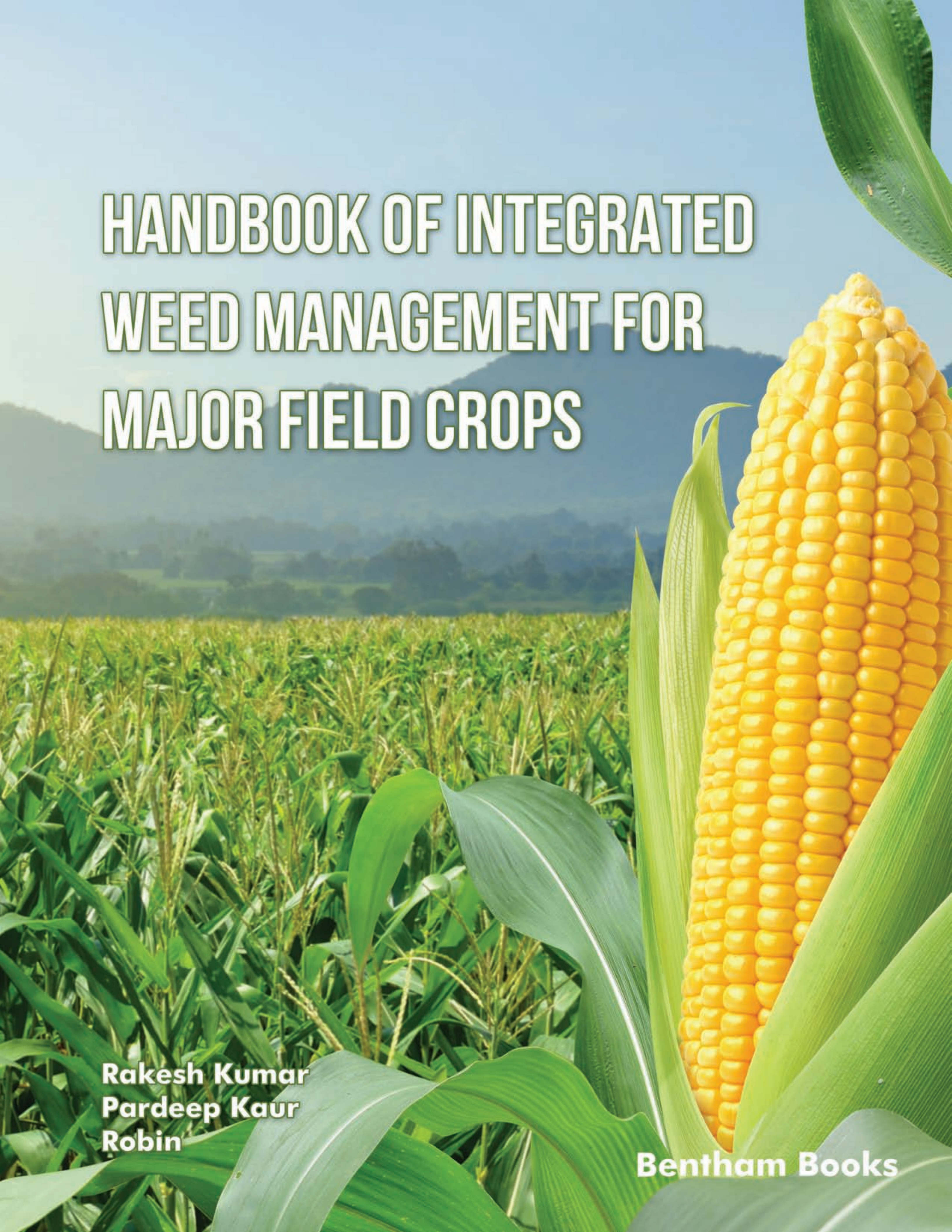

HANDBOOK OF INTEGRATED WEED MANAGEMENT FOR MAJOR FIELD CROPS

Rakesh Kumar
Pardeep Kaur
Robin

Bentham Books

Handbook of Integrated Weed Management for Major Field Crops

Authored by

Rakesh Kumar
Post Graduate Department of Agriculture
Khalsa College, Amritsar
Punjab, India

Pardeep Kaur
Post Graduate Department of Botany
Khalsa College, Amritsar
Punjab, India

&

Robin
Agilent Technologies India Private Limited and Regional Water Testing Laboratory
Department of Water Supply and Sanitation
Amritsar
Punjab, India

Handbook of Integrated Weed Management for Major Field Crop

Authors: Rakesh Kumar, Pardeep Kaur and Robin

ISBN (Online): 978-981-5305-09-8

ISBN (Print): 978-981-5305-10-4

ISBN (Paperback): 978-981-5305-11-1

First published in 2024.

need for a court order if at any point you breach any terms of this License Agreement. In no event will any delay or failure by Bentham Science Publishers in enforcing your compliance with this License Agreement constitute a waiver of any of its rights.

3. You acknowledge that you have read this License Agreement, and agree to be bound by its terms and conditions. To the extent that any other terms and conditions presented on any website of Bentham Science Publishers conflict with, or are inconsistent with, the terms and conditions set out in this License Agreement, you acknowledge that the terms and conditions set out in this License Agreement shall prevail.

Bentham Science Publishers Pte. Ltd.
80 Robinson Road #02-00
Singapore 068898
Singapore
Email: subscriptions@benthamscience.net

BENTHAM SCIENCE

CONTENTS

FOREWORD i

PREFACE ii

CHAPTER 1 WEEDS – INTRODUCTION, CONCEPT, CHARACTERISTICS AND IMPORTANCE IN AGRICULTURE 1

INTRODUCTION 1
ORIGIN OF WEEDS 2
Changing Status of Plants 2
Perpetual Problems from Perennials and New Threats from Annuals 3
CHARACTERISTICS OF WEEDS 3
HOW WEEDS HARM PLANTS OR LAND USE 4
Damage from Weeds: Contributing Factors 5
Species or Group of Weeds 5
Weed Density 5
Duration of the Weed Competition 5
Cultivation Method 5
CONCLUSION 5
REFERENCES 6

CHAPTER 2 SURVEY, COLLECTION, PRESERVATION AND IDENTIFICATION OF WEEDS 8

INTRODUCTION 8
WEED SURVEY 9
Roving Survey 9
Necessary Materials 9
Methods 9
Data Evaluation 9
Survey on Farm 10
ASSESSMENT OF WEED CONTROL TREATMENTS 11
Visual Estimation 11
Weed Counts and Weed Density 12
Weed Weight 13
COLLECTION AND PRESERVATION OF WEED SPECIMENS 13
Collection of Weeds 13
Materials Required for Collection 13
Guidelines for Collection 13
Diary or Notebook 14
Pressing the Weed Specimen 14
Materials Required 14
Guidelines for Pressing 14
Drying the Specimen 15
Chemical Treatment of Specimen 15
Chemicals Used for Treatment 15
Materials Required and Preparation of Solution 15
Mounting, Labeling, and Storing of Specimen 15
Materials Required for Mounting 15
Preservation of Succulent and Aquatic Weeds 16
Preparation of Solution 17
IDENTIFICATION OF WEEDS 17
Morphological Features 17

Grasses (Poaceae or Gramineae) 17
Sedges (Cyperaceae) 18
Broad-Leaves 18
Ferns 19
Algae 19
Weeds According to Their Life Cycle 19
Annuals 19
Biennials 19
Perennials 19
Other Classifications 20
Habitat 20
Soil Type 20
Origin 20
Special Weeds 20
According to Association 21
Waste Places and Roadsides 21
CONCLUSION 21
REFERENCES 22

CHAPTER 3 PARASITIC WEEDS AND THEIR MANAGEMENT 23
INTRODUCTION 23
Genus Striga (Witchweeds) 24
Genus Orobanche (Broomrapes) 26
Genus Cuscuta (Dodder) 27
Genus Loranthus (Mistletoe) 29
CONCLUSION 30
REFERENCES 31

CHAPTER 4 ECOLOGY AND BIOLOGY OF WEEDS 33
INTRODUCTION 33
WEED SUBSISTENCE 34
Weed Biology 35
Life Cycle and Growth Patterns 35
Reproductive Strategies 35
Adaptive Traits 35
Competitive Abilities 36
Allelopathy 36
Ecological Interactions 36
Invasive Behavior 36
VITAL CHARACTERISTICS 36
Seed Production 37
Seed Dormancy and Longevity 37
Vegetative Reproduction 37
Dispersal Mechanism 37
Crop Mimicry 37
CONCLUSION 38
REFERENCES 38

CHAPTER 5 AN INTEGRATED APPROACH TO THE CONTROL OF WEEDS IN RICE FIELDS 40
INTRODUCTION 40
INTEGRATED WEED MANAGEMENT IN RICE 41

IDENTIFICATION AND CLASSIFICATION OF MAJOR WEEDS OF RICE 41
Grasses: Important Traits of their Morphology 42
Prominent Grassy Weeds Affecting Rice Production 42
Sedges: Significant Morphological Traits 42
Prominent Sedges Affecting Rice Production 42
Broad Leaf: Significant Morphological Traits 42
Prominent Broad Leaf Weeds Affecting Rice Production 42
Ferns: Significant Morphological Traits 42
Algal Weeds: Significant Morphological Traits 43
WEED MANAGEMENT PRACTICES 44
Pre-emptive Measures 44
Cultural Practices 44
Crop Rotation 44
Selection of Cultivar 45
Field Preparation 45
Time of Planting 45
Seed Rate/Spacing and Plant Density 46
Age and Number of Seedlings/Hill 46
Fertilizer Management 46
Water Management 47
Mechanical Method 48
Biological Control/Bioherbicides 48
Chemical Weed Control 49
CONCLUSION 49
REFERENCES 50

CHAPTER 6 AN INTEGRATED APPROACH TO THE CONTROL OF WEEDS IN WHEAT CROP 52
INTRODUCTION 52
MAJOR WEED FLORA 53
CRITICAL PERIOD 54
WEED MANAGEMENT STRATEGIES 54
Preventive Methods 54
Good Management 54
Increasing Crop Vigor 54
Stale Seed Beds 54
Summer Fallowing 55
Crop Rotation 55
Competitive Cropping 55
Pre-Sowing Irrigation 55
Seed Rate/Sowing Method/Sowing Time 56
Fertilizer Application 56
Herbicide Rotation 56
Drainage 56
Mechanical and Physical Methods 56
Chemical Weed Control 57
Integrated Weed Control 58
Precautions in Use of Herbicides 59
CONCLUSION 59
REFERENCES 60

CHAPTER 7 AN INTEGRATED APPROACH TO WEED CONTROL IN SORGHUM AND PEARL MILLET 62
INTRODUCTION 62
MAJOR WEED FLORA 63
Common Weed Species in Sorghum and Pearl Millet Fields 63
Grasses 63
Broadleaf Weeds 63
Sedges 63
Other Weeds 63
CRITICAL PERIOD 64
Sorghum (Sorghum bicolor): 64
Pearl Millet (Pennisetum glaucum): 64
SORGHUM AND PEARL MILLET WEED MANAGEMENT STRATEGIES AND APPROACHES 64
High-Intensity Cropping 65
Field Preparation 65
Time of Sowing 65
Seed and Sowing 66
Fertilizer Management 66
Management of Water 67
Mechanical Weed Control 67
Chemical Control 67
Post-Harvest Weed Control 68
CONCLUSION 69
REFERENCES 70

CHAPTER 8 INTEGRATED WEED MANAGEMENT IN MAIZE 71
INTRODUCTION 71
PRIMARY WEED CONCERNS 72
WEED COMPETITION CRITICAL PERIOD 72
METHODS OF WEED CONTROL AND MANAGEMENT 73
Land Preparation 73
Method of Sowing/Planting 73
Varieties 73
Plant population 73
Fertilizer 73
Hand Weeding/Manual Control 74
Chemical Weed Control 74
INTEGRATED APPROACH 75
ADAPTATION TO LOCAL CONTEXTS 75
SUSTAINABILITY AND FUTURE PERSPECTIVES 75
CONCLUSION 76
REFERENCES 77

CHAPTER 9 INTEGRATED WEED MANAGEMENT IN SUGARCANE 78
INTRODUCTION 78
MAJOR WEED FLORA 80
Weeds Emerging in Autumn Planted Crop 80
Weeds Emerging in Spring-Planted Crop 80
Weeds Emerging during Rainy Season 80
MANAGEMENT STRATEGY 81

CONCLUSION 84
REFERENCES 85

CHAPTER 10 INTEGRATED WEED MANAGEMENT IN COTTON 86
INTRODUCTION 86
MAJOR WEED FLORA 87
WEED MANAGEMENT STRATEGY 87
Cultural Practices 88
Crop Rotation 88
Field Preparation 88
Timely Sowing 88
Seed Rate and Spacing 88
Method of Sowing 89
Inter Cropping and Mixed Cropping 89
Gap Filling and Thinning 89
Manure and Fertilizer Application 89
Mechanical Method 90
Herbicidal Control 90
Pre-Emergent Herbicides Recommended 90
Pre-Plant Incorporated (PPI) Herbicides 91
Recommended Herbicides for Post-Emergent Directed Spray 91
Post-Emergent Herbicides 91
Herbicide-Resistant Cotton Cultivars 91
CONCLUSION 91
REFERENCES 92

CHAPTER 11 INTEGRATED WEED MANAGEMENT IN OILSEEDS 94
INTRODUCTION 94
MAJOR WEED FLORA OF OILSEED CROPS 95
CRITICAL PERIOD OF CROP WEED COMPETITION AND EXTENT OF CROP LOSSES DUE TO WEEDS 95
WEED MANAGEMENT PRACTICES 96
Chemical Methods 97
Groundnut 97
Soybean 97
Safflower 97
Niger 97
Sunflower 97
Management of Weeds in Oilseed-Based Intercropping System 98
Parasitic Weed Control 98
Orobanche spp. in Mustard 98
Rapeseed-Mustard 98
Linseed 98
Integrated Weed Management (IWM) 98
CONCLUSION 99
REFERENCES 100

CHAPTER 12 INTEGRATED WEED MANAGEMENT IN PULSES 101
INTRODUCTION 101
MAJOR WEED FLORA 102
Kharif/Zaid Season 103
Rabi Season 103

Weed Management Strategy 103
Cultural Methods 103
Mechanical Methods 104
Chemical Methods 104
Inter-cropping System 104
Cuscuta spp. (Dodder) 105
Tolerant Varieties 105
Chemical Control 105
CONCLUSION 106
REFERENCES 107

CHAPTER 13 HERBICIDES 109
INTRODUCTION 109
LIST OF HERBICIDES REGISTERED IN INDIA 110
HERBICIDE CLASSIFICATION 110
Classification Based on Chemical Composition 111
Inorganic Herbicides 111
Organic Herbicides 111
Classification Based on Selectivity 111
Classification Based on Mode of Action 112
Classification Based on Site of Application 112
Classification Based on Time of Application 112
HERBICIDE APPLICATION TECHNIQUES 113
Usual Herbicide Formulations in the Market 113
Rate of Application 113
Herbicides Calculation 113
Methods of Application of Herbicides 114
Application Techniques 114
EQUIPMENTS 115
Conventional Manually Operated Sprayers 115
Requisites for Good Herbicides Sprayer 115
Hydraulic Knapsack Sprayer 115
Nozzle Types 115
Cone Types 115
Sprayer Calibration 116
Materials and Methods 117
Proper Safety Measures 118
CONCLUSION 118
REFERENCES 119

SUBJECT INDEX 121

FOREWORD

It is a great pleasure to know that the e-book entitled 'Handbook of Integrated Weed Management for Major Field Crops' has been written by Rakesh Kumar and co-authors. Weeds, the unwanted plants in the fields, are one of the major constraints in increasing the production and productivity of crops. Weeds cause over 25% loss in food production, in addition to the huge costs involved in weed control, either by hand weeding or through the application of herbicides. However, weeds also maintain a delicate balance between the vitality of ecosystems and food security. Effective management of weeds, thus, presents an exciting opportunity for innovation for sustainable crop production and conservation of the ecosystem. The weeds compete with the main crop for nutrients and sunlight and, thus, result in lower crop yields if they are not controlled at the appropriate time. However, weeds also play an important role in the ecosystem and serve as a source of pollen and nectar for beneficial insects. Many weed species are also used as medicinal plants and, thus, need to be conserved in the ecosystem. This book on integrated weed management in major field crops takes a critical look at the synergy between different approaches to develop strategies for weed management in field crops, including chemical, biological, cultural, and mechanical control of weeds based on sound ecological principles and foster a comprehensive understanding of weed-crop interactions. I am sure that this 'Handbook of Integrated Weed Management for Major Field Crops' will encourage the readers to engage in exploration, critical analysis, and collaboration to develop weed management strategies that are both sustainable and effective. This book will also help in bridging the gap between the theoretical concepts and practical weed management in the field and lead to increased collaboration between researchers, extension workers, industry workers and farmers. I am confident that this handbook will be highly useful for the students, researchers, and farmers by providing them with a comprehensive guide for weed control. I congratulate the authors for the timely publication of this book on integrated weed management to ensure food and nutritional security in India.

.

Hari C Sharma
Former - Vice Chancellor
YSP University of Horticulture and Forestry
Solan, H.P., India &
Former - President
Council of International Congress of Entomology (ICE)

PREFACE

This handbook is designed to help scholars understand the fundamentals of weeds, including their concept, characteristics, and importance in agriculture. The book covers all of the topics pertinent to integrated weed management in principal field crops. The topics include the core aspects of weeds, which encompass their survey, identification, collection, and preservation, as well as ecology and biology, along with integrated weed management techniques in some essential field crops such as rice, wheat, sorghum, pearl millet, maize, sugarcane, cotton, oil seeds, and various pulses grown in the Indian subcontinent. Readers in the field of agriculture may also benefit from the book since it contains fundamental knowledge on various herbicides and how they can be used effectively to get superior outcomes in yield and production. It serves as a foundational book for undergraduate and postgraduate students majoring in agriculture. Additionally, the book covers many facets of agriculture that are essential to learning. The main objective of writing this book is to induce better understanding in learners whose knowledge of the subject is new and who come into this line of work from various other streams of basic sciences. We strongly believe that this handbook will serve the greatest number of researchers, academicians, master trainers, and extension functionaries in providing comprehensive weed control approaches.

Rakesh Kumar
Post Graduate Department of Agriculture
Khalsa College, Amritsar
Punjab, India

Pardeep Kaur
Post Graduate Department of Botany
Khalsa College, Amritsar
Punjab, India

&

Robin
Agilent Technologies India Private Limited and Regional Water Testing Laboratory
Department of Water Supply and Sanitation
Amritsar, Punjab, India

CHAPTER 1

Weeds – Introduction, Concept, Characteristics and Importance in Agriculture

Abstract: In the initial phases of life on Earth, the prevalence of undesirable plants was not extensive. Humans developed the practice of differentiating between weeds and crops based on economic activities. It has been suggested that there are close to 30,000 species that can be classified as weeds. These have co-evolved with crops and are deemed undesirable because of their capacity to outcompete cultivated plants that are intended for food and fiber production. It is widely accepted that all primary cultivated plants have originated from wild weeds. Several plant species that were previously utilized for ornamental, therapeutic, or feed purposes are currently classified as weeds. The crop ecosystem has undergone significant changes due to the use of high levels of fertilizers, intensive cropping practices, and modifications in cropping patterns. Weeds possess specific characteristics that enable them to thrive and persist in environments where many cultivated plants would ultimately perish. The existence of weeds may have multiple effects on human existence. Apart from their economic implications, these cause hay fever in humans and can also exhibit toxicity in livestock and wildlife. The impact of weeds on crop productivity varies based on certain factors such as type of weed species, density of weeds, duration of weed competition, and method of cultivation.

Keywords: Agriculture, Economy, Management, Weeds.

INTRODUCTION

In the beginning of the existence of life on the earth, weeds were not prevalent. It is the man, who developed the concept of weeds and crops, depending upon his economic activities. There are around 300,000 distinct species of angiosperms found throughout the world [1]. Some estimates imply that as many as 30,000 of those species might be considered weeds *i.e.*, weeds make up around 1 in every 10 plant species on earth [2]. More than any other dispersal agent, humans are accountable for the spread of weeds. Consequently, weeds have evolved alongside crops and are undesirable due to their capacity to outcompete plants that man attempts to cultivate for food and fiber. The original habitat of the majority of weeds remains unclear. Many weeds are closely related to cultivated crops or ornamental plants, and it is this close relationship that makes some weeds more

Rakesh Kumar, Pardeep Kaur & Robin

challenging to control than others. A weed can be defined in many ways; some of the more common definitions are:

- A species of plant that is growing in an area where it is not intended.
- A plant out of place.
- A plant that has more negative effects than it has positive ones.
- A plant part or plant itself that causes problems for man and obstructs human goals.

Kentucky bluegrass (*Poa pratensis*) that spreads from a lawn into a flower bed, volunteer corn (*Zea mays*) in a sugarbeet or bean field, lamb's quarters (*Chenopodium album*), and red root pigweed (*Amaranthus retroflexux*) are all considered weeds [3 - 6]. As a result, a plant is considered a weed by humans or, to be more precise, by individuals. A plant that is a weed to one person may be a desirable plant to another. Any plant can be weed under certain circumstances.

ORIGIN OF WEEDS

All basic cultivated plants are believed to have been derived from weeds found in a wild state. Following are a few examples: Cultivated oat (*Avena sativa*) is considered to have descended from common wild oats *Avena sterilis* and *A. byzantina* [7]. Another food crop, barley (*Hordeum vulgare*), has originated from the domestication of a wild two-rowed form (*Hordeum spontaneum*) found in Israel, Jordan, Iran, and Iraq [8, 9]. Similarly, a cultivated form of sugarcane (*Saccharum officinarum*) has also been domesticated from its wild form, *S. robustum* [10].

Changing Status of Plants

The status of different plant species does not remain the same throughout time. Many plants and crops that were once ornamental, therapeutic, or used for feed are now considered weeds. Johnsongrass (*Sorghum halepense*) introduced to many areas for cattle feed is now one of the world's major trouble-some crop weeds [11, 12]. Crofton weed (*Eupatorium adenophorum*), native to Mexico, is currently a pasture weed in the Pacific region and Southeast Asia [13].

One of the most prevalent types of weed problems is the continuation of a crop species or cultivar into the subsequent (different) crop in a rotation. For example, potato plants arising from tubers remaining after harvest are common weeds in various vegetable crops and cereals. Therefore, the status of a plant as a weed differs depending on the time period and the geographical location.

Perpetual Problems from Perennials and New Threats from Annuals

Intensive cropping with a heavy input of fertilizers and irrigation, changes in cropping patterns, and cultural systems have all contributed to substantial variations in the crop ecosystem and, consequently, weed flora [14]. The short-statured and erect types of new crop cultivars and modern cultural technology have aggravated the perennial weed problem. Several species of these weeds have even started to develop resistance to herbicides under continuous use [15]. To mention a few examples, the development of resistance to herbicides as a result of consistent long-term use has led to the aggravated infestation of purple nutsedge (*Cyperus rotundus*) in sorghum, pigeon pea, and many other field crops, *Scirpus maritimus* in rice monoculture areas of Southeast Asia, *Imperata cylindrica*, *Panicum* spp., and *Paspalum scorbiculatum* in various plantation crops, *etc*.

Similarly, a strong build-up of annual weeds has been observed in certain field crops due to changes in the micro-environment, continuous use of herbicides, and consequent development of tolerance [16]. For example, the continuous use of benthiocarb in rice fields has resulted in a spontaneous increase in the population of broad-leaved annuals like *Monochoria vaginalis*. In a similar way, *Sphenoclea zeylanica* and *Phalaris minor* enhance very rapidly in wheat fields that have been treated with 2, 4-D. In the Punjab region of the Indian subcontinent, *Ischaemum rugosum* proliferate rapidly in rice fields due to the uninterrupted use of butachlor.

CHARACTERISTICS OF WEEDS

Plants that are commonly referred to as weeds have certain characteristics that enable them to proliferate and exist where most cultivated plants would eventually die off. Some of these characteristics are:

- Typically, weeds have a high rate of seed production [17]. For example, *Amaranthus spinosus* produces 2,35,000 seeds/plant, and for *Striga asiatica/ S. lutea,* 90,000 seeds/plant have been recorded [18, 19].
- Many weeds have unique ways of dispersing and spreading their seeds for *e.g.*, ground cherry (*Physalis* spp.) has a modified papery calyx that encloses the fruit loosely along with entrapped air [20].
- Many weed seeds can remain dormant in the soil for a long period of time and germinate when favorable conditions prevail (*Bidens pilosa*: 75 years, *Brassica*: 50 years, *Chenopodium album*: 30-40 years) [21].
- Most weed-like plants have the ability to thrive under adverse conditions *e.g.*, *Cyperus* spp [22].
- The majority of weeds successfully compete with crop plants for soil moisture, nutrients and sunlight *e.g.*, *Chenopodium album*, *Amaranthus* spp [23].

CHAPTER 2

Survey, Collection, Preservation and Identification of Weeds

Abstract: A weed survey provides valuable insights into the prevalence of various weed species, the interplay between weeds and crops, and the dynamic patterns of these associations in field conditions. A roving survey is implemented within a vast geographical region that includes either a single district or multiple districts. A weed survey with identical objectives to the roving survey can be conducted on a farm. Periodic evaluation of the weed control treatments is necessary to assess their impact on both the crop and weed populations. Visual estimation is a technique employed to quickly gather data when dealing with a substantial number of plots and plant species while facing resource constraints. The European Weed Research Council (EWRC) has developed a rating system to assess the efficacy of weed control. Weed assessments should be conducted during the initial stages of crop growth when weed competition is at its peak and weeds are in their early and manageable stages for counting. The collection and preservation of weed specimens are essential for future reference and study, as not all weed species are readily accessible at all times and locations. An herbarium is a collection of dried, pressed, and preserved plants, including weeds, organized according to an accepted classification system such as Bentham & Hooker or Hutchinson. In addition to this, accurate identification of weed plants is a fundamental requirement for the development of efficient management strategies.

Keywords: Identification, Management, Survey, Weed collection.

INTRODUCTION

In the intricate tapestry of our ecosystems, weeds play a pivotal role, influencing both natural landscapes and human-managed environments. The study on weeds transcends mere botanical curiosity, delving into ecological dynamics, agricultural impacts, and conservation efforts. Understanding their diversity, distribution, and attributes requires a multidisciplinary approach encompassing botany, ecology, and agronomy. This chapter serves as an introduction to the fascinating realm of weed research, focusing on the crucial aspects of surveying, collecting, preserving, and identifying these often-overlooked plants.

Rakesh Kumar, Pardeep Kaur & Robin

WEED SURVEY

A weed survey may offer information on the prevalence of different species, the relationship between weeds and crops, and the shifting patterns of these associations under field circumstances [1].

Roving Survey

A roving survey is conducted in a large area encompassing a district or several districts [2].

Necessary Materials

- A road map of the area.
- Vehicle (s) *e.g.*, jeep.
- Quadrats, 1 m x 1 m or 50 cm x 50 cm in size.
- Proforma for recording/listing the weed count data.
- Weed presses to press and preserve unidentified weeds.
- Blotting papers, scissors, *etc*.

Methods

- The surveyors set out on vehicles in different directions on previously fixed routes. Stops are made at a regular distance (say 5 to 10 km) to take samples. If the location happens to be a town or a village, stops are made just before or just after passing such locations.
- Samples are taken away from the main road to represent the natural weed flora. The number of samples taken varies from 3-10/ha. Samples are taken with the help of a l m x l m or 50 cm x 50 cm quadrat.
- Weeds are identified, counted, and recorded in an especially devised proforma. Unidentified weeds are also counted, collected, pressed, and preserved for identification. Listing of weeds is done species-wise or group-wise (*e.g.*, broad leaves, grasses, sedges).

Data Evaluation

Population Density = Total weed population per unit area

$$Absolute\ Density\ (A.D) = \frac{Total\ number\ of\ individuals\ of\ the\ species\ in\ all\ quadrats}{Total\ number\ of\ quadrats\ employed}$$

$$Relative\ Density\ (R.D) = \frac{Absolute\ density\ for\ a\ given\ species}{Total\ absolute\ density\ for\ all\ species} \times 100$$

$$Absolute\ Frequency\ (A.F) = \frac{Number\ of\ quadrats\ in\ which\ the\ species\ occur}{Total\ number\ of\ quadrats\ employed} \times 100$$

$$Relative\ Frequency\ (R.F) = \frac{Absolute\ frequency\ value\ for\ a\ species}{Total\ absolute\ frequency\ value\ of\ all\ the\ species} \times 100$$

Important Value Index (I.V.I) = Relative density (R.D) + Relative frequency (R.F)

$$Summed\ Dominance\ Ratio\ (S.D.R) = \frac{Importance\ value\ index (I.V.I)}{2}$$

$$Relative\ Dominance\ (cover) = \frac{Dominance\ (cover)\ of\ the\ species}{Total\ dominance\ (cover)\ of\ the\ species} \times 100$$

$$Relative\ Dry\ Weight\ (R.D.W) = \frac{Dry\ weight\ of\ a\ particular\ species}{Total\ dry\ weight\ of\ entire\ species} \times 100$$

$$Absolute\ Coverage\ (C\ \%) = \frac{Number\ of\ hits\ for\ a\ particular\ species}{Total\ number\ of\ points} \times 100$$

$$Relative\ Coverage\ (R.C) = \frac{Total\ number\ of\ hits\ for\ a\ given\ species}{Total\ number\ of\ hits\ for\ all\ species} \times 100$$

Survey on Farm

On a farm, a weed survey with the same goals as the one described above may be carried out. On the basis of the findings of the survey regarding the species composition of the weeds, the decision can be taken to use a prophylactic (pre-

CHAPTER 3

Parasitic Weeds and their Management

Abstract: Parasitic flowering plants deprive the host plants of water, nutrients, and assimilates. Data also suggests that parasites transmit inhibitory compounds to hosts. Several species of the genera Striga and Orobanche (root parasites), as well as some species of Cuscuta and Loranthus (stem parasites), are widely distributed worldwide and cause substantial damage to economically important plants. The chapter elucidates the optimal strategies for addressing the issues of parasite infestations by incorporating a range of well-established methodologies. The effective management of parasitic weeds can be achieved through the implementation of various strategies. These include the cultivation of crop varieties that exhibit resistance or low susceptibility to the parasites, utilizing non-host crops as trap crops, employing pre-emergent and post-emergent herbicides in combination with bio-herbicides, and manually removing the parasites.

Keywords: Identification, Management, Parasitic weeds.

INTRODUCTION

Parasitic weeds are a unique category of plants that have evolved an intricate strategy to thrive at the expense of other plants known as their hosts. These plants, belonging to various genera and families, possess specialized structures that allow them to attach to host plants, extract nutrients, and ultimately weaken or even kill their hosts. The impact of parasitic weeds on agriculture, natural ecosystems, and livelihoods is considerable, making their effective management a matter of paramount importance [1].

The coexistence of parasitic weeds and their hosts has been a challenge throughout history, with documented instances dating back to ancient civilizations. However, the proliferation of modern agriculture, changes in land use, and global trade have facilitated the spread of parasitic weeds, exacerbating their negative consequences. Crop yield losses, reduced quality of agricultural produce, and compromised land productivity are among the direct economic repercussions of these insidious plants. Parasitic flowering plants use other plants as hosts, therefore depriving them of essential resources such as water, minerals, and, in some instances, assimilates. Moreover, there exists supporting data

Rakesh Kumar, Pardeep Kaur & Robin

indicating the transmission of inhibitory chemicals from the parasite to the host. Certain species of the genera *Striga* and *Orobanche*, which are root parasites, as well as certain species of *Cuscuta* and *Loranthus*, referred to as stem parasites, are globally prevalent and inflict significant harm upon economically valuable plants [1, 2].

In response to the threat posed by parasitic weeds, extensive research has been conducted to understand their biology, ecology, and the various mechanisms they employ to attach to, invade, and exploit host plants. This knowledge has paved the way for the development of a range of management strategies that seek to control parasitic weeds while minimizing their impact on the environment and non-target species. The management of parasitic weeds involves a multidisciplinary approach that draws on the fields of agronomy, biology, ecology, and chemistry. Strategies encompass cultural practices, biological control methods, chemical interventions, and integrated weed management systems that are tailored to the specific characteristics of the parasite-host interactions and the local agroecosystem.

This chapter delves into the intricate world of parasitic weeds, exploring their biology, impact, and the arsenal of management techniques aimed at mitigating their threat. By gaining a deeper understanding of these challenges and the tools available to address them, stakeholders in agriculture and environmental management can work together to safeguard crops, enhance food security, and promote sustainable land use practices.

Genus *Striga* (Witchweeds)

Genus *Striga*, which has about 30 species, belongs to the family of Scrophulariaceae [3]. In India, notable species include *S. lutea* (*S. asiatica*) and *S. densiflora*, which pose a threat to several crops like sorghum, maize, pearl millet, finger millet, foxtail millet, and sugarcane. *S. lutea* is 10-30 cm tall, with a bright green stem and leaves displaying characteristics of a semi-parasite. Flowers are usually white, though yellow, pink or purple colored flowers are also observed in other countries [3 - 5]. *S. densiflora* also has white flowers but plant is more robust, less branched with dense inflorescence. Fruits are capsules that contain numerous dust-like seeds. A single plant has the potential to generate up to 500,000 seeds, with the seeds capable of remaining viable for a period of up to 20 years. The seed germinates in response to the stimulant (strigol), which is derived from the root exudate of the host plant. It produces a 5-10 mm long radicle, which, on contact with the host root, swells into bell-shaped haustorium and, through enzymatic secretion, dissolves the host cells and penetrates into the host root [6]. Finally, the tracheids of *Striga* rootlet force their way through the xylem of host, facilitating the uptake of water and essential nutrients. Consequently, the host (crop plant) is significantly reduced in height and vigor, even before any *Striga* shoot emerges from the soil [6, 7]. Moreover *S. lutea* induces pronounced wilting of its host, even under wet soil conditions. These aforementioned effects result in severe reduction in yield of affected crops, causing total loss of crop [3, 7]. The management of *Striga* presents significant challenges. Significantly improved outcomes might be achieved with the effective integration and use of the methodologies and strategies outlined below:

- Cultivation of resistant (or least susceptible) crop varieties like resistant/tolerant varieties of sorghum include N-l3, Co-20, SAR-l, and SAR-2 (*Striga asiatica*-resistant) bred at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which possess a very high degree of resistance to *S. lutea* [8]. Additionally, the Co-290 variety of sugarcane and TF-23 A and PT-499 varieties of pearl millet have also been reported to be resistant to *S. lutea*.
- The cultivation of resistant cultivars should be complemented by manual removal in order to limit the dispersion of viable parasites *via* seeding.
- In addition to several other techniques, the implementation of rotation with trap crops, which are non-host crops including cotton, soybean, sunflower, pea, linseed, cowpea, black gram, lucerne, sesame, and groundnut, may effectively induce suicidal germination. This process aids in diminishing the presence of reservoir seeds in the soil [9]. However, in order to significantly mitigate the *Striga* issue, it may be necessary to implement multiple years of crop rotation.
- Improvement of soil fertility, particularly with nitrogenous fertilizers, reduces host stimulant exudates and hence the occurrence of *Striga*.
- The use of inter-cropping practices involving leafy crops has been well recognized for their ability to effectively limit the growth and development of the parasitic weed known as *Striga*. The precise process behind suppression remains incompletely elucidated; nonetheless, it is essential that inter-crop placement occurs within rows rather than in alternating rows.
- Currently, there is a lack of pre-emergent herbicides that effectively eliminate *Striga* seeds in the soil. However, the administration of 2, 4-D as a post-emergence treatment at 30 days after sowing (DAS) may serve as an alternative to manual removal. It should be noted that many applications may be necessary to achieve desired results.
- In the United States, the use of ethylene gas in light soil has shown to be very effective in inducing suicidal germination of *Striga* seeds. The use of this concept may be facilitated by the utilization of comparatively simple knapsack injectors. However, this technology has not yet been fully used. The feasibility of bio-control methods for managing *Striga* remains uncertain, while there are potential avenues for the creation of micro-herbicides [10].

CHAPTER 4

Ecology and Biology of Weeds

Abstract: The field of weed ecology involves the examination of growth characteristics, adaptive traits, and survival mechanisms of weeds that allow them to effectively utilize environmental resources and successfully establish themselves in new habitats. The analysis of the ecological and biological characteristics of weeds enhances our understanding of the relationships between weeds and crops, as well as the factors contributing to their widespread establishment and management strategies. Climate, soil conditions, and biotic factors affect their geographic distribution, abundance, competitive abilities, behavioral tendencies, and survival. Despite the challenges posed by environmental factors and human interventions, weeds have a remarkable capacity to flourish and persist across many ecosystems. Several reasons may contribute to this phenomenon, including seed production in vast quantities, variable seed dormancy and longevity, propagation through vegetative organs, and mimicking the appearance of the crop.

Keywords: Biology, Ecology, Weeds.

INTRODUCTION

Weeds hold a crucial place within the intricate web of ecosystems. These seemingly uninvited plants have evolved unique strategies that enable them to flourish in diverse environments, making them significant players in ecological dynamics [1]. Understanding the ecology and biology of weeds is essential not only for effective weed management but also for gaining insights into the broader functioning of natural systems [1, 3].

Weeds, often characterized by their rapid growth and ability to colonize disturbed areas, play multifaceted roles in ecosystems. While some species contribute to soil stabilization and habitat restoration, others can outcompete native vegetation and disrupt the balance of local flora and fauna [4, 5]. The study of weed ecology delves into the interactions between these plants and their environment, shedding light on their adaptive mechanisms, reproductive strategies, and responses to environmental changes [6]. The biology of weeds further unravels the intricacies of their life cycles, growth patterns, and reproductive behaviors. Weeds have evolved a myriad of traits that enhance their success in various habitats, including

Rakesh Kumar, Pardeep Kaur & Robin

traits related to dispersal, germination, establishment, growth, and reproduction [2]. Understanding these traits provides insights into the factors that contribute to weed invasiveness and persistence, as well as the vulnerabilities that can be targeted for effective management.

In agricultural landscapes, weeds can lead to significant yield losses by competing with crops for resources such as water, nutrients, and sunlight. Beyond farms, invasive weeds can impact natural ecosystems, disrupt ecological processes, and threaten the survival of native species. As a result, scientists and land managers strive to comprehend the ecological relationships that shape weed dynamics and the underlying biological mechanisms that drive their proliferation.

This chapter explores the strategies that enable weeds to thrive, adapt, and sometimes dominate their surroundings. By delving into the mechanisms by which weeds interact with ecosystems and examining the underlying genetic, physiological, and ecological processes, we can develop more effective strategies for weed management, conservation, and sustainable land use. Ultimately, a comprehensive understanding of weed ecology and biology contributes to the broader endeavor of maintaining the health and resilience of both managed and natural landscapes.

WEED SUBSISTENCE

Ecology is the study of the reciprocal relationship between organisms and their surrounding environment. Weed ecology encompasses the study of growth characteristics, adaptive traits, and survival mechanisms of weeds that enable them to exploit the environmental resources and colonize new habitats in spite of changes in the environment [7]. The examination of the ecological and biological aspects of weeds facilitates comprehension of the interactions between weeds and crops, as well as the underlying reasons for their prolific colonization and formidable management challenges posed by weeds [7].

The environment entails various factors such as climate, soil conditions, and living organisms, which play a crucial role in influencing the spatial distribution, abundance, competitive ability, behavioral patterns, and overall survival of weeds. The distribution of plant species in a given region is primarily influenced by the prevailing temperature range in that area [7].

The aquatic plant *Eichhornia crassipes*, commonly known as water hyacinth, exhibits a limited geographical distribution, thriving exclusively in tropical and subtropical regions due to its inability to withstand freezing temperatures [8]. *Cyperus rotundus* exhibits peak growth rates within a temperature range of 25°C to 30°C, indicating its preference for higher temperatures. In contrast, *Agropyron* *repens* ceases growth when exposed to temperatures exceeding 25°C, which explains its distribution in temperate regions. The occurrence of plants in specific locations is influenced by various factors, including water availability (rainfall, soil moisture, and relative humidity), light conditions (intensity and day length), and soil characteristics (structure, texture, alkalinity, presence of toxic metals, and organic matter content) [8].

In this context, human beings also have a significant influence on the environment by means of their agricultural practices. Plants possess the potential to thrive as weeds when they exhibit certain traits, including a notable capability for vegetative reproduction, as well as the ability to compete and display aggressive habits.

Weed Biology

Weeds, in the context of plants, are defined as unwanted and competitive species that grow alongside cultivated crops or in natural ecosystems. Understanding weed biology is essential for effective weed management strategies and for gaining insights into how these plants thrive and spread. Weed biology encompasses various aspects of these plants, like their life cycles, growth patterns, reproductive strategies, and interactions with the environment.

Life Cycle and Growth Patterns

Weeds exhibit diverse life cycles, ranging from annuals that complete their life cycle within a year to perennials that live for multiple years. Annual weeds germinate from seeds, grow, reproduce, and die in a single year, while perennial weeds can regenerate from underground structures like roots, rhizomes, or bulbs. Understanding the life cycle of a weed is crucial for scheduling control measures effectively.

Reproductive Strategies

Weeds employ a wide array of reproductive strategies that contribute to their persistence and spread. Many produce large quantities of seeds, ensuring a high chance of at least some offspring surviving and establishing in favorable conditions. Some weeds also utilize vegetative reproduction, where plant fragments can root and grow into new plants. These reproductive strategies contribute to the rapid spread and colonization of weed species.

Adaptive Traits

Weeds have evolved various adaptive traits that enable them to thrive in diverse environments. These traits are related to seed dispersal (*e.g.*, wind, water, animal

CHAPTER 5

An Integrated Approach to the Control of Weeds in Rice Fields

Abstract: Rice is farmed as a dry-seeded upland, low-land, puddle-seeded, transplanted, and deep-water paddy crop. More than 350 weed species from 150 genera and 60 plant families have been recorded. The chapter provides a comprehensive overview of the botanical characteristics and ecological impact of the various species of plants commonly referred to as weeds (grasses, sedges, broad leaf, ferns, and algal weeds) that are found in rice fields. It also elucidates the diverse methodologies employed in the management of weeds, encompassing preventive measures, cultural practices, mechanical techniques, and biological and chemical interventions. The prudent integration of these methodologies is imperative for achieving cost-efficient and environmentally viable weed control in rice cultivation.

Keywords: Management, Rice, Weeds.

INTRODUCTION

Rice, a staple food for more than half of the world's population, is cultivated in a diverse array of environments, including dry-seeded uplands, lowlands, puddle-seeded fields, transplanted paddies, and deep-water ecosystems [1 - 3]. This versatility in cultivation methods reflects the adaptability of rice as a crop, but it also presents a myriad of challenges, particularly in weed management [4, 5]. Weeds, defined as any plants growing where they are not wanted, pose a significant threat to rice production by competing for nutrients, water, light, and space, ultimately reducing crop yield and quality [6].

More than 350 weed species, spanning 150 genera and 60 plant families, have been documented in rice fields worldwide [7]. These weeds encompass a wide range of botanical characteristics, including grasses, sedges, broadleaf plants, ferns, and algal species, each with unique ecological impacts and adaptive strategies [8]. Understanding the botanical and ecological aspects of these weed species is crucial for developing effective management strategies.

The control of weeds in rice fields requires a multifaceted approach, integrating various methods to achieve sustainable and cost-effective solutions. This chapter

Rakesh Kumar, Pardeep Kaur & Robin

explores the comprehensive range of weed control methodologies, including preventive measures to avoid weed infestations, cultural practices that enhance crop competitiveness, mechanical techniques for physical removal, and biological and chemical interventions aimed at suppressing weed growth. By prudently integrating these diverse approaches, farmers and agricultural professionals can enhance the efficacy of weed management, ensuring both economic viability and environmental sustainability in rice cultivation. This chapter aims to provide an in-depth understanding of the weeds that afflict rice fields and the integrated strategies available for their control, paving the way for improved rice production systems.

INTEGRATED WEED MANAGEMENT IN RICE

- Rice cultivation comprises several methods, including dry-seeded upland, transplanted, dry-seeded lowland, puddle-seeded, and deep aquatic paddy crops [9].
- The incidence of weed infestation is exceedingly pronounced in dry-seeded and direct rain-fed paddy fields in comparison to transplanted irrigated paddy fields [10].
- According to research findings, the current estimated average economic impact caused by the presence of weeds in India amounts to approximately USD 89/ha. This impact translates to a reduction in yield of 14% for transplanted crops and 21% for directly seeded crops [10].

IDENTIFICATION AND CLASSIFICATION OF MAJOR WEEDS OF RICE

- There have been reports of more than 350 distinct species of weeds, which belong to over 150 genera and 60 different plant families [7].
- The occurrence and population density of weeds in agricultural fields are subject to the influence of numerous factors, including the method used for seeding, moisture level in the soil, specific cropping system employed, rotation of crops, ambient air and soil temperatures, the manner in which the land is prepared, type and quantity of the particular rice cultivar used, the technology employed for weed control, and the intricate interplay among these diverse factors [10, 11].
- Weeds can be identified based on the external traits of their morphology. Therefore, for practical purposes and simplified categorization, weed classification can be according to morphological similarities into distinct groups such as broad-leaf plants, grasses, ferns, sedges, and algal weeds [10, 11].

Grasses: Important Traits of their Morphology

The plant has a fibrous root system and possesses a round, hollow stem characterized by nodes and internodes. The leaves are arranged on the stem in an alternating pattern, forming two rows. The leaf blade is elongated and thin, displaying parallel venation. Additionally, the plant may or may not have overlapping leaf sheaths, ligules, and auricles [12].

Prominent Grassy Weeds Affecting Rice Production

Echinochloa colona, E. glabrescens, E. crus-galli, Paspalum distichum, Ischaemum rugosum, Oryza breviligulata, Panicum repens, Leptochloa chinensis, Leersia hexandra, Digitaria ciliaris, Eleusine indica, and *Dactyloctenium aegyptium*.

Sedges: Significant Morphological Traits

Sedges exhibit morphological similarity to grassy plants (as monocots). However, they vary in salient characteristics with solid triangular stems and three distinct rows of arrangement of leaves. They lack tube-shaped leaf sheaths, auricles, and ligules [12].

Prominent Sedges Affecting Rice Production

Cyperus iria, Cyperus difformis, Fimbristylis aestivalis, Fimbristylis littoralis, Scirpus supinus, Scirpus maritimus, Eleocharis atropurpurea, S. juncoides, Cyperus compressus, and *Cyperus rotundus*.

Broad Leaf: Significant Morphological Traits

These contain both monocot and dicot plant species. In general, the leaves are more broad than grass and sedges, displaying a diverse range of size dimensions and forms [12].

Prominent Broad Leaf Weeds Affecting Rice Production

Eclipta alba, Caesulia axillaris, Ammannia baccifera, Monochoria vaginalis, Ludwigia parviflora, L. octovalvis, Moniera cuneifolia, Sphenoclea zeylanica, Commelina diffusa, Dopatrium junceum, Commelina benghalensis, and *Cynotis axillaris*.

Ferns: Significant Morphological Traits

Ferns are plants with vascular systems that do not produce seeds but instead reproduce through spores. The structure of their leaves can vary, with some

CHAPTER 6

An Integrated Approach to the Control of Weeds in Wheat Crop

Abstract: Wheat holds significant agricultural importance as it is extensively cultivated across diverse climatic conditions and soil types. The transition from cultivating tall varieties to dwarf and semi-dwarf (specifically Mexican wheat) varieties has exacerbated the issue of weeds in significant wheat cultivation regions. Both grassy and broadleaved weeds are commonly found in this agricultural crop. The detrimental effects of weeds are most pronounced when they are permitted to compete with wheat crops during the initial 45 days. The implementation of weed management strategies encompasses both preventive measures and effective management practices. These may include the use of uncontaminated agricultural seeds sourced only from accredited state and national organizations, enhancement of crop vigor, altering the crop sequence, application of phosphoric fertilizers in the absence of nitrogen, and rotation strategy for herbicides.

Keywords: Management, Wheat, Weeds.

INTRODUCTION

Wheat is the most important cereal crop grown in the country extensively over a wide range of climatic conditions and soil. The recent trend toward the shift in cultivation practices from tall varieties to dwarf and semi-dwarf (Mexican wheat) varieties responsive to more fertilizer and irrigation application has aggravated the problem of weeds in major wheat-growing areas. Both grassy and broad-leaf weeds are a common occurrence in this crop [1].

A wide diversity of species may be expected where frequent changes in rotations have been practiced in the past. In contrast, commonly adopted rice-wheat rotation has encouraged some weed species to build up to high numbers and become dominant. Depending upon the intensity and types of weeds, 30-60% of loss in grain yield is quite common. In order to attain the highest return from applied inputs in terms of seed, fertilizers, and irrigation water, it is of utmost importance to eliminate weed competition from the crop at least up to the initial period of 3 to 6 weeks of sowing [1, 2].

Rakesh Kumar, Pardeep Kaur & Robin

MAJOR WEED FLORA

Several weed species emerge simultaneously with the emergence of wheat crops. The population is mostly dominated by annual grasses and many broadleaved weeds. Among the sedges, *Cyperus rotundus* is the most problematic weed. The list of major weeds is given in Table **1** [2, 3].

Table 1. List of Major Weeds.

Grasses	Broadleaf Weeds	Perennials
Phalaris minor	*Chenopodium album*	*Agrostis gigantea*
Avena fatua	*Stellaria media*	*Cirsium arvense*
Avena ludoviciana	*Vicia sativa*	*Convolvulus arvensis*
Lolium temulentum	*Anagallis arvensis*	*Asphodelus tenuifolius*
Alopecurus myosuroides	*Fumaria parviflora*	
Cyperus rotundus	*Lathyrus aphaca*	
Poa annua	*Euphorbia hirta*	
Briza minor	*Cirsium arvense*	
Cynodon dactylon	*Medicago denticulata*	
Polypogon monspeliensis	*Ranunculus muricatus*	
	Silene conoidea	
	Rumex dentatus	
	Oxalis spp.	
	Cichorium intybus	
	Lepidium sativum	
	Trigonella polycerata	
	Spergula arvensis	
	Melilotus alba	

Grassy weeds dominate the field where rice-wheat rotation is followed under high moisture conditions, whereas broad-leaved weeds dominate under less moisture and dry land conditions. Canary grass, also known as *Phalaris minor*, is found in regions that have an abundant supply of precipitation during the rabi and kharif seasons. It is an extremely harmful weed in soil with a medium and heavy texture where rice-wheat rotation is practiced and the level of moisture is high, especially on the upper surface [2, 3]. Wild oat (*Avena* spp.) is a serious weed of wheat crop grown on well-drained, medium-textured soil where wheat is grown in rotation with sugarcane ratoon, maize, cotton, sorghum, and groundnut. Moreover, the change in sowing time from October in the case of tall wheat varieties to the middle of November for semi-dwarf wheat varieties provides a more congenial temperature for germination and growth of grassy weeds, hence enhancing their competitive ability with the crop. Among the grassy weeds, wild oats (*Avena ludoviciana*) and canary grass (*Phalaris minor*) exhibit a striking resemblance to the wheat crop, and the identification of these weeds is very difficult in the early stages of growth [2, 3].

CRITICAL PERIOD

Weeds emerging late in the season are less competitive than those emerging early in the season [4]. The weeds cause maximum harm when they are allowed to compete with wheat crops for an initial 45 days. The period between 30 to 450 days after sowing is most sensitive [5]. At a later stage, the crop successfully withstands competition from weeds.

WEED MANAGEMENT STRATEGIES

Preventive Methods

- Use of clean crop seeds from certified state and national agencies.
- Destroy the weed seeds in farmyard manure during the fermentation process.
- Keep banks of irrigation channels and ditches free from weeds.
- Clean the farm implements before they are moved from one place to another.
- Keep fence corners and non-cropped areas free from weeds.
- Vigilance *i.e.*, destruction of weed plants before flowering.

Good Management

In any weed control system for cropland, there is no substitute for good crop husbandry methods [2, 4, 6].

Increasing Crop Vigor

A crop with high vigor exhibits greater competitive ability against weeds compared to a crop with low vigor. In order to enhance crop vigor, several factors can be considered, including the utilization of high-quality seed varieties, seed treatment methods, techniques to break seed dormancy, application of growth hormones, appropriate soil preparation, and the optimization of sowing date and seed rate, as well as the judicious use of fertilizers and irrigation. Certain cultivars, such as WH-542, PBW-343, and PDW-34, exhibit prolonged phenological stages and demonstrate rapid growth rates. When these cultivars are planted at an early stage, they possess the ability to partially inhibit the proliferation and maturation of undesirable plant species [6].

Stale Seed Beds

Preparing the seedbed and leaving it undisturbed for some time increase the germination of weeds, which can be ploughed out finally before sowing. Paraquat @ 0.75-1.0 kg/ha can be applied on germinated weed seedlings (3-4 leaf stage), and after 2-3 days, fields can be ploughed, and sowing can be done or Glyphosate

CHAPTER 7

An Integrated Approach to Weed Control in Sorghum and Pearl Millet

Abstract: Sorghum and pearl millet are prominent cereal crops extensively cultivated in India. These plant species are intentionally cultivated by agriculturalists with constrained financial means who reside in arid and semi-arid geographical areas. The presence of weeds significantly hinders the successful cultivation of these crops. The unregulated growth of undesirable plant species has been empirically documented to have a substantial negative impact on the agricultural output of sorghum and pearl millet, potentially resulting in a decline of approximately 30-40%. Therefore, this chapter elucidates the amalgamated approaches for weed management in the cultivation of sorghum and pearl millet, encompassing cultural, cropping, and chemical methods that are both economically viable and readily implementable for farmers residing in arid and semi-arid regions.

Keywords: Management, Pearl millet, Sorghum, Weeds.

INTRODUCTION

Sorghum and pearl millet are significant cereal crops cultivated in India in addition to rice and wheat. These are selectively cultivated by farmers with limited economic resources who inhabit arid and semi-arid regions [1]. Weeds impose substantial limitations on the effective farming of these agricultural crops. Cultivated on comparatively spacious rows, usually on soil with lower nutrient content and initially displaying diminutive, feeble, and sluggish establishment, these crops are outperformed by weed species that are highly competitive and ecologically well-suited to the specific regions [2, 3].

In dry land, the struggle for nutrients commences during the initial phases of crop development. The competition for resources, such as light and moisture, occurs during periods of prolific foliage production by weeds. However, the race for moisture grows into a more vital step when the level of moisture stress intensifies. In a general context, it has been observed that weeds tend to exhibit higher rates of transpiration compared to the majority of crop plants while producing an equivalent quantity of dry matter. Uncontrolled growth of weeds has been

Rakesh Kumar, Pardeep Kaur & Robin

observed to significantly reduce crop yield in sorghum and pearl millet, with a potential decrease of up to 30-40% [2, 3].

MAJOR WEED FLORA

The major weed flora that can affect sorghum and pearl millet crops can vary depending on the region, climate, and specific agricultural practices. However, there are several weed species that are commonly found to compete with these crops. Here are some examples of major weed species that can be problematic in sorghum and pearl millet fields [4, 5].

Common Weed Species in Sorghum and Pearl Millet Fields

Grasses

- Barnyard grass (*Echinochloa crus-galli*)
- Witchgrass (*Panicum capillare*)
- Foxtail species (*Setaria* spp.)
- Jungle rice (*Echinochloa colona*)
- Shattercane (*Sorghum bicolor* x *S. propinquum* hybrid)

Broadleaf Weeds

- Pigweed species (*Amaranthus* spp.)
- Common lambsquarters (*Chenopodium album*)
- Velvetleaf (*Abutilon theophrasti*)
- Common purslane (*Portulaca oleracea*)
- Common wireweed (*Sida acuta*)

Sedges

- Yellow nutsedge (*Cyperus esculentus*)
- Purple nutsedge (*Cyperus rotundus*)

Other Weeds

- Johnson grass (*Sorghum halepense*)
- Annual morning glory (*Ipomoea* spp.)
- Hairy nightshade (*Solanum sarrachoides*)

The prevalence of these weed species can vary from one location to another. Additionally, weed populations can change over time due to factors like crop rotation, changes in agricultural practices, and herbicide resistance. Effective weed management strategies should include a combination of cultural, mechanical, and chemical methods tailored to the specific weed species in an area.

CRITICAL PERIOD

Managing weeds during the critical period of crop-weed competition is crucial to prevent significant yield losses in sorghum and pearl millet. The critical period can vary depending on factors like crop species, environmental conditions, and weed species.

When it comes to sorghum *(Sorghum bicolor)* and pearl millet (*Pennisetum glaucum*), the most crucial critical time for competition in weed crops is often during the early phases of crop development. Some general information is presented below; however, local conditions and specific varieties may influence the exact timing.

Sorghum (*Sorghum bicolor*):

- ***Emergence to 3-5 weeks after emergence:*** This is the most critical phase for weed control in sorghum. During this period, the crop establishes its root system, and weed competition during this time can significantly impact sorghum yield [6, 3].

Pearl Millet (*Pennisetum glaucum*):

- ***Emergence to 2-4 weeks after emergence:*** Similar to sorghum, pearl millet is most vulnerable to weed competition during its early growth stages [7, 8]. Effective weed control is important to ensure the crop has sufficient access to resources for establishment and development.

It is important to identify the specific weed species that are prevalent in an area, as well as the local climate and soil conditions. This information helps in determining the best practices and timing for weed control in sorghum and pearl millet crops. Integrated weed management strategies that combine cultural, mechanical, and chemical methods can be effective in minimizing weed-crop competition and maximizing crop yields. Always consider consulting with local agricultural extension services or experts for precise recommendations based on region and circumstances.

SORGHUM AND PEARL MILLET WEED MANAGEMENT STRATEGIES AND APPROACHES

Sorghum and pearl millet are cultivated by economically disadvantaged agriculturalists with small-scale land ownership, restricted access to agricultural resources, and limited implementation of mechanized farming techniques. Simultaneously, the soil and climatic conditions exhibit variability, thereby presenting a significant challenge in the form of weed infestation. Therefore, it is

CHAPTER 8

Integrated Weed Management in Maize

Abstract: Maize exhibits a high susceptibility to adverse effects caused by weed competition. Research conducted on crop loss has revealed the existence of a crucial time frame window commencing approximately fourteen days post-planting and persisting for a duration of approximately six weeks. It is imperative to eradicate weeds within this specific timeframe to maximize crop yield. The existence of both annual and perennial weeds presents a substantial obstacle in the cultivation of maize. Certain weed species have the potential to result in complete crop failure, with the severity of infestation varying across different geographical regions. Optimal land preparation techniques are crucial for achieving a seedbed that is devoid of weeds during the sowing process. Additionally, the practice of deep ploughing can effectively manage rhizomatous perennial weeds. The development of high-yield cultivars is crucial for enhancing competitive advantage against weeds by facilitating the rapid establishment of a dense canopy. Increased plant density results in greater shading, which subsequently leads to the suppression of early weed growth. The application of a balanced fertilizer promotes improved nutrient utilization by crops compared to weeds.

Keywords: Maize, Management, Weeds.

INTRODUCTION

Maize, one of the world's most widely cultivated cereal crops, plays a crucial role in global food security and agricultural economies [1]. However, the growth of weeds poses a significant challenge to maize cultivation, threatening yield potential and overall crop quality [2]. To address this challenge while ensuring sustainability, Integrated Weed Management (IWM) has emerged as a comprehensive and effective approach. IWM combines a spectrum of strategies that collectively manage weed populations while minimizing the environmental impact and economic burden associated with weed control [3].

The dynamic interplay between weeds, crops, and their environment underscores the complexity of weed management in maize cultivation. Weeds compete with maize for essential resources like water, nutrients, and sunlight, potentially reducing crop yields and quality. Traditional methods of weed control, such as heavy reliance on herbicides, can lead to issues such as herbicide resistance and ecological disturbances [3]. This necessitates a more holistic and adaptable

Rakesh Kumar, Pardeep Kaur & Robin

approach that IWM offers, recognizing that no single method can provide a comprehensive solution to the diverse challenges posed by weed species and environmental conditions [4].

The overarching goal of IWM in maize cultivation is to strike a balance between reducing weed pressure and maintaining the productivity, economic viability, and sustainability of the farming system. By incorporating multiple strategies, IWM aims to limit the reliance on any single tactic and reduce the likelihood of weed populations developing resistance to specific control methods. Maize (*Zea mays*) is recognized as one of the key crops that experience significant detrimental impacts due to weed competition. Crop loss studies indicate the existence of a critical timeframe, commencing as early as 14 days after sowing and lasting approximately 42 days, within which it is imperative to eradicate weeds in order to achieve maximum crop productivity. While the manifestation of symptoms such as yellowing and stunting is readily apparent in cases where weed growth is completely uncontrolled, it is important to note that significant reduction in crop yield can still occur even in the absence of such symptoms when weeds are not effectively managed during the initial stages of crop growth [5].

PRIMARY WEED CONCERNS

Various types of weeds, including annual and perennial plant species, pose a significant challenge in maize (*Zea mays*) cultivation. The slowed pace of development that is being shown by maize seedlings, coupled with the presence of widely spaced rows, fosters an optimal environment conducive to the proliferation of weeds. Unregulated proliferation of undesirable plant species can result in a reduction of maize grain production by approximately 51 to 100 percent [4, 6]. Certain weed species, such as *Rottboellia cochinchinensis* and *Striga* spp, have the potential to result in complete crop failure. The degree of infestation of various weed species exhibits variability across different geographic zones. The most frequently observed weed species found in the maize (*Zea mays*) crops are tropical crabgrass (*Digitaria ciliaris*), rice flatsedge (*Cyperus iria*), Indian goosegrass (*Eleusine indica*), Guinea grass (*Megathyrsus maximus*), yellow foxtail (*Setaria glauca*), jungle rice (*Echinochloa colona*), spotted dayflower (*Commelina maculata*), and whiteweed (*Ageratum conyzoides*) [7, 8].

WEED COMPETITION CRITICAL PERIOD

After planting, the first two to four weeks are the most critical period in terms of competitiveness for maize [5, 7]. The critical period of competition in maize refers to a pivotal timeframe during the crop's growth cycle when the presence of weeds can significantly impact its yield potential. This period, which varies depending on factors such as location, climate, and maize variety, is characterized by the maize plants transitioning from vulnerability to resilience. It is the phase when weeds and maize compete most intensely for essential resources like water, nutrients, and sunlight. Effective weed management during this critical period is crucial, as weeds that are allowed to flourish during this time can stunt the growth of maize plants and reduce final yields. Recognizing and addressing this window of vulnerability underscore the importance of timely intervention through strategies like timely cultivation, judicious herbicide application, and other integrated weed management practices. By understanding and managing the critical period of competition, farmers can optimize maize yields and ensure the crop's overall health and productivity [5, 7].

METHODS OF WEED CONTROL AND MANAGEMENT

Land Preparation

The process of land or field preparation should ensure the creation of a seedbed that is devoid of any weeds during the time of sowing. The implementation of deep ploughing techniques has been found to be effective in the management of rhizomatous perennial grass weeds, especially *Imperata cylindrica* [7, 9].

Method of Sowing/Planting

The sowing or planting of crops in organized rows at the earliest opportunity following rainfall results in favorable crop establishment and enhanced canopy development, consequently leading to improved weed suppression [7, 9, 10].

Varieties

The development of enhanced high-yield cultivars that exhibit resistance or tolerance to Striga stem borers, and diseases are expected to result in the prompt establishment of a dense canopy and strong competitiveness against weed species [7, 9, 10].

Plant population

A higher plant density facilitates early shading and minimizes weed growth. It is recommended to maintain plant densities between 40,000 and 60,000 plants per hectare [7, 9, 10].

Fertilizer

The equitable application of fertilizers (NPK) offers enhanced prospects for crops to efficiently utilize nutrients in comparison to weeds. Ideally, the application of fertilizer should be localized to prevent the stimulation of weed proliferation. The

CHAPTER 9

Integrated Weed Management in Sugarcane

Abstract: Sugarcane has considerable economic importance as a cash crop in India. Nevertheless, the yield of sugarcane cultivation in India is somewhat lower in comparison to other nations. The presence of weed infestation is a significant obstacle to the improvement of sugarcane farming in the majority of sugarcane-growing regions within the country. The issue of weed proliferation is intensified by the overutilization of fertilizers, increased plant spacing, frequent irrigation, and the prolonged duration needed for complete seedling germination. Therefore, the implementation of a comprehensive weed management strategy is crucial in the cultivation of sugarcane. This chapter entails the integration of many approaches that span the whole farming process, beginning with field preparation and persisting until the harvest stage. The objectives of these approaches are to facilitate the cultivation of sugarcane while concurrently inhibiting the proliferation of weeds.

Keywords: Management, Sugarcane, Weeds.

INTRODUCTION

Sugarcane (*Saccharum officinarum*), a vital cash crop with multifaceted applications ranging from sugar production to bioenergy, plays a crucial role in global agriculture and economies [1, 2]. However, the persistence of weeds poses a substantial threat to sugarcane cultivation, potentially leading to reduced yields, lowered product quality, and increased production costs [2]. In response to these challenges, Integrated Weed Management (IWM) has emerged as a comprehensive strategy aimed at not only mitigating weed pressure but also promoting the sustainability of sugarcane farming systems [3]. This chapter delves into the principles and practices of IWM as applied to sugarcane cultivation, emphasizing its potential to revolutionize weed management strategies, enhance productivity, and ensure the long-term viability of the sugarcane industry.

The complex relationship between sugarcane and weeds underscores the need for proactive and multidimensional approaches to weed control. Weeds compete with sugarcane for essential resources such as water, nutrients, and sunlight, potentially undermining crop growth and overall economic viability [4]. Traditional methods of weed management, including heavy reliance on herbicides, often fall short of

Rakesh Kumar, Pardeep Kaur & Robin

providing a sustainable and holistic solution. IWM addresses this challenge by integrating a variety of tactics—ranging from cultural and mechanical to biological and chemical methods—into a cohesive strategy that adapts to local conditions and weed species dynamics [3].

Integrated Weed Management represents a shift from isolated and reactionary weed control practices to a unified framework that harmonizes various interventions [5]. By optimizing the use of different methods during critical stages of sugarcane growth, IWM aims to reduce the reliance on any single approach, thereby diminishing the risk of weed resistance development and minimizing the environmental footprint of weed management.

In the ensuing chapter, we will explore the components of Integrated Weed Management in sugarcane cultivation, examining the role each strategy plays and their potential synergies. We will also delve into the challenges and benefits associated with IWM, all the while underscoring the significance of customizing these practices to suit specific regional and environmental contexts. By embracing the principles of Integrated Weed Management, sugarcane producers can forge a path toward sustainable productivity, economic prosperity, and environmental stewardship, ensuring the continued resilience and success of the sugarcane industry in the face of evolving agricultural and environmental challenges.

Sugarcane is a significant cash crop in India. However, its productivity in India is relatively lower when compared to other countries where sugarcane is cultivated [6]. Low productivity can be attributed to several factors, such as varietal imbalances, inadequate utilization of irrigation and fertilizers, and increased incidence of insect and disease infestation. However, the most significant factor contributing to low productivity is the presence of weed infestation. The threat of weed infestation poses a major barrier to the enhancement of sugarcane cultivation in most of the sugarcane-growing areas within the nation. Numerous researchers have reported that uncontrolled weed growth can lead to a significant reduction of 60-80 percent in cane yield [3]. In addition to the aforementioned effects, the presence of weeds can also lead to an increase in harvest costs. This is primarily due to the necessity of leaving a greater amount of sugarcane un-harvested in the field. Furthermore, weeds can negatively impact sugar yield within the factory by contributing to an elevated level of thrash residue during the milling process. Weeds have the ability to deplete soil nutrients, reduce soil moisture, and release root exudates that can be harmful to crops [3].

The problem of weed proliferation is exacerbated by the excessive use of fertilizers, wider plant spacing, frequent irrigation, and the extended time required for the full germination of seedlings [7]. The growth of weeds is observed to occur significantly within 4-6 weeks after planting and becomes extremely vigorous between 8-12 weeks. It has been empirically observed that the presence of weeds in the agricultural field during the initial 2-5 months can result in a reduction of crop yield ranging from 50-80 percent. The extent of this reduction is contingent upon the specific weed species present and their density within the given area. Hence, the most critical period of weed-crop competition is said to be 1-3 months after planting [7].

MAJOR WEED FLORA

Weed flora in sugarcane varies from place to place depending upon agro-climatic conditions and the season of cane cultivation [7, 8]. Some important weeds of different seasons are listed below:

Weeds Emerging in Autumn Planted Crop

During the autumn season, specifically in October, it is observed that broadleaf weeds tend to grow before the emergence of sugarcane seedlings in the winter. The names of some of these weeds are *Chenopodium album, Lathyrus aphaca*, *Vicia* spp., *Anagallis arvensis, Convolvulus arvensis, Fumaria parviflora, and Solanum nigrum*. A second flush of weeds that emerges with the onset of monsoon are mostly grassy weeds [7, 8].

Weeds Emerging in Spring-Planted Crop

The predominant plant species found under such conditions primarily include broadleaf winter annuals, along with a few perennial weeds such as *Cyperus rotundus*, *Cynodon dactylon*, and *Sorghum halepense*. These species have been observed to persist even during the rainy season [7, 8].

Weeds Emerging during Rainy Season

The emergence of weeds during the rainy season primarily consists of annual grass species, such as *Echinochloa colona, Dactyloctenium aegyptium, Digitaria sanguinalis, Eleusine indica, Brachiaria mutica, Eragrostis tenella,etc* [7, 8]. Some broadleaf weeds that commonly appear during this period are *Trianthema portulacastrum, Portulaca oleracea, Digera arvensis, Eclipta alba, Ageratum conyzoides, Commelina benghalensis, Achyranthes aspera, Ipomoea pes-tigridis, Physalis divaricata, Phyllanthus niruri, Tridax procumbens, Tribulus terrestris, Euphorbia hirta, Celosia argentea,* and *Amaranthus viridis* [7, 8].

CHAPTER 10

Integrated Weed Management in Cotton

Abstract: Cotton is generally cultivated during the wet season. As a result, a large number of weeds thrive in this crop. It is very susceptible to weed competition, especially during the first 50-60 days post-planting, resulting in yield losses ranging from 16% to 63%. Consequently, it is critical to maintain a weed-free environment throughout this period in order to maximize crop output. The chapter highlights the significance of integrating cultural, mechanical, chemical, and biological control methods to create a synergistic effect that reduces weed competition, enhances crop yield, and sustains soil health.

Keywords: Cotton, Management, Weeds.

INTRODUCTION

Weeds have long been recognized as a significant challenge in cotton cultivation, causing substantial economic losses and reducing crop quality and yield. Conventional methods of weed control, such as the overreliance on herbicides, have led to issues like herbicide resistance, environmental concerns, and the disruption of natural ecosystems. In response to these challenges, Integrated Weed Management (IWM) has emerged as a holistic and sustainable approach to effectively manage weed populations in cotton fields.

Integrated weed management involves the thoughtful integration of various weed control strategies to minimize weed competition and damage while promoting sustainable cotton production. This approach recognizes that weeds are not isolated entities but rather a complex part of the agroecosystem. As such, IWM combines cultural, biological, physical, and chemical control methods to create a comprehensive and adaptable weed management strategy.

Cotton, a globally vital fiber and cash crop, is particularly susceptible to weed competition due to its relatively slow early growth and limited ability to outcompete aggressive weed species [1, 2]. The negative impacts of weeds on cotton include reduced nutrient and water availability, increased susceptibility to pests and diseases, hindered mechanical harvesting, and reduced fiber quality. IWM addresses these concerns by emphasizing strategies that enhance crop

Rakesh Kumar, Pardeep Kaur & Robin

competitiveness, disrupt weed growth and reproduction, and minimize the reliance on single control measures.

This chapter sets the stage for exploring the multifaceted approach of integrated weed management in cotton production. By understanding the underlying principles and diverse techniques that constitute IWM, cotton farmers can make informed decisions to strike a balance between weed control, economic viability, and environmental sustainability. Through the integration of various approaches, IWM offers a promising pathway to mitigate the challenges posed by weeds, ensuring a more resilient and productive cotton cultivation system for the future.

Cotton cultivation often occurs during the rainy season. Consequently, a substantial number of weeds proliferate in this crop. Furthermore, the presence of weeds in cotton cultivation presents significant challenges, mostly because of their ability to thrive in wider spacing, their delayed germination and initial slow development, and the need for increased fertilizer treatment [3]. The existence of tall-growing and climbing weed species, which have a tendency to appear later in the growing season, might impede the process of harvesting and other agricultural activities. Weed seeds and desiccated foliage falling onto exposed cotton balls are known to diminish the overall quality of lint [4].

Cotton is highly vulnerable to weed competition, particularly over the initial 50–60 days after planting the seeds, resulting in a yield reduction ranging from 10% to 90% [2, 5]. Hence, it is important to maintain a weed-free environment during this particular time in order to get the highest possible crop production [4, 6].

MAJOR WEED FLORA

Though weed species vary from region to region, the most common species that seem to occur are *Cynodon dactylon, Echinochloa colona, Digitaria sanguinalis, Cyperus rotundus, Digera arvensis, Xanthium strumarium,Corchorus* spp. *Trianthema portulacastrum, Portulaca oleracea, Celosia argentea, Tridax procumbens, Commelina benghalensis, Tribulus terrestris, Leucas aspera, Convolvulus arvensis, Cyanotis axillaris, Setaria viridis, Sorghum halepense,* and *Eleusine indica* [2, 6, 7].

WEED MANAGEMENT STRATEGY

Methods of weed control may be classified as cultural, mechanical, and chemical measures. The effective management of weeds in cotton can be achieved through the judicious integration of various methods. Cultural practices play a crucial role in preventing the occurrence and spread of weeds, as well as reducing the severity of weed-related issues. Additionally, the application of herbicides before the emergence of cotton plants effectively manages weeds during the early stages of crop growth. Furthermore, mechanical weeding serves as a subsequent measure to control weeds during later stages [6, 7].

Cultural Practices

It includes systematic routine agricultural activities. These include crop rotation, field preparation, careful selection of appropriate crop varieties, precise timing and methods of sowing, determining optimal seed rates and spacing, performing gap filling and thinning operations, implementing intercropping strategies, applying manure and fertilizers, and ensuring proper irrigation techniques, among others. Judicious execution and manipulation of these operations reduce the incidence and intensity of the weed problem [7, 8].

Crop Rotation

It is a practice that helps prevent the detrimental association between weeds and crop plants, as well as the subsequent proliferation of weeds. In the northern region of India, the cultivation of various crops such as wheat, gram, pea, linseed, and berseem follows the harvest of cotton. In the irrigated regions of Southern India, a rotational cropping system involving sorghum, finger millet (ragi), and cotton has been observed [7, 8].

Field Preparation

Due to its deep-rooted nature, cotton necessitates a thoroughly pulverized seedbed to ensure consistent germination and optimal crop stand. Additionally, it is imperative to eradicate perennial weeds and eliminate the stubbles of the previous crop during the process of field preparation [7 - 9].

Timely Sowing

It is an important factor that considerably determines cotton yield. Sowing cotton late in the season not only leads to a significant decrease in yield but also contributes to an increase in insect pests, disease, and weed infestation. Therefore, it is imperative to adhere to the recommended optimal sowing time for a specific geographical region [7 - 9].

Seed Rate and Spacing

The seed rate and spacing of cotton plants can vary depending on factors such as the variety of cotton, the growth habit of the plants, the fertility of the soil, and the specific production practices being employed. To effectively suppress weed

CHAPTER 11

Integrated Weed Management in Oilseeds

Abstract: In India's economy, oilseeds rank second only to cereal grains as the main source of vegetable oils. They are grown on 24 million hectares under various agroecological conditions, cropping techniques, and management practices. Weeds compete with crops for light, moisture, nutrients, and space and pose significant threats to oilseed crops, impacting yield and quality. This chapter provides a concise overview of the primary weed species found in oilseed crops, along with their associated reduction in crop yield and recommended methods for control. Integrated weed management establishes a balanced agricultural ecosystem, strengthening sustainability and productivity in oilseed cultivation.

Keywords: Management, Oil seeds, Weeds.

INTRODUCTION

Oilseeds serve as the primary source material for vegetable oils and hold a prominent position in India's national economy, second only to food grains. They are cultivated in an area of about 24 million hectares, encompassing a diverse array of agroecological conditions, cropping systems, and management practices [1]. India ranks as the fifth most significant global contributor to the vegetable oil economy, with 7.4% oilseed production [2]. However, the average productivity remains notably low, primarily attributed to the cultivation of oilseeds in marginal and sub-marginal lands, as well as the utilization of inadequate quantities of seeds, fertilizers, water, pesticides, and other necessary inputs [2, 3].

The Kharif crops are cultivated under rain-fed conditions, whereas Rabi crops are cultivated utilizing residual moisture from previous crops or with limited access to irrigation facilities [4, 5]. One of the primary limitations in augmenting production is the insufficient implementation of weed control strategies for these crops. The prevalence of weed infestation in Kharif oilseeds is amplified as a result of the prominent presence of grasses, in addition to sedges and broadleaved weeds [1]. The presence of a warm and moist climate, coupled with abundant precipitation, creates optimal conditions for the proliferation of weeds, which in turn negatively impacts the growth and development of crops. The issue of weed

Rakesh Kumar, Pardeep Kaur & Robin

infestation during the Rabi season exhibits a reduced level of severity and is comparatively more manageable.

The primary cause of diminished productivity in oilseed crops can be attributed to the application of insufficient inputs. Insufficiency in the implementation of weed control strategies in oil seed crops is a significant limiting factor in achieving increased production levels. Weeds engage in competitive interactions with oilseed crops, vying for essential resources such as light, moisture, nutrients, and space [6]. This competition results in a reduction in crop yield, ranging from 18% in castor to as high as 76% in soybean. The critical phase in which crop weeds compete for resources exhibits variation, ranging from 30 to 60 days after sowing (DAS) in groundnut and soybean to 15 to 40 DAS in linseed, sesame, safflower, niger, and rape seed-mustard. In order to surmount this obstacle and achieve increased oilseed production and productivity, a comprehensive approach will be required to mitigate weed competition [1].

MAJOR WEED FLORA OF OILSEED CROPS

The major weeds that cause severe yield loss in oilseed crops are shown in Table **1**.

Table 1. Major weed flora affecting oilseed crops.

S. No.	Weed Flora	Scientific Name
1	Grassy weeds	*Digitaria adscendens, Eleusine indica, Bracharia mutica, Phalaris minor, Avena ludoviciana*
2	Broadleaf weeds	*Commelina benghalensis, Celosia argentea, Amaranthus polygamous, Amaranthus viridis, Argemone mexicana, Chenopodium album, Cichorium intybus, Anagallis arvensis*
3	Common perennial and annual grasses	*Cynodon dactylon, Echinochloa colona, Panicum* spp., *Cyperus rotundus*
4	Parasitic weeds	*Cuscuta* spp. on niger and linseed, *Orobanche* spp. on mustard
5	New problem weeds	*Vicia* spp. on lentil *Asphodelus tenuifolius* on mustard

CRITICAL PERIOD OF CROP WEED COMPETITION AND EXTENT OF CROP LOSSES DUE TO WEEDS

Oilseed crops exhibit a comparatively prolonged duration for establishment during their initial growth phase, with the exception of certain crops such as groundnut and soybean. In general, oilseeds exhibit a reduced canopy structure that limits their ability to compete with weeds. If the weeds are effectively controlled during a specific stage of crop growth, it has been observed that the oilseed crop yield can be enhanced [1, 7]. The extent of crop losses due to weeds is briefed in Table **2**.

Table 2. Critical period of crop weed competition, nutrient removal, and yield losses in oilseeds due to weeds.

S. No.	Oilseed Crop	Critical Period of Crop-weed Competition (DAS)	Average Yield Loss (%)	Nutrient Depletion by Weeds (kg/ha)		
				N	P	K
1.	Groundnut	40-60	46	39.0	9.1	23.5
2.	Rapeseed-mustard	15-40	23	22.0	3.0	12.0
3.	Sesamum	15-45	49	-	-	-
4.	Linseed	20-45	39	32.0	3.0	13.0
5.	Soybean	30-50	76	26.1	2.7	79.9
6.	Safflower	15-45	28	-	-	-
7.	Sunflower	15-40	-	-	-	-
8.	Castor	30-60	18	-	-	-
9.	Niger	15-45	22	-	-	-

WEED MANAGEMENT PRACTICES

Cultural Practices

A major portion of the weed can be managed by preparatory cultivation, adjustment in time of sowing, planting methods, careful selection of suitable oilseed crop varieties, precise time, rate, and methods of fertilizer application, inter-cultivation, hoeing, hand weeding or mechanical weeding with tools and implements [7]. In general, hand weeding during the critical time phase of crop and weed competition is required to control the weeds in oilseed crops [7, 8].

Groundnut: Manual weedings on 20 and 40 DAS.

Sesamum and Sunflower: Manual weedings on 30 and 40 DAS.

Soybean: Harrowing twice before sowing, followed by manual weeding on 20 DAS.

Castor: Inter-cultivation with bullock drawn cultivator (or) push and pull types wheel hoes.

Niger: Manual weeding between 30-35 DAS.

CHAPTER 12

Integrated Weed Management in Pulses

Abstract: The cultivation of pulses in India is carried out across 23 million hectares, which encompasses a wide range of agroecological conditions, cropping techniques, and management practices. They are planted throughout both the Kharif and Rabi seasons. The average productivity of pulse crops in India is somewhat lower than the productivity levels reported in several other pulse-growing countries globally. The problem of weed infestation is a substantial hindrance to attaining the highest possible crop output. This chapter discusses the critical period of crop-weed competition in different pulse crops. The list of predominant weed species systematically classified based on their seasonal occurrences, along with corresponding herbicides recommended for their control, is also included.

Keywords: Management, Pulses, Weeds.

INTRODUCTION

In the realm of agriculture, pulses play a crucial role, not only for their nutritional value but also for their ability to enhance soil fertility [1]. However, the bountiful growth of pulses can often be challenged by the relentless presence of weeds, which compete for resources and hinder optimal crop development [2]. This is where Integrated Weed Management (IWM) steps in as a comprehensive approach, amalgamating various strategies to efficiently tackle weed-related predicaments while maintaining the sustainability and productivity of pulse crops.

In India, the cultivation of pulses spans approximately 23 million hectares, encompassing a diverse array of agroecological conditions, cropping systems, and management practices. They are cultivated in both the Kharif and Rabi seasons. The legume crops like red gram, black gram, green gram, cowpea, moth bean, and horse gram are typically cultivated during the Kharif season. On the other hand, chickpeas, peas, lentils, and french beans are commonly sown during the Rabi season. During the Zaid season, which occurs from February to April, the cultivation of green gram and black gram is also undertaken [3].

The average productivity of pulse crops in India is significantly lower, specifically at 755 kg/ha, when compared to the productivity levels observed in

Rakesh Kumar, Pardeep Kaur & Robin

several other pulse-growing nations worldwide [4]. The issue of weed infestation poses a significant obstacle to achieving the maximum potential yield. The observed reductions in crop yield resulting from weed infestation exhibited a range of values, with red gram experiencing a 26.9% decrease, chickpeas experiencing a 75.3% decrease, and peas experiencing an 80.5% decrease. The cumulative pulse crop losses resulting from conventional agricultural practices have been calculated to be 739.80 thousand metric tons, with an estimated market value of 3251.10 million [2].

MAJOR WEED FLORA

The issue of weed infestation is particularly prominent in pulse crops during the Kharif season, which is characterized by high temperatures and frequent precipitation. In Kharif pulses, grasses typically exhibit a higher abundance compared to sedges and broad-leaved weeds. In the case of “Rabi” pulses, the issue of weed infestation is relatively minimal and can be effectively controlled [2, 5].

The initial growth of pulse crops is slow, and hence, they are more susceptible to weed competition at the early stages. The first 20 to 40 days are critical for short-duration summer and rainy season pulses, whereas the first 15 to 60 days are crucial for medium and late-maturing crops like pigeon pea. For winter pulses, the first 30 to 60 days are determined to be critical for crop-weed competition of several crops, which are listed in Table **1** [6, 7].

Table 1. Competition between crops and weeds during a critical period for a variety of pulse crops.

S. No.	Name of the Pulse Crop	Critical Period (days after sowing)
1.	Red gram	15-60
2.	Green gram	15-45
3.	Black gram	15-45
4.	Cowpea	15-35
5.	Chickpea	30-60
6.	Peas	30-45
7.	Lentil	30-60

Although the occurrence of weeds in pulses varies with agroecological circumstances and level of management, some of the most common weeds are listed here. *Echinochloa colona, Eleusine indica, Digitaria sanguinalis, Setaria glauca,* and *Dactyloctenium aegyptium* are predominant grassy weeds, while

Commelina benghalensis, Celosia argentea, Digera arvensis, Euphorbia hirta, Phyllanthus niruri, and *Trianthema monogyna* are the major broadleaved weeds in Kharif and Zaid pulses. In Rabi pulses, *Chenopodium album, Asphodelus tenuifolius, Melilotus alba, Melilotus indica,* and *Vicia* spp. are the most serious non-grassy weeds. *Phalaris minor* and *Avena ludoviciana* are common grassy weeds found in North India in Rabi pulses, whereas *Pluchea lanceolata* and *Carthamus oxycantha* are extremely detrimental non-grassy weeds in unirrigated Rabi pulses. *Cyperus rotundus* and *Cynodon dactylon* are the most prevalent perennial weeds in pulses found almost everywhere and in all seasons. *Cuscuta* spp. (in Andhra Pradesh) is reported to be a very problematic parasitic weed, particularly in rice fallow pulses, mainly in green gram and black gram [2, 5]. The following is a comprehensive list of the primary weed species encountered in pulse cultivation, categorized according to their respective seasons.

Kharif/Zaid Season

Digitaria sanguinalis, Cynodon dactylon, Echinochloa colona, Dactyloctenium aegyptium, Eleusisne indica, Eragrostis japonica, Setaria glauca, Trianthema portulacastrum, Digera arvensis, Celosia argentea, Cleome viscosa, Commelina benghalensis, Euphorbia hirta, Eclipta alba, Phyllanthus niruri, Portulaca oleracea, Physalis devaricata, Solanum nigrum, Cyperus rotundus, Cyperus difformis, and *Cyperus iria* [6, 7].

Rabi Season

Phalaris minor, Avena ludoviciana, Lolium temulentum, Poa annua, Polypogon monspeliensis, Cyperus rotundus, Chenopodium album, Spergula arvensis, Carthamus oxycantha, Pluchea lanceolata, Convolvulus arvensis, Fumaria parviflora, Melilotus alba, Melilotus indica, Vicia sativa, Asphodelus tenuifolius, Anagallis arvensis, Lathyrus aphaca, Medicago denticulata,etc [6, 7].

Weed Management Strategy

Cultural, mechanical, and chemical approaches play significant roles in the management of weeds. The strategic incorporation and use of these techniques may provide efficient, cost-effective, and long-lasting weed management in pulse crops [5, 7].

Cultural Methods

Cultural practices such as crop rotation, preparatory cultivation, appropriate timing of sowing, adequate planting methods, and precise timing and methods of

CHAPTER 13

Herbicides

Abstract: Herbicides are chemicals used to kill weeds or inhibit their growth. According to the latest compilation of registered pesticides under the Insecticide Act of 1968, a total of 33 herbicides have been officially registered in India. Herbicides are classified on the basis of their chemical composition, selectivity, mode of action, site, and time of application. The chapter provides a comprehensive overview of diverse instances of herbicides categorized accordingly. The typical herbicide formulations commonly found in the market include water-soluble powders, hydrophilic powder, water-soluble concentrates, emulsifiable concentrates, and granules. The application rates of herbicides are influenced by several factors, including soil composition, weed crop species/varieties, the growth stage of weeds, herbicide formulations, and the duration of weed control programs. The current chapter also examines different methodologies for efficiently managing the proliferation of undesired vegetation, such as foliar spraying, soil application, and seed treatment.

Keywords: Herbicides, Management, Weeds.

INTRODUCTION

Herbicides, a crucial category of agrochemicals, play a pivotal role in crop production and weed management. Herbicides are chemical substances specifically designed to target and eliminate unwanted plants, commonly referred to as weeds, while minimizing the impact on desirable crops and vegetation. Their development and application have revolutionized agricultural practices and have had far-reaching implications for food production, environmental conservation, and sustainable land use. There are currently more than 250 herbicides that are commercially available in the global market [1].

The history of herbicides dates back to ancient times when early civilizations employed various natural substances to control weed growth. However, it was not until the 20th century that substantial progress was achieved in the development of the technology of synthetic herbicides. These innovations paved the way for more targeted and efficient weed management, allowing farmers to enhance crop yields and streamline cultivation practices [1].

Rakesh Kumar, Pardeep Kaur & Robin

Today, herbicides come in various formulations and modes of action, each tailored to address different weed species and environmental conditions. They can be broadly categorized into two main types: selective herbicides, which target specific weed types while leaving desirable crops undamaged, and non-selective herbicides, which eliminate a wide range of vegetation and are often used in scenarios such as clearing land or maintaining weed-free areas like sidewalks and driveways [1].

As the worldwide population continues to increase, the demand for food and other agrarian crops intensifies. This places increased pressure on agricultural systems to maximize productivity and efficiency. Herbicides, when used judiciously and in combination with other sustainable practices, contribute to achieving these goals by reducing competition between crops and weeds for resources such as water, nutrients, and sunlight [2, 3].

However, the use of herbicides also raises important discussions concerning potential environmental and health impacts. The potential for herbicide residues in food products and their effects on non-target organisms and ecosystems have prompted ongoing research and regulatory efforts to strike a balance between agricultural productivity and ecological integrity [4, 5].

It is essential to continually evaluate and adapt the use of herbicides in light of advancing scientific knowledge and a growing emphasis on sustainability to ensure the long-term health of both agricultural systems and the environment.

LIST OF HERBICIDES REGISTERED IN INDIA

In India, only 33 herbicides have been registered so far, as per the recent list of pesticides registered under the Insecticide Act 1968. These include alachlor, anilofos, atrazine, benthiocarb (thiobencarb) butachlor, chlorimuron ethyl, dalapon, diclofop methyl, diuron 2,4-D, fluchloralin, glyphosate, glufosinate ammonium, iso-proturon, MCPA (4-chloro-2-methylphenoxy)acetic acid), methabenzthiazuron metolachlor, metoxuron, metsulfuron methyl, metribuzin, MSMA oxadiargyl, oxadiazon, oxyflourfen, paraquat dichloride, pendimethalin, pretilachlor, propanil, simazine sirmate, triallate, T.C.A. (trichloroacetic acid), and trifluralin [1, 6].

HERBICIDE CLASSIFICATION

Herbicides are classified in many ways [1, 6]. Some of these are:

Classification Based on Chemical Composition

Inorganic Herbicides

These herbicides have only limited use.

Acids: Arsenic acid, sulfuric acid

Salts: Borax, copper sulfate, sodium chlorate

Organic Herbicides

Most of the herbicides in use are organic compounds. Some important groups are as follows:

Aliphatics: Acrolin, dalapon, TCA, *etc*.

Amides: Alachlor, butachlor, propanil

Arsenicals: MSMA, DSMA

Bipyridiliums: Paraquat, diquat

Di-nitroanilines: Fluchloralin, pendimethalin

Phenols: Dinoseb

Dipenylethers: Nitrofen, oxyfluorfen

Phenoxyacids: 2, 4-D, MCPA

Thiocarbamates: Thiobencarb, triallate

Triazines: Atrazine, simazine, terbutryn, metribuzin

Urea: Diuron, iso-proturon, methabenz thiazuron, metoxuron

Unclassified: Glyphosate, oxadiazon, anilofos, and many others

Classification Based on Selectivity

Selective Herbicides: These herbicides kill or damage the weeds and do not harm the crop plants, provided they are applied at recommended rates and in a proper way *e.g.*, 2, 4-D, atrazine, butachlor, *etc*.

SUBJECT INDEX

A

Abutilon theophrasti 63, 91
Acanthospermum hispidum 20
Achyranthes aspera 80
Acid 17, 110, 111, 113
acetic 110
arsenic 111
glacial acetic 17
sulfuric 111
trichloroacetic 110
Adapting irrigation practices 69
Adsorptive capacities 113
Agricultural 5, 6, 19, 21, 27, 28, 31, 36, 38, 41, 52, 58, 62, 67, 69, 70, 77, 80, 84, 87, 88, 92, 110
activities 87, 88
crops 27, 52, 62, 67
ecosystem 6, 21, 70, 92
fields 28, 41, 80
management 5
production 19
productivity 5, 36, 38, 110
sustainability 77
systems 31, 69, 84, 110
techniques 58
Agriculturalists 62
Agroecological conditions 94, 101
Agropyron repens 19
Air, entrapped 3
Algae, horse hair 43
Allelopathy 36
Allium cepa 19
Amalgamated approaches 62
Arid, inhabit 62
Atrazine, application of 74, 83
Autumn planted crop 80
Avena sativa 2

B

Balanced fertilizer 71
Bank, seed 30
Barnyard grass 43, 63, 69
Basal fertilizer 47
Bio-control agent 27
Biodiversity loss 36
Bioherbicides 27, 48
Biological 30, 48, 49, 59
agents 49
control 30, 48, 59
Biotic factors 33
Blank herbarium label 15, 16
Brassica 3, 55
juncea 55
napus 55
Broadleaf weeds 53, 63, 69, 80, 95, 98, 99

C

Canary grass 53, 56
Cane 80, 81, 84
cultivation 80
sprouting, rapid 81, 84
Canopy 71, 73, 76, 82
dense 71, 73
development 76
Chemical(s) 24, 49
inhibitory 24
weedicides 49
Climate 4, 33, 34, 52, 63, 64, 72, 75, 94
conditions 52, 64
moist 94
Collection and preservation of weed specimens 13
Conditions 3, 29, 35, 49, 69, 70, 80, 84, 94, 97
agro-climatic 80
drought 29
preventing 70
rain-fed 94
weather 97
Conduct sawing activities 65
Content 35, 113
organic matter 35

Rakesh Kumar, Pardeep Kaur & Robin

Control 24, 57, 58, 105, 106, 118
germination 105
grassy weeds 58
leguminous 57
parasitic weeds 24
spray drift 118
grasses and broadleaved weeds 106
Control measures 29, 67, 82, 98
isolated 98
mechanical weed 67
weed 82
Control methods 24, 30, 36, 69, 72, 75, 84, 86, 92, 104
biological 24, 86
chemical 86
mechanical weed 104
traditional 75
weed 69, 84
Control techniques 44, 58
weed 44
Cotton 86, 87, 88, 90
fields 86
plants 88
production 87
seedlings 90
Crops 1, 2, 3, 5, 12, 25, 27, 29, 30, 37, 38, 41, 48, 54, 57, 59, 62, 64, 65, 69, 73, 82, 84, 86, 87, 89, 94, 95, 96, 99, 102, 104, 105, 106, 109, 119
canopy 89
critical 69
cultivation 119
development 48, 57, 62, 64, 82
economic 84
ecosystem 1, 3
growth 8, 72, 78, 88, 92, 96
harming 30
injury 12
mimicry 37
plantation 3, 29
production 87, 109
productivity 1, 5, 119
seed 95
seeds 37
transplanted 41
vegetable 2
weed competition 95
Cropland 4, 21, 41, 94, 98, 101
weeds 21
systems 4, 41, 94, 98, 101
Cropping techniques 65, 94, 101

D

Dense canopy formation 76
Deplete soil nutrients 79
Detached stem fragments 27
Digestive system 29
Diseases 4, 28, 36, 45, 46, 55, 65, 73, 81, 82, 86, 88
broom 28
infectious 4
mycoplasmal 28
Dispersal, seed 27, 35, 43, 75
Diversity, weed 21, 107
Drainage, efficient 65

E

Economic 1
activities 1
implications 1
Economies 1, 5, 71, 78, 94, 99
agricultural 71
vegetable oil 94
Ecosystems 5, 8, 21, 23, 31, 33, 34, 35, 36, 38, 40, 69, 86, 110
deep-water 40
natural 23, 34, 35, 36, 86
Eragrostis japonica 103

F

Farmer collaboration 75
Farming system 69, 72
Farmyard manure 54, 66
Fertilization 29, 76
applying balanced 76
Fertilizer management 46, 66, 76
Flowering 26, 27, 28, 47, 54, 90, 105
process 28
stage 90
Food 5, 6, 24, 50, 77, 110
products 110
security 5, 6, 24, 50, 77
Food production 6, 109, 118, 119
enhancing 119
global 118
systems 6
Forest trees 29

Fumaria parviflora 80, 103
Fungal pathogens 48
Fungicides 81, 116
  organic-mercurial 81

G

Germinates, seed 24
Germination 26, 28, 34, 36, 37, 43, 45, 53, 54, 65, 66, 79, 81, 82, 83, 88, 89
  accelerated 81
  behavior 37
  consistent 65, 66, 81, 88
  weed 54, 83
Glyphosate-resistant cotton 91
Grain formation 46
Grassy 52, 55, 56, 59
  infested 55
Grassy weeds 53, 55, 74, 80, 91, 98, 99
  controlling 55, 98
  managing 91
Green gram intercropping systems 104
Growth 28, 29, 33, 34, 35, 36, 45, 53, 54, 56, 57, 66, 68, 76, 81, 82, 83, 89, 101
  bountiful 101
  hormones 54
  rapid 33, 76

H

Hand hoeing techniques 83
Harrowing techniques 67
Harvesting, hindered mechanical 86
Hay fever 1, 4
Health 5, 77, 107, 118, 119
  ecosystem 118
  environmental 5, 77, 107, 119
Herbicide 49, 50, 56, 59, 63, 71, 75, 81, 86, 92, 109, 110, 113, 115
  application techniques 113
  applications 59, 75, 81
  chemical 49
  classification 110
  formulations 109, 113
  microbial 49
  residues 110
  resistance 50, 63, 71, 86, 92
  rotation 56
  spraying 115
High 65, 71, 76
  -intensity cropping 65
  -yield cultivars 71, 76
Hoeing 56, 57, 82, 83, 90, 96, 97
  initial 57, 90
  performing 83
  single dry 56

I

Imidazolinones 27
Indian goosegrass 72
Indigenous weeds 20
Infestation 15, 16, 26, 27, 29, 44, 59, 65, 71, 72, 79, 95
  disease 79
  fungal pest 15
  insect 16
Inhibitory compounds, transmitting 30
Inorganic herbicides 111
Integrated weed control 58
Inter-cropping 30, 65, 68, 83, 89, 90, 91, 104
  systems 68, 83, 91, 104
  techniques 65, 89
Inter-cultivation 89, 90, 96
  techniques 90
Inter-row cultivation equipment 75
Irrigation 29, 52, 88, 89, 94
  facilities 94
  method 89
  techniques 88
  water 29, 52

L

Leaf 17, 42, 83
  blade 17, 42
  canopy 83
Leaf sheaths 17, 18, 42
  overlapping 42
  tube-shaped 42

M

Maize 71, 72, 73, 74, 76
  crop 74
  cultivation 71, 72, 74, 76
  grain production 72
  plants transitioning 73
  seedlings 72
Maize farming 76, 77

systems 76
Manual 74, 92
control methods 92
removal, single 74
Manual weeding 48, 75, 76, 90, 92, 96, 99, 107
repeated 48
techniques 75
Manure, organic 82, 89
Mechanical 40, 41, 90, 92, 104
cultivation 92
techniques 40, 41, 90, 104
Mechanical weed 48, 67, 70, 76, 82
control 67, 70, 76, 82
management systems 48
Mechanical weeding 55, 104
methods 55
techniques 104
Mechanized farming techniques 64
Mold fungus 16
Monocropping systems 44

N

Nations, pulse-growing 102
Natural enemies 37
Nitrogen 44, 56, 90
-based fertilizers 56, 90
fixation 44
Nutrient(s) 69, 84, 96
benefit 84
depletion 96
management 69

O

Oil 30, 94, 95
diesel 30
seeds 94
Oilseed 94, 100
cultivation 94
production 94, 100
Organic 111, 113
compounds 111
herbicides 111
matter 113

P

Parasite(s) 23, 24, 25, 26, 27, 29, 30
infestations 23
viable 25
Phosphoric fertilizers 52, 56
Plant(s) 4, 27, 30
breeding 30
communities 4
orchard 27
Plant density 46, 66, 73, 81
target 66
Process 19, 22, 25, 26, 28, 45, 47, 48, 54, 73, 75, 78, 79, 81, 82, 83, 87, 90
farming 78, 81
fermentation 54
milling 79
picking 90
propagation 19
puddling 47
Productivity 23, 72, 73, 77, 78, 79, 85, 94, 95, 99, 101
compromised land 23
sustainable 79
sustaining 77, 99

R

Rabi crops 65, 94
irrigated 65
Rabi pulses 103
unirrigated 103
Rabi seasons 95, 101, 103
Resistant crops 105
Rice 3, 37, 40, 41, 43, 44, 45, 46, 47, 48, 49, 50, 53, 114
crops 43
cultivars 41, 50
fields 3, 40, 43, 49
herbicides 114
plants 37, 45, 46, 48, 49, 50
production 40
puddle-seeded 46
red 44
seeded 45
seedlings 47
systems 50
transplanted 46, 47
-wheat rotation 53
Rice cultivation 40, 41, 43, 44, 47, 48, 50
system 50
Rottboellia cochinchinensis seeds 38

S

Saccharum officinarum 2, 78
Seed 28, 47, 48
  coat, hard 28
  germination 47, 48
Soil 3, 4, 25, 27, 28, 33, 34, 35, 36, 46, 47, 48, 49, 52, 53, 55, 56, 57, 59, 64, 66, 67, 69, 75, 79, 82, 86, 97, 101, 104, 106, 109, 112
  composition 36, 109
  conditions 33, 34, 56, 64, 67, 75, 104
  erosion 57
  fertility 25, 27, 101, 106
  health 86
  hydrated 49
  moisture 3, 35, 36, 59, 79, 82, 106
  nutrient-poor 69
  reclaimed 56
Sowing 45, 46, 48, 49, 54, 55, 56, 57, 58, 59, 66, 73, 74, 88, 89, 96, 99
  cotton 88
  seed 74
Sugar production 78
Sugarcane 78, 79, 80, 81, 82, 84, 85
  cultivation 78, 79, 81, 84
  farming 78, 84
  growth 79, 81
  industry 78, 79, 85
  plants 82
  producers 79
  seedlings 80
Suicidal germination 25

T

Terrestrial weeds 20
Tobacco plants 26
Traditional methods of weed management 78

V

Vascular systems 19, 42, 43

W

Water absorption 29
Weed(s) 5, 8, 12, 40, 41, 48, 54, 60, 62, 64, 65, 66, 68, 70, 71, 73, 74, 76, 78, 79, 80, 82, 86, 87, 91, 92, 104
  control 5, 8, 12, 64, 65, 71, 73, 74, 76, 78, 82, 86, 87
  management 40, 41, 48, 60, 62, 66, 68, 70, 71, 74, 78, 79, 91, 92, 104
  plants 54
  emerging in autumn planted crop 80
  emerging in spring-planted crop 80
Wheat 52, 53, 54, 56, 57
  crops 52, 53, 54, 57
  cultivation 56

Rakesh Kumar

Rakesh Kumar is an associate professor in the Post Graduate Department of Agriculture at Khalsa College Amritsar, Punjab, India. He is a Ph.D. in agriculture from Guru Nanak Dev University, Amritsar. He has over two decades of teaching and research experience, his expertise are in agronomy, focusing on integrated nutrient management, crop productivity, and sustainable agricultural practices. He has a prolific publication record in peer-reviewed journals and has guided numerous post graduate students. He has actively contributed to national and international conferences and has delivered several invited lectures.

Pardeep Kaur

Pardeep Kaur is an assistant professor in the Post Graduate Department of Botany, Khalsa College Amritsar, Punjab, India. She did Ph.D. in botany from Guru Nanak Dev University, Amritsar. Her research interests include medicinal plants, multi-herbal combinations, natural plant products, in-vitro/in-vivo evaluation of plant extracts and isolated compounds for different bioactivities, and determining the molecular mechanisms of action. She has published articles in peer-reviewed international journals with a cumulative impact factor of more than 50. She is also a reviewer of various international scientific journals.

Robin

Robin is an application scientist in Agilent Technologies India Private Limited and Regional Water Testing Laboratory, Amritsar, Department of Water Supply and Sanitation, Punjab, India. He earned Ph.D. in environmental sciences from Guru Nanak Dev University, Amritsar. With expertise in plant extraction and activity-guided fractionation, he has over ten years of research experience and an in-depth specialization in analytical instruments. He has published several research articles in journals of international repute. His research interests are anticancer medicinal plants, natural plant products, food chemistry, evaluation of isolated compounds for different bioactivities such as antioxidant, anti-mutagenic, anti-proliferative, and anti-topoisomerase activities, and determining the molecular mechanisms of action.