha and 952.5 Rs/ha respectively. The required total operational energy of weeder W1, W2, W3, W4 and W5 are 1643 MJ/ha, 2083 MJ/ha, 1137 MJ/ha, 983 MJ/ha and 3685 MJ/ha respectively. The highest energy required for weeding was observed in weeder W5 and lowest was obtained in W4.

शोध सारांश

शोध शीर्षक	: विभिन्न प्रकार के पावर वीडर का तकनीकी आर्थिक मूल्यांकन
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प्रमुख सलाहकार के हस्ताक्षर


छात्र के हस्ताक्षर


विभागाध्यक्ष के हस्ताक्षर

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सारांश

खरपतवार अवांछित पौधे हैं जो भूमि और जल संसाधनों के उपयोग में बाधा डालते हैं, फसल उत्पादन को नकारात्मक रूप से प्रभावित करते हैं। खरपतवार के पौधे मिट्टी के पोषक तत्वों, नमी, प्रकाश और स्थान के लिए फसल के पौधों के साथ प्रतिस्पर्धा करते हैं, उत्पादन कम करते हैं और खेत के रखरखाव की लागत में वृद्धि करते हैं। खरपतवार महत्वपूर्ण उपज में कमी के मुद्दों का प्राथमिक कारण हैं। फसल उत्पादन में अवांछित पौधों

को हटाने के लिए निराई-गुड़ाई एक व्यवहार्य समाधान है। खरपतवार नियंत्रण आधुनिक कृषि के सबसे महत्वपूर्ण पहलुओं में से एक है। कई खरपतवार नियंत्रण विधियों (यांत्रिक, रासायनिक, पारम्परिक, जैविक) को सफलता की अलग-अलग डिग्री के साथ आजमाया गया है। अन्य विधियों की तुलना में, पारम्परिक और जैविक विधियों में खरपतवारों को नियंत्रित करने में लंबा समय लगता है। रासायनिक विधियों में, खरपतवारनाशी का अनुप्रयोग आम तौर पर पर्यावरण और मानव स्वास्थ्य दोनों के लिए महंगा और हानिकारक होता है, इसलिए निराई के अन्य तरीकों में यांत्रिक निराई को प्राथमिकता दी जाती है। इसके अलावा, यांत्रिक निराई मृदा मल्व का उत्पादन करके मिट्टी की सतह को ढीला करती है, जिसके परिणामस्वरूप बेहतर वातन और नमी संरक्षण होता है। खाद्य सुरक्षा और दीर्घकालिक कृषि विकास सुनिश्चित करने के लिए रासायनिक मुक्त कृषि उत्पादों को विकसित करना महत्वपूर्ण है। खरपतवार नियंत्रण के विभिन्न तरीकों में, यांत्रिक विधि उच्च गुणवत्ता वाले खाद्य उत्पाद प्रदान करती है और खाद्य सुरक्षा सुनिश्चित करती है। निराई-गुड़ाई में देरी और लापरवाही से फसल की उपज कम हो जाती है। अधिकांश किसान हाथ के औजारों जैसे दरांती, खुरपी आदि से खरपतवारों को नियंत्रित करते हैं। अच्छी उपज के लिए समय पर निराई करना महत्वपूर्ण है; यह केवल यांत्रिक शक्ति वीडर्स का उपयोग करके पूरा किया जा सकता है, जो एक साथ निराई करते हैं और मैनुअल निराई में शामिल निराई और कड़ी मेहनत पर खर्च किए गए समय को कम कर सकते हैं।

कठिन परिश्रम को कम करने, परिचालन समयरेखा में सुधार करने और छोटे किसानों के लिए निराई लागत को कम करने के लिए उपयुक्त मशीनीकरण तकनीक की आवश्यकता है ताकि रासायनिक और हाथ से खरपतवार हटाने के तरीकों का उपयोग कम किया जा सके। पावर वीडर कम मेहनत में खरपतवार निकालने में मदद करता है। यह बड़े क्षेत्र के संक्रमण के लिए उपयुक्त है। इसलिए, पावर वीडर 52 सीसी (डब्ल्यू 1), पावर वीडर 67 सीसी (डब्ल्यू 2), साइडपैक ब्रश कटर पावर वीडर (डब्ल्यू 3), बैकपैक ब्रश कटर पावर वीडर (डब्ल्यू 4) जैसे विभिन्न प्रकार के पावर वीडर के प्रदर्शन की जांच करने के लिए एक अध्ययन किया गया था। और सौर ऊर्जा सह विद्युत संचालित वीडर (डब्ल्यू 5) का मूल्यांकन चयनित फसल क्षेत्रों यानी सरसों, फूलगोभी और खीरा में निराई के लिए किया गया था। परिणामों से पता चला कि पावर वीडर्स में, डब्ल्यू 5 और सरसों की फसल के साथ उच्चतम

निराई दक्षता (88.6 %) प्राप्त की गई थी और सबसे कम मूल्य (73.8 %) डब्ल्यू 1 और फूलगोभी की फसल के साथ प्राप्त की गई थी। बिजली वीडर्स डब्ल्यू 1, डब्ल्यू 2, डब्ल्यू 3, डब्ल्यू 4 और डब्ल्यू 5 का औसत संयंत्र क्षति प्रतिशत क्रमशः 1.33 %, 1.43 %, 1.33 %, 1.55 % और 1.58 % पाया गया। सबसे अधिक पौधे की क्षति डब्ल्यू 5 में हुई और सबसे कम वीडर डब्ल्यू 1 और डब्ल्यू 3 में देखी गई। वीडर डब्ल्यू 5 की अधिकतम प्रभावी क्षेत्र क्षमता 0.042 हेक्टेयर/घंटा थी, जबकि वीडर डब्ल्यू 1 की सबसे कम प्रभावी क्षेत्र क्षमता 0.030 हेक्टेयर/घंटा थी। तीन अलग-अलग फसल क्षेत्रों में वीडर की क्षेत्र दक्षता वीडर डब्ल्यू 3 (85 %) में सबसे अधिक और वीडर डब्ल्यू 1 (79.3 %) में सबसे कम पाई गई। सौर ऊर्जा सह विद्युत संचालित वीडर का प्रदर्शन सूचकांक उच्चतम (357) पाया गया, जबकि पावर वीडर 67 सीसी का मूल्य सबसे कम (95) था। पावर वीडर डब्ल्यू 1, डब्ल्यू 2, डब्ल्यू 3, डब्ल्यू 4 और डब्ल्यू 5 की कुल परिचालन लागत (रु/हेक्टेयर) क्रमशः रु 2744.1 प्रति हेक्टेयर, रु 2611.3 प्रति हेक्टेयर, रु 2513.9 प्रति हेक्टेयर, रु 2450.8 प्रति हेक्टेयर और रु 952.5 । वीडर डब्ल्यू 1, डब्ल्यू 2, डब्ल्यू 3, डब्ल्यू 4 और डब्ल्यू 5 की आवश्यक कुल परिचालन ऊर्जा 1643 एमजे / हेक्टेयर, 2083 एमजे / हेक्टेयर, 1137 एमजे / हेक्टेयर, 983 एमजे / हेक्टेयर और 3685 एमजे / हेक्टेयर है। निराई के लिए आवश्यक उच्चतम ऊर्जा वीडर डब्ल्यू 5 में देखी गई और सबसे कम डब्ल्यू 4 में प्राप्त की गई।

CHAPTER -I

INTRODUCTION

Agriculture is the primary source of income for approximately 58 per cent of India's population. Agriculture plays a vital role in Indian economy. As it contributes about 19.9 per cent to the total GDP (PIB Report, 2020-21). It generates almost 30 per cent of the country's income and employs roughly 70 per cent of the working population and generates a significant portion of the country's foreign exchange earnings. It offers food grains to feed a population of over a hundred crore people. It also serves as a raw material provider for a variety of industries.

In today's input-intensive agricultural systems, reducing economic losses in agricultural production caused by abiotic and biotic variables is crucial. Maintaining production levels necessitates the development of fresh ways for reducing the negative effects of these elements. As with abiotic causes, such as a lack or excess of moisture during the growing season, extreme temperatures, high or low irradiance and nutrient supply, biotic stresses have the potential to significantly reduce yields (Oerke, 2006). Among the major biotic constraints, weeds are the most destructive to agricultural production, as well as agrobiodiversity and natural water bodies. They also have an indirect impact on crop productivity by competing for resources with the crop, sheltering agricultural pests, interfering with water management, diminishing yield and quality, and so raising processing costs. Weed control is thus an important factor of crop production.

Weeds reduced crop yield by 31.5 per cent in India (22.7 % in Rabi and 36.5 % in Kharif seasons) (Bhan *et al.*, 1999). There are approximately 250,000 plant species worldwide; approximately 3 per cent, or 8,000 species, behave as weeds. Only 200 to 250 of those 8,000 are major issues in global cropping systems. A plant is considered as weed if it exhibits characteristics that set it apart from other plant species. Weeds are plants that have grown in an unfavourable location. Weeds are common, dominant, and pervasive in agricultural fields. Weed interference is a major cause of low agricultural productivity. Invasion of weed into crop-growing areas have been a problem for humans since the beginning of plant cultivation. Since around 1000 BC, weeds have been a major limiting factor in profitable crop production. It is the most significant biological controls

which limits the crop productivity. They compete with crops for natural and applied resources while also reducing agricultural productivity quantity and quality (Rao and Chauhan, 2015). The control of weed is essential as it compete with crop nutrients and hence, affects the plant growth.

Weeds are classified in several ways. Two of the most common methods are gross morphological features and their lifecycle. Weeds are classified as grasses, sedges or broadleaf weeds based on their gross physical characteristics. They are divided into three categories based on their life cycle: annual, biennial, and perennial. The latter classification method has the potential to significantly affect the effectiveness of control measures.

Weed composition and competition are dynamic and are affected by soil, climate, cropping, and management factors. Therefore, weeding operation is essential. Weeding is the process of removing weeds from a field. It is an effective pre-harvest crop protection and crop production management method. Weeds are controlled using a variety of mechanical and chemical methods. Weed eradication with herbicides and weedicides is a simple and quick method, but it is limited due to the negative effects on both the environment and humans. Spraying/applying herbicides has some drawbacks, including water pollution, increased weed resistance to the herbicide, which reduces its effectiveness and health risks to the operator. Mechanical weeding can be used to overcome these limitations. Mechanical methods are more beneficial than chemical methods in terms of yield because they aerate the soil, uproot the weeds completely from the root and are eco-friendly. Mechanical weed control is a physical activity that prevents unwanted plant growth.

For many years agriculture has been depended on the herbicides for controlling weeds but increasing costs and concern over the health and environmental risk, is necessary search for an alternative method to control weeds. Now a days, wide variety of mechanical weeders are used, which may be categorized in three groups.

- I. Self-propelled power weeders
- II. Animal drawn weeders

III. Tractor drawn weeders

Due to a lack of knowledge about mechanical weeders, farmers generally prefer manual weeding. Weeding is an important but time-consuming agricultural unit operation. Manual weeding has some limitations, including being labour-intensive and time-consuming, causing labour drudgery, stress and being difficult if the soil surface is not moist and loose.

When using the mechanical weeding method, self-propelled power weeders are less expensive than tractors, smaller in size and can be used in a various crop field, which making them popular among small farmers. A power weeder is a two-wheeled agricultural machine that is outfitted with weeders. To guide the equipment, the operator of a power weeder has to walk it behind. After the crop has begun to grow, power weeders are used to remove weeds, stir, and pulverise the soil, and loosen the soil. Tractors can be hard to operate in hilly and sloping terrain. Thus, in such terrains power weeders are extremely useful because they can be easily moved across small farms. Power weeders cause less soil compaction than tractors because they are lighter in weight.

Developing economies depend heavily on agriculture, and their growing populations fuel the demand for high farm yield. As a result, governments and other organisations have launched a variety of initiatives to promote agricultural mechanisation. As a result, the global power weeder market is expected to grow. In India, for example, the government released 748 crores to state governments across the country in August 2020 under the Sub-Mission on Agricultural Mechanization in order to boost inclusive growth and productivity in agriculture through mechanisation (Transparency market research,2020).

Non-chemical weed control that ensures food safety is now required in the agriculture sector. Consumers want high-quality food and are concerned about food safety. Because of growing concern about environmental degradation and a growing demand for organically produced food, there is a growing interest in the use of mechanical power weeders. Mechanical weeders, which are powered by either gasoline or diesel engines, are more effective than bullock power. The demand and interest of using power weeder increases and different types of power weeder are

available. Now a days, power weeder is available with different power, weeding unit and working width. Thus, it is imperative to test and evaluate different types of available power weeder to find out their suitability with different crops and to study their performance in actual field conditions.

Keeping in view the above fact, the present research problem entitled “Techno economic evaluation of different types of power weeder” is undertaken with following objectives:

1. To record types of weeds and prevailing weeding practices in selected *Rabi* crops.
2. To test and evaluate the performance of power weeders in selected crops.
3. To recommend suitable power weeder as per crop requirement.

CHAPTER – II

REVIEW OF LITERATURE

Mechanization of weeding operation in crop is essentially needed in fields of small and marginal farmers to harness the benefits of mechanized crop cultivation and to increase their farm income. A lot of works has been done on this aspect in India and abroad by many researchers. This chapter aims to briefly discuss the past research work done related to weeding operations. To make it easier to understand, the review of literature is divided into the following sections:

2.1 Weeds

2.2 Mechanical and physical properties of weeds

2.3 Losses due to weeds

2.4 Weed control methods

2.5 Cost and economics involved in weeding

2.6 Concluding remarks

2.1 Weeds

Weed is a plant that is competitive, persistent, harmful and interferes negatively with human activity. Weeds is undesirable plant grown in association with crop which snatches major parts of nutrients, water, light, place, and CO₂ available to the crop.

Smith (1964) reported that inter-cultivation is an operation that required a tool to stir the surface of the soil to a shallow depth in order to promote crop growth and destroy young weeds. The primary goals of crop cultivation are preserved moisture by killing weeds, applying loose mulch to the surface, retaining rainfall, create plant foods, aerate the soil to allow oxygen to penetrate and encourage micro-organism activity

Biswas (1984) classified weeds in various ways based on their location, habitat, life cycle duration, plant family etc. Weeds can be classified into two broad groups based on their occurrence.

1. Upland weeds
2. Aquatic weed

Upland weeds may further be classified as:

- a) Weeds of agricultural land
- b) Weeds of pasture 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

Rao and Nagamani (2010) reported the integrated weed management (IWM) which is a science-based decision-making process that coordinates the use of macro and micro environment information, weed biology and ecology and all available technologies to control weeds in the most economical and ecologically viable ways. The concept of IWM is not new and many advances have been made in India in recent years. Certain problematic weeds have received limited ecological attention. Herbicides were used in the majority of IWM research in India. Herbicides used in association with hand weeding were found to be the most cost-effective.

Weeds are dynamic and it is necessary to redesign strategies on a regular basis in order to successfully manage the ever-increasing weed problem.

Naidu (2012) identified types of weeds according to its leaf shape, scientific name, family index at directorate of weed science research, Jabalpur. He concluded that proper weed identification can enable the selection of the best herbicide to control a specific weed. Identification is also important in terms of herbicide application timing. Correct identification can sometimes indicate that no action is required if the identified plant is not a troublesome weed, and it also helps in the protection of economically important weeds and the conservation of biodiversity. Knowing how to identify weeds is important because it helps determine the expected level of the problem because weeds vary in their ability to reduce yield and quality or in their ability to be beneficial. Weed identification could be the first step toward balancing weed control needs with biodiversity needs

Patidar *et al.* (2019) studied life history of weed species according to their nature of growth and weed biology. They reported that each weed has its own strategy for defeating crops and thus, its habits must be understood in order to know how to get rid of weeds.

2.2 Mechanical and Physical Properties of Weeds

Mcranal and McNulty (1978) conducted theoretical and experimental investigations of impact cutting behaviour of forage crops. The crop is cut by impact with blades moving at sufficient high velocity for crop inertia to provide the required cutting resistance. It concluded that the minimum blade velocity for satisfactory impact cutting was approximately 20 m/s for both grass and oat straws. As blade velocity increased from 20 to 60 m/s, energy consumption in cutting grass and oat straw decreased by approximately 25 per cent. The decrease was less than predicted by theory, due to increased blade-stem friction and stem acceleration. These factors were also responsible for the low values of cutting efficiency, which was less than 5 per cent in all cases.

O'dogherty and Gale (1991) studied the behaviour of grass and straw stems when cut at speeds ranging from 5 to 35 m/s by sharp and blunt blades. Based on stem wall area, they found that the minimum cutting energy per unit dry matter

content for grass with a sharp blade was 55 MJ/mm². Significant stem deflection occurred before cutting was complete at speeds below the critical speed, resulting in long stubble lengths and high cutting energy (up to 400-500 MJ/mm² in grass). The mean peak force per unit dry matter content for grass was 18 N/mm of stem diameter.

2.3 Losses Due to Weeds

Weeds cause a reduction in production, resulting in significant economic losses. Many studies have been conducted in order to determine the losses. It varies by region and is also affected by a number of other factors, including the cultivation practises.

Suresha *et al.* (2015) found that 28 weed species growing in association with various maize-based cropping systems over a two-year period. This clearly illustrated the greater diversity of weed flora that affected crops and cropping systems. The proportion of various *kharif* and *rabi* weeds observed at the maximum population stage in August and January respectively, under undisturbed conditions. They reported and observed that weed is dynamic in nature and are greatly influenced by cropping system, season, and crop management practices during crop growth. They cause significant nutrient and yield losses, suggesting to adopt strong management strategies.

Gharde and Singh (2018) conducted study at the ICAR-Directorate of Weed Research, Jabalpur, to estimate yield and economic losses due to weeds. They use collected data from On-Farm Research trials conducted by different centres of All India Coordinated Research Project on Weed Management (AICRP-WM) in 16 major crops in different districts of 18 states. Major crops were chosen for yield loss calculations, but in some states, only one or two crops were chosen depending on the availability and suitability of the data for consideration. Average yield loss data for major crops in each state were obtained and this data was then used to calculate economic losses due to weeds in each state. The research depended on yield data from farmers practice, weedy check, and weed free. According to the study, potential yield losses in soybean (50-76 %) and groundnut (45-71 %) were high. Groundnut (35.8 %), soybean (31.4 %), green gram (30.8 %), pearl millet (27.6 %), maize (25.3

%), sorghum (25.1 %), sesame (23.7 %), mustard (21.4 %), direct-seeded rice (21.4 %), wheat (18.6 %), and transplanted rice (13.8 %) were estimated to have a total economic loss of approximately USD 11 billion due to weeds alone.

2.4 Weed Control Methods

Weed control is a way of reducing weed infestation so that plants can grow profitably, and humans can perform other tasks well. Various researchers have tried a variety of weed control methods with varying degrees of success. Knowledge of several methods for controlling weeds and their systematic application, depending on the needs and circumstances, can keep the weed on the agricultural farm under control and this problem solved. There are four different common weed control methods are generally used, these are

- I. Chemical control of weeds.
- II. Cultural control of weeds.
- III. Mechanical control of weeds.
- IV. Biological control of weeds.

2.4.1 Chemical weed control method

Tripathy *et al.* (2013) studied weed management in onion (*Allium cepa L.*). Study showed that different weed management practises significantly reduced weed density and increased onion bulb yield with either an application of oxyflurofen 23.5 per cent EC before planting + one hand weeding at 40-60 days after transplanting or a combined spray of pendimethalin 30 per cent EC + quizalofop ethyl 5 per cent EC at planting and a second application at 30 days after transplanting. They conducted a field experiment to compare various weed management practices in onion at the College of Horticulture of OUAT, Chiplima, Odisha. Randomised Block Design was used to plan the experiment. Agrifound Dark Red variety of onion seedlings were planted in the plot at a spacing of 1510 cm. They concluded that except for agronomic practices, all recommended packages of practices were uniformly adapted to all treatments in order to raise a good crop.

Sankar *et al.* (2015) studied weed management in onion (*Allium cepa L.*) during *Rabi* season. They conducted an experiment at the Directorate of Onion and Garlic Research, Rajgurunagar, Pune, using rabi onion cultivar N 2-4-1 with

different herbicides such as Oxyflurofen, Quizalofop Ethyl, and Pendimethalin in comparison to weedy control. The application of Oxyflurofen 23.5 per cent before planting and one hand weeding at 40-60 days after onion seedlings transplanting produced the highest marketable bulb yield (43.5 t/ha) with a maximum weed control efficiency of 78.4 per cent. The same treatment had a higher cost-benefit ratio of 1:3.06. Pre-emergence application of Oxyflurofen 23.5 per cent EC before planting + one hand weeding at 40-60 days after transplanting resulted in higher marketable bulb yield.

2.4.2 Cultural methods of weed control

Datta *et al.* (1974) reported that weeding is traditionally done with indigenous hand tools. These take a significant amount of time and effort.

Patel and Pandey (1983) reported that the hand weeding was found to be more effective than chemical weed control in direct seeded upland rice.

Venugopal *et al.* (1983) observed that weed competition was to be more intense in the broadcast situation. Weeds are uprooted by hand in this method. Hand weeding exceed herbicide treatments in terms of weed control efficiency (89.74 %) and grain yield (63.55 qt/ha). In rice and vegetable crops, hand weeding is very popular.

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

2.4.3 Mechanical weed control methods

Mechanical weed control is widely used in many developing countries including India because in these countries agricultural labour is cheap and readily available. It is simple and easily understood by farmers and farm labourers. Mechanical weed control is very effective, and the results can be seen immediately in the field. Weeds are mechanically controlled by using weeders powered by human labour, animals or tractors, self-propelled weeders are also being introduced and adapted these days. The mechanical weeders are classified, according to its source of power as follows:

- i. Manual weeders

- Small tools
 - Chopping hoes
 - Pull type hoes
 - Push type weeder
 - Push – pull weeder
- ii. Animal drawn weeders
- Triangular and straight blades hoes
 - Shovels, sweeps and duck foot sweeps type cultivators
 - Animal drawn rotary weeders
 - Rotary tines hoes
- iii. Power operated weeders

2.4.3.1 Manual weeders

Moorthy and Das (1992) compared the effectiveness of two types of manually operated implements (the paddy wheel hoe and the finger weeder) used once (15 days after sowing) or twice (15 and 30 days after sowing) field trials conducted in sandy loam soil. The paddy wheel hoe was used twice, resulting in 80 per cent weed control and yields of 1.65 t/ha of rice grain and 3.54 t/ha of straw. The finger weeder was used twice and resulted in 86.7 per cent weed control and grain yields of 2.18 t/ha. All weed control treatments increased percentage weed control, grain yields and straw yields from un-weeded control. The benefit-cost ratio was highest when the paddy wheel hoe was used twice.

Yadav and Pund (2007) developed and ergonomically tested the manual weeder. The developed weeder with a field capacity of 0.048 ha/h and a weeding efficiency up to 92.5 per cent works to a depth of 30 mm. During the weeding operation, peak heart rate of the subjects was ranged from 142 to 150 beats per minute. The subjects needed a 14-minute rest period after heavy work in a densely grassed field to return to normal heart rate.

Shiru (2011) designed and developed a push-pull mechanical manual weeder with a handle, soil cutter (wedge), spikes, wheel bearing, bicycle chain and sprockets. The developed weeder has a weeding index of 74.53 per cent, cutting

blade efficiency of 88 per cent and field capacity of 0.02 ha/h. The developed weeder has the advantage of being simple to use and cost effective for small farmers.

Muhammad and Attanda (2012) developed a hand push mechanical weeder with two sets of cone rotor blades, an adjustable main frame and a float. The weeder overall width and depth of cut were 180 mm and 20 mm respectively. It was found that weeding efficiency was 84.5 per cent in a single pass between the rows on the field at a soil moisture content of 40.8 per cent, while weeding efficiency was 53.1 per cent at a soil moisture content of 10.5 per cent. The highest plant damage is 8.33 per cent was recorded at 10.5 per cent soil moisture content and 0.035 ha/h effective field capacity at 64.87 N draft. A weeder requires 0.058 hp of power to be pushed by a single person.

Attanda *et al.* (2013) developed a hand-pushed weeder and evaluated the performance of developed weeder compared with a traditional hand-held hoe in the field of maize crop. The developed weeder working in forward speed 0.092 m/s actual field capacity 0.028 ha/h, and weeding efficiency 75.17 per cent as compared to forward speed 0.013 m/s, actual field of 0.0059 ha/h and weeding efficiency of 77.98 per cent for the manual hoe respectively. The mean effective operation time for the developed weeder was 91 seconds with 164 number of weeds removed, while the traditional hoe was found to be 189 sec with 153 number of weeds removed.

Kamal and Oladipo (2014) developed a manually operated ridge profile weeder. The weeder was designed for row spacings of 750 – 900 mm and was not limited by crop height. Preliminary tests on the weeder showed that it was effective for control of young weeds. However, the energy required to push the weeder was quite high. The weeder was equipped with two rotary hoes, each weeding one half of adjacent ridges. The inclination of the rotary hoes to the ridge profile could be adjusted to conform to the angle of repose of the ridge.

Rajashekar and Kumar (2015) designed and fabricated a single row weeder. A virtual prototype weeder framework is designed and tested for field performance. It costs Rs.1600/- and operates at a depth of 25 to 40 mm with a field capacity of 0.01 to 0.012 ha/h. They found that weeding costs were cut by 40 per cent and labour requirements were cut by 48 per cent when compared to hand hoe weeding.

Khardiwar *et al.* (2016) developed a manually operated single row weeder for groundnut crop. The developed weeder has a working depth of 40 mm and a field capacity of 0.0285 ha/h. The highest weeding efficiency up to 80.42 per cent was obtained, the draught requirement was 34.4 kg for 200 mm width of the weeder and the performance index of the developed weeder was 1210.53.

2.4.3.2 Animal drawn weeders

Yadav and Anderson (1980) described serrated hoe and harrow blades in bullock drawn blade cum tine hoes for weeding. The intercultural operations performed in dry land farming. The traditional blade hoe or blade harrow can be fitted with serrated blades of various sizes. The serrated blades penetrate the soil easily and aid in moisture conservation.

Murthy and Gowda (1996) evaluated the performance of a bullock drawn blade hoe at three different approach angles (120°, 130°, and 140°) to determine the most effective angle with respect to implement draught, soil moisture conservation, weeding efficiency and crop yield of finger millet under dry land conditions. They concluded that the overall performance of the blade hoe was best with an approach angle of 140° in terms of ridge and furrow formation, soil moisture conservation was best, but draught was significantly higher at 19.5 kg.

Biswas *et al.* (1999) reported that animal drawn weeder worked between crop row spacing, the weeds left over a long row might be removed manually. The straight blades in traditional hoes tend to remove weeds up to the working width of the blades. They found that, due to clogging of the straight edges, the output was adversely affected. So, they concluded there was need to study and use improved blades.

Balachand (2006) designed and developed an animal-drawn weeder. The functional requirements as well as the required strength to resist soil forces acting on it. The performance of the Animal weeder was evaluated using three types of blades: straight blade, curved blade, and sweep blade and it was compared to the performance of the Ambika paddy weeder and hand weeding. When compared to other blades, weeding with an animal drawn weeder with a sweep blade provided a

higher field capacity of 0.0759 ha/h, field efficiency (73.87 %), and performance index (738.75).

2.4.3.3 Power operated weeder

Tewari (1987) developed a weeder cum herbicide applying machine. The machine work as a weeder, it could be conveniently fitted with various weeding range blades, including flat inclined, flat inclined with serrated edges, four time double, and improved double blades. It consists of ground wheel made of MS flats with 40 cm diameter and MS rod spokes, as well as a wheel guide that enlarge rearward and was fixed to a main platform made of angle iron with slots for different weeding blades. This unit could be used in both mechanical weeder and an herbicide applicator. The applicator mechanism included a feed tank, a dripping mechanism and an applying mechanism. Herbicide consumption ranged between 100 and 200 l/ha.

Tajuddin (1989) developed an engine operated blade harrow for weeding and analysed the weeding efficiency at 15-degree, 25-degree, and 35-degree blade angles, 200, 300, 350, and 450 mm blade widths, and 30, 40, and 50 mm depths of operation. Results obtained from study showed that, when blade angle increased, weeding efficiency is increasing. The draught of the blade harrow increased with increase in the depth of operation. However, the rate of increase in unit draught was found to be decreased with increasing depth of operation.

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

Sahay (1997) tested a petrol-powered 35-cc engine-driven manually operated bush cutter. Its cutter could be completely held in both hands. It consists of three-bladed star-shaped knife used a solid shaft to transmit engine power and the entire unit was mounted on a wheeled frame. The machine operated between two rows of a crop to cut weeds just above the ground surface and also machine required 22 man-hours per ha to cut the grass. The limitation of machine was that it

overheated after 30 minutes of operation and required cooling for at least 10 minutes. As machine was held in the hands while being operated, drudgery increased significantly, and it was necessary to rest for at least 10 minutes after every 30 minutes of operation.

Panwar (1999) developed a lightweight, low horsepower engine-powered weeder cum seeder. It consists of 1.5 hp petrol start kerosene run engine. The developed weeder primarily used for weeding row crops and seeding any crop in a single row. The common chasis was designed for low rolling resistance and good traction. The engine power was transferred to a 280-rpm ground wheel via a reduction gear box and chain sprocket system. Three types of weeding blades (hoe, sweep, and L-shaped) are attached at the rear of the machine. This machine was a walk behind type. The top speed of machine was 2.5 km/h. The field capacity of machine ranged between 0.5 and 0.6 ha/day for 8 working hours per day. The average fuel consumption was found to be between 300 and 350 ml/h.

Pannu *et al.* (2002) evaluated a self-propelled diesel engine operated power weeder of 3.8 hp. This weeder was found to be suitable for weeding in wider row crops such as maize, cotton, sugarcane etc. The moisture content of the soil was 17-18 per cent at the time of evaluation. The weeding depth ranged from 4 to 7 cm and the weeding efficiency was 88 per cent.

Victor and Verma (2003) designed and developed a power operated rotary weeder for wetland rice cultivation with a 0.5 hp petrol engine at the faculty of agriculture engineering workshop, IGKV, Raipur, India. A belt, pulley, and chain sprocket were used to transmit power from the engine to the traction wheel and the cutting unit as well as a reduction gear box. For the weeding operation, four L-shaped standard blades were mounted on the hub, which was then mounted on the rotary shaft. The field capacity of machine ranged from 0.04 to 0.06 ha/h and the field efficiency was 71 per cent with 200 mm spacing. The weeding efficiency of machine was 90.5 per cent. The machine was simple, easy to fabricate by local artisan.

Tajuddin (2006) designed and tested a motorised weeder with 3 hp petroleum turned over lamp fuel run motor. The belt-pulley and sprocket-bind

system were used to reduce the estimated speed of 3300 rpm at 60 rev/min of the ground wheel. For added strength, a sweep type weeding cutting edge was connected. The machine effective field capacity was 0.10 ha/h with fuel consumption ranging from 0.60 to 0.75 l/h, depth of operation was 37-39 mm and field efficiency of 85.71 per cent. Operating cost of weeder was Rs. 580/ha.

Padole (2007) compared the field performance of a rotary power weeder and a bullock drawn blade hoe. The rotary power weeder consists of engine, gearbox, clutch, main frame, depth control wheel, V-shaped sweep, cutter wheels, handle, controls, and transportation wheels. It performed better than the bullock drawn blade hoe in terms of working depth 5.67 cm (16.67 % more), effective field capacity 0.14 ha/h (40 % more) and field efficiency 90 per cent (34.11 % more). The cost of operation was determined to be Rs. 798.46 per ha, as opposed to Rs. 894.87 per ha for a bullock drawn blade hoe. As a result, it is more cost effective and efficient than a bullock drawn blade hoe, saving 10.77 per cent on weeding costs, reducing plant damage by up to 54.23 per cent and achieving weeding efficiency of up to 92.76 per cent.

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, 0.65 m, respectively. The cutting blade width is 0.24 m which rotates at 800 rpm. The field test was conducted in moist soil condition and determined weeding efficiency as 95 per cent with effective weeding capacity of 0.053 ha/h and fuel consumption of 0.7 l/h.

Nkakini *et al.* (2010) developed a rotary weeder and compared with manual hand hoe. The rotary weeder consists of 1.4 hp petrol engine. Effective field capacity 0.34 ha/h and theoretical field capacity of machine was 0.47 ha/h, which was approximately twenty times that of manual weeding. They found performance index as 1,700 and the fuel consumption as 3.2 litres per day. The rotary weeder had a weeding efficiency of 71 per cent.

Ratnaweera *et al.* (2010) developed and designed a power weeder. This weeder had a capable of weeding three rows at the same time. It consists of 1.3 kW gasoline engine which was used to power a double action weeding drum, capable of removing weeds and propelling the weeder forward. The cone-shaped weeding drums were also designed to free up soil while minimising damage to the rice crop and a row changing system was also developed, which allows a single person to operate the machine without harming the rice. To improve shearing impact for productive weeding, a helical shaped tooth was assembled on the weeding drums.

Srinivas *et al.* (2010) evaluated the performance of three commercially available weeder blades in the sweet sorghum crop. The weeding efficiency of a power weeder with an L-shaped blade was 91 per cent, while the weeding efficiency of a power weeder with a C-shaped blade and a sweep type blade was 87 per cent and 84 per cent respectively. Power weeder blades with L-shaped, sweep-type, and C-shaped shapes had performance indexes of 169.84, 153.23 and 114.30 respectively. Power weeder field capacity with sweep type blade was 0.12 ha/h, which was greater than C-shaped and L-shaped blade. Plant damage was the least in the sweep type when compared to the other two. In conclusion, the power weeder with L-shaped blades was very economical and simple for using, saving 10.88 per cent on weed removal costs and providing effective weed control.

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 and at rotational speeds of 150, 218, 278 and 348 rpm by down-cut process in clay soil.

Alizadeh (2011) investigated the field performance of four types of mechanical weeders in paddy fields: single row conical weeder (W1), two rows conical weeder (W2), rotary weeder (W3), and power weeder (W4). They concluded that among mechanical weeders, W4 had the highest weeding efficiency (84.33 %) and W3 had the lowest weeding efficiency (72.80 %). The average percentage of damaged plants in mechanical weeders was 3.83 per cent, compared to 0.13 per cent

in hand weeding. W1, W2, W3, and W4 weeding costs were reduced by 15.70, 38.51, 22.32 and 48.70 per cent, respectively, when compared to W5.

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 per cent respectively. The cost of operation with this weeder was estimated as Rs. 2,700 as against Rs. 12,000 as manual weeding.

Ojomo *et al.* (2012) developed and tested a motorised weeding machine. The performance of the weeder was investigated by taking into consideration the effects of three types of cutting blades (flat blade, spike tooth blade, and curved blade) and three moisture contents (10 %, 13 % and 16 %). They concluded that spike tooth blades with a moisture content of 16 per cent provided the best machine efficiency of 94 per cent, the best quality performance efficiency of 84 per cent, the highest percentage of uprooted weeds of 2.8 per cent and the lowest percentage of partially uprooted weeds of 1.8 per cent.

Mahilang *et al.* (2013) developed a power-driven rotary weeder with a 1.4 hp petrol start/kerosene-run engine as the prime mover. Belt and pulley power transmission from engine to cutting units was used in the developed weeder. Six standard L-shaped blades were mounted on a rotary shaft for weeding. Weeding efficiency, quality of work and field efficiency were found to be 91 per cent, 14 per cent and 60 per cent, respectively, with a weeder operational cost of Rs. 808.42 per ha.

Thorat *et al.* (2014) designed and developed a potato crop ridge weeder. The principle highlights of the weeder were cutting blades and the rotor shaft. Three types of cutting edges (type L, type C, and Flat sort) with lengths, widths, and thicknesses of 100 mm, 25 mm, and 6 mm respectively, were chosen to work with a rotor shaft 18 mm in diameter. At a gang speed of 200 rpm and 15.26 ± 0.96 per cent (d.b) soil moisture. C-type cutting blades was found most appropriate, with weeding efficiency, plant damage and field capacity of 99.37 per cent, 2.66 per cent, and

0.086 ha/h respectively. It was also found that the ridge profile power weeder saves 92.7 per cent of time when compared to manual weeding.

Kumar *et al.* (2014) tested three different weeders: khurpi, push type cycle weeder and power weeder. The efficiency of the khurpi, push type cycle weeder, and power weeder was 91.5 per cent, 85.4 per cent, and 71.25 per cent respectively. The power weeder had a field capacity of 0.065 ha/h, followed by the khurpi and push type cycle weeders, that have field capacity of 0.035 and 0.025 ha/h respectively. The cost of operation was found lowest in the push type cycle weeder and highest in the khurpi.

Hegazy *et al.* (2014) developed a power weeder for maize crops that featured modified vertical blades mounted on a circular rotating element on its horizontal side, the motion was transferred to blade units through an altered transmission system. Weeder forward speeds, depth of operation, number of blades, and soil moisture content were studied for their effects on fuel consumption, plant damage, weeding index, effective field capacity, field efficiency, energy required per unit area, and total cost. Three soil moisture content levels (7.73, 12.28 and 16.18 per cent), two blade 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 20 to 40 mm) were selected.

Sabaji *et al.* (2014) developed a ridge profile power weeder for weeding ridge-planted crops. The main working components of weeder were cutting blades (L-type, C-type, and Flat-type blades with lengths, widths, and thicknesses of 100 mm, 25 mm, and 6 mm, respectively) and an 18 mm diameter rotor shaft. At gang speeds of 200 rpm, C-type blades were best suited. Machine weeding efficiency, plant damage, and field capacity were calculated to be 91.37 per cent, 2.66 per cent, and 0.086 ha/h, respectively. When compared to manual weeding, the ridge profile power weeder saved 92.97 per cent of the time.

Karale *et al.* (2015) evaluated a self-propelled inter-row cultivator for rainfed crop. It was found that the actual field capacity was found 0.21 to 0.27 ha/h with 80 to 83 per cent field efficiency. The weeding efficiency was 91 to 97 per cent.

The operational cost was found as Rs. 225. The overall saving in cost of operation was observed in the range of 25 to 29 per cent over the traditional method.

Kunnathadi *et al.* (2016) developed and tested a self-propelled cono-weeder for mechanized rice cultivation at College of Horticulture, Kerala Agricultural University. The main components of the newly developed self-propelled cono-weeder were the main frame, a prime mover, front and rear floats and a rotor. The developed weeder compared with manual weeder. It was found that the self-propelled cono-weeder had a field capacity of 0.1 ha/h at an operating speed of 2.0-3.0 km/h.

Deshmukh *et al.* (2017) fabricated engine operated weeder with 175 cc two stroke petrol engine for reducing human effort. The differential mechanism is used for forward movement of the machine. The chain was mounted on the sprocket and sprocket is on the shaft. Engine gives power to shaft. The shaft rotates, the driving wheel was attached to it with chain. So, the wheels were also rotate. The blades were mounted on the back side of the machine. During forward motion, the blades were also started moving because the blades were attached rigidly to the body.

Govardhini and Reddy (2017) developed a solar-powered multi-crop weeder. One solar panel, two dc motors, two batteries, a rotary blade, and a chain sprocket mechanism comprise the drive mechanism. J-type rotary blades are implemented by adjusting the operated voltage, the speed controller was able to vary the motor speed. The DC output power of the solar panel ranged from 100 W to 360 W. Two 12 V DC motors were used to power the equipment. The knobs connected to the potentiometer provided in the circuit were used to control the speed of the motor through the speed controller.

Mahilang *et al.* (2017) designed and developed a power-driven rotary weeder for rice. The machine was equipped with a 1.30 kW petrol start-kerosene run engine as the prime mover. Power was transmitted from the engine to the ground wheel through a belt and pulley system. Two ground wheels were provided to ensure smooth operation and prevent jerks. Three L-shaped blades were installed on the

rotary shaft for the cutting unit. The weeder has a field capacity of 0.14 ha/h, a weeding efficiency of 91 per cent and a field efficiency of 60 per cent.

Singh *et al.* (2017) modified a single row power operated rice weeder for dry field condition. The modified weeder helps to build up the soil organic matter and subsequently large and diverse microbial population thus it facilitates the process of aeration. The existing power weeder works well in wet land conditions but by modified some parts of weeder i.e., adding C type blade, removing extension shaft and transport wheel it performs well in dry field condition and it works more effectively in dry land condition compared to wet land field condition.

Sirmour (2017) designed and developed single row power weeder. The average speed of operation was found as 2.45 km/h. The average fuel consumption of power weeder was found as 0.55 l/h. The maximum field capacity was found 0.054 ha/h. The working width of the developed machine may be adjustable between 140 mm to 250 mm. The weeding efficiency was observed as 88.62 per cent under single row active power weeder. The saving in cost of weeding was 60 per cent and saving in time was 65 per cent compared to manual weeding.

Kumar *et al.* (2018) evaluated the performance of power weeder, wheel hoe and star weeder on maize crop with row to row spacing of 60 cm under dry land condition. The actual field capacity was found to be 0.0494 ha/h, 0.022 ha/h and 0.021 ha/h respectively for power weeder, wheel hoe and star weeder. Weeding efficiency for power weeder, wheel hoe and star weeder were 78.4 per cent, 74.0 per cent and 75.4 per cent, respectively. Field efficiency and operational cost was highest in case of power weeder and was lowest in case of wheel hoe. Drudgery involved during weeding operation was more in wheel hoe when compared with the other two.

Ragesh *et al.* (2018) studied the performance of power weeder for paddy crop at 20 and 45 days after sowing (DAS) and the performance was compared with traditional hand weeding and ambika paddy weeder. The weeding efficiency was found to be 74.22 per cent and 86 per cent for 20 DAS and 45 DAS, respectively. The highest field efficiency was shown by paddy power weeder as 70 per cent for

45 DAS and no significant variation in field efficiency was found in ambika paddy weeder at 20 and 45 DAS. The cost of operation per hectare with power weeder was Rs. 928 and Rs. 850 against ambika paddy weeder as Rs. 2617 and Rs. 2346 for 20 and 45 DAS.

Srinivas *et al.* (2018) evaluated a walking type multi crop power weeder. Machine worked at varying width of 15-45 cm so that it can be used for multi crops. Weeding efficiency was found 85.6 per cent and 86.2 per cent for okra and chili respectively. Plant damage was 2.29 per cent and 2.61 per cent and field capacity of the weeder was 0.0309 ha/h and 0.0302 ha/h, respectively for okra and chili crop working at 25 cm width. Optimum performance was found for maize crop at 45 cm cutting width.

Kumari *et al.* (2019) developed a solar-powered weeder. The developed weeder was tested on a maize crop with 600 mm row spacing. Three different cutting blade widths 50 mm, 60 mm, and 70 mm were chosen with two, three, and four blades per flange. The weeder shaft is powered by a 150 W DC motor that is powered by a 160 W solar panel. The maximum field capacity was found to be 0.175 ha/day, with a weeding efficiency of 88.03 per cent. The maximum and minimum plant damage caused by the developed weeder for maize crop were 3.03 and 1.961 per cent for 2 blades 60 mm width and 4 blades 70 mm width, respectively.

Shamkuwar *et al.* (2019) studied different weed controlling techniques used by the different researchers to be adapted in agricultural work. It concluded that many self-propelled and tractor drawn weeding machine have been developed for weeding operation for medium and large farmer, but little work has been carried out for small and marginal farmers. Thus, there is need to develop an efficient weeding machine for small and marginal farmers.

Singh *et al.* (2019) developed a battery-powered four-wheel weeder to ease farm workers drudgery. The weeder was designed using the mechatronics concept. The developed weeder was powered by a 24 V-14 Ah battery and a 250 W- 24 V DC motor. The weeder working width was 30 cm, and a sweep type weeding tool was used for weeding. At a walking speed of 2.52 km/h, the weeding capacity and efficiency were 0.0554 ha/h and 97.5 per cent, respectively.

Ragesh *et al.* (2019) designed and developed a power weeder for upland paddy. The machine can be made up of easily available machine components such as engine, gearbox, sprockets and chain etc. The machine worked satisfactorily for weeding in 28 to 30 % moisture content (db) in the field. The machine maximum weeding efficiency of 85.9 % at 45 days and plant damage percentage was less 3.75 % at 20 DAS than 45 DAS (8.26 %).

Vadher *et al.* (2020) designed and developed a solar operated walking type power weeder. The machine consisted of BLDC motor, solar panel, battery, motor charge controller, speed controller system, blade assembly and transmission system. The effective field capacity and field efficiency were obtained 0.129 ha/h at 2.0-2.5 km/h and 85.68 % respectively. For the three different speed of operation 1-1.5, 1.5-2.0, 2.0-2.5 km/h, weeding efficiency were found to be 90.24, 84.69 and 83.50 % respectively. The parts and components were strong enough to work with higher efficiency. They concluded that the higher weeding efficiency and lesser plant damage was observed at the forward speed of 1.5 km/h. At this speed, better weeding was observed without clod formation, plant damage and better inversion of uprooted weeds.

Mishra (2021) designed and developed a solar power cum electric operated weeder for horticulture crops. It was designed and fabricated by assembling different parts such as DC motor, chain sprocket mechanism, solar panel, battery, rotary cutting blades and transport wheel. The stored electrical energy in battery was used to run the DC motor. The developed weeder could be worked in three and half hours continuously in fully charge battery condition and on bright sunshine day. The developed weeder complete weeding in one hectare of area within 22.7 hours. The cost of operation of developed weeder was Rs. 52.14/ha.

2.5 Cost and Economics Involved in Weed Management

Weeds compete with plants for water, nutrients, space, and light, due to this lowering crop productivity and reduced income. Weeds also cause significant losses by increasing the cost of cultivation, tolerating several insect pests, pathogens of vital and fungal diseases, and affecting the quality of farm produce, resulting in lower farm product prices.

Ram and Paul (1978) found that cost of weed control was more in case of hand weeding. Hand weeding was superior to chemical weed control, which resulted in higher yields and subsequently, higher profit from hand weeding.

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

Govindra *et al.* (1982) found that the highest net return when two weedings at 15 and 30 DAS obtained maximum net return. When herbicide application 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 thiobencrab at 1.5 kg a.i./ha each combined with one hand weeding at 45 DAS.

Rangasamy *et al.* (1993) developed and tested the performance of a power weeder. The weeder was tested against a manually operated dry land weeder and the traditional method of manual weeding with a hoe. It was found that the field capacity of machine was 0.04 ha/h, its weeding efficiency was 93 per cent, and its performance index was 453. The developed weeder had an operational cost of Rs. 250/ha. While the operational costs of a dryland weeder and manual weeding with a hoe were Rs. 490 and Rs. 720 per hectare respectively. When compared to manual weeding with a hoe, the developed weeder saves 93 per cent of the time and 65 per cent of the money.

Pradhan *et al.* (1995) developed a power tiller-operated groundnut weeder. The field capacity of machine was determined to be 0.164 ha/h, with a field efficiency of 72 per cent. The weeding efficiency was observed to be 65 per cent. They concluded that when compared to manual weeding, this weeder saved Rs. 255.0/ha.

Padole (2007) compared the effectiveness of a rotary weeder and a bullock drawn blade hoe. A rotary power weeder is made up of the gear box, clutch, engine, frame, depth wheel, handle, sweep blade, and transport wheels. The rotary weeder had a field efficiency of 90 per cent, which was 34.11 per cent higher than the bullock drawn blade hoe. The effective field capacity of the rotary weeder was 0.14 ha/h, which was 40 per cent greater than the bullock drawn blade hoe. The

operational costs of a rotary weeder and a bullock drawn blade hoe were determined to be Rs. 798.46/ha and Rs. 894.87/ha, respectively. As a result, the rotary weeder saved weeding cost by 10.77 per cent.

Shrinivasa *et al.* (2017) designed and tested a mechanical weeder for finger millet crops with two and four blade harrows for weeding two and four rows at a time. Weeding efficiency (88 and 85 %), plant damage (2.5 and 3.6 %), effective field capacity (0.108 and 0.144 ha/h), field efficiency (90 and 60 %), fuel consumption (4.181 and 3.424 l/ha) and weeding cost (Rs. 572 and Rs. 447.42 per ha) were found to be higher at 2 rows and 4 rows weeding conditions respectively.

2.6 Concluding Remarks

This chapter summarises previous research on various aspects of weeds, weeding methods and the performance of manual, animal and power operated weeders under various conditions. Mechanical weeders powered by gasoline engine, diesel engine and battery-operated weeder are currently more effective than bullock power. The use of power weeders is becoming more popular, various types of power weeders are available in different power, weeding unit and working width configurations. It was crucial to examine the performance of these power weeders in field conditions for crop production. According to performance of weeder, to recommend the suitable power weeder as per crop requirement to have proper growth and production of crop yield. It is expected that weeder could be a better viable option for the farmers on the cost basis.

CHAPTER-III

MATERIALS AND METHODS

A study was carried out to evaluate the performance of five different types of power weeder. The weeders were tested under field conditions to evaluate its performance. Different test parameters were considered as independent and dependent parameters. These weeders were tested in three selected crops. This chapter deals with the materials used and methodology followed in conducting experiments of this study and described in following sections.

3.1 Experimental site

3.2 Details of selected power weeder

3.3 Experimental details

3.4 Operational parameters for testing of weeder

3.5 Machine performance and evaluation of weeders

3.6 Operational cost of different weeders

3.7 Operational energy analysis of weeders

3.1 Experimental Site

The testing of weeders was carried out in the research field of Swami Vivekananda College of Agricultural Engineering Technology and Research Station, Faculty of Agricultural Engineering, IGKV, Raipur (C.G.) during *Rabi* season in the year 2021-2022. The study field was situated at 21° 14' 02" N latitude and 81° 43' 11" E longitude. The soil texture of experimental field is clay loam, and the average annual rainfall of the area varies around 1064 mm.

3.1.1 Climate

The climate of Raipur is tropical wet and dry climate, temperature remain moderate throughout the year, except from March to June, which can be extremely hot. The temperature rises above 48°C in the month of April-May. Hot and dry winds blow during the summer seasons, temperature goes rises to 50°C. In rainy season

receives about 1,300 mm of rain, mostly in the monsoon season from late June to early October. Winters starts in the last week of October and staying until February. During winter seasons, temperature ranges from 22°C in the daytime to 12°C in the night.

3.1.2 Experimental details

Five different types of power weeder were tested in three selected crops. One oil seed crop, mustard and two vegetable crop, cauliflower and cucumber were selected to conduct this study. The details of selected crops are described as follows.

3.1.2.1 Mustard

Indian mustard (*Brassica juncea*) belongs to the family of Cruciferae and is grown in a subtropical climate. In India, they are grown in the *Rabi* season from September-October to February-March, which requires a temperature between 10 °C and 25 °C and areas receiving 625–1000 mm of yearly rainfall. India is the fourth largest producer of oilseeds. Mustard seeds and their oil are used for cooking purposes, while young leaves are used for vegetable purposes and their oil cake is used for feeding purposes. Mustard seeds were planted in 900 m² area having a row-row distance of 0.48 m and a plant-to-plant distance of 0.04-0.06 m. Proper irrigation was applied to the crop during its life period. The mustard crop at its weeding stage is shown in fig. 3.1.



Fig. 3.1: Mustard crop at weeding stage

3.1.2.2 Cauliflower

Cauliflower (*Brassica oleracea*) is a popular vegetable crop in India and this vegetable belongs to the cruciferous family. The edible portion of cauliflower is known as "curd." This vegetable's edible portion is approximately 45 per cent of the vegetable as purchased. It contains minerals like potassium, sodium, iron, phosphorus, calcium, and magnesium. Intercultural operations should be done on a regular basis to keep the crop free from weeds and to aerate the root system. The cauliflower was planted in a 900 m² area, having a row to row spacing of 0.50 m, and plant to plant spacing of 0.50 m was maintained.



Fig. 3.2: Cauliflower field after weeding operation

3.1.2.3 Cucumber

Cucumbers are originated in India and *Cucumis sativus* is the botanical name for cucumber. It is a climbing plant that is widely used as a summer vegetable in India. Cucumber fruit is eaten raw, as a salad, or cooked as a vegetable. Cucumber seeds are used to extract oil, which is beneficial to both the body and the brain. Cucumbers content 96 % water, making them good for the summer months. The plants are large, the leaves are hairy and triangular, and the flowers are yellow. In summer season it requires frequent irrigation. The cucumber was planted in 900 m²

area having row to row spacing of 0.80 m and plant to plant spacing of 0.08-0.10 m was maintained.



Fig. 3.3: Cucumber field after weeding operation

3.2 Details of Selected Power Weeders

To assess and quantify the relative effectiveness of different weeding machinery, a field experiment was conducted at research field of Indira Gandhi Krishi Vishwavidyalaya, Raipur. The details of selected five different power weeders are described below:

3.2.1 Power weeder 52 cc

The power weeder 52 cc is compact and light weight machine, easy to operate. This weeder used two stroke petrol engine to provide rotational energy to the shaft connected to it. Cutting blades are mounted on the shaft. Due to the rotary motion of blade when it touches the soil the process of weeding gets started. The handle is provided to guide the vehicle in desired direction. The power button and starter rope are provided to start the engine easily. To stop the weeder, engine power-off button is provided on the handle. The detailed technical specification of the weeder is furnished in Table 3.1.

Table 3.1: Technical specification of power weeder 52 cc

S.No.	Particulars	Specifications
1	Model name	INTER CULTIVATOR
2	Model number	OX0152
4	Power, hp	2
5	Fuel type	Petrol
6	Fuel tank capacity, l	1.2
7	Oil (Mixing)	40 ml oil / l of petrol
8	Displacement volume, cc	52
9	Engine type	Air-cooled, 2-stroke, single cylinder
10	Engine starting system	Recoil starter
11	Carburetor	Diaphragm type
12	Engine, rpm	6500
13	Cutting width, mm	250-300
14	Cutting depth, mm	45-60
15	Type of blade	Curved strip type blades
16	No. of blades	16
17	Dimensions (L x B x H), mm	920 x 480 x 260
18	Weight, kg	25
19	Price, Rs	12,500

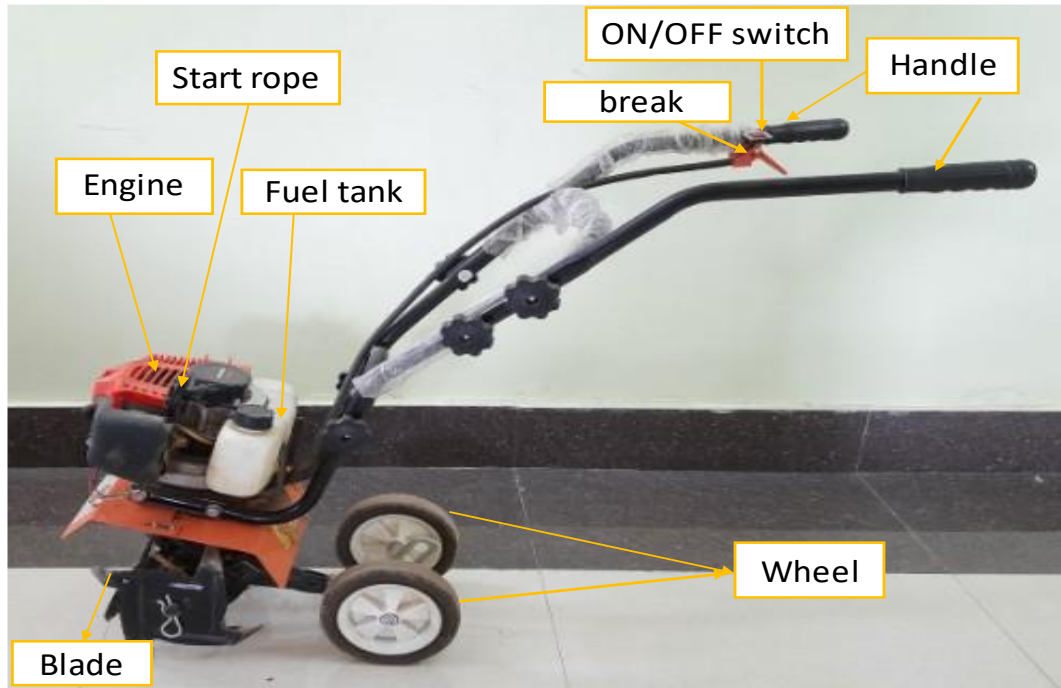


Fig. 3.4: View of power weeder 52 cc

3.2.2 Power weeder 67 cc

The machine consists of 2-stroke petrol engine mounted on the main frame. Fuel tank is fitted on the side of engine having 1.2 litre capacity. Two rotary blades are mounted below the frame and two wheels are attached at the rear side of the weeder. This weeder is easy to handle and operated in field crop for intercultural operations.

The petrol engine provides rotational energy to weeding unit. The rotating blades helps to cuts the weeds and make the soil loose in field which provides proper aeration of soil and growth of crop. The forward gear is provided in the shaft to drive the weeder in forward direction and handle is used to guide the vehicle in desired direction.

The break lever, accelerator lever, power button is provided on handle. It can be easily operated by either male or female farm worker, it is light in weight and easy to handle. The power weeder 67 cc is slightly similar to the power weeder 52 cc. The dimension of both the weeders are same. The detailed technical specification of the weeder is furnished in Table 3.2.

Table 3.2: Technical specification of power weeder 67 cc

S.No.	Particulars	Specification
1	Model name	Inter Cultivator
2	Model number	OX0168
3	Power, hp	3
4	Fuel used	Petrol
5	Fuel tank capacity, l	1.35
6	Oil (Mixing)	40 ml oil / l of petrol
7	Displacement volume, cc	68
8	Engine type	2-Stroke, air cooled, single cylinder engine
9	Engine starting system	Recoil
10	Engine, rpm	6500
11	Cutting width, mm	250-300
12	Cutting depth, mm	45-60
13	Type of blade	Curved strip type blade
14	No. of blades	16
15	Dimensions (L x B x H), mm	920 × 480 × 260
16	Weight, kg	32
17	Price, Rs	18,500

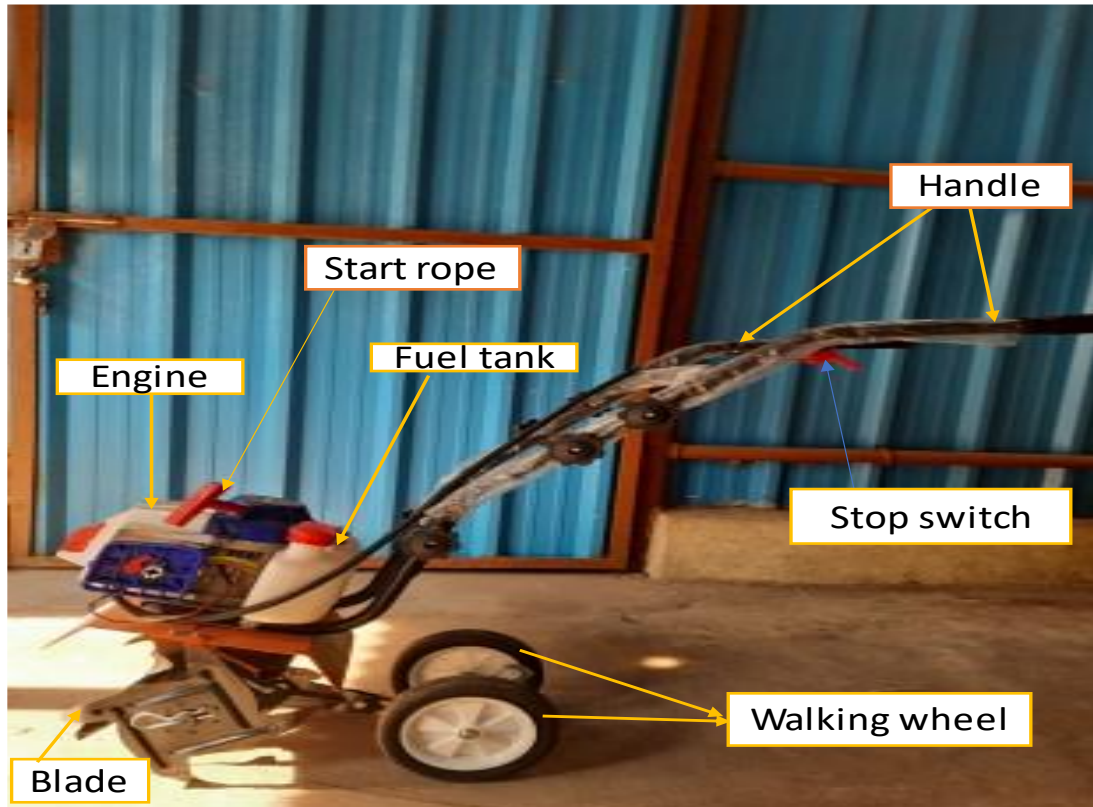


Fig. 3.5: View of power weeder 67 cc

3.2.3 Sidepack brush cutter power weeder

This weeder is very useful to all farmers for controls the weeds in agricultural field. This machine is also very fuel efficient consumes very less fuel. The weeding operation is done by carrying the engine part of the machine in the shoulder. Machine is supported in the shoulder by the supporting belt provided. The recoil engine starter system is provided which is mounted in top of the engine. The engine is fitted at one end of the shaft and rotary cutter tiller blade is attached at the other end. This weeder used two stroke petrol engine to provide rotational energy to the cutting unit. The detailed technical specification of the weeder is furnished in Table 3.3.

Table 3.3: Technical specification of sidepack brush cutter power weeder

S.No.	Particulars	Specification
1	Model name	Xtra-Power
2	Power, hp	2
3	Fuel used	Petrol
4	Fuel tank capacity, l	1
5	Oil (Mixing)	40 ml / l of petrol
6	Displacement volume, cc	43
7	Engine type	2-stroke, air cooled, single cylinder engine
8	Engine starting system	Recoil
9	Engine, rpm	7000
10	Cutting width, mm	280-320
11	Cutting depth, mm	40-80
12	Type of blade	Tiller type blade
13	No. of blades	16
14	Dimensions (L x B x H), mm	183×630×260
15	Weight, kg	17
16	Price, Rs	10490

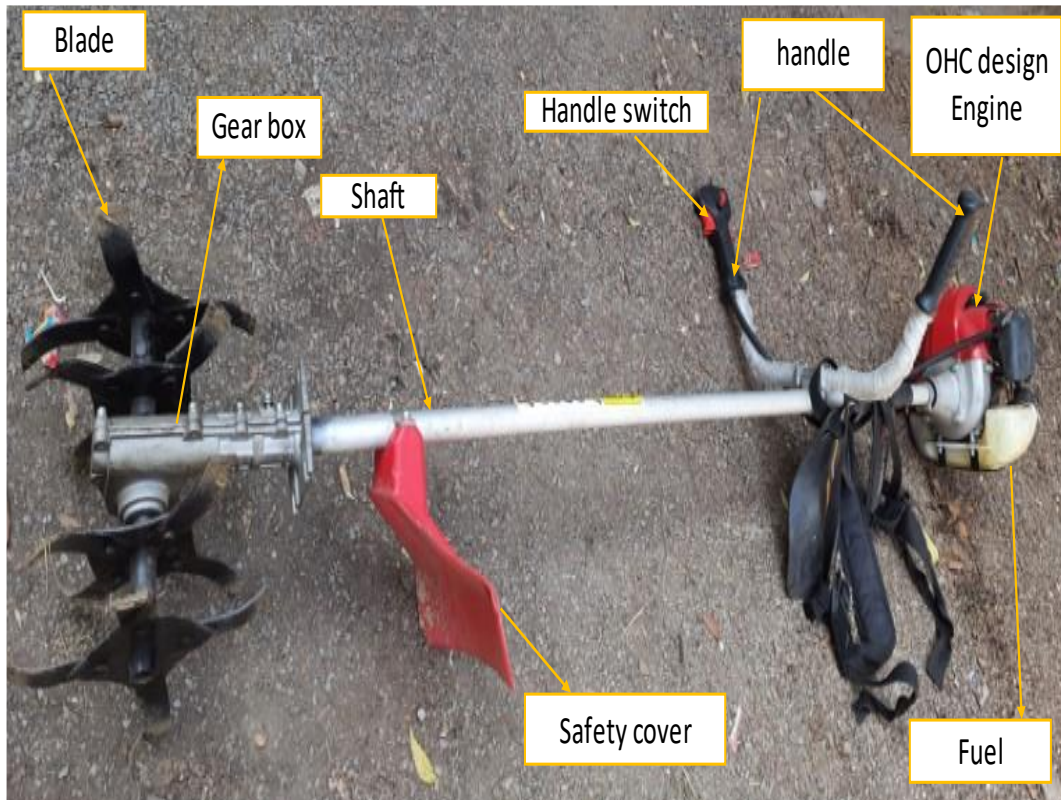


Fig. 3.6: View of sidepack brush cutter power weeder

3.2.4. Backpack brush cutter power weeder

The backpack brush cutter power weeder is extremely beneficial to all farmers. It enables time-consuming weeding activity to be completed in a less time and at a lower cost. This weeder is also extremely fuel efficient, requiring very little fuel. The weeding operation is done by carrying the engine part of the machine at the back of the operator. The recoil engine starter system is provided which is mounted in top of the engine. The engine is fitted at one end of the shaft and at other end is attached with weeder blade and gear box. This weeder consists of 4-stroke petrol engine unit provides rotational energy to cutting unit. The detailed technical specification of the weeder is furnished in Table 3.4.

Table 3.4: Technical specification of backpack brush cutter power weeder

S.No.	Particulars	Specification
1	Model name	XTRA-POWER
2	Power, hp	3.2
3	Power source	Petrol
4	Engine starting system	Recoil
5	Engine, rpm	12000
6	Engine type	4-stroke, air cooled, single cylinder engine
7	Fuel Tank Capacity, l	1.2
8	Displacement volume, cc	50
9	No. of blades	12
10	Cutting width, mm	200-240
11	Cutting depth, mm	20-40
12	Type of blade	Rotor type blade
13	Blade length, mm	80
14	Blade width, mm	40
15	Dimensions (L×B×H), mm	1510×250×120
16	Weight, kg	12-15
17	Price, Rs	12,000

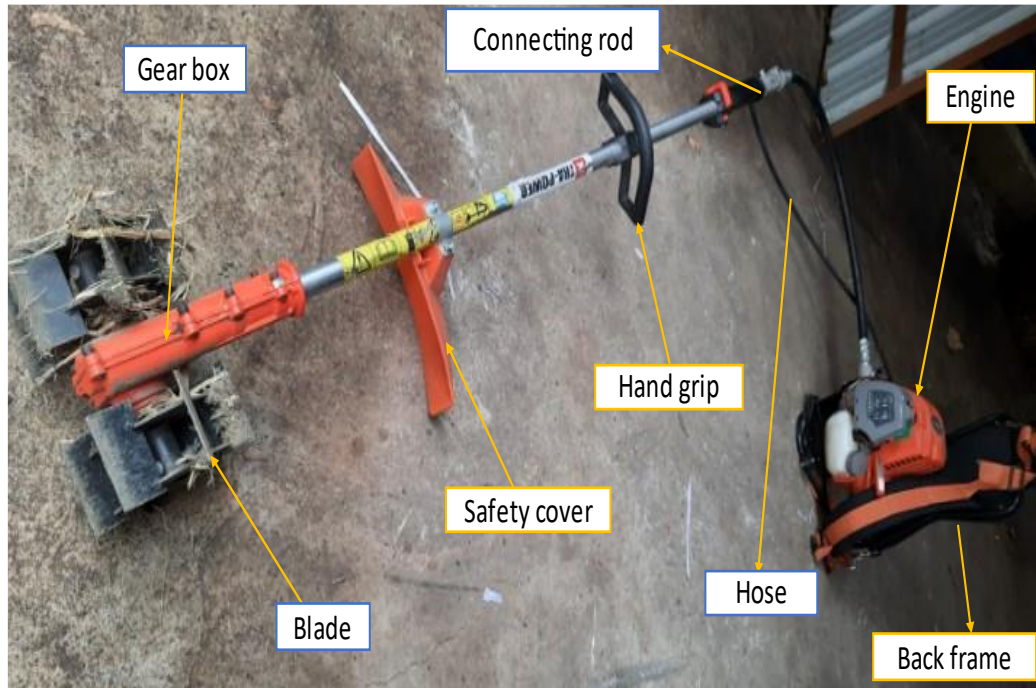


Fig. 3.7: View of backpack brush cutter power weeder.

3.2.5 Solar power cum electric operated weeder

The solar power cum electric weeder operates on the principle of converting electric energy into mechanical energy. Machine consists of DC motor, a battery, a solar panel, a chain-gear arrangement, a handle, blades, a flexible shaft, a blade cover, and wheels for transportation. Weeder blades cut and loosen the soil, allowing the weeds to be removed. When the switch was turned on, current began to flow from the battery to the motor and the system is ready to operate. When the acceleration lever is moved, a chain gear arrangement begins to transmit power to the rotor shaft. The electrical energy from the battery was used to power the DC motor, which drives the rotor shaft via a chain sprocket mechanism. Flanges connect the rotor shaft to the blades. The cutting width can be adjusted from 300 mm to 450 mm depending on crop row to row spacing. The rotary action of the blades cuts and loosens the soil, disrupting weed roots and removing weeds from the soil. It also loosens the soil, allowing for proper aeration. There was a controller with speed and voltage control. Furthermore, in the event of excessive current flow, the controller acts as a cut-off device to protect the battery and DC motor from damage. The detailed technical specification of the weeder is furnished in Table 3.5.

Table 3.5: Technical specification of solar power cum electric operated weeder

S.No.	Particulars	Specification
1	Main frame (L × B), mm	1202 × 540
2	Solar panel frame (L × B), mm	680 × 650
3	Power source	Battery (12 V, 30 amps)
4	No. of batteries	4
5	Nominal voltage, V	48
6	Power, W	700
7	Idle Speed, rpm	480
8	Wheel overall diameter, mm	340
9	Material of blade	Mild steel
10	Shape of blade	'L' type
11	Cutting width, mm	400-460
12	Cutting depth, mm	30-45
13	Thickness of blade, mm	4
14	Flange thickness, mm	4
15	Number of flanges	4
16	Number of blades per flange	4
17	Total no. of blades	16
18	Weight, kg	58
19	Price, Rs	55,040

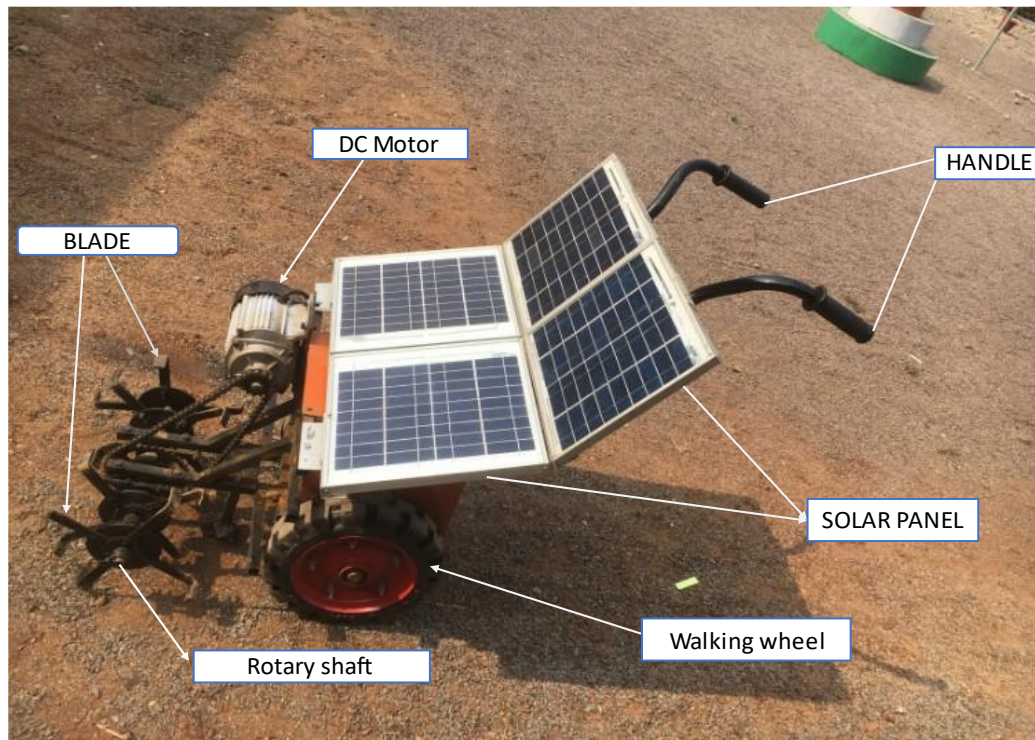


Fig. 3.8: View of solar cum electric operated weeder

3.3 Experimental Design

The experiments were planned and conducted to fulfill the objectives of research problem. The experimental data collected on various aspects were tabulated and analysed statistically by using the technique of analysis of variance for split plot design and significance was tested by F-test. For weeder testing, the independent parameters viz. different types of crops and different types of weeders were taken and dependent were taken i.e., speed of operation, field capacity, weeding efficiency, effective field capacity, theoretical field capacity, plant damage, field efficiency, performance Index, fuel consumption. The independent and dependent parameters of weeder were analysed by split plot design. The summarized details of experiment is shown in Table 3.6, 3.7, 3.8.

Table 3.6: Plan of experiments on test setup

Factor A: Crops (3)	Factor B: Weeder (5)
C1: Mustard crop	W1: Power weeder 52 cc Engine
C2: Cauliflower crop	W2: Power weeder 67 cc Engine
C3: Cucumber crop	W3: Sidepack brush cutter power weeder
	W4: Backpack brush cutter power weeder
	W5: Solar power cum electric operated weeder
Design	Split plot design
Replication	4
Number of plots	3
Number of sub-plots	15
Number of treatments	15

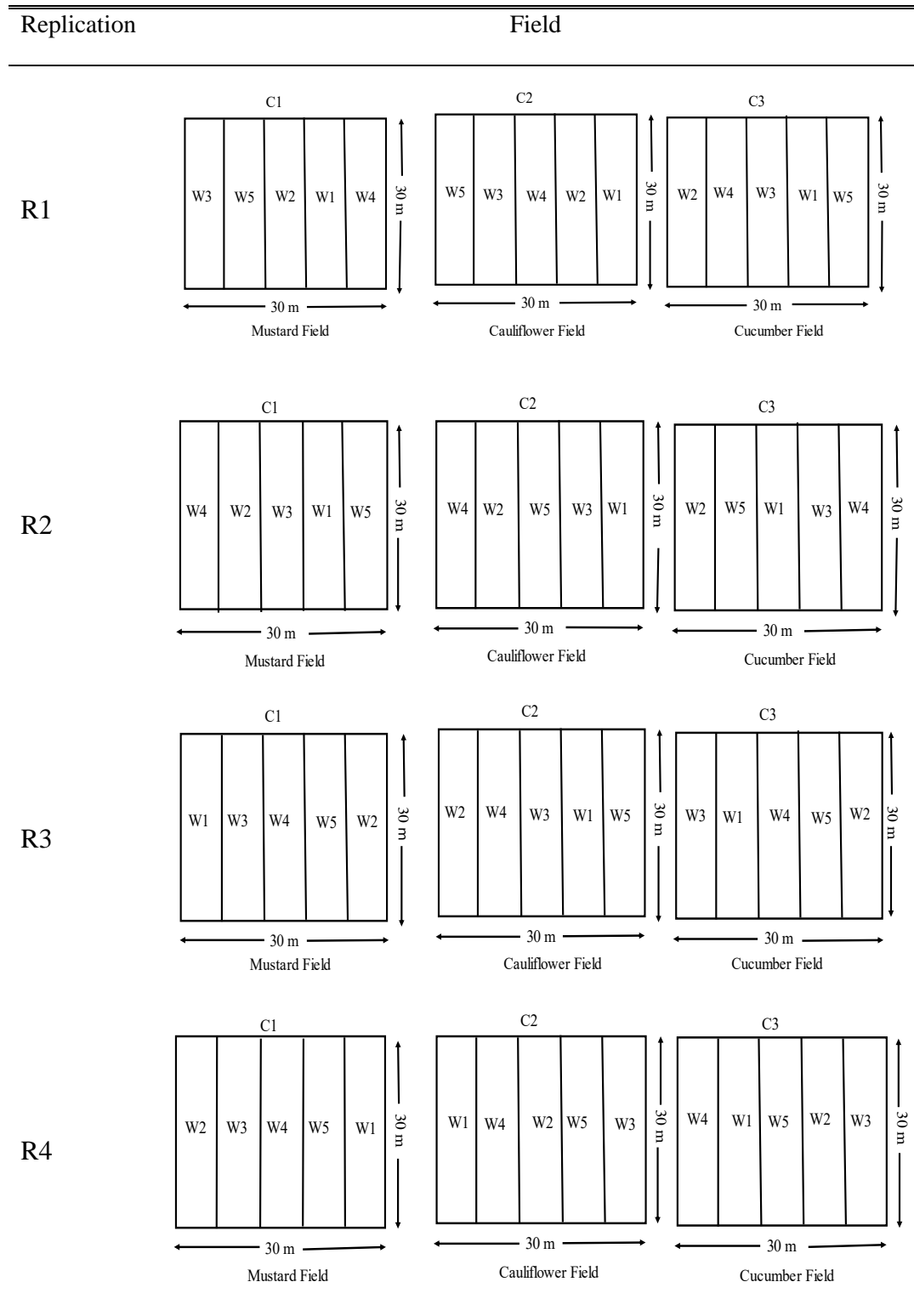
Table 3.7: Identification of treatments

Crop	Treatment
Mustard (C1) field	T1(C1W1), T2(C1W2), T3(C1W3), T4(C1W4), T5(C1W5)
Cauliflower (C2) field	T6(C2W1), T7(C2W2), T8(C2W3), T9(C2W4), T10(C2W5)
Cucumber (C3) field	T11(C3W1), T12(C3W2), T13(C3W3), T14(C3W4), T15(C3W5)

Four replications were done for each treatment. Analysis was done at a 5 % level of significance. Software OPSTAT developed by O. P. Sheoran, Computer

Programmer at CCS Haryana Agricultural University, Hisar, was used to analyze data.

Table 3.8: Layout of experimental plot



3.4. Operational Parameters for Testing of Weeder

The blades of power weeder directly interact with soil to uproot the weeds. Hence, the properties of soil directly affect the weeding performance of weeder and moreover weeding performance also depend on weed density. Following operational parameters were determined:

- i. Moisture content of soil
- ii. Bulk density of soil
- iii. Plant population
- iv. Weed population
- v. Effective working width
- vi. Effective working depth

3.4.1 Measurement techniques

The standard methodologies were adopted to measure the different parameters.

3.4.1.1 Moisture content of soil

To determine moisture content of soil, soil sample were taken up to a depth of 10 cm. The samples were collected randomly from three locations of test plot before a day of weeding in the field. These samples were weighed and kept in an oven at $105 \pm 50^\circ\text{C}$ for 24 hours. The moisture content was determined by using the following formula (Thorat *et al.*, 2014).

$$\text{M. C.} = \frac{W_1 - W_2}{W_2} \quad \dots (3.1)$$

Where,

M.C. = Moisture content, % db;

W_1 = Weight of wet soil sample, g; and

W_2 = Weight of dry soil sample, g.



Fig. 3.9: Measurement of moisture content by oven dry method

3.4.1.2 Bulk density of soil

To determine bulk density of soil, core sampler having 50 mm diameter and 300 mm length, marked at each 10 mm interval along its length was used. Firstly, it was vertically inserted into the soil up to 50 mm only and the soil was collected in it was removed immediately as the first sample. Same procedure was repeated for collection of three sample from random locations. Samples were weighed and kept in the oven at 105 ± 5 °C for 24 hours. The weight of dry soil was recorded, and bulk density was calculated by using the following relationship (Thorat *et al.*, 2014).

$$\rho = \frac{M}{V} \quad \dots (3.2)$$

Where,

ρ = Bulk density of soil, gcm^{-3} ;

M= Moisture content of dry soil, g and

V= Volume of core cutter, cm^3 .



(a)

(b)

Fig. 3.10: Measurement of bulk density

3.4.1.3 Plant population

To determine plant damage percentage, the total number of plants was counted in a 10 m row length from randomly selected locations in each plot before and after each weeding operation.

3.4.1.4 Weed population

Before and after each weeding operation, the total number of weed plants were counted in an area of one square metre using a quadrat, from randomly chosen location in each plot.



Fig. 3.11 Counting of weeds after weeding

3.4.1.5 Effective working depth

In the field, the depth of cut of the machine was measured by measuring the depth of soil layer tilled by the blade in a row. The depth of the weeding was measured using a measuring scale in various locations. The depth of weeding was calculated as the average of five observations and expressed in centimetres.

3.4.1.6 Effective working width

To measure effective working width of machine in field using concept of tilled and untilled strip from the original selection in between rows.

3.5 Machine Performance and Evaluation of Weeders

The following machine performance parameters were calculated on actual field condition from the field.

3.5.1 Operating speed

Two poles were placed at 30 m apart, and a weeder was operated between them, with the crossing time between these two poles measured. The forward speed of operation is calculated by observing the distance travelled and the time required to cover these two poles and using following formula to calculate operating speed (Mehta *et al.*, 2005).

$$S = \frac{L}{t} \quad \dots (3.3)$$

Where,

S = Forward speed of operation, m/s;

L = Distance travelled, m; and

t = Time taken, s.

3.5.2 Weeding efficiency

Weeding efficiency is a percentage that is calculated by dividing the number of weeds removed by a weeder by the number of weeds present in a unit area (Tajuddin, 2006).

$$\text{Weeding efficiency, (\%)} = \frac{w_1 - w_2}{w_1} \quad \dots (3.4)$$

Where,

w_1 = No. of weeds counted in per unit area before weeding operation.

w_2 = No. of weeds counted in same unit area after weeding operation.

3.5.3 Plant damage

Plant damage is the ratio of number of plants damaged after operation in a row to the number of plants present in that row before operation and is expressed in percentage. It was calculated by using the following formula (Tewari *et al.*, 1993).

$$\text{Plant damage, \%} = \left(1 - \left(\frac{q}{p} \right) \right) \times 100 \quad \dots (3.5)$$

Where,

q = Number of plants in a 10 m row length after weeding, and

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

3.5.4 Theoretical field capacity

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

$$TFC = \frac{w \times s}{10} \quad \dots (3.6)$$

Where,

TFC = Theoretical field capacity, ha/h;

w = Cutting width, m; and

s = Speed of operation, Km/h.

3.5.5 Effective field capacity

The actual covered area during operation was called effective field capacity. In this term we consider the useful time and time loss for turning the machine (Kepner *et al.*, 1978).

$$EFC = \frac{A}{T_p + T_l} \quad \dots (3.7)$$

Where,

EFC = effective field capacity, ha/h;

A = Area, ha;

T_p = Productive time, h; and

T_l = Non-productive time, h.



(a)



(b)



(c)



(d)



(e)

Fig. 3.12: Weeding operation: (a) power weeder 52 cc (b) power weeder 67 cc (c) sidepack brush cutter power weeder (d) solar power cum electric operated weeder (e) backpack brush cutter power weeder

3.5.6 Field efficiency

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

$$\eta_e = \frac{EFC}{TFC} \times 100 \quad \dots (3.8)$$

Where,

η_e = Field efficiency, %;

EFC = Effective field capacity, ha/h; and

TFC = Theoretical field capacity, ha/h.

3.5.7 Fuel consumption

The fuel consumption of power weeder was measured by top fill method. In this method, fuel tank was filled up to top level before testing. After completing of test operation, the fuel tank was filled up again. The difference of two observations gave the fuel consumed in the concerned operations and was expressed in litre per hour.

3.5.8 Performance index of weeder

Performance index is a measurement of performance of a weeder and is directly related to the field capacity, plant damage and weeding efficiency and inversely related to power exerted. Following relation as suggested by Srinivas *et al.* (2010).

$$PI = \frac{FC \times (100 - PD) \times WE}{P} \quad \dots (3.9)$$

Where,

FC = Field capacity, ha h⁻¹;

PD = Plant damage, %;

WE = Weeding efficiency, %; and

P = Power, hp.

3.6 Cost Analysis of Different Types of Power Weeder

The cost of owning and operating farm machinery is one of the most important factors influencing farm profitability. Accurate cost estimates are important in every machinery management decision, as in when to trade, which size to purchase, how much to purchase, and so on. The study was carried out to check the performance of different weeders, there is need to calculate operational cost of power weeders by accounting fuel consumption, labour charges per day, lubrication cost, repair, and maintenance of machine. These expenses are incurred only when the machine is used. Cost of weeding operation of power weeders was calculated in Rs/ ha.

3.6.1 Operational cost

Operational cost of machine is the total sum of fixed cost and variable cost of machine. It is expressed in Rs/ha.

$$\text{Operational cost} = \text{Fixed cost} + \text{Variable cost} \quad \dots (3.10)$$

3.6.1.1 Fixed cost of machine

- i. Depreciation
- ii. Interest
- iii. Housing
- iv. Insurance and taxes

i. Depreciation

It is the amount by which the value of machine decreases over time. The annual depreciation is calculated as follows (Kepner *et.al.*, 1978):

$$D = \frac{C - S}{L \times H} \quad \dots (3.11)$$

Where,

C = Capital cost, Rs;

D = Depreciation, Rs/h;

S = Salvage value, 10 per cent of capital cost;

H = Number of working hours per year; and

L = Life of machine, year.

ii. Interest

Interest is calculated based on the average investment of a machine, considering the value of the machine in the first and last years. These estimates are calculated on an annual basis. The annual interest on the investment can be calculated using the formula below (Kepner *et al.*, 1978).

$$I = \frac{C + S}{2} \times \frac{i}{H} \quad \dots (3.12)$$

Where,

I = Interest per year, Rs;

i = Interest rate per year, Rs; and

C = Capital cost, Rs.

iii. Housing cost

Housing costs are determined by local market rates, but in general, housing costs account for 1% of the initial machine cost per year.

iv. Insurance

Insurance and taxes are typically calculated as 1% of the initial machine cost per year. The insurance is calculated based on actual insurance payments.

3.6.1.2 Variable cost of machine

- i. Labour charges
- ii. Fuel cost
- iii. Lubrication cost
- iv. Repair and maintenance

i. Labour charges

The wages of the operator were calculated as the actual wages of the worker per hours depending on the current rates.

ii. Fuel cost

The cost of actual fuel consumption can be used to calculate fuel consumption. The size of the power unit affects fuel consumption. The quality of fuel consumed measured in litre per hour and cost of fuel in Rs. /l. The fuel cost was calculated by using following equation as expressed in Rs/hr.

$$\text{Fuel cost} = \text{Quantity of fuel consumed per hour} \times \text{Cost of fuel} \dots (3.13)$$

iii. Lubricants

The machine needed periodic maintenance and lubrication is a crucial element in the efficiency and life-expectancy of any rotating equipment. Lubrication allows machine parts to slide smoothly and helps to reduce friction. The average cost of lubrication was taken as 1.5 % of fuel cost in Rs/h (Kamboj *et al.*, 2012).

iv. Repair and maintenance cost

To keep machine in perfect working condition, repair and maintenance is necessary due to wear and failure of machine parts, renewal of tyre and tube and accidents. It is the product of machine price and repair and maintenance percentage factor (Kepner *et al.*, 1978). The repair and maintenance may be approximately 5 to 10 per cent of the initial cost of machine per year.

3.7 Operational Energy Analysis of Weeders

Energy is one of the most valuable inputs in agricultural production. The energy consumption of each treatment is based on total time taken during the weeding operation, weight of the implement and number of labours required for operation. For hand weeding, only manpower was required and for power weeder, the total fuel consumption was also considered (Ragesh *et al.*, 2018). For determining the operational energy, data collected on weeding operations was multiplied by respective energy conversion coefficient. The following formula was used to calculate the energy input during the weeding operation (Ragesh, 2015)

$$\text{Input energy} = \text{Human energy} + \text{Fuel energy} + \text{Electrical energy} + \text{Machine energy} \dots (3.14)$$

Where,

$$\text{Human energy} = \text{Useful man hour (h)} \times \text{Energy equivalent (MJ/h)}$$

$$\text{Fuel energy} = \text{Fuel consumption (l/h)} \times \text{Energy equivalent (MJ/h)}$$

$$\text{Machine Energy} = \text{Weight of machine (kg)} \times \text{Energy equivalent (MJ/h)}$$

$$\text{Electrical energy} = \text{Generated electric power (kW-h)} \times \text{Energy equivalent (MJ/h)}$$

Table 3.9: Energy conversion coefficients

Particulars	Unit	Energy equivalent (MJ unit ⁻¹)
Human Energy	hour	1.96
Fuel Energy	Litre	48.23
Machine Energy	kWh	62.7
Electrical Energy	kWh	11.93

CHAPTER- IV

RESULTS AND DISCUSSION

This chapter deals with the results obtained for different objectives of a study entitled techno economic evaluation of different types of power weeder. It describes the results of field performance evaluation of five different power weeders i.e., power weeder 52 cc, power weeder 67 cc, sidepack brush cutter power weeder, backpack brush cutter power weeder, solar power cum electric operated weeder. The studied and record the types of weeds in selected *Rabi* crops is illustrated in this chapter.

4.1 Weed Studies

Weed is a plant whose virtues have not yet been discovered. The yield loss due to weeds is almost always caused by a group of different weed species and the competitive ability of these species can vary significantly (Weaver and Ivany., 1998). The weed diversity and weed density was observed in three selected crops i.e., mustard, cauliflower, and cucumber in present research work.

4.1.1 Floristic composition of weeds

According to gross morphological characteristics weeds are divided into three major groups such as grasses, sedges, and broadleaf weeds. The density of weed in *Rabi* crops were observed in the selected crops i.e., mustard, cauliflower, and cucumber crop, which is shown in Fig 4.1, 4.2, 4.3. The weedy species exhibit similarities such as aggressive growth, competition with other plants for light, water, nutrients and space, the ability to grow in a variety of soils and adverse conditions and resistance to control measures.



Fig. 4.1: Weed density in mustard crop



Fig. 4.2: Weed density in cauliflower crop



Fig. 4.3: Weed density in cucumber crop

In general, it was noticed that grasses weeds contributed the most weed flora, followed by broad-leaved weeds and sedges in mustard field. The broad-leaved weeds dominated over grasses and sedges in cauliflower and cucumber field. The diversity of weed species was observed in the selected crop field i.e., mustard, cauliflower, and cucumber crop, which is given in Table 4.1, 4.2 and 4.3.

Table 4.1: Weeds found in mustard

S.No.	Weed name	Scientific name	Local name
1	Bathua	<i>Chenopodium album</i>	Bathuaa
2	Wild oat	<i>Avena fatua</i>	Jungle jae
3	Bermuda grass	<i>Cynodon dactylon</i>	Dub ghash
4	Nut grass	<i>Cyperus rotundus</i>	motha
5	Asthma plant	<i>Euphorbia hirta</i>	dudhadhi
6	Sweet clover	<i>Melilotus indicus</i>	Kumoniga
7	Purslane	<i>Portulaca oleracea</i>	gol bhaji
8	Black pig weed	<i>Trianthema monogyna</i>	Patar chatta
9	Carrot grass	<i>Parthenium hysterophorus</i>	Gajar ghash
10	Scarlet pimpernal	<i>Anagallis arvensis L.</i>	Dhekna
11.	Indian turnsole	<i>Heliotropium indicum L.</i>	Hati sundhia
12	Sickle pod	<i>Cassia tora</i>	Charota

Table 4.2: Weeds found in cauliflower

S.No.	Weeds name	Scientific name	Local name
1	Black pig weed	<i>Trianthema monogyna</i>	Patar chatta
2	Carrot grass	<i>Parthenium hysterophorus</i>	Gajar ghash
3	Java grass	<i>Cyperus rotundus</i>	motha
4	Bermuda grass	<i>Cynodon dactylon</i>	Dub ghash
5	Crab grass	<i>Digitaria sanguinalis</i>	sua ghas
6	Indian turnsole	<i>Heliotropium indicum L.</i>	Hati sundhia
7	Dog-tooth grass	<i>Panicum repens</i>	Chandini
8	Swine grass	<i>Coronopus didymus</i>	Pithpapa
9	Gale of the wind	<i>Phyllanthus niruri</i>	hazardana
10	Pig weed	<i>Trianthema portulacastrum</i>	Puruni

S.No.	Weeds name	Scientific name	Local name
11	False daisy	<i>Eclipta alba</i>	Bhangara
12	Sickle pod	<i>Cassia tora</i>	Charota
13	Scarlet pimpernal	<i>Anagallis arvensis L.</i>	Dhekna

Table. 4.3: Weeds of cucumber field

S.No.	Weeds name	Scientific name	Local name
1	Carrot grass	<i>Parthenium hysterophorus</i>	Gajar ghash
2	Sickle pod	<i>Cassia tora</i>	Charota
3	Bermuda grass	<i>Cynodon dactylon</i>	Dub ghash
4	Scarlet pimpernal	<i>Anagallis arvensis L.</i>	Dhekna
5	Cathedral bells	<i>Kalanchoe pinnata</i>	Patharchhatta
6	Slender amaranth	<i>Amaranthus viridis</i>	Silyari
7	Indian turnsole	<i>Heliotropium indicum L.</i>	Hati sundhia
8	Asthma plant	<i>Euphorbia hirta</i>	dudhadhi
9	Gale of the wind	<i>Phyllanthus niruri</i>	Hazardana
10	Carpet grass	<i>Axonopus compressus</i>	porpodi
11	Java grass	<i>Cyperus rotundus</i>	Motha
12	Khakiweed	<i>Alternanthera caracasana</i>	Resamkata



Scientific name - *Parthenium hysterophorus*
 Common name - Carrot grass
 Local name - Gajar ghass



Scientific name - *Cassia tora*
 Common name - Sickle pod
 Local name - Charota



Scientific name - *Heliotropium indicum L.*
 Common name - Indian turnsole
 Local name - Hati sundhia



Scientific name - *Anagallis arvensis L.*
 Common Name - Scarlet pimpernel
 Local name - dhekna



Scientific name - *Cynodon dactylon*
 Common name - Bermuda grass
 Local name - Dub ghass



Scientific name - *Cyperus rotundus*
 Common name - Nut grass
 Local name - chuha ghass

Fig. 4.4: Some common weeds found in all experimental sites

4.1.2 Studies about prevailing weeding practices in selected crops

In general, it was found that manually hand weeding, weeding by hand tools like khurpi, sickle and spade and use of chemicals are the most common method adopted by farmers to control weeds in selected crops in this region.

For mustard cultivation, weeds are controlled by mechanical and chemical methods. Usually, for weeding operations farmers prefer manual method. In this method, weeds are removed manually with the help of a khurpi or any other sharp tool. But there are certain limitations of manual weeding. But manual weeding is arduous in nature and requires more no. of man hours to complete the job. Also, if weeding operation is not performed at the desired time, it will reduce the productivity of the crop. Hence, manual weeding is not economic to be preferred. In the chemical method of weed control, certain chemicals like 2,4-D, Bidder etc.

Weeds in cauliflower cultivation require special attention because weeds in the field reduce yield and damage the quality of the produce for vegetable purposes. The crop remains in the field for about four months and faces competition due to the presence of monocot and dicot weeds during its growth period. Weeds can be effectively controlled by hand weeding. However, labour is currently very expensive, and there is a labour shortage. Herbicides, on the other hand, may not be the only solution because environmentalists believe they are harmful to sustainable agriculture. Mulching was used by some farmers, particularly plastic mulch, and rice straw mulch.

Weed interference is a major issue in cucumber farming, resulting in yield losses ranging from 45 to 95 per cent. Hand weeding and herbicide application are the most common weed control methods used to avoid such losses. Each weed control method used in cucumber farming has its own set of limitations. Hand weeding is time-consuming and labour-intensive. Only a few herbicides are registered for weed control in cucumber, and these herbicides do not provide season-long weed control when used alone, and not control the entire weed spectrum with diverse physiology, morphology, and time of emergence.

4.2 Operational Parameters for Testing of Weeders

The operational parameter of present study included moisture content of soil, bulk density of soil, plant population, weed population, effective working depth, effective working width. The results of these parameters were explained below:

4.2.1 Moisture content of soil

The soil texture of experimental field is clay loam. Soil moisture content was an independent parameter. Three soil samples were taken randomly from each field. The average moisture content of mustard field (C1), cauliflower (C2) and cucumber (C3) are found as 27.3 %, 22.1 %, 19.3 % respectively on dry basis. Observed data of soil moisture content are represented in Table 4.4, 4.5, 4.6. The maximum moisture content (%) of soil was observed in mustard crop (C1) and minimum value (%) was observed in cucumber (C3). The graphical representation of soil moisture content of different crops is given in Fig. 4.5.

Table. 4.4: Soil moisture percentage of mustard field

S. No	Dish weight (g)	Dish + Wet soil wt. (g)	Wet soil wt. (g)	Dish + Dry soil wt. (g)	Dry soil wt. (g)	Moisture content (%)
1	41.2	71.0	29.8	64.4	23.2	28.45
2	39.2	69.2	30.0	63.2	24.0	25.00
3	39.4	69.2	29.8	62.6	23.2	28.45
Avg.	39.9	69.8	29.9	63.4	23.5	27.3

Table. 4.5: Soil moisture percentage of cauliflower field

S.No.	Dish weight (g)	Dish + Wet soil wt. (g)	Wet soil wt. (g)	Dish + Dry soil wt. (g)	Dry soil wt. (g)	Moisture content (%)
1	44.3	78.5	34.2	70.2	25.9	32.05
2	40.6	76.7	36.1	71.8	31.2	15.71
3	39.1	77.1	38.0	71.1	32.0	18.75
Avg.	41.3	77.4	36.1	71.0	29.7	22.2

Table. 4.6: Soil moisture percentage of cucumber field

S.No.	Dish weight (g)	Dish + Wet soil wt. (g)	Wet soil wt. (g)	Dish + Dry soil wt. (g)	Dry soil wt. (g)	Moisture content (%)
1	38.9	88.9	50.0	80.9	42.0	19.04
2	40.1	82.4	42.3	75.8	35.7	18.48
3	39.9	79.9	40.0	73.1	33.2	20.48
Avg.	39.6	83.7	44.1	76.6	37.0	19.3

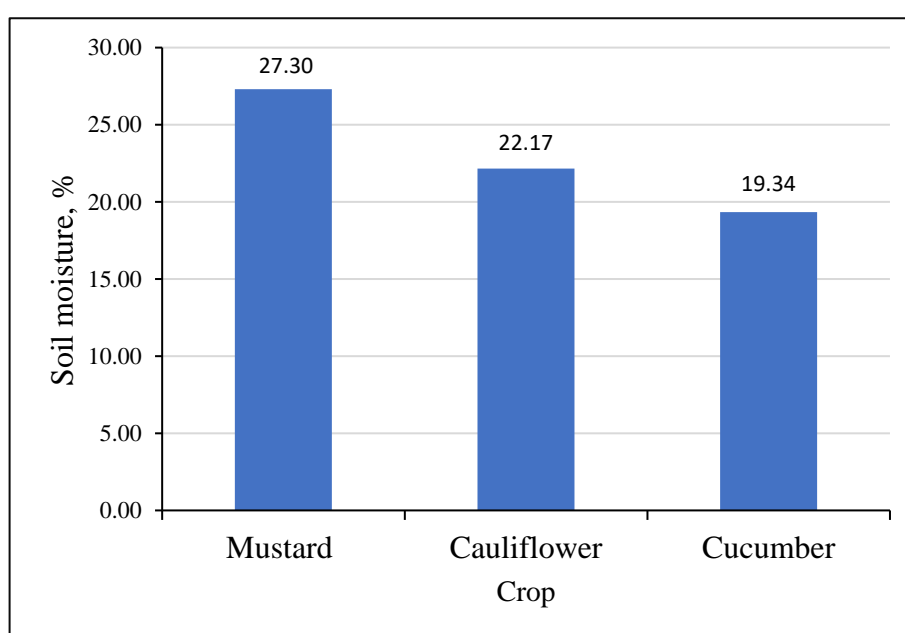


Fig. 4.5: Variation of moisture content in different crop field

4.2.2 Bulk density of soil

Bulk density was determined by core cutter method. The core sampler of the soil of known volume was collected randomly from field before operation of weeder. The sample were weighted initially before placing into an oven for 24 hours at 105 °C. After drying the sample were measured again. Details observed data of soil bulk density are represented in Table 4.7, 4.8 and 4.9. The average soil bulk density of mustard field, cauliflower and cucumber is found as 1.15 g/cm³, 1.24 g/cm³, 1.27 g/cm³ respectively. Fig. 4.6 represents the graph of bulk density of soil of different crops.

Table. 4.7: Soil bulk density of mustard field

S.No.	Container wt. (g)	Container + Wet soil wt. (g)	Wet soil wt. (g)	Container + Dry soil wt. (g)	Dry soil wt. (g)	volume of core cutter (cm ³)	Bulk Density (g/cm ³)
1	266.6	1876.6	1610	1516.8	1250.2	1020.5	1.2251
2	256.4	1478.6	1222	1214.8	958.4	1020.5	0.9391
3	265.8	1990.6	1724	1586.8	1321	1020.5	1.2945
Avg.	262.9	1781.9	1518.7	1439.5	1176.5	1020.5	1.1529

Table. 4.8: Soil bulk density of cauliflower field

S.No.	Container wt. (g)	Container + Wet soil wt. (g)	Wet soil wt. (g)	Container + Dry soil wt. (g)	Dry soil wt. (g)	volume of core cutter (cm ³)	Bulk Density (g/cm ³)
1	255.6	1998.2	1742.6	1626.2	1370.6	1020.5	1.34
2	266.7	1559.1	1292.4	1349.5	1082.8	1020.5	1.06
3	264.8	1925.2	1660.4	1593.1	1328.3	1020.5	1.30
Avg.	262.4	1827.5	1565.1	1522.9	1260.6	1020.5	1.23

Table. 4.9: Soil bulk density of cucumber field

S.No.	Container wt. (g)	Container + Wet soil wt. (g)	Wet soil wt. (g)	Container + Dry soil wt. (g)	Dry soil wt. (g)	volume of core cutter (cm ³)	Bulk Density (g/cm ³)
1	266.7	1898.3	1631.6	1543.3	1276.6	1020.5	1.25
2	256.9	1896.4	1639.5	1549.2	1292.3	1020.5	1.27
3	269.8	1994.4	1724.6	1584.5	1314.7	1020.5	1.29
Avg.	264.5	1929.7	1665.2	1559	1294.5	1020.5	1.27

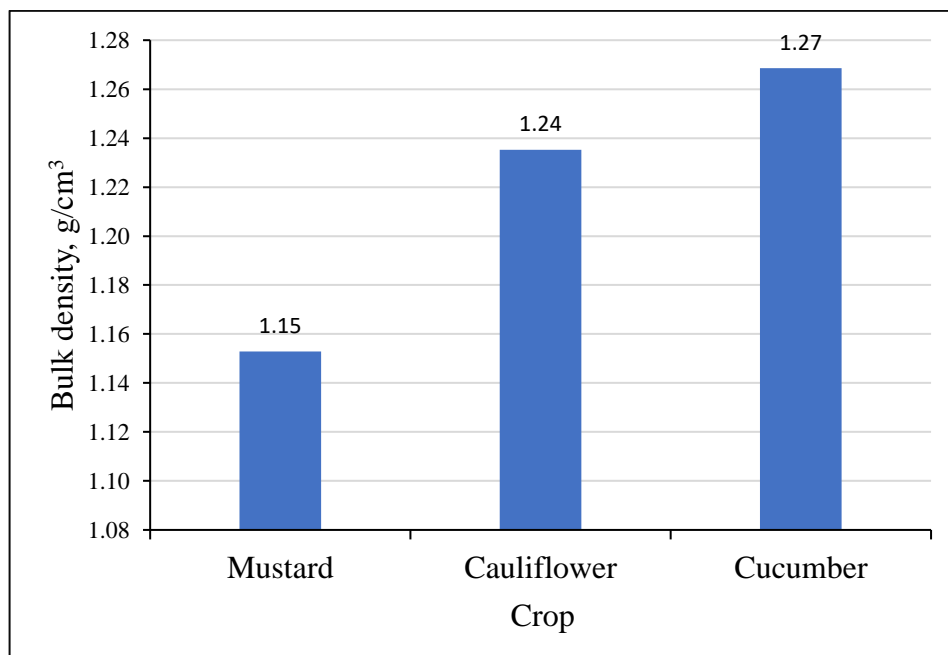


Fig. 4.6: Variation of bulk density of soil in different crop field

4.2.3 Plant population

The plant to plant spacing of mustard, cauliflower, and cucumber is 40-60 mm, 500 mm, and 60-80 mm, respectively. Thus, the number of plants counted in a 10 m row length was found to be the maximum in mustard crop fields is 166 and the least number of plants is seen in a 10 m row length in cauliflower is 20.

4.2.4 Weed population

All the weeds found in each plot were categorised as grasses, sedges, or broad-leaved weeds. The grasses dominated over broad-leaved weeds and sedges in mustard fields among other crop fields. The broad-leaved weeds dominated over grasses and sedges in cauliflower and cucumber field. The weed population of crop fields before and after weeding operations is seen in Fig. 4.7, Fig. 4.8, and Fig. 4.9.

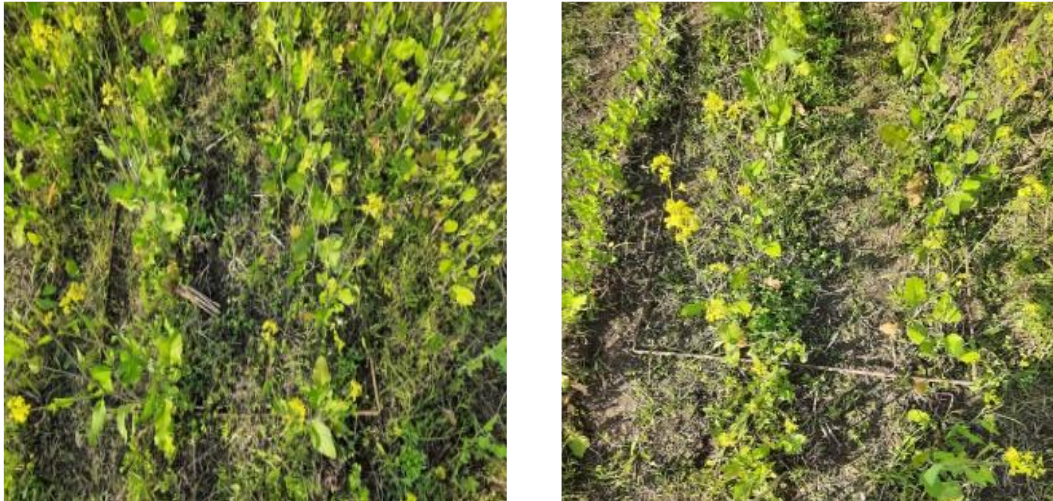


Fig. 4.7: Before and after weeding operation in mustard



Fig. 4.8: Before and after weeding operation in cauliflower



Fig. 4.9: Before and after weeding operation in cucumber

4.2.5 Effective working depth

The depth of the weeding operation was measured using a measuring scale in different rows at different places. The effective working depth of weeders was observed in mustard (C1), cauliflower (C2) and cucumber (C3) crop fields in different row to row spacing 0.48 m, 0.50 m, and 0.80 m, respectively. The statistically analysed result of effective working depth is tabulated in Table 4.10 (Appendix-A). Fig. 4.10 represents the graph of effective working depth.

Table 4.10: Statistically analysed results with mean effective working depth (mm)

Weeder (W)						
Crop (C)	W1	W2	W3	W4	W5	Mean C
C1	40.00	43.00	52.00	32.00	40.50	41.50
C2	39.75	38.50	53.25	35.25	45.25	42.40
C3	40.25	39.75	51.00	37.00	43.75	42.35
Mean W	40.00	40.42	52.08	34.75	43.17	
Factors	CD (0.05)		SE(d)		SE(m)	
Crop (C)	NS		0.096		0.068	
Weeder (W)	0.274		0.134		0.095	
Interaction (W×C)	NS		0.233		0.152	
Interaction (C×W)	NS		0.229		0.162	

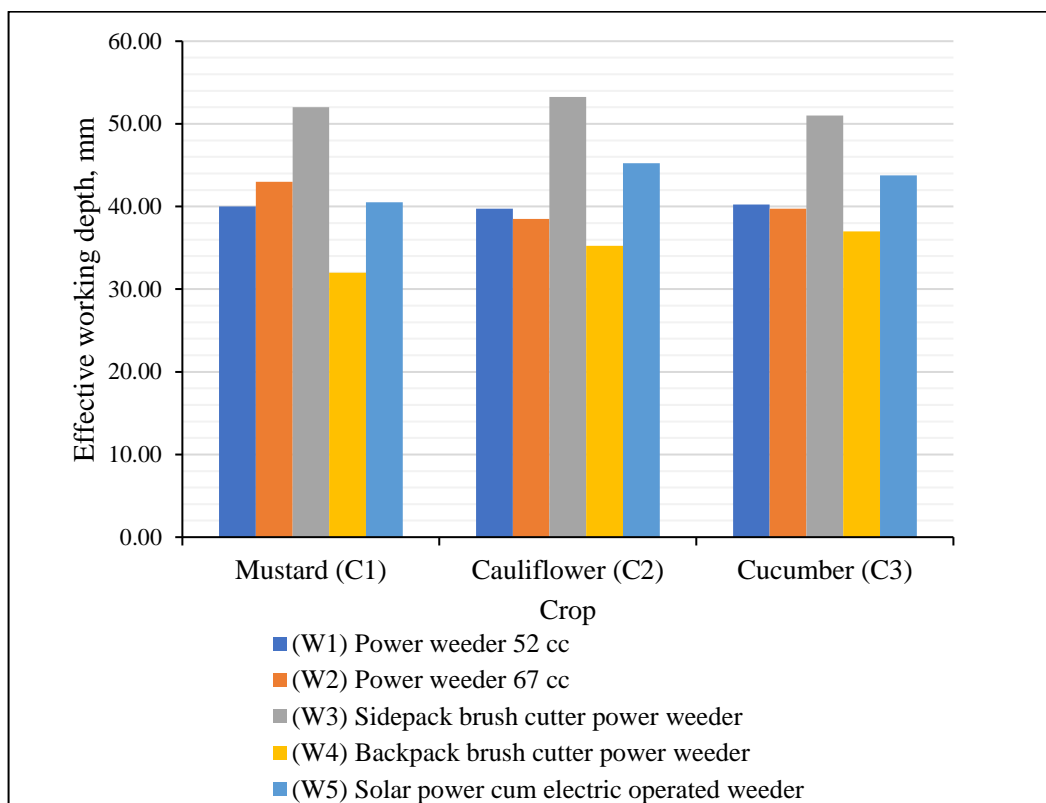


Fig. 4.10: Variation in effective working depth of weeders in selected crop fields

The average effective working depth of weeder W1, W2, W3, W4 and W5 in all experimental crop field is 40 mm, 40.4 mm, 52 mm, 34.7 mm, and 43.1 mm respectively were recorded and showed significant variation at 5 per cent level. The working depth of weeder W3 was observed higher (53.2 mm) at treatment T8, and lowest depth of working was seen in weeder W4 (32 mm) at treatment T4. The variation of effective working depth of weeder is shown in Fig 4.10. The working depth of weeder is depended on the type of blade, size of blade and moisture content of soil. A proper soil moisture is necessary for effective weeding.

4.2.6 Effective working width

During field operation the effective width of cut of the machine was measured by observing the strip of soil and weeds cut in a row. The effective working width of weeders was observed in mustard (C1), cauliflower (C2) and cucumber (C3) crop fields in different row to row spacing 0.48 m, 0.50 m, and 0.80 m, respectively. The statistically analysed result of effective working width is presented in Table 4.11 (Appendix-A).

Table 4.11: Statistically analysed results with mean effective working width (mm)

Weeder (W)						
Crop (C)	W1	W2	W3	W4	W5	Mean C
C1	272.5	270.0	294.8	224.5	451.3	302.6
C2	268.8	272.5	296.3	231.5	428.8	299.6
C3	264.0	268.5	301.5	230.0	445.5	301.9
Mean W	268.4	270.3	297.5	228.7	441.8	

Factors	CD (0.05)	SE(d)	SE(m)
Crop (C)	NS	0.544	0.385
Weeder (W)	1.139	0.559	0.395
Interaction (W×C)	NS	0.968	0.86
Interaction (C×W)	NS	1.023	0.723

The effective working width of power weeder 52 cc (W1), power weeder 67 cc (W2), sidepack brush cutter power weeder (W3), backpack brush cutter power weeder (W4) and solar power cum electric operated weeder is 268.4 mm, 270.3 mm, 297.5 mm, 228.7 mm, and 441.8 mm, respectively. The cutting width (400-460 mm) of weeder W5 is highest among other weeders. It shows that weeder W5 covers much row length area of crop fields among other weeders. In crop C1, C2 and C3 experimental field the variation of effective working width of different weeders is shown in Fig 4.11.

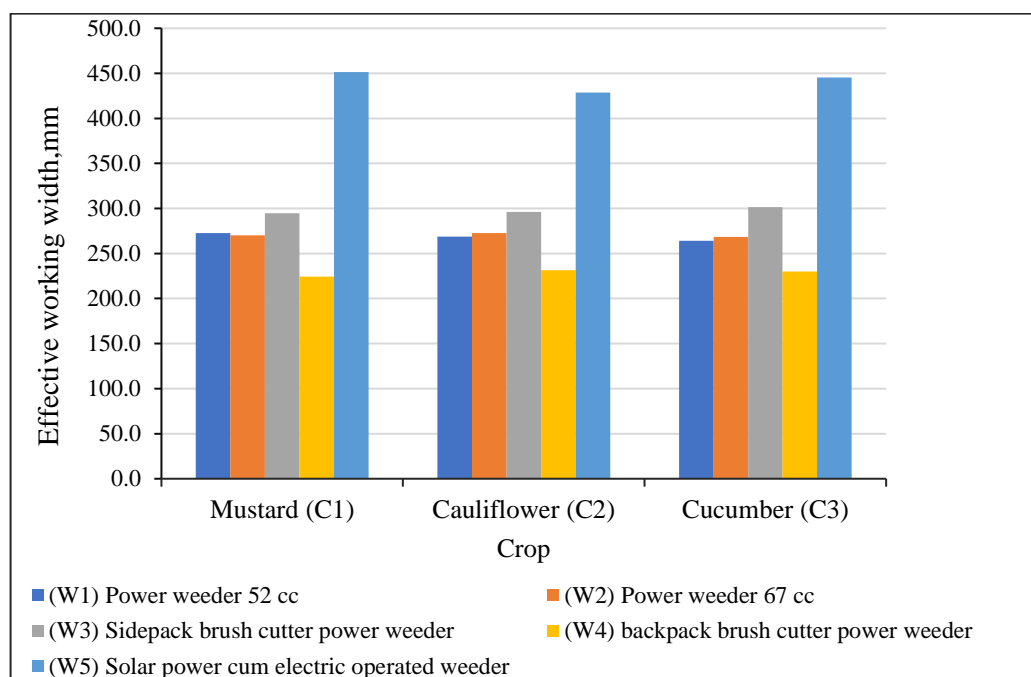


Fig. 4.11: Variation of effective working width of weeders in selected crop fields

4.3 Machine Performance and Evaluation of Weeders

The machine performance parameters such as operating speed, weeding efficiency, plant damage, effective field capacity, theoretical field capacity, field efficiency, performance index was determined in actual field conditions. The five weeders namely power weeder 52 cc (W1), power weeder 67 cc (W2), sidepack brush cutter power weeder (W3), backpack brush cutter power weeder (W4) and solar power cum electric operated (W5) weeder were used in this study. The performance of these power weeders was observed in the selected crop fields i.e., mustard field (C1), cauliflower field (C2) and cucumber field (C3). For statistical analysis, split plot design was used.

4.3.1 Operating speed

The operating speed of different power weeder was determined by noting down the time required to cover 30 m of weeding length. Amongst power weeders (W1, W2, W3, W4 and W5), the highest speed of operation (1.8 km/h) was obtained in W2 and W3 power weeder at treatment T2 and T8, respectively. The power weeder 67 cc with 3 hp engine, 6500 rpm and 250-300 mm working width and sidepack brush cutter power weeder with 2 hp engine, 7000 rpm and 280-320 mm

working width perform better in field in term of soil tilth and weed removal. This may be due to high power and high speed rotary blades used in these machines. The weeder W1, W2 and W3 are having almost same speed of operation. The lowest operating speed (1.2 km/h) was obtained in solar power cum electric operated weeder (W5). The value of operating speed of weeders varied at 5 per cent level of significance and tabulated in Table 4.12 (Appendix-A). The graph of operating speed of different weeders is shown in Fig. 4.12.

Table 4.12: Statistically analysed results with mean operating speed (km/h) and CDs values.

Crop (C)	Weeder (W)					Mean C
	W1	W2	W3	W4	W5	
C1	1.7	1.8	1.6	1.4	1.3	1.5
C2	1.5	1.7	1.8	1.6	1.3	1.6
C3	1.6	1.6	1.4	1.4	1.2	1.4
Mean W	1.6	1.7	1.6	1.4	1.2	
Factors	CD (0.05)		SE(d)		SE(m)	
Crop (C)	0.114		0.046		0.032	
Weeder (W)	0.147		0.072		0.051	
Interaction (W×C)	NS		0.125		0.073	
Interaction (C×W)	NS		0.121		0.085	

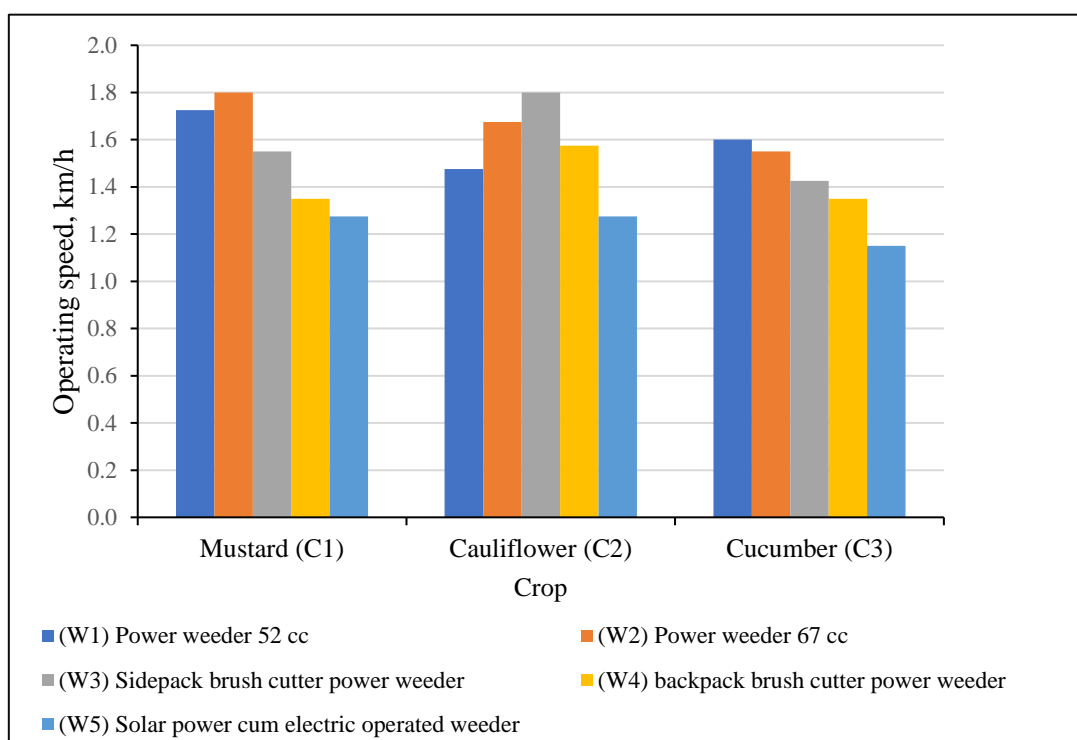


Fig. 4.12: Variation of operating speed in different crop fields

4.3.2 Fuel consumption

The fuel consumption of selected power weeders was measured using top fill method. It was found that variation occur in fuel consumption by power weeder W1, W2, W3 and W4 at different test condition. The obtained data in fuel consumption showed that there was significant difference in different treatments at 5 per cent level of significance represented in Table 4.13 (Appendix-A). Fig. 4.13 represents the graph of fuel consumption. The maximum fuel consumption (0.63 l/h) was found in power weeder 67 cc (W2). This may be due to that, high horsepower (3hp) engine was used in weeder W2, which is highest among other tested weeders. The engine power is directly proportion to fuel consumption. Hence, more fuel consumed in weeder W2. Whereas the minimum fuel consumption (0.45 l/h) was found in backpack brush cutter power weeder (W4). It was also observed that power weeder equipped with 2-stroke engine consumed more fuel compared to 4-stroke engine power weeder. The average fuel consumption of W1, W2, W3 and W4 is 0.50 l/h, 0.63 l/h, 0.50 l/h and 0.45 l/h respectively.

Table 4.13: Statistically analysed data with mean fuel consumption (l/h) values

Weeder (W)					
Crop (C)	W1	W2	W3	W4	Mean C
C1	0.495	0.605	0.505	0.448	0.513
C2	0.503	0.655	0.515	0.463	0.534
C3	0.51	0.645	0.505	0.463	0.531
Mean W	0.503	0.635	0.508	0.458	

Factors	CD (0.05)	SE(d)	SE(m)
Crop (C)	NS	0.008	0.005
Weeder (W)	0.021	0.01	0.007
Interaction (W×C)	NS	0.018	0.011
Interaction (C×W)	NS	0.017	0.012

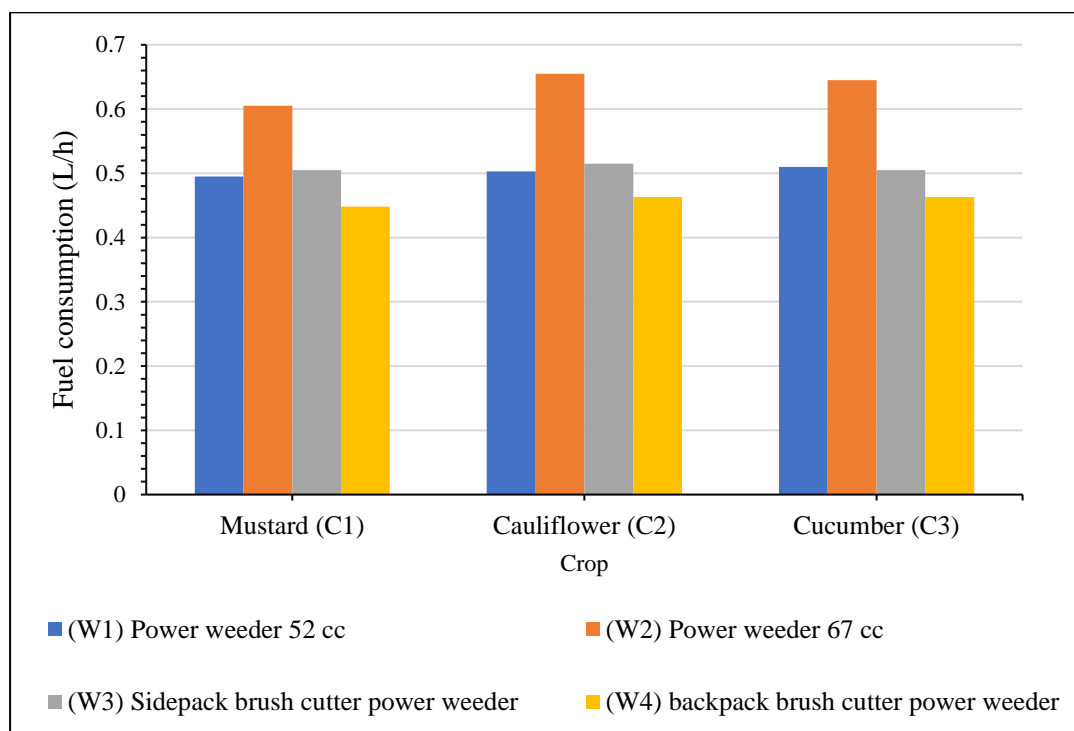


Fig. 4.13: Variation of fuel consumption of weeders

4.3.3 Theoretical field capacity

The theoretical field capacity computed based on the forward speed and the cutting width of weeder. Assuming that the machine is using its full working width. The highest value of theoretical field capacity 0.051 ha/h was found in solar power cum electric operated weeder(W5) while, the least value is 0.037 ha/h was found in power weeder 52 cc (W1). The highest TFC in weeder W5 is may be due to the fact that weeder W5 have maximum (400 mm) working width. It was also observed that the weeder W5 covers almost row width area of cauliflower field (C2) and its showed maximum value (0.055 ha/h) of theoretical field capacity at treatment T10. The details of observed data of theoretical field capacity of different treatments are given in Table 4.14 (Appendix-A). The graphical representation of theoretical field capacity is shown in Fig. 4.14. Similar results were also reported by Devojee *et al.*, 2019.

Table 4.14: Statistically analysed results with mean theoretical field capacity (ha/h)

Weeder (W)						
Crop (C)	W1	W2	W3	W4	W5	Mean C
C1	0.035	0.045	0.039	0.052	0.050	0.044
C2	0.036	0.047	0.041	0.033	0.055	0.042
C3	0.041	0.041	0.052	0.032	0.050	0.043
Mean W	0.037	0.044	0.044	0.039	0.051	
Factors	CD (0.05)		SE(d)		SE(m)	
Crop (C)	NS		0.001		0.001	
Weeder (W)	0.002		0.001		0.001	
Interaction (W×C)	0.004		0.002		0.002	
Interaction (C×W)	0.005		0.002		0.001	

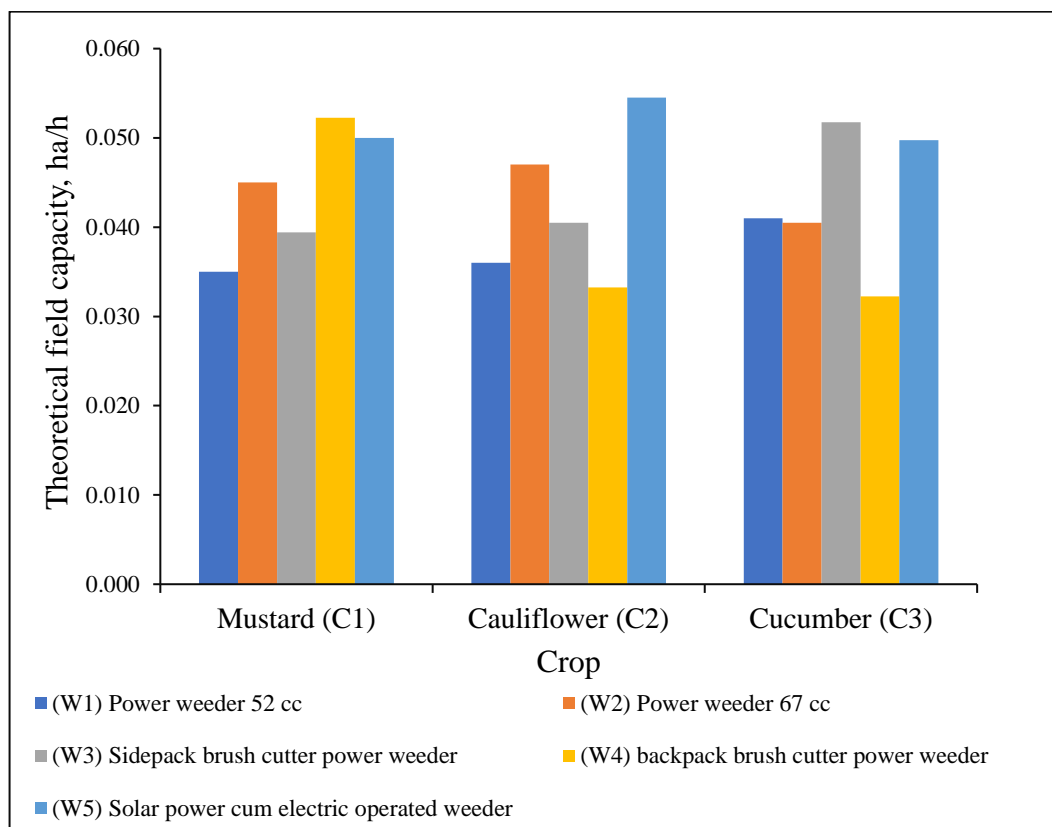


Fig. 4.14: Variation of theoretical field capacity of weeders in different crop fields

4.3.4 Effective field capacity

The actual area covered by weeder per unit time is called effective field capacity of weeder. The effective field capacity of weeders with different row to row spacing on different crop was determined. Effective field capacity of all selected weeders was recorded for the desired operation and calculated as per the procedure mentioned in section 3.5.5. The effective field capacity recorded for selected weeders are presented in Table 4.15 (Appendix-A). The value of EFC is significantly different at 5 per cent level of significance. The maximum effective field capacity 0.042 ha/h was found in weeder W5, and minimum value 0.030 ha/h was seen in weeder W1. The results proven solar power cum electric operated weeder (W5) covers almost row width area of cauliflower crop and least row width area of crop per unit time covered by power weeder 52 cc (W1). The highest value of effective field capacity of weeder W5 is 0.047 ha/h was found in treatment T10. The interaction between weeder (W) to crop (C) on effective field capacity is also observed to be significant at 5 per cent level and vice versa. Graphical representation

of effective field capacity of different treatments is given in Fig. 4.15. Similar results were also obtained by Mishra, 2021.

Table 4.15: Statistically analysed results with mean effective field capacity (ha/h)

Weeder (W)						
Crop (C)	W1	W2	W3	W4	W5	Mean C
C1	0.028	0.036	0.031	0.044	0.043	0.037
C2	0.029	0.040	0.033	0.030	0.047	0.036
C3	0.031	0.030	0.045	0.026	0.037	0.034
Mean W	0.030	0.035	0.037	0.033	0.042	
Factors		CD (0.05)		SE(d)		SE(m)
Crop (C)		NS		0.001		0.001
Weeder (W)		0.002		0.001		0.001
Interaction (W×C)		0.004		0.002		0.002
Interaction (C×W)		0.004		0.002		0.001

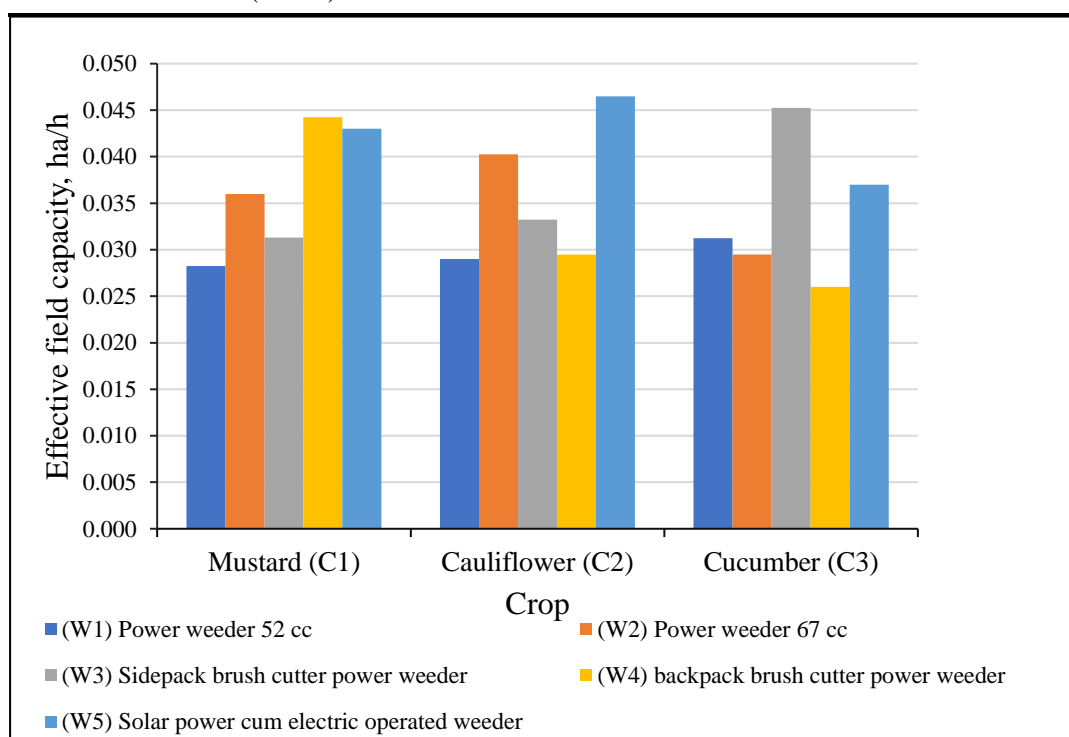


Fig. 4.15: Variation of effective field capacity of weeders in different crop fields

4.3.5 Field efficiency

The field efficiency of all the selected weeders was recorded for the desired operation and calculated as per the procedure mentioned in section 3.5.6. The mean

value of field efficiency of weeder in three different crop field was found highest in weeder W3 (85 %) and lowest was observed in weeder W1 (79.3%). The backpack brush cutter power weeder (W3) showed maximum field efficiency 89.1 percent in treatment T9, while the minimum field efficiency (73.6 %) was found in power weeder (W5). The power weeder 67 cc (W2) have almost same field efficiency as of power weeder 52 cc (W1). The data showed that field efficiency of power weeder in different crop fields differ significantly at 5 per cent level of significance. The statistically analysed data of field efficiency of weeders with its mean values and CDs are shown in Table 4.16 (Appendix-A). Fig. 4.16 represents the graph of field efficiency of different treatments. Results obtained were corroborated with the findings of Diwan, 2018.

Table 4.16: Statistically analysed results with mean field efficiency per cent of weeders

Crop (C)	Weeder (W)					Mean C
	W1	W2	W3	W4	W5	
C1	81.2	80.3	84.7	83.4	84.7	82.8
C2	80.2	85.5	82.6	89.1	85.3	84.5
C3	76.4	72.7	87.8	76.5	73.6	77.4
Mean B	79.3	79.5	85.0	83.0	81.2	
Factors	CD (0.05)		SE(d)		SE(m)	
Crop (C)	2.279		0.914		0.646	
Weeder (W)	3.455		1.697		1.2	
Interaction (W×C)	6.13		2.939		1.445	
Interaction (C×W)	5.804		2.783		1.968	

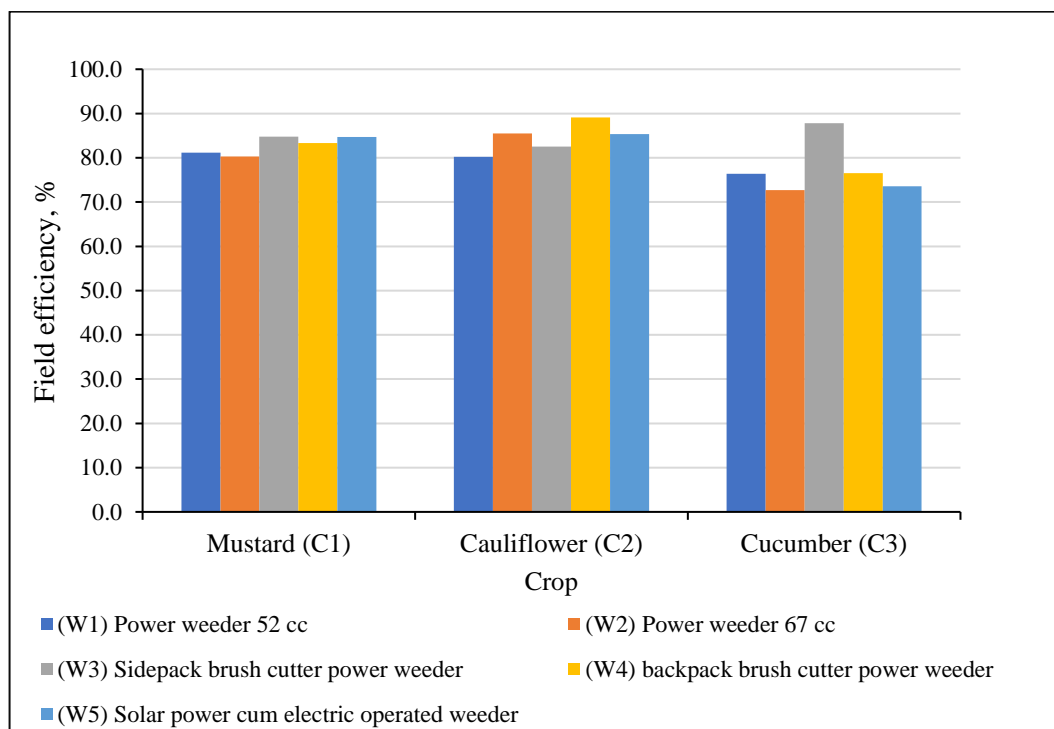


Fig. 4.16: Variation of field efficiency per cent of weeders

4.3.6 Weeding efficiency

Weeding efficiency of a power weeder was observed under various weeding conditions. The average weeding efficiency of power weeder W1, W2, W3, W4 and W5 is 76.9 %, 82 %, 83.1 %, 79.2 % and 86.4 % respectively. The weeding efficiency of power weeder 67 cc and sidepack brush cutter power weeder is almost same. The mean highest weeding efficiency was found in weeder W5 as 86.4 % and lowest weeding efficiency was observed in weeder W1 (76.9 %). The maximum value of weeding efficiency of weeder W5 as 88.6 % at treatment T5 and minimum value of weeding efficiency of weeder W1 as 73.8 % at treatment T6 was observed. The weeder W5 shows highest weeding efficiency because of its highest cutting width of blade, it covers almost row length area of mustard crop (C1) in treatment T5 and cut all the weeds. The detail of weeding efficiency of weeder is shown in Table 4.17 (Appendix-A). Fig. 4.17 represents the graph of weeding efficiency of different treatments. The weeding efficiency depends on weed flora, weed intensity, effective working width, effective working depth, and soil moisture at the time of weeding. Similar findings were also reported by Mishra, 2021.

Table 4.17: Statistically analysed results with mean weeding efficiency (%) of weeders

Weeder (W)						
Crop (C)	W1	W2	W3	W4	W5	Mean C
C1	75.6	80.8	82.7	80.3	88.6	81.6
C2	73.8	80.6	80.1	75.1	87.8	79.5
C3	81.4	84.7	86.6	82.2	82.7	83.5
Mean W	76.9	82.0	83.1	79.2	86.4	
Factors	CD (0.05)		SE(d)		SE(m)	
Crop (C)	2.692		1.079		0.763	
Weeder (W)	2.182		1.071		0.758	
Interaction (W×C)	4.031		1.856		1.706	
Interaction (C×W)	4.301		1.980		1.400	

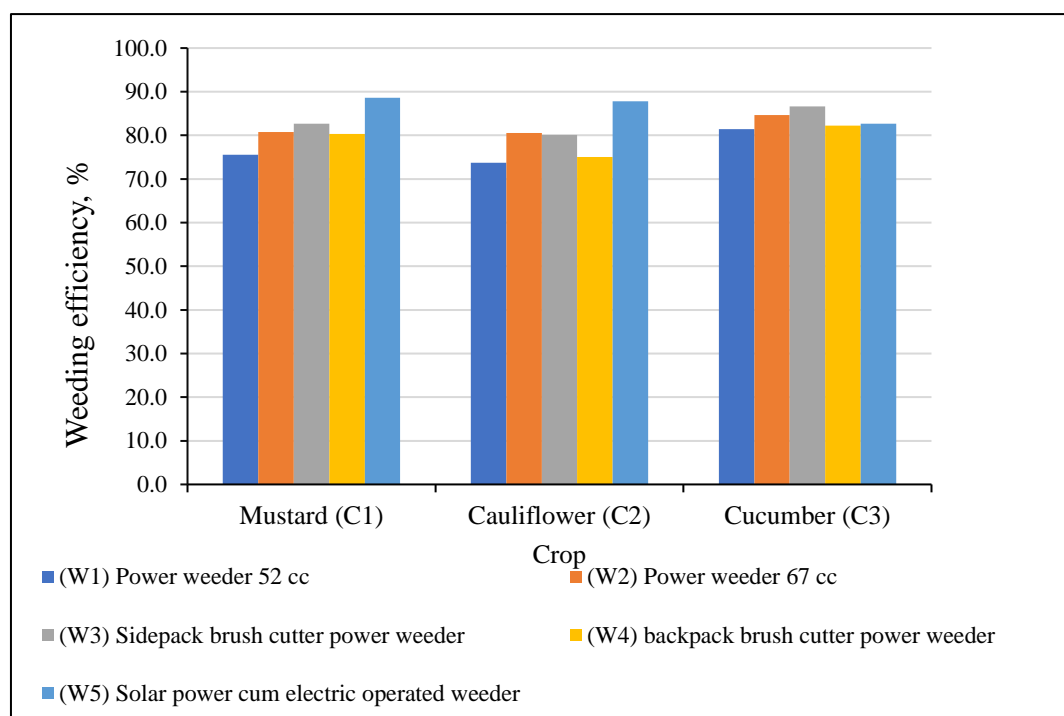


Fig. 4.17: Variation of weeding efficiency (%) of weeders in different crop fields

4.3.7 Plant damage

The highest plant damage (1.81 %) was observed in backpack brush cutter weeder (W4) in cucumber (C3) field at treatment T14, whereas lowest (0.90 %) seen in sidepack brush cutter power weeder (W3) in cucumber (C3) field at treatment 13. The average plant damage per cent of weeder W1, W2, W3, W4 and W5 is 1.33 %, 1.43 %, 1.33 %, 1.55 % and 1.58 % respectively. Data showed that plant damage percentage by power weeder at different treatments was found significant at 5 % level of significance represented in Table 4.18 (Appendix-A). The plant damage of weeder depends upon the working width of weeder and row to row spacing of crops. The plant damage is maximum in weeder W4 in C3 field because working width of weeder is 200-240 mm and row to row spacing of cauliflower is 500 mm. therefore, weeding operation is to be carried out twice in every row of cauliflower crop field, thus the plant damage of W4 is highest in cauliflower compared to other weeders. The average maximum plant damage was observed in weeder W5, and the minimum was found in weeder W1 and W3. The graphical representation of plant damage of different treatments is given in Fig. 4.18.

Table 4.18: Statistically analysed results with mean plant damage (%)

Weeder (W)						
Crop (C)	W1	W2	W3	W4	W5	Mean C
C1	1.31	1.08	1.71	1.57	1.68	1.47
C2	1.61	1.64	1.39	1.26	1.56	1.49
C3	1.08	1.59	0.90	1.81	1.51	1.38
Mean W	1.33	1.43	1.33	1.55	1.58	
Factors		CD (0.05)		SE(d)	SE(m)	
Crop (C)		NS		0.155	0.11	
Weeder (W)		NS		0.141	0.1	
Interaction (W×C)		0.536		0.245	0.245	
Interaction (C×W)		0.587		0.268	0.19	

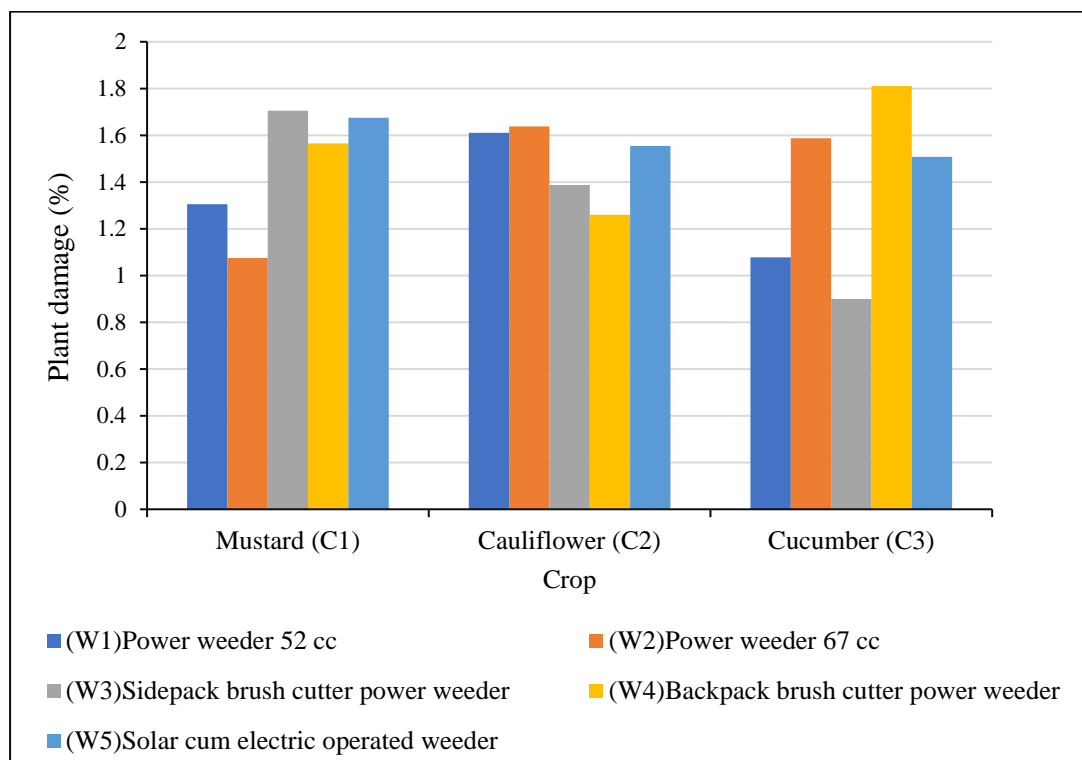


Fig. 4.18: Variation of plant damage (%) of weeders in different crop fields

4.3.8 Performance index of weeder

Performance index shows the overall performance of weeder. The solar power cum electric operated weeder shows best performance than other power weeders. The average performance index of weeder W1, W2, W3, W4 and W5 is 112.33, 94.58, 151.00, 129.91 and 357.25 respectively was observed in crop C1, C2 and C3. The statistical analysed data of performance index weeder is summarized in Table 4.19 (Appendix-A) and variation graph of performance index of weeders shows in Fig. 4.19. The highest performance index was obtained in weeder W5 and lowest was observed in W2. The performance index of weeder is directly proportion to the field capacity, weeding efficiency and plant damage and inversely proportion to the power. The engine power of weeder W2 is highest (3 hp) thus, the performance index of weeder W2 was observed lowest among all tested weeders. Results obtained were the similar to the findings of Srinivas *et al.*, 2010.

Table 4.19: Statistically analysed data with mean performance index of weeders

Weeder (W)						
Crop (C)	W1	W2	W3	W4	W5	Mean C
C1	105.25	96.00	127.25	175.50	372.25	175.25
C2	105.75	106.00	131.50	109.50	400.00	170.55
C3	126.00	81.75	194.25	104.75	299.50	161.25
Mean W	112.33	94.583	151.00	129.91	357.25	

Factors	CD (0.05)	SE(d)	SE(m)
Crop (C)	NS	7.671	5.424
Weeder (W)	13.206	6.485	4.586
Interaction (W×C)	24.769	11.233	12.129
Interaction (C×W)	27.874	12.641	8.938

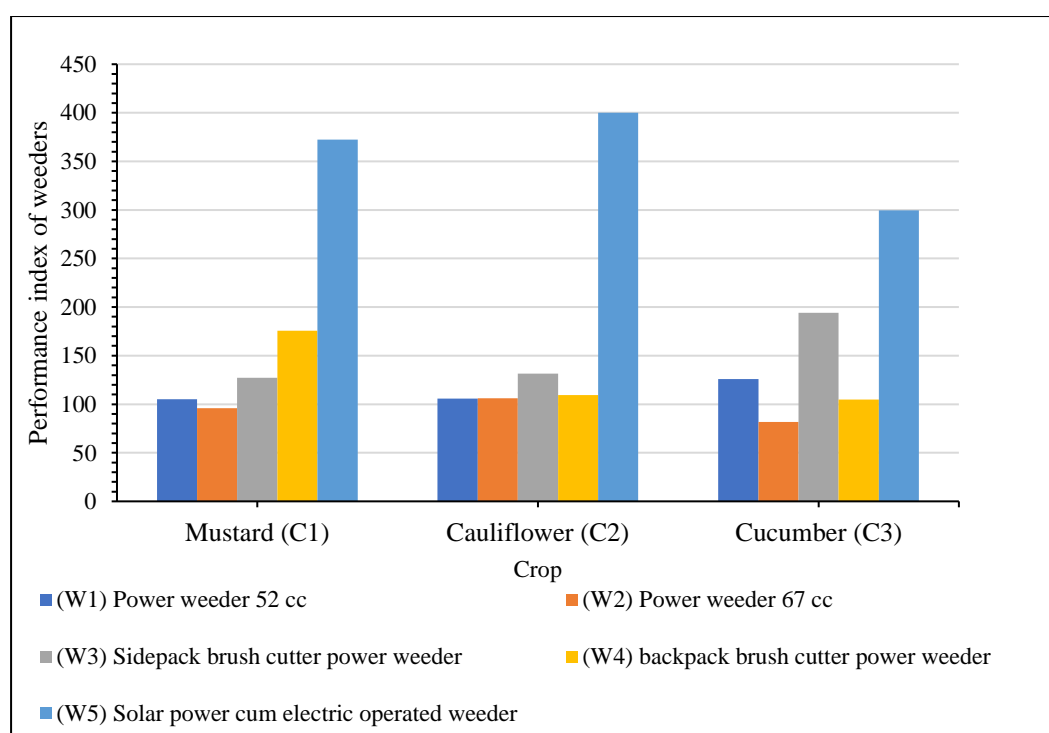


Fig. 4.19: Variation of performance index of weeders in different crop fields

4.4 Operational cost of different types of power weeder

The total cost of weeding is obtained from machine operational cost and labour cost for weeding (Ragesh *et al.*, 2018). Operational cost of machine was determined by considering fixed cost and variable cost of machine. Fixed cost is independent of operational use whereas variable cost varies proportionally with the amount of use. The total cost of weeding is determined by summation of total fixed cost per hour with total variable cost per hour. The Fixed cost and variable cost analysis of weeders was shown in Table 4.20 and Table 4.21, respectively.

Table 4.20: Fixed cost analysis of weeders

	Fixed cost (Rs/h)			
	Depreciation	Interest	Housing	Insurance and tax cost
Power weeder 52 cc	2.5	1.38	0.25	0.5
power weeder 67 cc	3.3	2.04	0.37	0.7
Sidepack brush cutter power weeder	1.9	1.15	0.21	0.4
Backpack brush cutter power weeder	2.2	1.20	0.24	0.5
Solar cum electric operated weeder	9.9	6.05	1.10	2.2

Table 4.21: Variable cost analysis of weeders

	variable cost (Rs/h)			
	Fuel cost	lubrication cost	Repair and maintenance cost	Wages of operator
Power weeder 52 cc	51	10	1.2	34.5
power weeder 67 cc	65	13	1.8	28.6
Sidepack brush cutter power weeder	53	13	1.0	27.8
Backpack brush cutter power weeder	50	10	1.2	30.3
Solar cum electric operated weeder			5.5	23.8

The highest operational cost (2744.1 Rs/ha) was obtained in power weeder 52 cc and lowest operational cost (952.5 Rs/ha) was obtained in solar power cum electric

operated weeder. The graphical representation of total operational cost was shown in Fig. 4.20. The detailed data of total operational cost is given in Appendix-B. Similar finding were also reported by Ragesh *et al.*, 2018.

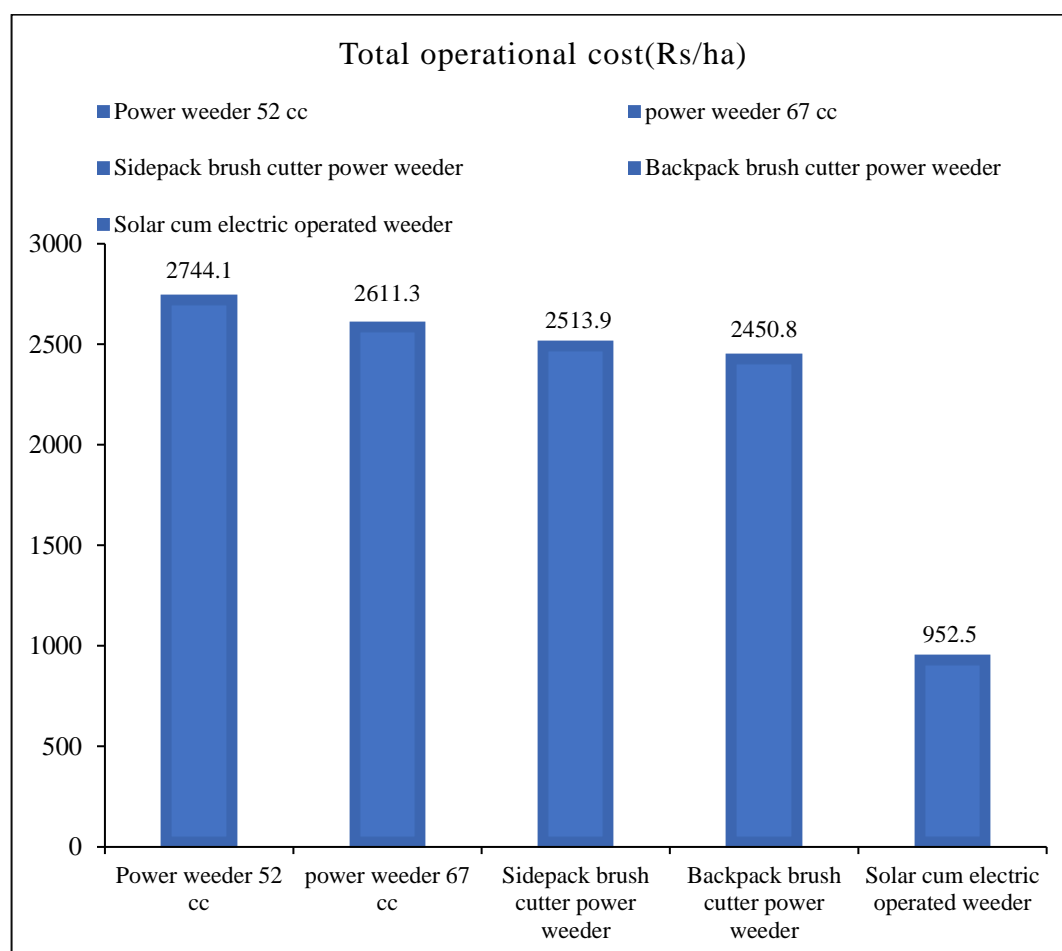


Fig. 4.20: Cost requirement of power weeders in Rs/ha

4.5 Operational Energy Analysis of Weeders

The input energy of the weeding operation through the power weeder was determined after the weeding operation. It is called as operational energy. It includes human energy, chemical energy (fuel energy), machine energy and electrical energy represents the energy required by different types of weeders for weeding operation. The electric energy was only required in solar power cum electric operated weeder (W5). The equivalent of human energy, fuel energy, machine energy and electric energy was taken 1.96 MJ/h, 48.23 MJ/h, 62.7 MJ/h and 11.93 MJ/h for energy

calculation. The required energy for weeding of different weeder in different treatments is given in Table 4.22 (Appendix-C).

Table 4.22: Results of operational energy of weeders

Particulars	Fuel energy (MJ/ha)	Electric energy (MJ/ha)	Machine energy (MJ/ha)	Human energy (MJ/ha)	Total energy (MJ/ha)
Power weeder 52 cc	22.18		1567.5	52.92	1643
Power weeder 67 cc	29.9		2006.4	47.04	2083
Sidepack brush cutter power weeder	25.56		1065.9	45.08	1137
Backpack brush cutter power weeder	22.66		909.15	50.96	983
Solar power cum electric operated weeder		10.73	3636.6	37.24	3685

The energy consumption contributes higher in terms of machine energy, electrical energy, and fuel energy in addition with human energy contribution. The energy consumption is much more in solar power cum electric operated weeder (3685 MJ/ha) because of its low engine power compared to other weeders. The lowest energy consumption was observed in backpack brush cutter power weeder (983 MJ/ha). The pie chart representation of total operational energy of each selected weeders is shown in Fig. 4.21. Similar findings were reported by Ragesh *et al.*, 2018 and Mishra, 2021.

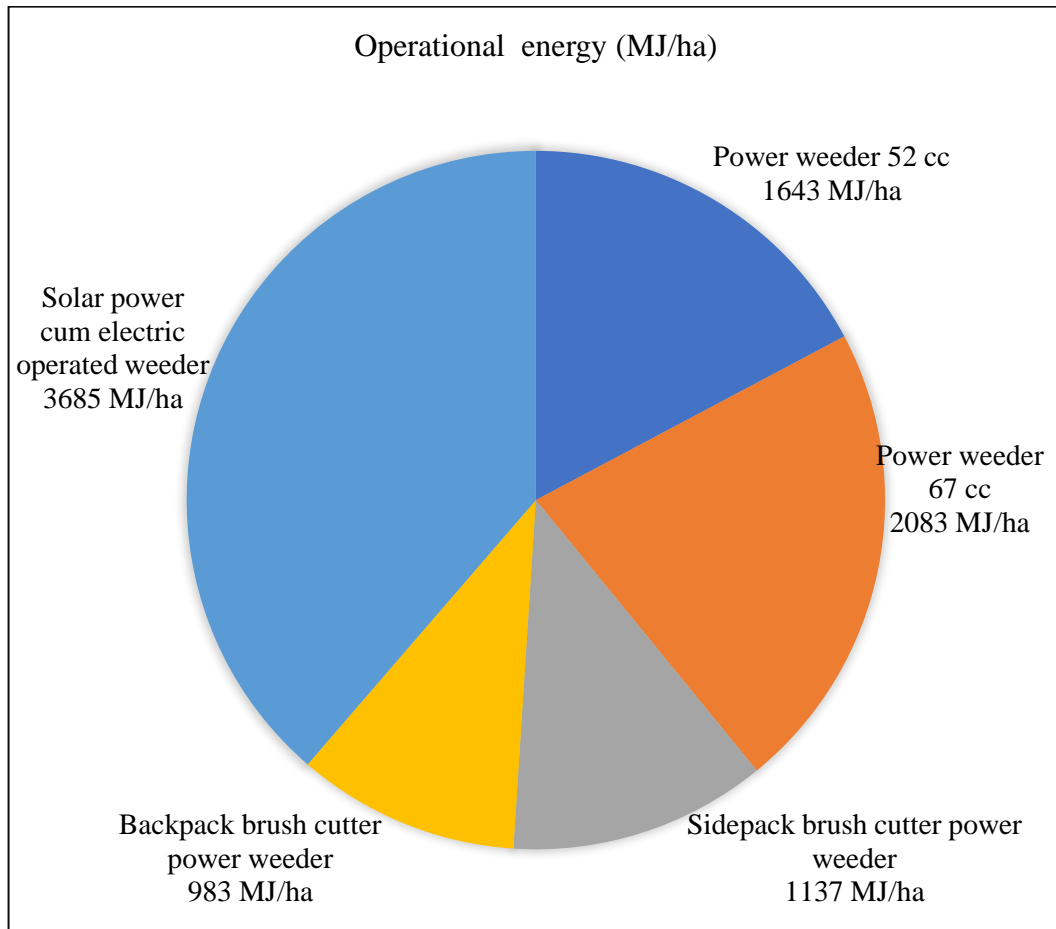


Fig. 4.21: Energy requirement of different types of power weeder in MJ/ha

CHAPTER-V

SUMMARY AND CONCLUSIONS

Agriculture and agro-based industries and businesses support the majority of the Indian population. One of the significant barriers to improving agricultural productivity is a lack of mechanization. One of the major causes of low agricultural productivity is weeds. Mechanization in agricultural practices is able to reduce these problems. The mechanical weeding creates favourable condition for plant by loosening the soil, it properly aerates the soil for proper growth. Weeding is one of the most time consuming and costly operation in agriculture. The rate of weed removal by mechanical weeder is determined by a number of parameters related to machine performance parameters and soil properties, such as the type of cutting blades used, machine efficiency, moisture content etc. The weeding efficiency of machine also depends on weed density and soil properties.

The performance evaluation of five different types of weeders were selected for the study. This research was conducted in the field of SVCAET & RS, IGKV, Raipur. The performance of weeder was observed in selected three crops i.e., mustard, cauliflower, and cucumber. To fulfill the objectives of the study, record weed species and floristic composition of weeds were studied and recorded in mustard, cauliflower, and cucumber crop. For testing of weeder, the operational parameters were calculated such as soil moisture content, bulk density of soil, weed population, plant population, effective working depth and effective working width, the performance parameters were determined such as operating speed, effective field capacity, theoretical field capacity, field efficiency, weeding efficiency, plant damage percentage, performance index of weeder and fuel consumption. The operational cost and energy analysis of different weeders were calculated.

Many factors are being considered for the advancement of mechanisation in weeding. The developed or existing weeder works well in the field without causing too much damage to the plants, its operating life is long and less expensive to operate. Thus, it is essential to evaluate the performance of power weeders. Therefore, the study was

conducted on techno economic evaluation of different types of power weeders. The following objectives were taken.

1. To record types of weeds and prevailing weeding practices in selected *Rabi* crops.
2. To test and evaluate the performance of power weeders in selected crops.
3. To recommend suitable power weeder as per crop requirement.

FINDINGS

1. The weed studies in experimental fields depicted that the grasses dominated over broad-leaved weeds and sedges in mustard crop whereas broad leaved weeds dominated over grasses and sedges had seen both in cauliflower and cucumber field.
2. The 12, 13 and 12 different type of weeds was found in mustard, cauliflower and cucumber field respectively. The number of weeds were highest in mustard whereas least in cucumber.
3. Among the five tested power weeders, the highest weeding efficiency (88.6 %) was found in solar cum electric operated weeder in mustard field at treatment T5 and the highest field efficiency (89.1 %) was found in backpack brush cutter power weeder in cauliflower field at treatment T9.
4. The maximum value of performance index was recorded in solar power cum electric operated weeder (357.25) and minimum was obtained in power weeder 67 cc (94.58).
5. Highest operational cost (2744.1 Rs/ha) was found in power weeder 52 cc and lowest operational cost (952.5 Rs/ha) was obtained in solar power cum electric operated weeder.
6. The energy consumption observed maximum in solar power cum electric operated weeder (3685 MJ/ha) and minimum in backpack brush cutter power weeder (983 MJ/ha).

Out of these findings following can be concluded:

1. In this region also similar types of weeds were observed as found in other parts of country. Total 12 different types of weeds were recorded in mustard and cucumber crop respectively. However, in cauliflower 13 weeds were observed.

2. Solar power cum electric operated weeder was found suitable for weeding in vegetable crops with higher weeding efficiency (86.4 %) and lower operational cost (952.5 Rs/ha) was obtained in solar powered weeder. It is recommended for use in mustard and cauliflower fields.
3. The brush cutter weeder performance was also found satisfactory and so also it is recommended for cauliflower and mustard crops including weeding in hilly area cultivation.

SUGGESTIONS FOR FUTURE WORK

1. On farm testing on assessment of different type of power weeders.
2. Performance evaluation of solar power cum electric operated weeder with different adjustment of cutting width of blade.

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Appendix A

1. Effective field capacity (ha/h)

Table A-1: EFC of weeders

		R1	R2	R3	R4	Mean	SD	CV %
C1	W1	0.028	0.029	0.028	0.028	0.028	0.0005	1.770
	W2	0.036	0.038	0.034	0.036	0.036	0.0016	4.536
	W3	0.031	0.030	0.033	0.031	0.031	0.0012	3.986
	W4	0.039	0.048	0.050	0.040	0.044	0.0056	12.566
	W5	0.039	0.043	0.046	0.044	0.043	0.0029	6.846
C2	W1	0.029	0.031	0.026	0.030	0.029	0.0022	7.449
	W2	0.042	0.042	0.038	0.039	0.040	0.0021	5.122
	W3	0.034	0.032	0.033	0.034	0.033	0.0010	2.879
	W4	0.032	0.028	0.030	0.028	0.030	0.0019	6.491
	W5	0.053	0.042	0.047	0.044	0.047	0.0048	10.314
C3	W1	0.03	0.035	0.031	0.029	0.031	0.0026	8.416
	W2	0.031	0.029	0.028	0.030	0.030	0.0013	4.376
	W3	0.044	0.047	0.043	0.047	0.045	0.0021	4.556
	W4	0.025	0.024	0.029	0.026	0.026	0.0022	8.309
	W5	0.037	0.035	0.04	0.036	0.037	0.0022	5.839

Table A-2: Two way mean table for EFC

	W1	W2	W3	W4	W5	Mean C
C1	0.028	0.036	0.031	0.044	0.043	0.036
C2	0.029	0.040	0.033	0.029	0.046	0.035
C3	0.031	0.029	0.045	0.026	0.037	0.033
Mean W	0.029	0.035	0.036	0.033	0.042	

Table A-3: SEM, SED and C.D for EFC

Factors	C.D.	SE(d)	SE(m)
Factor(C)	NS	0.001	0.001
Factor(W)	0.002	0.001	0.001
Factor(W)at same level of C	0.004	0.002	0.002
Factor(C)at same level of W	0.004	0.002	0.001

2. Theoretical field capacity (ha/h)

Table A-4: TFC of weeders

		R1	R2	R3	R4	Mean	SD	CV %
C1	W1	0.034	0.035	0.036	0.035	0.035	0.0008	2.33
	W2	0.042	0.044	0.048	0.046	0.045	0.0026	5.74
	W3	0.040	0.036	0.044	0.038	0.039	0.0034	8.63
	W4	0.045	0.055	0.059	0.050	0.052	0.0061	11.63
	W5	0.049	0.050	0.050	0.051	0.050	0.0008	1.63
C2	W1	0.035	0.036	0.034	0.039	0.036	0.0022	6.00
	W2	0.049	0.048	0.046	0.045	0.047	0.0018	3.88
	W3	0.041	0.038	0.040	0.043	0.041	0.0021	5.14
	W4	0.035	0.033	0.034	0.031	0.033	0.0017	5.14
	W5	0.059	0.053	0.051	0.055	0.055	0.0034	6.27
C3	W1	0.042	0.041	0.040	0.041	0.041	0.0008	1.99
	W2	0.042	0.039	0.040	0.041	0.041	0.0013	3.19
	W3	0.052	0.055	0.047	0.053	0.052	0.0034	6.58
	W4	0.032	0.033	0.031	0.033	0.032	0.0010	2.97
	W5	0.049	0.048	0.055	0.047	0.050	0.0036	7.22

Table A-5: Two way mean table for TFC

	W1	W2	W3	W4	W5	Mean C
C1	0.035	0.045	0.039	0.052	0.050	0.044
C2	0.036	0.047	0.041	0.033	0.055	0.042
C3	0.041	0.041	0.052	0.032	0.050	0.043
Mean W	0.037	0.044	0.044	0.039	0.051	

Table A-6: SEM, SED and C.D. for TFC

Factors	C.D.	SE(d)	SE(m)
Factor(C)	NS	0.001	0.001
Factor(W)	0.002	0.001	0.001
Factor(W)at same level of C	0.004	0.002	0.002
Factor(C)at same level of W	0.005	0.002	0.001

3. Speed of operation (km/h)

Table A-7: Speed of operation of weeders

		R1	R2	R3	R4	Mean	SD	CV%
C1	W1	1.70	1.80	1.60	1.80	1.73	0.10	5.55
	W2	1.70	1.80	1.90	1.80	1.80	0.08	4.54
	W3	1.60	1.40	1.70	1.50	1.55	0.13	8.25
	W4	1.40	1.30	1.30	1.40	1.35	0.06	4.28
	W5	1.10	1.30	1.50	1.20	1.28	0.17	13.39
C2	W1	1.40	1.60	1.50	1.40	1.48	0.10	6.49
	W2	1.50	1.60	1.80	1.80	1.68	0.15	8.96
	W3	1.60	2.50	1.50	1.60	1.80	0.47	26.06
	W4	1.70	1.50	1.60	1.50	1.58	0.10	6.08
	W5	1.50	1.20	1.10	1.30	1.28	0.17	13.39
C3	W1	1.70	1.60	1.60	1.50	1.60	0.08	5.10
	W2	1.60	1.50	1.50	1.60	1.55	0.06	3.72
	W3	1.60	1.50	1.30	1.30	1.43	0.15	10.53
	W4	1.20	1.30	1.40	1.50	1.35	0.13	9.56
	W5	1.10	1.00	1.30	1.20	1.15	0.13	11.23

Table A-8: ANOVA for speed of operation

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.011			
Factor C	2	0.247	0.124	5.866	0.03874
Error(c)	6	0.126	0.021		
Factor W	4	1.508	0.377	12.061	0
Interaction C X W	8	0.471	0.059	1.885	0.09298
Error(w)	36	1.125	0.031		
Total	59	3.489			

Table A-9: Two way mean table for speed of operation

	W1	W2	W3	W4	W5	Mean C
C1	1.7	1.8	1.5	1.3	1.2	1.5
C2	1.4	1.6	1.8	1.5	1.2	1.5
C3	1.6	1.5	1.4	1.3	1.1	1.4
Mean W	1.6	1.6	1.5	1.4	1.2	

Table A-10: SEM, SED and C.D. for speed of operation

Factors	C.D.	SE(d)	SE(m)
Factor(C)	0.114	0.046	0.032
Factor(W)	0.147	0.072	0.051
Factor(W)at same level of C	NS	0.125	0.073
Factor(C)at same level of W	NS	0.121	0.085

1. Field efficiency, %

Table A-11: Field capacity of weeders

		R1	R2	R3	R4	Mean	SD	CV %
C1	W1	80.9	83.9	78.9	81.0	81.2	2.1	2.5
	W2	86.7	85.0	70.1	79.2	80.3	7.5	9.3
	W3	85.0	87.6	85.8	80.5	84.7	3.0	3.5
	W4	80.0	82.4	84.2	86.8	83.4	2.9	3.4
	W5	80.3	86.4	84.4	87.6	84.7	3.2	3.8
C2	W1	83.0	86.4	75.2	84.2	82.2	4.9	5.9
	W2	84.6	86.8	83.7	87.0	85.5	1.6	1.9
	W3	82.4	85.2	82.3	80.3	82.6	2.0	2.4
	W4	91.7	84.9	89.5	90.4	89.1	3.0	3.3
	W5	89.5	80.1	92.1	79.6	85.3	6.4	7.5
C3	W1	72.4	85.9	76.7	70.6	76.4	6.8	8.9
	W2	73.3	75.1	69.8	72.7	72.7	2.2	3.0
	W3	85.4	86.1	91.2	88.6	87.8	2.6	3.0
	W4	79.1	76.4	76.1	74.4	76.5	1.9	2.5
	W5	74.9	71.2	72.5	75.6	73.6	2.1	2.8

Table A-12: ANOVA for field efficiency

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	47.685			
Factor C	2	555.382	277.691	33.264	0.00057
Error(c)	6	50.088	8.348		
Factor W	4	286.744	71.686	4.15	0.00725
Interaction C X W	8	551.618	68.952	3.992	0.0018
Error(w)	36	621.842	17.273		
Total	59	2,113.36			

Table A-13: Two way mean table for field efficiency

	W1	W2	W3	W4	W5	Mean C
C1	81.175	80.25	84.738	83.35	84.675	82.838
C2	80.2	85.525	82.55	89.138	85.325	84.548
C3	76.4	72.725	87.838	76.54	73.55	77.411
Mean W	79.258	79.5	85.042	83.009	81.183	

Table A-14: SEM, SED and C.D. for field efficiency

Factors	C.D.	SE(d)	SE(m)
Factor (C)	2.279	0.914	0.646
Factor(W)	3.455	1.697	1.2
Factor(W)at same level of C	6.13	2.939	1.445
Factor(C)at same level of W	5.804	2.783	1.968

2. Plant damage, %

Table A-15: Plant damage (%) of weeders

		R1	R2	R3	R4	Mean	SD	CV %
C1	W1	1.06	1.01	2.19	0.96	1.31	0.59	45.32
	W2	0.98	0.68	1.63	1.01	1.08	0.40	37.10
	W3	1.01	2.10	1.88	1.83	1.71	0.48	28.03
	W4	2.00	1.00	1.36	1.90	1.57	0.47	30.03
	W5	1.90	2.00	1.80	1.00	1.68	0.46	27.30
C2	W1	1.54	1.62	1.58	1.20	1.49	0.19	12.98
	W2	1.20	1.50	1.85	2.00	1.64	0.36	21.93
	W3	1.10	1.60	1.35	1.50	1.39	0.22	15.67
	W4	1.93	1.29	0.88	0.94	1.26	0.48	38.24
	W5	1.43	1.65	1.54	1.60	1.56	0.09	6.09
C3	W1	0.68	1.26	0.97	1.40	1.08	0.32	29.68
	W2	0.92	1.81	1.72	1.90	1.59	0.45	28.41
	W3	0.50	1.10	0.80	1.20	0.90	0.32	35.14
	W4	1.37	2.19	1.78	1.90	1.81	0.34	18.79
	W5	1.29	1.60	1.44	1.70	1.51	0.18	11.96

Table A-16: Analysis of variance table for plant damage

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.675			
Factor C	2	0.142	0.071	0.295	0.7546
Error(c)	6	1.446	0.241		
Factor W	4	0.65	0.163	1.358	0.26761
Interaction C X W	8	3.187	0.398	3.328	0.00598
Error(w)	36	4.309	0.12		
Total	59	10.409			

Table A-17: Two way mean table for plant damage

	W1	W2	W3	W4	W5	Mean C
C1	1.305	1.075	1.705	1.565	1.675	1.465
C2	1.610	1.638	1.388	1.260	1.555	1.49
C3	1.078	1.588	0.900	1.810	1.508	1.377
Mean W	1.331	1.433	1.331	1.545	1.579	

Table A-18: SEM, SED and C.D. for plant damage

Factors	C.D.	SE(d)	SE(m)
Factor(C)	NS	0.155	0.110
Factor(W)	NS	0.141	0.100
Factor(W)at same level of C	0.536	0.245	0.245
Factor(C)at same level of W	0.587	0.268	0.190

3. Weeding efficiency, %

Table A-19: Weeding efficiency of weeders

		R1	R2	R3	R4	Mean	SD	CV%
C1	W1	75.2	73.6	79.2	74.2	75.6	2.521	3.34
	W2	76.1	84.9	79.5	82.6	80.8	3.822	4.73
	W3	82.4	83.7	84.4	80.1	82.7	1.891	2.29
	W4	77.2	82.6	80.5	81.0	80.3	2.268	2.82
	W5	89.4	91.2	87.5	86.4	88.6	2.117	2.39
C2	W1	73.9	74.6	71.0	75.5	73.8	1.947	2.64
	W2	79.3	75.7	82.9	84.3	80.6	3.859	4.79
	W3	78.3	77.9	80.7	83.6	80.1	2.622	3.27
	W4	79.3	73.6	76.5	70.9	75.1	3.622	4.82
	W5	88.3	85.1	87.4	90.3	87.8	2.156	2.46
C3	W1	77.5	83.2	84.6	80.4	81.4	3.146	3.86
	W2	84.3	86.7	85.5	82.1	84.7	1.962	2.32
	W3	91.8	86.4	82.9	85.3	86.6	3.762	4.34
	W4	81.2	83.7	82.5	81.4	82.2	1.148	1.40
	W5	81.2	83.7	82.5	83.2	82.6	1.087	1.32

Table A-20: Analysis of variance table for weeding efficiency (%)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	6.079			
Factor C	2	164.013	82.006	7.043	0.02665
Error(c)	6	69.86	11.643		
Factor W	4	633.157	158.289	22.983	0
Interaction C X W	8	285.3	35.663	5.178	0.00024
Error(w)	36	247.942	6.887		
Total	59	1,406.35			

Table A-21: Two way mean table for weeding efficiency

	W1	W2	W3	W4	W5	Mean C
C1	75.55	80.77	82.65	80.32	88.62	81.58
C2	73.75	80.55	80.12	75.07	87.77	79.45
C3	81.42	84.65	86.60	82.20	82.65	83.50
Mean W	76.90	81.99	83.12	79.20	86.35	

Table A-22: SEM, SED and C.D. for weeding efficiency

Factors	C.D.	SE(d)	SE(m)
Factor(C)	2.692	1.079	0.763
Factor(W)	2.182	1.071	0.758
Factor(W)at same level of C	4.031	1.856	1.706
Factor(C)at same level of W	4.301	1.98	1.4

4. Effective working depth (mm)

Table A-23: Effective working depth of weeder

		R1	R2	R3	R4	Mean	SD	CV %
C1	W1	41	44	36	39	40	0.337	8.4
	W2	43	46	44	39	43	0.294	6.8
	W3	48	53	49	58	52	0.455	8.7
	W4	29	34	33	32	32	0.216	6.8
	W5	37	39	45	41	41	0.342	8.4
C2	W1	41	43	38	37	40	0.275	6.9
	W2	40	42	38	34	39	0.342	8.9
	W3	48	58	55	52	53	0.427	8.0
	W4	31	35	37	38	35	0.310	8.8
	W5	47	44	42	48	45	0.275	6.1
C3	W1	36	39	44	42	40	0.350	8.7
	W2	41	36	39	43	40	0.299	7.5
	W3	47	49	53	55	51	0.365	7.2
	W4	33	38	41	36	37	0.337	9.1
	W5	44	45	39	47	44	0.340	7.8

Table A-24: Analysis of variance table for effective working depth

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.616			
Factor C	2	0.102	0.051	0.553	0.60213
Error(c)	6	0.555	0.093		
Factor W	4	19.448	4.862	44.87	0
Interaction C X W	8	1.423	0.178	1.641	0.14756
Error(w)	36	3.901	0.108		
Total	59	26.046			

Table A-25: Two way mean table for effective working depth

	W1	W2	W3	W4	W5	Mean W
C1	40	43	52	32	40	41
C2	39	38	53	35	45	42
C3	40	39	51	37	43	42
Mean C	40	40	52	34	43	

Table A-26: SEM, SED and C.D. for effective working depth

Factors	C.D.	SE(d)	SE(m)
Factor(C)	N/A	0.096	0.068
Factor(W)	0.274	0.134	0.095
Factor(W)at same level of C	NS	0.233	0.152
Factor(C)at same level of W	NS	0.229	0.162

5. Effective working width (mm)

Table A-27: Effective working width of weeders

		R1	R2	R3	R4	Mean	SD	CV %
C1	W1	264	271	269	286	270	0.947	3.475
	W2	271	286	267	256	270	1.241	4.596
	W3	283	294	287	315	290	1.424	4.833
	W4	208	216	231	243	220	1.559	6.944
	W5	441	474	437	453	450	1.662	3.683
C2	W1	275	262	283	255	270	1.261	4.691
	W2	269	257	288	276	270	1.297	4.761
	W3	279	285	305	316	300	1.723	5.816
	W4	229	238	243	216	230	1.185	5.117
	W5	427	435	446	407	430	1.646	3.839
C3	W1	258	261	274	263	260	0.698	2.642
	W2	295	264	257	258	270	1.794	6.680
	W3	287	295	318	306	300	1.348	4.470
	W4	218	219	238	245	230	1.359	5.908
	W5	438	456	424	464	450	1.799	4.038

Table A-28: Analysis of variance table for effective working width

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	6.559			
Factor C	2	1.006	0.503	0.17	0.84758
Error(c)	6	17.757	2.96		
Factor W	4	3,249.57	812.393	433.057	0
Interaction C X W	8	13.795	1.724	0.919	0.51218
Error(w)	36	67.534	1.876		
Total	59	3,356.22			

Table A-29: Two way mean table for effective working width

	W1	W2	W3	W4	W5	Mean C
C1	272.5	270.0	294.7	224.5	451.2	302.6
C2	268.7	272.5	296.2	231.5	428.7	299.5
C3	264.0	268.5	301.5	230.0	445.5	301.9
Mean W	268.4	270.3	297.5	228.6	441.8	

Table A-30: SEM, SED and C.D. for effective working width

Factors	C.D.	SE(d)	SE(m)
Factor(C)	NS	0.544	0.385
Factor(W)	1.139	0.559	0.395
Factor(W)at same level of C	NS	0.968	0.86
Factor(C)at same level of W	NS	1.023	0.723

6. Performance index

Table A-31: Performance Index of weeders

		R1	R2	R3	R4	Mean	SD	CV %
C1	W1	104	106	108	103	105	2.4	2.3
	W2	90	107	89	98	96	8.3	8.6
	W3	127	123	137	122	127	6.7	5.3
	W4	148	196	199	159	175	25.9	14.8
	W5	340	382	393	374	373	22.9	6.1
C2	W1	106	114	91	112	105	10.4	9.8
	W2	110	104	103	107	106	3.0	2.8
	W3	132	123	131	140	131	7.1	5.4
	W4	124	102	114	98	110	11.9	10.9
	W5	459	350	402	389	400	45.2	11.3
C3	W1	115	144	130	115	126	13.7	10.9
	W2	86	82	78	81	82	3.3	4.1
	W3	201	201	177	198	194	11.6	6.0
	W4	100	98	117	104	105	8.7	8.3
	W5	295	287	323	293	300	16.3	5.4

Table A-32: Analysis of variance table for performance index

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	351.517			
Factor C	2	2,030.53	1,015.27	1.725	0.25592
Error(c)	6	3,530.93	588.489		
Factor W	4	5,52,462.23	1,38,115.56	547.305	0
Interaction C X W	8	45,600.97	5,700.12	22.588	0
Error(w)	36	9,084.80	252.356		
Total	59	6,13,060.98			

Table A-33: Two way mean table for performance index

	W1	W2	W3	W4	W5	Mean C
C1	105.2	96.00	127.25	175.5	372.2	175.2
C2	105.7	106.0	131.50	109.5	400.0	170.5
C3	126.0	81.75	194.25	104.7	299.5	161.2
Mean W	112.3	94.5	151	129.9	357.2	

Table A-34: SEM, SED and C.D. for performance index

Factors	C.D.	SE(d)	SE(m)
Factor(C)	N/A	7.671	5.424
Factor(W)	13.206	6.485	4.586
Factor(W)at same level of C	24.769	11.233	12.129
Factor(C)at same level of W	27.874	12.641	8.938

Table A-35: Performance characteristics of weeders

S. No.	Parameters	Power weeder 52 cc	Power weeder 67 cc	Sidepack brush cutter power weeder	Backpack brush cutter power weeder	Solar cum electric operated weeder
1	Operating speed	1.6	1.6	1.5	1.4	1.2
2	Effective field capacity	0.029	0.035	0.036	0.033	0.042
3	Theoretical Field capacity	0.037	0.044	0.043	0.039	0.051
4	Field efficiency	79.2	79.5	85.0	83.0	81.1
5	Effective working width	26.8	27.0	29.7	22.8	44.1
6	Effective working depth	4.00	4.04	5.02	3.47	4.31
7	Weeding efficiency	76.9	81.9	83.1	79.2	86.3
8	Plant damage	1.3	1.4	1.3	1.5	1.5
9	Performance index	112.3	94.5	151	129	357
10	Average Fuel consumption	0.56	0.62	0.49	0.47	-

7. Fuel consumption

Table A-36: Fuel consumption of weeders

		R1	R2	R3	R4	Mean	SD	CV %
C1	W1	0.50	0.48	0.56	0.44	1	0.053	10.577
	W2	0.57	0.62	0.62	0.61	1	0.024	3.935
	W3	0.60	0.62	0.65	0.66	1	0.028	4.354
	W4	0.46	0.43	0.43	0.47	0	0.021	4.607
C2	W1	0.54	0.48	0.49	0.50	1	0.026	5.234
	W2	0.68	0.64	0.64	0.66	1	0.019	2.923
	W3	0.60	0.63	0.65	0.62	1	0.021	3.331
	W4	0.48	0.45	0.46	0.46	0	0.013	2.721
C3	W1	0.51	0.52	0.50	0.51	1	0.008	1.601
	W2	0.64	0.66	0.65	0.63	1	0.013	2.002
	W3	0.61	0.60	0.63	0.60	1	0.014	2.318
	W4	0.49	0.45	0.44	0.47	0	0.022	4.794

Table A-37: Analysis of variance table for fuel consumption

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	3	0.001			
Factor C	2	0.002	0.001	2.25	0.18661
Error(c)	6	0.003	0.001		
Factor W	3	0.279	0.093	151.673	0
Interaction C X W	6	0.005	0.001	1.48	0.22256
Error(w)	27	0.017	0.001		
Total	47	0.307			

Table A-38: Two way mean table for fuel consumption

	W1	W2	W3	W4	Mean C
C1	0.50	0.61	0.63	0.45	0.55
C2	0.50	0.66	0.63	0.46	0.56
C3	0.51	0.65	0.61	0.46	0.56
Mean W	0.50	0.64	0.62	0.46	

Table A-39: SEM, SED and C.D. for fuel consumption

Factors	C.D.	SE(d)	SE(m)
Factor(C)	NS	0.008	0.006
Factor(W)	0.021	0.01	0.007
Factor(W)at same level of C	NS	0.017	0.011
Factor(C)at same level of W	NS	0.017	0.012

Appendix B

➤ Cost analysis

Table B-1: Fixed cost analysis of weeders

weeder	Fixed cost				
	Initial cost of machine	Depreciation/h	Interest/h	Housing/h	Insurance and tax cost/h
Power weeder 52 cc	12500	2.5	1.38	0.25	0.5
power weeder 67 cc	18500	3.3	2.04	0.37	0.7
Sidepack brush cutter power weeder	10490	1.9	1.15	0.21	0.4
Backpack brush cutter power weeder	12000	2.2	1.20	0.24	0.5
Solar cum electric operated weeder	55040	9.9	6.05	1.10	2.2

Table B-2: Variable cost analysis of weeders

	variable cost				
	Fuel Consumption (L/h)	Fuel cost (Rs/h)	lubrication cost/h	Repair and maintenance cost/year	Wages of operator/h
Power weeder 52 cc	0.56	51	10	1.3	34.5
power weeder 67 cc	0.62	65	13	1.9	28.6
Sidepack brush cutter power weeder	0.49	63	13	1.0	27.8
Backpack brush cutter power weeder	0.47	50	10	1.2	30.3
Solar cum electric operated weeder				5.5	23.8

Table B-3: Total operating cost analysis of weeders

	Total Operational cost/h	cost of operation of weeder per hectare
Power weeder 52 cc	101.5	2744.1
power weeder 67 cc	114.9	2611.3
Sidepack brush cutter power weeder	108.1	2513.9
Backpack brush cutter power weeder	95.6	2450.8
Solar cum electric operated weeder	48.6	952.5

Appendix C

➤ Energy Analysis

1. Energy required by power weeder 52cc (W1)

a. Machine energy

Weight of Power weeder 52 cc = 25 kg
 Energy equivalent = 62.7 MJ/kg
 Then, Machine energy = $25 \times 62.7 = 1567.5$ MJ/ha

b. Fuel energy

Fuel consumption (L/h) = 0.46 l/h
 Energy equivalent (MJ/h) = 48.23 MJ/h
 Then, Fuel energy = $0.46 \times 48.23 = 22.18$ MJ/ha

c. Human energy

Energy equivalent human (man) = 1.96 MJ/h
 Man required for operate power weeder 52 cc = 1
 Required man hour per hectare = 27 h
 Then, Human energy = $27 \times 1.96 = 52.92$ MJ/ha

Total energy for Power weeder 52 cc = $(1567.5 + 22.18 + 52.92)$ MJ/ha
 = 1642.6 MJ/ha

2. Energy required by power weeder 67cc (W2)

a. Machine energy

Weight of Power weeder 67 cc = 32 kg
 Energy equivalent = 62.7 MJ/kg
 Then, Machine energy = $32 \times 62.7 = 2006.4$ MJ/ha

b. Fuel energy

Fuel consumption (L/h) = 0.62 l/h
 Energy equivalent (MJ/h) = 48.23 MJ/h
 Then, Fuel energy = $0.62 \times 48.23 = 29.90$ MJ/ha

c. Human energy

Energy equivalent human (man) = 1.96 MJ/h

Man required for operate power weeder 52 cc = 1

Required man hour per hectare = 24 h

Then, Human energy = $24 \times 1.96 = 47.04$ MJ/ha

Total energy for Power weeder 67 cc = $(2006.4 + 29.90 + 47.04)$ MJ/ha
 $= 2083.34$ MJ/ha

3. Energy required by sidepack brush cutter power weeder (W2)

a. Machine energy

Weight of sidepack brush cutter power weeder = 17 kg

Energy equivalent = 62.7 MJ/kg

Then, Machine energy = $17 \times 62.7 = 1065.9$ MJ/ha

b. Fuel energy

Fuel consumption (L/h) = 0.53 l/h

Energy equivalent (MJ/h) = 48.23 MJ/h

Then, Fuel energy = $0.53 \times 48.23 = 25.56$ MJ/ha

c. Human energy

Energy equivalent human (man) = 1.96 MJ/h

Man required for operate power weeder 52 cc = 1

Required man hour per hectare = 23 h

Then, Human energy = $23 \times 1.96 = 45.08$ MJ/ha

Total energy for Power weeder 52 cc = $(1065.9 + 25.56 + 45.08)$ MJ/ha
 $= 1136.54$ MJ/ha

4. Energy required by backpack brush cutter power weeder

a. Machine energy

Weight of sidepack brush cutter power weeder = 14.5 kg

Energy equivalent = 62.7 MJ/kg

Then, Machine energy = $14.5 \times 62.7 = 909.15$ MJ/ha

b. Fuel energy

Fuel consumption (L/h) = 0.47 l/h

Energy equivalent (MJ/h) = 48.23 MJ/h

Then, Fuel energy = $0.47 \times 48.23 = 22.66$ MJ/ha

c. Human energy

Energy equivalent human (man) = 1.96 MJ/h
 Man required for operate power weeder 52 cc = 1
 Required man hour per hectare = 26 h
 Then, Human energy = $26 \times 1.96 = 50.96$ MJ/ha

Total energy for Power weeder 52 cc = $(909.1 + 22.66 + 50.96)$ MJ/ha
 = 982.72 MJ/ha

5. Energy required by solar power cum electric operated weeder

a. Machine energy

Weight of sidepack brush cutter power weeder = 58 kg
 Energy equivalent = 62.7 MJ/kg
 Then, Machine energy = $58 \times 62.7 = 3636.6$ MJ/ha

b. Electrical energy

Electric power (kWh) = 0.90 kWh
 Energy equivalent (MJ/h) = 11.93 MJ/h
 Then, Electric energy = $0.90 \times 11.93 = 10.73$ MJ/ha

c. Human energy

Energy equivalent human (man) = 1.96 MJ/h
 Man required for operate power weeder 52 cc = 1
 Required man hour per hectare = 19 h
 Then, Human energy = $19 \times 1.96 = 37.24$ MJ/ha

Total energy for Power weeder 52 cc = $(3636.6 + 10.73 + 37.24)$ MJ/ha = 3684.57 MJ/ha

RESUME



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