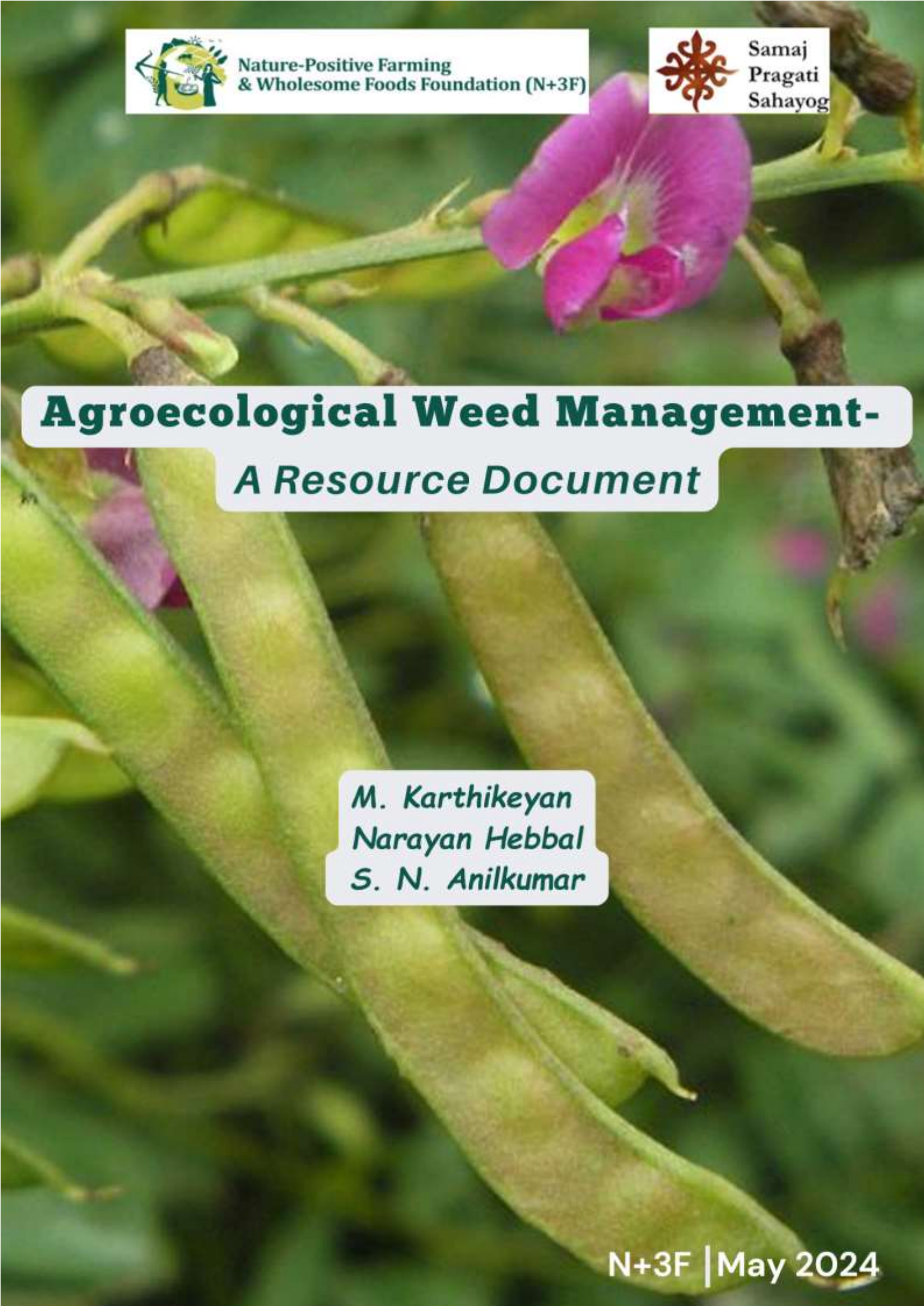

Nature-Positive Farming
& Wholesome Foods Foundation (N+3F)

Samaj
Pragati
Sahayog

Agroecological Weed Management-

A Resource Document

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Cover page: *Tephrosia purpurea* commonly known as wild indigo. It is a common wasteland weed. Photo credit: BR Digital, Freelance photographer

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Contents

Preface

Weed management is an important part of agriculture. In some crops and in some regions, it remains an important challenge for farmers. It is also considered an important challenge for farmers engaged in organic, natural, pesticide-free or any form of nature-positive agriculture and, consequently, for the agencies engaged in promoting such alternate agriculture approaches. The response of farmers to weeds depends to a large extent on their understanding of weeds. Though weeds were considered a problem earlier, they were also seen as soil binder, fertility enhancer, fodder, uncultivated edible greens and medicine. They were seen as an issue only if they compete with the crops by multiplying out of proportion. The actions taken were also situation specific in nature, emerging from a holistic perspective of weeds in the agricultural ecosystem. With the promotion of a modern agriculture mindset/worldview, the dichotomy of crops and weeds is given a lot of attention, with weeds seen as a general menace without understanding their roles in agricultural ecosystems. The actions taken also reflect the same. Reductionist approaches to weed management like clean cultivation, wherein all plants other than the crop are removed from the field, and the use of herbicides have come into vogue. In the recent past, there has been an increase in the adoption of herbicides by farmers even in remote backward regions, mainly due to labour scarcity and the intensive promotion of herbicides by private companies. These trends may result in widespread issues, including, i) a decline in the ability of agricultural ecosystems to support agriculture arising from the wiping out of various macro- and microflora and fauna, disruption of nutrient cycles, soil erosion, etc.; ii) a loss of use of weeds for various purposes mentioned above; and iii) a change in cropping systems to accommodate these drastic measures. It is crucial that the farmers and all the stakeholders engaged in agriculture relook at their current weed management measures and move towards an informed approach that helps in managing the weeds in a holistic way. This resource document was developed to trigger such changes in the outlook of the farmers and the staff of the promoting agencies in their journey in agriculture by aiding them in understanding weeds, their roles in the agricultural ecosystem, and possible ways they can manage them.

We expect that this document will be useful to staff of NGOs/CSOs, and individual farmers in reviewing their practices related to weed management and developing an informed set of context-specific measures to manage them in an agroecological way. We will be updating this document periodically. We welcome your suggestions and additional details for improving this document.

Section 1

Perspective on 'plants labelled as weeds'

Weeds are defined as 'unwanted and undesirable plants growing out of place' (Singh T, *et al*. 2023). Generally speaking, "weeds" are those plants that interfere with human activities, and this interference is perceived to cause problems (Sruti & Soumik, 2018). Such definitions are inappropriate, because they are anthropocentric and culturally-biased. They mislead by creating a negative perception that all weeds are bad, under all circumstances (Chandrasena 2023). But in nature, there are no "weeds" - it's only a human connotation. A plant becomes a "weed" only through its position relative to cultivated areas, seasons, etc. (Sruti & Soumik, 2018). Science tells us that weeds are only 'colonising plants'. Wherever or whenever man disturbs a habitat, they will be among the first pioneers to make use of the opportunity of space.

The plants, which are called 'weeds' are part of the Earth's rich bio-diversity in our agricultural ecosystem for thousands of years, except for the introduced ones; they are, in a way older than the domesticated crops. The currently cultivated crops were earlier opportunistic weeds, but their cultivation as crops after domestication expelled them out of the 'weed' category. For example, *Secale cereale* was a serious weed problem in North America for hundreds of years, but in the early 1960s, farmers cultivated rye for human consumption, and now it is ranked as one of the world's top 10 cultivated grain crops. *Zea mays*, the cultivated maize, was domesticated from *Zea mays* spp. Parviglumis; *Manihot esculenta*, being a rich source of carbohydrate, was domesticated from *Manihot esculenta* spp. flabellifolia (Singh T, *et al*. 2023).

The diversity of weeds varies across crop ecosystems and soil types. For example, in the rainfed lands of South India, one can see Bermuda grass (*Cynodon dactylon*, *Arugu* (Tamil), *Doob* (Hindi), *Garike hullu* (Kannada)), Worm killer (*Aristolochia bracteolate*, *Aduthinna palai* (Tamil) *Eshwari balli* (Kannada)), Country mallow (*Abutilon indicum, Thuthi* (Tamil) *Kuruve gida/ Shree Mudregida* (Kannada), Cock's comb (*Celosia argentea, Pannai or Mahili keerai* (Tamil) *Anne soppu* (Kannada), Lime basil (*Ocimum americanum*, *Naithulasi* (Tamil) *Hoori Tulasi* (Kannada) and Puncture vine (*Tribulus terrestris*, *Nerunji* (Tamil) *Neggila Mullu* (Kannada). In garden lands and sandy soil, one can see Paper thorns (*Alternanthera echinate Smith., Mul Ponnankanni* (Tamil), *Mullu Honagonne* (Kannada), Bellyache bush or Black physicnut (*Jatropha gossypiifolia, Kattamanakku* (Tamil), *Chikka kadaharalu* (Kannada) and Purple nut sedge (*Cyperus rotundus, Korai* (Tamil) *Jekina hullu* (Kannada). In loamy soils, one can see Horse purselane carpet weed (*Trianthema portulacastrum, Saranai* (Tamil), *Kappu handi kale* (Kannada), Indian acalypha (*Acalypha indica, Kuppaimeni* (Tamil) *Kuppigida* (Kannada), Garden spurge (*Euphorbia hirta, Ammanpacharisi* (Tamil) *Hacchegida/Kempu nene hakkisoppu* (Kannada), Slender pigweed (*Amaranthus viridis, Kuppai keerai* (Tamil) *Jangali choulai* (Hindi) *Keeresoppu* (Kannada) and Prickly chaff flower (*Achyranthes aspera, Nayuruvi* (Tamil) *Latjira* (Hindi) *Uttaranigida* (Kannada)). In clayey soils, one can see Wild mustard (*Cleome viscosa*, L., *Kattukadugu* (Tamil) *Kaadusasive/Nahisasive* (Kannada), Wild indigo (*Tephrosia purpurea*, *Kolinji* (Tamil) *Banneela* (Hindi), *Sharapunka/Kooggegida* (Kannada)) and Jungle mat bean (*Phaseolus trilobus Linn., Naripayaru* (Tamil) *Mudgaparni* (Kannada)). Weeds also vary from season to season and over the years. They are part of the 'plant succession'[1] in an ecosystem.

[1] Plant succession is an ecological process of change in a plant community that occurs over time in response to management.

The relationship between weeds and men is an old one; however, it is changing fast. One needs to understand human culpability for promoting weed abundance. Whenever humans laid the land bare of plant cover with excessive clearing, disturbing the environment, they 'created' niches that weeds, aka colonising species, took up; this happened whenever humans arrested ecological succession by turning vast swathes of land into cropping fields. Many weeds were introduced in different geographic regions when humans deliberately introduced crops from one location to another for profit (Chandrasena 2014).

An ethno-biological perspective -link between plants and humans: Humans have for long used colonising species as foods, medicinal plants, animal feeds, housing materials, and raw materials for handicrafts, ornaments, etc. Traditional societies all over the world have used weeds wisely and have 'co-existed' with them. In many parts of the world, it is common to see herbal treatments and ethno-veterinary practices. In traditional agriculture, there was an implicit understanding that weeds are part of the agricultural ecosystem, and they were seen as an issue only under certain conditions when weeds compete with the crops for resources like moisture, nutrients, light, and space. Multiple efforts were taken to avoid and lessen these competing situations, and it was common to observe productive utilisation of these weeds as foods, fodder, medicine, green manure, etc.

But all these have started to change with the 'productivity worldview' propagated as part of the green revolution induced modern agriculture, wherein getting the maximum yield of the cultivated crop from a piece of land was given primacy. With increasing investment made in externally sourced inputs for cultivating a crop, the quantum of yield from that crop was the only focus so as to recover the money invested. So, the land, from being a provider of multiple streams of produce, was transformed into a provider of one or two crop produce grown by the farmer. Any factor that hampers this becomes a menace and must be controlled with strict measures. This includes plants other than the crop(s) coming up in the field. In the attempt to maximise agricultural production, anything other than the crop plant whose yield brings profit is regarded as undesirable. Over the years, the farmers have reached a stage where the overarching impression of weeds is that they are quite harmful or damaging and have to be eradicated from the farms at any cost. After forming the perception that weeds are a big problem, farmers then go about trying to kill or destroy them. This perception was created and sustained by the extension agencies and the entities marketing agro-chemicals. This has led to the adoption of an 'weed control approach' leading to various drastic measures. This is how clean cultivation came into being and has become a mainstream practice. Many farmers like "clean" fields for psychological reasons (Sruti and Soumik, 2018). Herbicides became a handy tool to achieve the clean cultivation objective, given the increasing cost of manual weeding and labour scarcity. Deadly chemicals are being used as weed killers, which will come back to haunt farm families' health sooner or later. Diverse cropping systems made way for monocrops to make it possible to use selective herbicides.

There have been increasing public concerns over this approach, which involves the use of herbicides, and other destructive farming practices, as part of our goal of ensuring human food security. Such concerns have encouraged some to think critically about whether we ought to and need to continue maximum control programs against plant taxa that only pose problems under certain sets of conditions. *As stated by Ehrenfried Pfeiffer* (c. 1950), "*Nature has a reason for allowing weeds to grow where we do not want them. If this reason becomes clear to us, we will have learned from Nature how to deprive weeds from their 'weedy' character; that is, how to eradicate them from cultivated land, or rather, how to improve our methods of cultivation so that weeds are no longer a problem…" (Chandrasena 2019).* They have a role to

play. We need to understand the roles of weeds at the farm level and beyond farm levels in our agricultural ecosystem to critically look at the existing weed management practices.

But weeds have been poorly understood for the past many decades. These plants have also been subject to excessive malign, primarily driven by misconceptions and perhaps, even influenced by the prevalent worldview that everything on earth has been created to be subdued and exploited to satisfy man's selfish interests.

In natural or man-made ecosystems, many weeds serve valuable ecological functions that need more recognition. Examples of their complex biological role, such as providing resources for wildlife, pollinating insects, slowing erosion, building soil, and generally enriching biological diversity, are abundant in global literature; these need to be understood. In a strategic approach to managing weeds, more people – farmers, CSOs, scientists, and other stakeholders – should explore different ways of using these taxa to improve the human condition. The summary condemnation of plant taxa because we dislike them in particular situations is not a sensible way to approach a complex man-made problem. The genetic attributes of weeds that confer superior colonising ability, competitiveness, and survival could be beneficial, not just in repairing damaged ecosystems but also in sustainably providing food and fibre for both humans and animals.

The utility value of a plant to humans is related to: (1) abundance and distribution of the plant; (2) length of time the plant and a human group have been in contact; (3) invention or transmission of traditional ecological knowledge of the plant; (4) ease of managing, acquiring, and processing the plant; (5) its physical and chemical qualities (*e.g.,* pharmaceutical or toxicological properties, fibre characteristics, nutritional values); and (6) availability and quality of alternate species. Discussion of such ethno-biological perspectives is essential to building better relationships with weeds by humans, particularly where the conflicts between the two are more profound (Chandrasena, 2014). We need to understand weeds better in terms of their roles, uses, inherent abilities, and when they pose difficulties for crop cultivation if we are to have a balanced approach to managing them well.

The following sections offer these insights. The second section informs the readers of the most common uses of weeds, their ecological functions, and how they are part of the cropping system. The third section deals with the issues with the current approach to managing weeds. The fourth section covers the agroecological management of weeds.

Section 2

Roles of weeds in the agricultural ecosystems

As mentioned in the earlier section, humans have seen 'plants categorised as weeds' as part of their agricultural ecosystems and have been using them from time immemorial for various purposes. These plants offer various benefits for the betterment of human conditions and environmental health and play many important roles in the cropping system. Section 2 offers a glimpse of these aspects.

2.1 Common uses of weeds

Weeds as food and medicine

Many of the "weeds" are green leafy vegetables, which greatly supplement nutrition, have medicinal value, and also provide food in times of scarcity. Many can be sold in the markets. Common Lambsquarters (*Chenopodium album*) or *Bathua,* which is a prominent "weed" in wheat fields, is a nutritious green relished in different preparations. In a study conducted by Thanal in Wayanad district (Kerala), 83 species of weeds were found to be consumed by the community as leafy vegetables, with 20 found in the paddy fields (Sruti & Soumik, 2018). In another study by the DHAN Foundation at three sites in Tamil Nadu, 31, 27, and 41 species of weeds were found to be consumed by the community as leafy vegetables (Karthikeyan *et al.,* 2014). A study in Rudraprayag district of Uttarakhand found that a total of 113 species (from 90 genera and 38 families) of weeds were used by the local people for numerous purposes (Bharti Rautela and Prabhawati Tiwari, 2021). These weeds were found to be packed with iron, calcium, vitamins, antioxidants, and fibre, and can serve as a healthy, balanced diet as indigenous super foods. Some of them are also used as medicines in home-made remedies and in traditional health systems. Some of these weeds are also used for ethno-veterinary care. The table below describes the use of some of the weeds as food and medicine.

1		**Common name:** Wild Amarantha/ *Jungli Chaulayi* (Hindi)/*Kuppai Keerai* (Tamil) *Keeresoppu* (Kannada) **Botanical name & Family:** *Amaranthus viridis* & Amaranthaceae **Used plant parts:** Leaves, Stem, Flower and seed **Recipes:** Added to salads and soups, used as vegetables, cooked as spinach and seeds can consumed as cooked food **Pharmacological Activity:** a) Antidiabetic, Antihyperlipidemic, Antioxidant, Emollient and Vermifuge, b) Root juice use in inflammation during urination, Treat constipation, Leaf show diuretic, febrifuge and purgative action, Leaf sap used for eye wash to treat eye infections and c) Use for preparation of soap

2		**Common name:** Purslane/ *Badi-noni Khursa, Lunia* (Hindi)*/ Kozhi keerai, Tharai keerai* (Tamil)/ *Ghoni gida* (Kannada) **Botanical name & Family:** *Portulaca oleracea* & Portulacaceae **Used plant parts:** Leaves, stem and seeds **Recipes:** Added to salads and stews and stuffing, Leaves, stems raw or cooked used as a food, used as a thickener in soup, Whole seeds /powder mixed with cereals for use in gruels, bread, pancakes, etc. **Pharmacological Activity:** a) Leaves are a rich in Beta Carotene, Mg, and K, b) Rich in Alpha Linolic Acid, oxalic acid, Omega 3 Fatty Acid; Antibacterial, Antiscorbutic, Depurative and Diuretic, c) Use to treat coughs, sores, skin infections, stomach aches, headaches and dyspepsia, d) Preventing heart attacks and strengthening the immune system, e) Muscle-relaxing effects and Wound healing activity, f) Use in treatment of insect bite /snake bites, boils, sores, diarrhoea, haemorrhoids, postpartum bleeding, and intestinal bleeding
3		**Common name:** Bull Clover **Botanical name & Family:** *Trifolium fucatum* & Fabaceae or Leguminosae **Used plant parts:** Leaves, Stems, Flowers, Seed pods and Root **Recipes:** Leaves added to salads and flower to tea, cooked as spinach, powder obtained by dried seed, pods and flowers utilized as a flour **Pharmacological Activity:** a) Blood purifier, Use in treatment of Gaut, Anti-rheumatic, Anti-scrophulatic, Depurative, Surfactant and Tonic, b) For the treatment of fevers, coughs, colds, leucorrhoea plant infusion is utilized, c) Plant root is also slightly aperient, cholagogue, depurative, strongly diuretic, hepatic, laxative, stomachic and tonic
4		**Common name:** Dandelion/ *Kukraundha, Kanphool, Dudhi, Baran, Dudal, Dudh-batthal, Dudhal* (Hindi)/*Kattu mullangi* (Tamil) **Botanical name & Family:** *Taraxacum officinale* & Asteraceae /Compositae **Used plant parts:** Leaves, Root, Stem and Flowers **Recipes:** a) Leaves added to salads, roots added to soups and stews, roast to boil to make a coffee substitute, add flowers to salads or coat with batter and fry, b) It is also used to prepare Pink Dandelion Wine, Dandelion Root coffee, Dandelion Jelly

		Pharmacological Activity: a) Rich in Vit A, K and C, Ca, Fe and K, b) Rich source of Protein, c) Roots are hypoglycaemic, d) Roots are mild antibiotic for yeast infections, e) Use in gall bladder and urinary disorders, gallstones, jaundice, cirrhosis, dyspepsia treatment
5		**Common name:** Bacon weed, Fat hen, Goosefoot, Lambsquarters, Pigweed Lambquarters/*Bathua* (Hindi)/ *Sakkaravarthi keerai* (Tamil), *Huchch chakkota* (Kannada) **Botanical name & Family:** *Chenopodium album* Family: Chenopodiaceae **Used plant parts:** Leaves, shoots, seeds and flowers **Recipes:** a) Added to salads and stews, b) Raita, paratha can be prepared **Pharmacological Activity:** a) Rich in Iron Vit A, C and K. Ca, Mg and fibre, b) Anthelmintic, antiphlogistic, antirheumatic, laxative, and odontalgic activity commonly shown by the leaf part of the plant, c) Use in the treatment of rheumatism, d) For urinary problems seeds are chewed, e) The stem juice applied to patches and sunburn
6		**Common name:** Chicory (Hindi and Kannada)/ *Kasini keerai* (Tamil) **Botanical name & Family:** *Cichorium intybus* & Asteraceae **Used plant parts:** Leaves, shoots, seeds and flowers **Recipes:** a) Used as vegetables, b) Added to salads, c) Used for preparation of tea: chicory tea **Pharmacological Activity:** a) Stimulant, Mild Laxative, b) Use in Constipation, Anaemia and Respiratory Disorder, c) Potential effective in swellings and skin irritations, d) Helps to decline symptoms of PMS or premenstrual syndrome, e) Boosting capacity to absorb vivacious nutrients like calcium, f) The juice is folk medicine for uterus cancer / tumours, g) Plant syrup, leaves, seeds are liver tonic and purifying medicine for infants, i) Leaves for wound healing, j) Flowers used in gallstones, gastroenteritis, sinus problems, cuts, bruises, k)Tea or decoction can be utilized as a depurative, l) Leaves and seed used as a Blood purifier, m) Roots are very effective in arteriosclerosis, Internal haemorrhage, digestive disorder, renal disease and used as antiarthritis, antispasmodic.

7		**Common name:** Greater plantain, Waybread, White man's footprint/ *Lesan-ol-haml, Barhang, Lahuriya* (Hindi)/ *Ishappukol vitai* (Tamil) **Botanical name & Family:** *Plantago major &* Plantaginaceae **Used plant parts:** Leaves, seed and root **Recipes:** a) Sauté in butter and garlic for Asthma, Ascites and Fever, b) Foodstuff with lentil, Plaster on Forehead in Epilepsy, c) Vaginal suppository, wash in urinary tract infection, d) Decoction as tea for Kidney's ducts obstruction, Haematuria, Ulcerative colitis, Dysentery, e) Eye ointment for eye infection. **Pharmacological Activity:** a) Rich in Vit A, C and K Iron and Ca, b) Used in treatment of various diseases such as constipation, coughs, wounds, infection, fever, bleeding and inflammation, c) Leaf tea effective for eyes sores, eye choroid diseases, day blindness, conjunctivitis, etc., d) Leaf juice used for toothache, mouth sores, halitosis, oral lesions, epistaxis, haemoptysis, loose teeth, gingivitis, earache, tonsillitis, etc., e) Decoction/ tea used in treatment of asthma, haemoptysis, tuberculosis, lung and plural lesions f)Dried seeds and leaf extract effective for hematemesis, dysentery, gastrointestinal bleeding /ulcers, haemorrhoids and dyspepsia, g) Mucilage commonly used for constipation, h) Used as Immune booster, Anti-hypercholesteremia, Anti-atherosclerosis and Hypoglycaemic effect, Antinociceptive effects, Antioxidant, Anti-infective, Antibiotic, Anti-giardiasic, Anticancer, etc
8		**Common name:** Common chickweed, Chickenwort, Craches, Maruns, Winterweed/ *Buch bucha* (Hindi)/ **Botanical name & Family:** *Stellaria media* & Caryophyllaceae **Used plant parts:** Leaves, stem and roots **Recipes:** a) Used in salads, b) Used as a tea or tincture for physical fatigue and debilitation, c) Tea/ decoction used as an emmenagogue, postpartum depurative, galactagogue, d) Infusion of Leaf used in bathing can helps to reduce rheumatic pain, e) Eat as a salad **Pharmacological Activity:** a) Antioxidant, b) Fresh plant more effective in constipation, but excess dose can cause diarrhoea, and vomiting, c) Dried plant infusion effective in coughs, hoarseness, etc., d) Whole plant decoction effective for piles, sores, skin irritations, swelling on legs which show

		emollient, anti-inflammatory property, tissue repair activity, e) In scurvy plant juice is very effective as a rich source of vitamin, f) Folk medicine as a slimming agent g)Whole plant utilized as Antirheumatic, Astringent, Carminative, Demulcent and Diuretic
9		**Common name:** Mallow, Cheese weed/ *Gurchanti Socholi* (Hindi)/ **Botanical name & Family:** *Malva sylvestris* & Malvaceae **Used plant parts:** Leaves, flowers, seed pods and fruits **Recipes:** a) Leaves added to tea, flowers used as a remedy for cough, b) Use in preparation of green smoothie, salads / soups, c) Tea can be prepared from dried leaves **Pharmacological Activity:** a) Rich source of Tannins, Vitamin A/C, Flavonoids, potassium, calcium, iron, selenium magnesium etc (beneficial in pregnancy,) b) Used to treat Asthma, Bronchitis, Kidney stone, insomnia, chest congestion, respiratory illness, Diarrheal, dry cough, wounds, c) Show anti-inflammatory, diuretic, demulcent, emollient, laxative, expectorant, analgesic, Immunostimulant, Antibacterial, Antiaging, and demulcent effects
10		**Common name:** Curly dock, Garden Patience, Parell, Patience herb, Narrow dock, Sour dock/ *Sukku keerai* (Tamil) **Botanical name & Family:** *Rumex crispus* & Polygonaceae **Used plant parts:** Root, Bark **Recipes:** a) Leaves, seeds are boiled with milk and flour b) Leaves can be utilized for the preparation of salads, potherb soups, etc. c) Seed powder can be used as flour or coffee substituent **Pharmacological Activity:** a) Root part used to treat Cancer, and Necrosis, b) The root is utilized as antiscorbutic, alterative, cholagogue, astringent, laxative depurative, and mildly tonic, c) Root can be used for numerous skin diseases in form of dusting powder, d) Used internally in the treatment of constipation, piles, bleeding of the lungs, e) Root can be mashed and used as a poultice and salve, or dried, f) Seeds are useful in diarrhoea Fresh roots used for cough

11		**Common name:** Garlic mustard/*Poondu kadugu* (Tamil) **Botanical name & Family:** *Alliaria petiolate* & Brassicaceae **Used plant parts:** Leaves and roots **Recipes:** Used in salads, added to spices **Pharmacological Activity:** Contain Vit. A, C, E, Ca, Mg, Cu, Omega -3 Fatty Acids, Selenium, Fe
12		**Common name:** Red clover/ *Tripatra* (Hindi) **Botanical name & Family:** *Trifolium pretens* & Fabaceae **Used plant parts:** Flowers **Recipes:** Added to salads, pan roast **Pharmacological Activity:** Rich In Protein, Phyto Estrogen, Beta Carotene, Bio Flavanoids, Vit C, B
13		**Common name:** Stinging nettle/ *Bichchhu, Kali, Kandadli, Bichchhu buti* (Hindi)*/Perunkanchondi* (Tamil) **Botanical name & Family:** *Urtica dioica* & Urticaceae **Used plant parts:** Leaves **Recipes:** Added to omelettes, dips, teas, soups and pesto **Pharmacological Activity:** a) Diuretic, b) Use in Kidney Stone treatment

Source: Powar Priyatama *et al.,* 2019

Weeds as fodder

Many weeds have been used as green fodder. For example, *Rynchosia aurea, R. copiata*, and *Clitoria lerne* (legume fodder).

Weeds as a source of biopesticides

Many weeds have properties that help in managing crop pests. The following tables illustrate the bio-pesticidal properties of some of the weeds.

Weed	Botanical name	Control
Thornapple, *Dhatura* (Hindi)/ *Umathai* (Tamil) *Ummathi* (Kannada))	*Datura stramonium*	Alternaria leaf spot (*Alternaria macrospora*), Bacterial blight (*Xanthomonas campestris* pv. malvacearum) on cotton. And also, seeds are used for rat poison.
Apple of Peru/ *Sudukku thakkali* (Tamil), *Bilibuddegida* (Kannada)	*Nicandra physalodes*	Contain an antifeedant compound, nicandrenone. It is used as a household fly repellent.
Camphor basil/ *Karpur Tulasi* (Hindi, Tamil, Kannada),	*Ocimum kilimandscharicum*	Extracts from the leaves are found to be insecticidal against common stored product pests
Dog basil, *Nai tulasi* (Tamil & Kannada)	*Ocimum canum*	Linalol extracted from freshly milled leaves was effective against stored product pests, protecting beans against *Zabrotes subfasciatus*.

Weeds as nematode control: Compounds such as 4-quinolone waltherione and waltherione-A inhibits egg hatching and have larvicidal activity. More details on the nematicidal properties of some of the weeds are given below.

Weed	Botanical name	Nematode control
Bristly starbur/ *Kaanthi* (Hindi)) / *Kombumul mullichedi* (Tamil)/ *Kadalemullu* (Kannada)	*Acanthospermum hispidum*	*Meloidogyne javanica*
Goat weed/ *Visadodi* (Hindi))/ *Pumppillu, Appakkoti* (Tamil)/ *Oorala gida* (Kannada)	*Ageratum conyzoides*	
Spanish needles/ *Mayir kucham* (Tamil)/ *Kaadu hucchellu* (Kannada))	*Bidens pilosa, Bidens schiperi/*	
Jew's mallow/ *San-Pat* (Hindi), *Kattu thuthi* (Tamil))/ *Chunchali gida* (Kannada)	*Corchorus olitorius*	
Small flower galinsoga/ (*Pipali* (Hindi)/ *Mookuthi malar* (Tamil)/ *Haladikale* (Kannada))	*Galinsoga parviflora*	
Green amarantha/ *Katili Choulai* (Hindi)/ *Thandukeerai, Punjikkeerai* (Tamil)/ *Dantusoppu* (Kannada)	*Amaranthus hybridus*	*Pratylenchus zeae*
Spiny pigweed/ (*Katili Choulai* (Hindi), *Mullu keerai* (Tamil))	*Amaranthus spinosus*	*Rotylenchulus reniformis*
Climbing dayflower/ *Kan kauia* (Hindi)/ *Kanavazhai* (Tamil)/ *Kannesoppu* (Kannada))	*Commelina diffusa*	
Mexican fire plant/ *Badi Dudhi* (Hindi)/ *Palperukki* (Tamil) *Bedhisoppu* (Kananda))	*Euphorbia heterophylla*	
Garden spurge/ (*Chhoti Dudhi* (Hindi)/ *Amman pacharisi* (Tamil))/ *Hacchegida/Kempu nene hakkisoppu* (Kannada)	*Euphorbia hirta*	

Hairy quickweed/ *Peruvian jadi* (Hindi), *Mukuthi Poo* (Tamil)	*Galinsoga ciliate*	
Nettle leaf goosefoot/ *Karund* (Hindi)/ *Paruppukirai* (Tamil)/*Kaduoma* (Kannada)	*Chenopodium murale*	*Meloidogyne incognita*
Day flower/ (*Latjira* (Hindi), *Aduthinna thazhai* (Tamil)/ *Kanne soppu* (Kannada))	*Commelina benghalensis*	*Pratylenchus zeae*
Rattleweed (*Jagli Sanai* (Hindi),*Kilukiluppai* (Tamil)/ *Guliuguluppahalli* (Kannada))	*Crotalaria incana*	*P. zeae, Bean common mosaic virus*
Bermuda grass/ *Arugu* (Tamil), *Doob* (Hindi), *Garike hullu* (Kannada)	*Cynodon dactylon*	*Sporisorium sorghi*
Common purslane/ Purslane/ *Badi-noni Khursa, Lunia* (Hindi)/ *Kozhi keerai, Tharai keerai* (Tamil)/ *Ghoni gida* (Kannada)	*Portulaca oleracea*	*P. solanacearum*
cocklebur/ *Gokhru* (Hindi)/ *Maru umathai* (Tamil)/ *Maralummathi* (Kannada))	*Xanthium pungens*	*Verticillium dahliae*

Source: Alka Sahrawat, *et al*., 2020

Weeds as a field fence

Weeds, being hardy, persistent, and prolific seed producers, can be used for fencing. Lantana camara can efficiently be used as a fence weed; with its beautiful inflorescence it can add aesthetic purpose to the landscape. Spinous species of weeds, viz. Fleshy spurge/ Malayan tree spurge (*Euphorbia antiquorum*, *Sadurakalli* (Tamil)*),* Indian Spurge tree (*Euphorbia neriifolia*), Dog's Tongue/holy milk hedge (*Euphorbia nivulia* (*Ilai kalli* (Tamil)), Peruvian apple cactus (*Cereus peruvianus*, *Ulakkai kattrazhai* (Tamil)), Chinese chaste tree *(Vitex negundo/ Sammalu, Shivari* (Hindi), *Nochi* (Tamil), *Indrani* (Kannada)) Century plant (*Agave americana / Gwarpatha* (Hindi), *Nilakattalai* (Tamil) *Kattale* (Kananda)), Wild sage (Lantana camara, *Thenpoo* (Tamil) *Roojakaddi* (Kannada)), Cactus (*Nagakani* (Hindi), *Karalai* (Tamil), *Kalli* (Kannada)), etc., can efficiently be used for fencing.

Dog's tongue (Euphorbia nivulia)

Century plant (Agave americana)

Cactus (Opuntia sp)

Use of weeds for cultural purposes

In Tamil Nadu, flowers of Cock's comb (*Celosia argentea, Pannai keerai* (Tamil)), a common weed in rainfed lands, are used for decorating the horns of cattle during Pongal festival. Bermuda grass (*Cynodon dactylon*) shoots are used to pray to Lord Vinayaga. Mountain Knot Grass (*Ouret lanata*, *Kapurjadi* (Hindi), *Poolopoo* (Tamil), *Bilihindi soppu* (Kannada)), and Thumbai (*Leucas aspera/ Ghopa* (Hindi), *Tumbai* (Tamil), *Thumbe* (Kannada)) used for Pongal celebration in Tamil Nadu.

The Apatanis are one of the major tribes of the Eastern Himalayan state of Arunachal Pradesh and are ardent believers of nature. Apatanis have mainly three major festivals called Murung, Myoko and Dree which are celebrated in the months of January, March and July, respectively. *Saccharum arundinaceum*

(Devil sugarcane/ *Nanal* (Tamil) /*Munjihullu* (Kannada)) is important plant used for all the agriculture related rituals be it Tamu or Dree. This plant is believed to keep away the harmful insects from the plants. In case of un-natural death, a ritual called *Ropii* (*Talii Gontii*) is performed. During this the priests and relatives or family members whoever takes part in the death procession puts a piece of *Cyclosorus glandulosus* (*Millo Tarih*) on their Piiding (hair-knot on the forehead), lecha (rucksack) so as to prevent themselves from the spirit of the souls who faced an unnatural death (Yakang and Padma, 2015).

Crown flower/ Giant swallow wort *(Calotropis gigantea)* flowers are used during Hanumajayanthi, Ganeshpuja and Mangalagauri festivals. Common basil (*Ocimum basilicum)* leaves are used during Satyanarayana pooja. *Achyranthes aspera* (*Nayuruvi* (Tamil) *Latjira* (Hindi) *Uttaranigida* (Kannada)) is used during Rushipanchami (Jayant and Dalal, 2021).

Devil sugarcane
(Saccharum arundinaceum)

Swamp shield-fern
(Cyclosorus glandulosus)

2.2 Ecological functions of the weeds

The role of weeds in soil conservation

Soil is a fundamental component of sustaining life on earth. Soil degradation represents the loss of natural capital assets and the loss of ecosystem services in nature. Weeds play various roles in soil conservation, as described below.

Controlling soil erosion

The extensive root system of weed plants prevents soil from water erosion, while above-surface growth prevents soil from wind erosion. Weeds intercept raindrops, which reduces the impact of water on the soil surface. Weeds also maintain the infiltration of water, which reduces the crusting of the soil surface. Shallow rooted weeds such as Barnyard and Jungle rice (*Echinochloa spp*.), Large crabgrass (*Digitaria* spp., Brome grass/ Cheat grass (*Bromus* spp., Bermuda grass (*Cynodon dactylon)*, Ground Ivy (*Glechoma hederacea*), and Common chickweed (*Stellaria media*) prevent soil erosion. Weeds act as mulch on barren soil, sloppy areas, or areas with high wind velocity and thus prevent its erosion (Singh et al., 2023). Maize plants have very little ability to retain soil due to their shallow root system, but common weeds, including grass species like Hairy finger grass (*Digitaria*), Broom grasses (*Thysanolaena maxima*), Napier (*Pennisetum purpureum*), sedges like Purple nutsedge (*Cyperus*), Giant Pigweed, Black Pigweed (*Trianthema*), Purslane (*Portulaca*), Kidney leaf morning glory (*Merremia emarginata*), etc. provide very good soil protection with their extremely intensive root systems. Their competitive effect is small in comparison to the soil binder role. They store up minerals and nutrients that would be washed or leached away from the bare ground and keep them available.

Site of rhizobacteria

The rhizosphere is a close interaction among the soil-plant-microorganism continuum. The microbial biomass of the rhizosphere is determined by the composition of plant efflux, which is particular to different plant species. The rhizosphere is enriched with photosynthates leaked from plant roots, which are energy-rich carbon compounds. The large availability of exudates in the root zone generally facilitates the much higher microbial activity and biomass in the root zone of weeds. The percentage of microbes present in the root zone varied according to particular weed species; for example, 19.4% of *Bacillus sphaericus* were observed in roots of Barnyard grass (*Echinochloa crusgalli*), 12.9% of *Pseudomonas chlororaphis* in roots of Corn spurry (*Spergula arvensis*), 17.5% of *Stenotrophomonas maltophilia* in roots of Canadian Goldenrod (*Solidago canadensis*), 7.5% of *Variovax paradoxus* in roots of Italian rye grass (*Lolium multiflorum*), 6.3% of *Arthrobacter ilicis* in roots of Lambsquarters (*Chenopodium album*) and 14.5% of *Bacillus sphaericus* in roots of Couch grass (*Elymus repens*, *Mattathandu kilangu* (Tamil)).

Rhizobacteria in the weed roots act as plant growth promoting agents by releasing volatile compounds and antibiotics, like phenazine. It is observed that HCN increases the solubility of phosphorus by metal chelation and sequestration in the rhizosphere. Rhizobacteria also produce siderophores, which help in iron sequestering for plants and delay senescence. Plant hormones like gibberellins influence the germination of seeds and the elongation of stems. Auxins like indole acetic acid (IAA) help in root development and differentiation.

Source of organic matter

Weeds can act as a source of organic matter for soil. Carrot grass (*Parthenium hysterophorus*), One leaf senna (*Cassia sericea*, *Oosi thagarai* (Tamil)), Devil's horsewhip/ prickly chaff flower (*Achyranthus aspera*, *Nayuruvi* (Tamil)), Giant swallow wort (*Calotropis gigantea*, *Neela Erukku* (Tamil)), Dog chilli (*Croton sparsiflorus*, *Rail poondu* (Tamil)), Wild indigo (*Tephrosia purpurea*, *Kozhinji* (Tamil)) and Wild poinsettia (*Euphorbia geniculate)* act as good sources of organic matter. Wild sage (*Lantana camara*, *Thenpoo* (Tamil)) can also be used for preparing compost. Weeds can be used in soils with higher sand content to improve soil organic matter, which positively affects the absorption of nutrients and retention of water for

better root growth in soil (Singh. T *et al.*, 2023). Weeds removed from the field have to be applied to the same field.

Rail poondu (Crotons sparsiflorus)

Kozhinji (Tephrosea purpurea)

Supplier of atmospheric nitrogen

Weeds falling in the Fabaceae family fix nitrogen, and the crop benefits from available nitrogen in its ready form. Dicotyledons like White clover (*Trifolium repens*), Indian sweet clover (*Melilotus indicus*, *Ban methi, Morila, Senji methi* (Hindi)), Vetch weed (*Vicia sativa*, *Akra, Akta* (Hindi)), Crimson clover, Yellow trefoil (Black medick), Three flowered Grona triflora (*Desmodium triflorum*, *Sirupullati* (Tamil)), Bur clover (*Medicago polymorpha*, *Maina, Chandausi* (Hindi)) and grass species like Pangola grass (*Digitaria eriantha*), Switch grass (*Panicum virgatum*) and Bahiagrass/ Common Bahia (*Paspalum notatum*) also fix the nitrogen (See Plate 1).

Plate 1: Nitrogen fixing weeds- *don't remove them from your field*

Indian sweet clover
Melilotus indicus

Grona triflora
Desmodium triflorum

Yellow Trefoil
Trifolium dubium

White clover
Trifolium repens

Bur clover
Medicago polymorpha

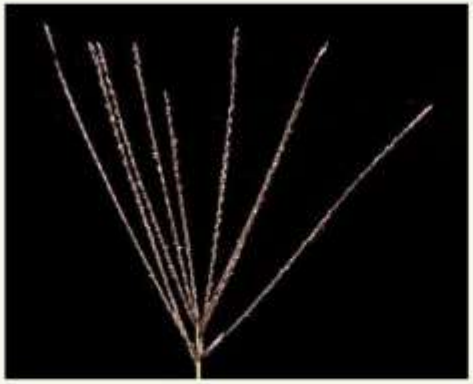
Vetch Weed
Vicia sativa

Plate 1: Nitrogen fixing weeds- *don't remove them from your field*

Panola grass
Digitaria eriantha

Switch grass
Panicum virgatum

Common bahia grass
Paspalum notatum



Panola grass inflorescence

Switch grass inflorescence

Bahai grass inflorescence

Indicator of soil quality

Weeds indicate a lot about soil conditions, i.e., acidic/alkaline/neutral, well drained/poor drained, high/low moisture, humus levels, etc. An old saying in Tamil informs that presence of following weeds in the land indicate the fertility of the soil, viz. Wild indigo (*Tephrosia purpurea, Kozhinji* (Tamil)) indicates high fertility, East Indian globe thistle (*Sphaeranthus indicus, Karanthai* (Tamil)) indicate medium fertility and Calotrophis (*Erukku* (Tamil)) indicate low fertility. Dollar weed (*Hydrocotyle umbellata*) grows in high soil moisture conditions, and Goose grass (*Eleusine indica*, Kunjappul (Tamil)) thrives well in dry areas. Foxtail barley (*Hordeum jubatum*) indicates poorly drained soils. Bindweed (*Convolvulus arvensis*) grows in crusty or compacted soil. Dandelions (*Taraxacum officinale*) draw up nutrients like calcium and nitrogen from earth depths, and White clover (*Trifolium repens*) has nitrogen-fixing bacteria living in roots that fertilise the ground. The presence of mosses indicates soggy, acidic soil that is low in nutrients. Purslane and Horse purslane indicate the soil is saline. Toothcups (*Ammania* sp.) show water logging (Priyanka *et al*., 2014). More details on weeds indicating various aspects of soil quality are given below.

a) Indicators of soil nutrients

Indicator weeds	***Soil nutrient***
Burdock (*Arcium lappa*)	Low calcium, high potassium and high gypsum soils
Crabgrass (*Digitaria sanguinalis*)	Soils depleted of nutrients and is low in calcium
Foxtail barley (*Hordeum jubatum*), Oxalis or wood sorrel	Low calcium and high magnesium
Lambsquarters (*Chenopodium album*)	Low phosphorus, high potassium
Redroot weeds (*Amaranthus retroflexus*)	Low manganese, high iron
Knapweed (*Centaurea maculosa*)	Low calcium and very low phosphorus, etc.

b) Indicators of soil status

Indicator weeds	***Acidic/alkaline/neutral soils***
Wormwood (*Artemisia indica, Masi pathiri (Tamil)*)	Alkaline soils
Horsetails (*Equisetum spp*), Corn spurry, *Spergula arvensis* and Knapweed (*Centaurea maculosa*)	Acidic soil

See Plate 2 to get familiar with some of these weeds.

Plate 2: Soil nutrient indicating weeds–*Know your soil quality*

Burdock

Low Ca & High K, gypsum

Crab grass

Low nutrient & Low Ca

Foxtail barley

Low Ca & High Mg

Lambsquarters

Low P & High K

Redroot weeds

Low Mn & High Fe

Knapweed

Low Ca & Very low P

Plate 2: Soil status indicating weeds-*Know your soil quality*

Wormweed

Indicate alkaline soils

Horsetails

Indicate acidic soils

Corn spurry

Indicate acidic soils

Knapweed

Indicate acidic soil

Indicator of heavy metals in soil

Weeds act as bio-monitoring and indicative agents by accumulating heavy metals in soil. For example, Common dandelion (*Taraxacum officinale* L.) and Egyptian clover/ Berseem clover: *Trifolium pratense* L.) accumulated a higher concentration of copper (Cu), which depends linearly with the amount of copper present in soil. Greater plantain, Waybread, White man's footprint (*Plantago major* L.) accumulated a small fraction of Mn (5-10%) in its leaves, while the presence of Stinging nettle (*Urtica dioica* L.) and Berseem clover (*Trifolium pratense* L.) indicated lead (Pb) in the soil. Indication of heavy metals using weeds appears to be an easily accessible method to prevent the transfer of heavy metals across several trophic levels of the food chain (See plate 3).

Phyto-remediation of heavy metals in the soil

Many weed species from Cruciferae, Asteraceae, Capparaceae, Fabaceae, etc. are useful for phytoremediation of heavy metals. Phyto-extraction is the accumulation of heavy metals in different plant parts, and it can be done by using weeds, which are hyperaccumulators [high metal accumulating (10-500 times)] and/or heavy biomass accumulators (high metal mobilising capacity).

Examples: Moss sandwort (*Minuartia verna)* is a lead hyperaccumulator; Rock sage (*Aeollanthus subacaulis)* is a Copper hyperaccumulator; Field pennycress (*Thlaspi tatrense)* is a Zinc hyperaccumulator; Cobalt wisemany (*Haumaniastrum roberti),* Dandelion *(Taraxacum mongolicum)* and Globe yellowcress *(Rorippa globosa)* indicated Cobalt hyper accumulative properties; Geloniode poison leaf (*Dichapetalum gelonioides/ Cherumaram* (Malayalam)*)* is a Nickel hyperaccumulator; and Spike thorn (*Maytenus bureaviana)* is a Manganese hyperaccumulator (Singh *et al.*, 2023). Vetiver (*Vetiveria zizinoides)*, Giant reed (*Arundo donax),* Giant milkweed (*Calotropis procera)* and East indian globe thistle (*Sphaeranthus indicus)* are lead and manganese accumulators (Khankhane and Jay, 2011).

Vetiver (*Vetiveria zizinoides)* and Giant reed (*Arundo donax)* can be used for phytoremediation of lead and manganese contaminated sites (Khankhane and Jay, 2011). Crown flower (*Calotropis*) aids in the remediation of soil contaminated with lead and arsenic. Indian copper leaf (*Acalypha indica*) is a good accumulator of lead, nickel and chromium, Country mallow (*Abutilon indicum*) is good accumulator of chromium and Sunberry (*Physalis minima*) is good accumulator of lead and chromium (Subhashini *et al*., 2017).

Khankhane and Varshney (2008) made an investigation to evaluate the ability of weed species for nickel, copper, iron and zinc accumulation growing in various contaminated drain sites of Jabalpur and adjoining areas. Results of the study indicated that, Alligator weed (*Alternanthera philoxeroides*) accumulated higher nickel (26 µg/g) and zinc (553 µg/g) content followed by Indian chickweed or Green carpetweed (*Mollugo verticillate*) (24 µg/g Ni) and Slender pigweed (*Amaranthus viridis*) (488 µg/g Zn). The *M. verticillata* accumulated higher copper content (94 µg/g) whereas Bindweed (*Convolvulus arvensis*) accumulated higher iron (1900 µg/g) followed by Water primrose (*Ludwigia adscendens*) (1878 µg/g), *A. philoxeroides* (1507 µg/g) and *M. verticillata* (1487 µg/g).

Narinderjit *et al*., 2023 compared the tolerance capacity of Rice flat sedge (*Cyperus iria),* Prickly chaff flower *(Achyranthes aspera)*, and Rocket salad (*Eruca sativa)* to lead-contaminated and chromium-contaminated soils and to check their phytoremediation potential by pot culture experimentation. The result of the study indicated that *C. iria* has the maximum potential to accumulate both the metals in its roots than other two plants. The order of chromium metal accumulation was found to be *C. iria* > *E. sativa* >*A. aspera*. On the other hand, the order of lead metal accumulation was found to be *C. iria* >*A. aspera* > *E. sativa*.

Plate 3: Heavy metal indicating and accumulating weeds -

improve soil quality using weeds

Common dandelion

Indicates Copper

Plantain weed

Indicates Manganese

Stinging nettle

Indicates Lead

Alligator weed

Accumulates Nickel

Slender pigweed

Accumulates Zinc

Globe Yellowcress

Accumulates Cobalt

Rejuvenating saline soils

Basophile weeds like Mesquite (*Prosopis juliflora),* Saltwater couch/silt grass (*Paspalum vaginatum),* Sea Purslane (*Sesuvium portulacastrum, Kadal vazhukkai keerai* (Tamil)), Rosin weed (*Cressa cretica (arecta)), Salt wort* (*Salsola spp.)* and Drop seed grass (*Sporobolus diander)* are dominant in saline soils and alkaline soils. Such weeds can be allowed to grow in salt-affected soils. These will add organic matter and humus to soils, which diverges the earlier barren soils to productive land. This effort can revolutionise the concept of rejuvenating degraded soils. Similarly, Herbaceous sea blite (*Suaeda maritima, Nilavumarai* (Tamil)), Sea Purslane (*Sesuvium* portulacastrum), Indian privet (Clerodendrun inerme, *Sangam peechangu* (Tamil)), Salt heliotrope (Heliotropium curassavicum, *Siruthel kodukku* (Tamil)) and Beach morning glory/ Goat's foot (Ipomoea pescaprae, *Adumbu, Attappan kodi* (Tamil)) reduced the EC of the soil. Weeds are efficient extractors of salts from soil because of their small life span, many cohorts per season, and germination over variable environments. An old saying in Tamil mentions that incorporating Veld Grape (*Cissus quadrangularis, Pirandai* (Tamil)) can help in improving saline soil (See plate 4).

The role of weeds in biodiversity conservation

Donor of useful genes to crops

Some weed species are wild relatives of cultivated species and are part of crop-weed complexes. Such wild relatives are an important genetic resource with the ability to provide characteristics of disease and insect resistance for breeding programmes. Weeds act as reservoirs of germplasm that function as an important source of genes for tolerating biotic and abiotic stresses in crop plants, aiming for crop improvement in terms of fitness and a lesser yield penalty. Bearded sprangletop (*Diplachne fusca)* is a perfect example for imparting salt tolerance, as these plants comprise micro-hairs on leaves that secrete salts from the leaf surface to protect it from salts (Singh et al., 2023).

Maintenance of pollinator populations

The primary agricultural crops of the world flower *in mass* at particular times. Mass flowering produces floral resources simultaneously, but these provide food only for a fraction of the active season of pollinators. For the remainder of their lives, pollinators must rely on alternative foraging, which is generally provided by 'non-crop' flowering plants and colonising taxa in agricultural landscapes. Weeds contribute to the conservation of pollinator populations through the provision of nectar and pollen before and after crop flowering and by providing more diverse resources otherwise. The benefits of a particular weed species depend on its attractiveness (*e.g.,* associated with the flower colour, ultra-violet (UV) reflectance or flower symmetry), its accessibility (*e.g.,* determined by the form and size of the corolla), and the quantity and quality of the floral rewards (*e.g.,* pollen and/or nectar).

Mangesh (2019) reported that 54 species of wild plants serving as nectar, pollen, and both nectar and pollen sources for natural population of honey bees. Among 54 different species of wild plants/ weeds as bee flora, 7 plants were pollen sources, 27 plants were nectar sources and 20 plants were both nectar and pollen sources. Satyanashi (*Argemone Mexicana*), Bala (*Sida cordifolia*), Sour clover (*Oxalis stricta*), Singapore daisy (*Wedellia trilobata*), Dudhi (*Sonchus sp*.), Sontikli (*Pulicaria wightiana*) and Grass (*Sorghastrum sp*) are the pollen sources for bees. Stinkweed (*Cleome gyanandra*), Purple night shade (*Solanum Americanum*), Sweet basil (*Ocimum basilicum*), Golden berry (*Physalis peruviana*) etc are some the plants on which honey bees depends for nectar. Chandwel (*Convolvulus arvensis*), Bush morning glory (*Ipomoea fistulosa*), Jharwad (*Lagascea mollis*), Kantakari (*Solanum xanthocarpum*), Coat buttons (*Tridax procumbens*), Fasle mallow (*Malvastrum coromandelianum*) etc are the sources of pollen and nectar for honey bees.

Pollen grains of 55 species were recorded in the honey from south-western, central and eastern parts of Uttar Pradesh, where Goat weed (*Ageratum conyzoides)*, a noxious invasive weed, is a very dominant plant taxon. The second plant community used for foraging by honeybees consists of Mesquite *(Prosopis juliflora)*, Field mustard (*Brassica campestris*), Hairy Pimpinel (*Pimpinella tomentosa*) and Commom

Plate 4: Weeds rejuvenating saline soil- *reclaim your land with weeds*

Mesquite

Prosopis juliflora

Rosin weed

Cressa cretica

Saltwater couch

Paspalum vaginatum

Sea Purslane

Sesuvium portulacastrum

Drop seed grass

Sporobolus diander

Indian privet

Clerodendrun inerme

cocklebur (*Xanthium strumarium*). The last group of plants foraged by honeybees comprises of 37 species sparsely present in the vicinity (Mohan Singh *et al*., 2017).

Weeds as a host for natural enemies of insect-pests and pathogens

Weeds act as reservoirs of beneficial insects, and these provide physical shelter, pollen, nectar, and water to diverse insects. The preservation of certain population densities of predators of pests can also be advantageous in preventing sudden population explosions. Weeds provide suitable habitats for predators, whose lives are dependent on ground cover. For example, damsel bugs are found on weeds in a crop infested with *Helicoverpa* caterpillars, eggs and larvae. This is the basic concept behind Entomophage Park. In Uganda, *Cissus adenocaulis* was exploited as a trap crop for controlling cotton pest *Taylorilygusv osseleri* (Tejinder Singh, 2023). Syrphidae larvae are predators of aphids. *Matricaria chamomilla* L. and *Galinsoga Parviflora* are a refuge and food source for adult Syrphidae. Bitter broom*, P. hysterophorus* a common wild plant attracts the parasitoid *A colemani*. It was observed that the adults and larvae of *Aphidoletes spp* prey on *Aphis gossipii* in Least Pepperwort (*Lepidium virginicum*), a weed found in most of crops and roadside (Manuel Darío *et al*., 2023). More details on weeds hosting different beneficial insects are shared below.

Sl. No	Beneficial insects	Hosting weeds
1	Lace wings	Fern-leaf yarrow (*Achillea filipendulina*), Four-wing saltbush (*Atriplex canescens)* Dandelion (*Taraxacum officinale)*
2	Ladybugs	Butterfly weed (*Asclepias tuberosa),* Prairie sunflower (*Helianthus maximilianii*), Spike speedwell (*Veronica spicata)* Alpine cinquefoil (*Potentilla villosa)*
3	Hoverflies	Fern-leaf yarrow (*Achillea filipendulina*) Common yarrow *(Achillea millefolium)* Carpet bugleweed *(Ajuga reptans)* Basket of Gold *(Alyssum saxatilis)* Gloriosa daisy *(Rudbeckia fulgida)*
4	Braconid wasps, Ichneumonid wasps and Trichogramma wasps	Fern-leaf yarrow (*Achillea filipendulina*) Common yarrow *(Achillea millefolium)* Tansy *(Tanacetum vulgare)* Alpine cinquefoil *(Potentilla villosa)*
5	Tachinid flies	Golden marguerite (*Anthemis tinctoria)* Phacelia *(Phacelia tanacetifolia)* Tansy *(Tanacetum vulgare)* Pennyroyal (*Mentha pulegium)*
6	Minute pirate bugs, damsel bugs and big-eyed bugs	Peter Pan goldenrod *(Solidago virgaurea)* White sensation (*Cosmos bipinnatus)*

Source: Fred Hoffman, 2014

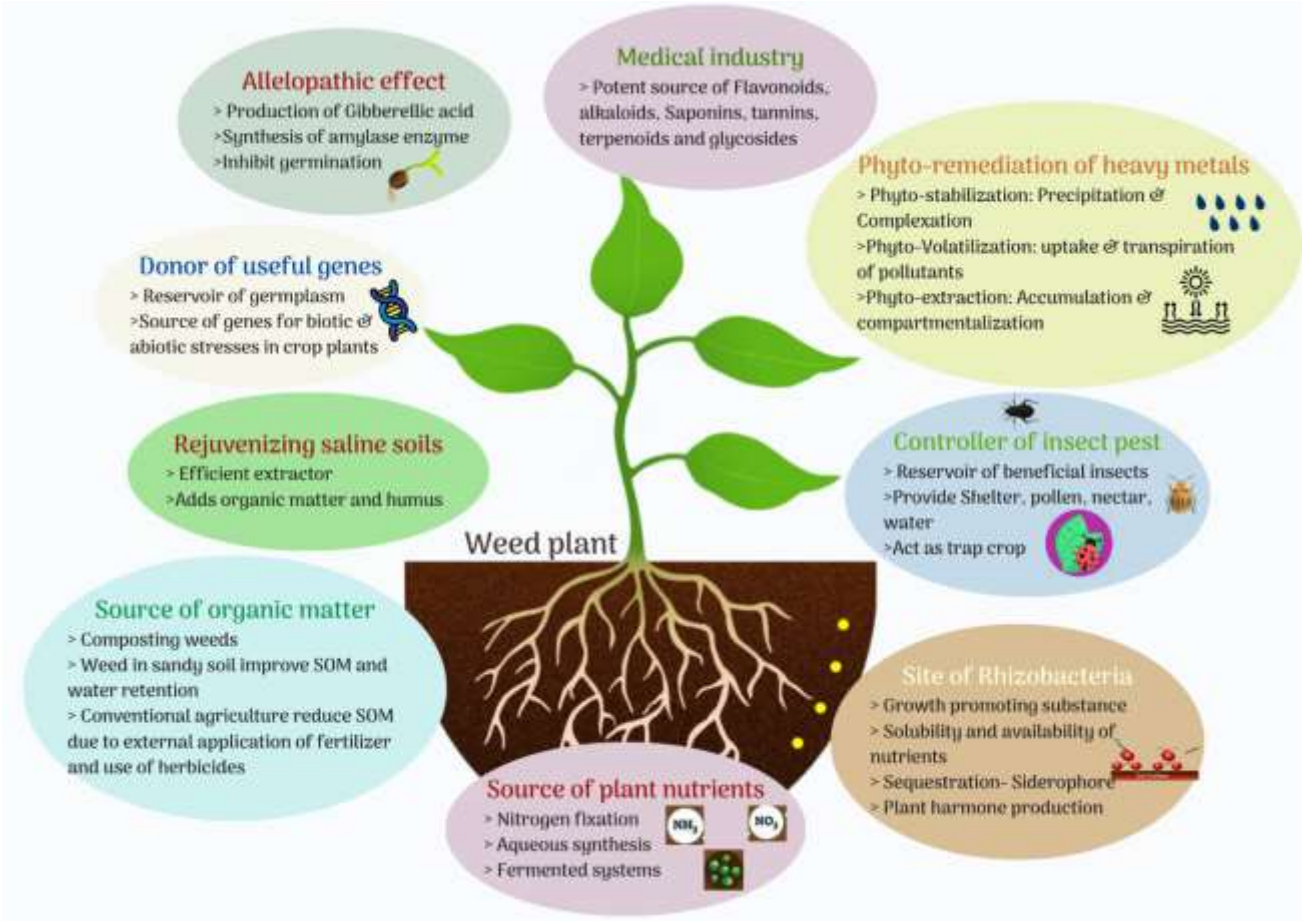
It was observed that when weeds were removed under tropical climatic conditions, there was an increase in crop damage by insect-pests. In a weed-free monocropping system, a large number of sprays were used to control cotton bollworm as compared to a weedy system (Tejinder Singh *et al*., 2023). All these examples favour that weeds act as hosts for natural enemies of insect-pests and keep the pest population below the economic threshold level (ETL). There is also a chance that weeds harbour some beneficial microorganisms in their aerial parts and root zone, helping to balance the farm ecology. Weeds cover bare

soil after harvest, keeping beneficial soil microorganism communities alive through their root exudates of sugars and proteins. Some parasites prefer weeds, and if the field is made weed-free, feed on the crops!

2.3 How are weeds part of the cropping system?

It would have been evident from the common uses and ecological functions of the weeds that they play many important roles in the cropping systems they are part of (See figure below). Some of these roles are mentioned below:

1) Weeds **reduce soil erosion** by serving as a cover crop or live mulch; they also cover the soil after harvest of the crop.
2) They **add considerable organic matter** to the soil.
3) Weeds **improve soil structure, soil health, and water penetration**.



Role of plants labelled as weeds in cropping systems
Adopted from Tejinder Singh *et al*., 2023

4) Some of them **help in improving the fertility of the soil**. For example, Wild indigo (*Tephrosia purpurea*) is used by farmers as a green leaf manure for coconut; similarly, Country mallow (*Abutilon indicum*) and Crown flower (*Calotropis*), which are rich in calcium and boron, respectively, can be used to improve soil fertility. An old saying in Tamil informs that addition of Tanner's Cassia, Senna (*Senna auriculata, Avaram* (Tamil)) helps improving grain yield of the crop.
5) **Making available nutrients to the crop:** Deep-rooted weeds bring up nutrients from deep soil layers that most of the crop species cannot reach anymore.
6) Some of them **fix atmospheric nitrogen**, thereby making available N to the main crop.

7) They **contribute to the natural biocontrol** of crop pests by attracting predators and serving as hosts.

8) Many of them **serve as ingredients in biopesticides,** thereby aiding in pest and disease control.

9) Some weeds **serve as companion plants** to crops (Priyanka *et al*., 2014) described in the following table:

Beneficial weeds	***Companion crop***	***Role***
Bashful mimosa (*Mimosa pudica, Thottal sinungi* (Tamil))	Tomato and Pepper	Act as natural ground cover in agriculture
Borage (*Borago officinalis*)	Legume, Brassica, and Tomato	Its flowers attract predatory wasps, which act as bio-control against pests
Dandelion (*Taraxacum officinale, Seemai kattu mullangi (*Tamil*))*	Any crop	Attract pollinators and benefit nearby plants through their taproot system, which breaks up hard soil, goes deep into the ground, and then brings up nutrients
Clover (*Trifolium pratense*)	Cabbage and broccoli	Attract pollinators; clover, being a legume, fixes nitrogen and fertilizes soil
Stinging nettle (*Urtica dioica)*	Broccoli, tomato, valerian, mint, and fennel	
Wild garlic *(Allium vineale, Kattu poondu (Tamil))*	Fruit trees, nightshades (tomatoes, peppers, potatoes, etc.), brassicas (cabbage, broccoli, kohlrabi, etc.), and carrots	

See Plate 5 to get to know some these weeds.

10) **Weeds create microclimate:** Many weeds help in lowering ambient temperature and regulating moisture around the plants of economic importance. Sometimes, especially for the first 2-3 years of orchard plants, weeds serve as good company to the deserted, isolated plant in harsh conditions. Without weeds around, the plant will have more difficulty surviving. Weeds break hardpans and allow subsequent crop roots to feed deeply. They fiberize and condition the soil and provide a good environment for microbes, thus enriching soil. Weeds being deep feeders enable the less hardy surface feeder crop to withstand drought better. Weed occurrence creates a microclimate that favours soil organisms like earthworms.

11) **Improving crop yield and quality**: Scientists have found that competition can result in an increased production of at least some morphological and chemical (secondary metabolites, protein content, etc.) parts of the stronger partner. Also, the effects of allelopathy are not always negative – sometimes an emitted substance can be beneficial to individuals of another species. For example, Common corn cockle (*Agrostemma githago*) is a noxious weed in wheat fields in 1960s and 1970s; but it had a positive effect on the protein production of wheat.

12) **Provide foods rich in nutrient supplements** like vitamins, minerals, and dietary fibre.

13) **Provide nutritious fodder** for animals.

For a visual treat on the various benefits of weeds see the following video:
Benefits of Weeds in Agriculture | Beneficial weeds in Agriculture (youtube.com)

Plate 5: Companion weeds- *do not remove them*

Bashful mimosa

Mimosa pudica

Borage

Borago officinalis

Dandelion

Taraxacum officinale

Clover

Trifolium pratense

Stinging nettle

Urtica dioica

Wild garlic

Allium vineale

Section 3

Issues with the current approach to managing weeds

3.1 Misconceptions related to weed management

As mentioned earlier, the general perception is that weeds are very harmful and would reduce the yields of the crop very significantly. The possible issues that may arise from weeds that make farmers see them as pests include:

1. Weeds compete with the crop for resources like space, light, water, and nutrients, and some of them have allelopathic effects; all these may result in a significant reduction in yield.
2. Weeds sometimes act as alternate hosts for some insects, microorganisms, and parasites, which are pests for crops.
3. In some cases, weeds can be directly parasitic. For example, *Cuscuta, Orobanche, Striga*, and *Loranthus*.
4. In some cases, weeds can reduce the quality of crop produce as their parts can adulterate crop produce, which gives it an undesired colour, taste, or odour. The produce may also be poisoned. The most famous example is mixing of Argemone seeds with mustard seeds. In some cases, weeds or parts of weed plants mix with fodder and have a toxic effect on livestock.

Inadequate understanding of these issues has led to the perception that all weeds or 'plants other than crops in the field' will affect the yield and quality of crops and all necessary action to be taken to control weeds. This led to the condemnation of all the plants other than the crops as villains.

But this perception has many misconceptions, as mentioned below:

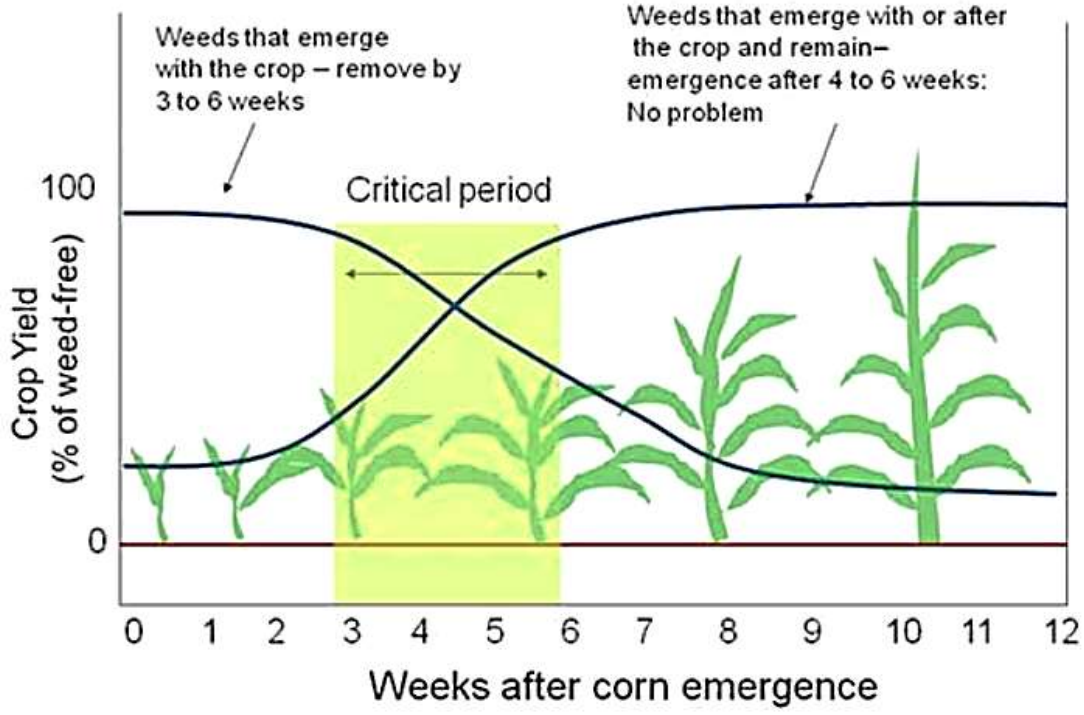
Misconception 1: All plants other than crops are bad for crop performance.

Given the various roles weeds play in the cropping system (see the earlier section on this), all of them do not affect crop performance. In fact, many of them improve crop performance by acting as a companion plant to the crop and assisting it in various ways. Some weeds protect the soil from erosion by improving its structure and providing organic matter; they generate, in many cases, a microclimate favourable to crops; and they improve biodiversity, harbouring beneficial fauna such as pollinators. These weeds are like the companion crops that are part of the mixed-, inter-, and polyculture cropping systems. So, farmers will lose a lot if they see every plant other than the crop as a menace and spend manpower and money to control it.

Misconception 2: Weeds are problematic all the time.

As mentioned in the earlier paragraph, not all plants other than the crop affect the crop performance. Even the weeds that compete with the crops do not affect the performance of the crops all the time. Such weeds are problematic only when their population crosses a threshold limit and only during the critical period of weed competition. It is usually the early stage of the crop. Such weeds are not problematic if their population is less or if they compete in different period of the crop lifecycle. See Box 1 for more details.

Box 1: When weeds become a problem: Early stages



The weeds become a problem only when they compete with the crop for nutrients, water, and sunlight. The critical period of weed competition is the shortest time span during crop growth when weeding results in the highest economic returns. The crop yield level obtained by weeding during this period is almost similar to that obtained by full season weed-free conditions. The critical period of weed competition is approximately 1/3rd of the duration of the crop (TNAU). This is the time when the weed reduces crop yield. Weeds that are removed before the critical period, or that emerge after the critical period do not cause any appreciable yield loss. The exact timing of this period is not an "inherent property of the crop" and varies for different crops, for different weed species, and under different conditions, such as year or location. In general, weeds should be removed at early crop growth stages (Johnson).

Misconception 3: Weeds act as alternate hosts for some insects, microorganisms, and parasites, which are pests for crops.

While this may be true for some weeds, and this is not the case with all weeds. Even when some weeds serve as an alternate host to pests, if there is an ecological balance in the farm and agricultural ecosystem, the damage from these pests is very limited and does not warrant the all-out elimination of weeds.

Misconception 4: Clean cultivation is best for the performance of the crops.

Clean cultivation: In this method of soil management, the space between plants is kept clean by tillage and the removal of weeds. The notion of clean cultivation goes against our understanding of the proven benefits of polycultures. In most of the cases, clean cultivation is implemented to provide a psychological comfort for the farmer than to create an environment conducive to the crops.

Clean cultivation indicates a simplistic understanding of how crops thrive as a component of the overall agriculture ecosystem.

The major disadvantages of clean cultivation include:

- Loss of soil through erosion, even on flat lands, through water and wind.
- Loss of organic matter.
- Loss of nutrients through excessive leaching.
- Injury to roots and the creation of entry points for pathogens.
- Increase in the cost of cultivation.
- Foregoing all the benefits of plants labelled as weeds to crops like natural biocontrol, addition of soil fertility, etc.

Clean cultivation practices adopted in Maize crop

- Foregoing all the uses of plants labelled as weeds for humans such as alternate food source, fodder, medicine, etc.

3.2 Issues with use of herbicides for weed management

Herbicides are composed of tiny chemical molecules (typically 500 MW) that primarily target the physiological processes of plants. Herbicides work by interfering with the plant's metabolic processes, causing them to die or cease growing. Depending on the types and application methods, herbicides can be selective, targeting only certain plants, or nonselective, affecting all vegetation. Herbicides quickly supplanted other weed management methods in many parts of the world (Ghazi *et al*., 2023).

Herbicide use in the world is increasing rapidly due to the high cost of labour and decreasing labour force. Approximately 33% of agricultural products are produced by using pesticides. Herbicides make up more than 80% of the total pesticide consumption used to protect crops. There is a misconception that herbicides are safe for human health and have little impact on the environment. As a result, tons of herbicides are applied in agricultural areas every day. The major drawbacks of herbicide application are shared below:

i. **Effect of herbicides on human health**: Herbicides enter the human body as residues in foods and affect the health of humans in various ways. People who have been exposed to herbicides occupationally, or by eating foods or liquids containing herbicide residue, or inhaled herbicide-contaminated air, have experienced a broad range of chronic health effects, including impaired neurobehavioural function, Alzheimer's and Parkinson's diseases, hormone disruption, asthma, allergies, hypersensitivity, obesity, diabetes, hepatic lesions, kidney failure, multiple sclerosis, and cancer.

ii. **Effect of herbicides on targeted plants**: It is reported that repeated application of herbicides in farms has resulted in the development of resistance among the weeds, which in turn led to the development of 'super weeds'. Repeated use of herbicides with similar modes of action for weed control in wheat has resulted in the evolution of multiple herbicide resistances in Canary grass (*Phalaris minor*), which could threaten the sustainability of the rice-wheat cropping system in north-western India. Herbicide resistance could also become a problem in direct-seeded rice and

soybean crops, which rely heavily on acetolactate synthase (ALS) and acetyl coenzyme A carboxylase (ACCase) inhibiting herbicides. (Makhan *et al*., 2017)

iii. **Effect of herbicides on non-target plants***:* Herbicides, especially broad-spectrum herbicides, affect plant biological diversity and damage environmental balance. In addition to the possibility of killing crops, herbicides can reduce plant yields and increase susceptibility to diseases. Due to these effects and increased weed tolerance and resistance, farmers have to use fungicides and supplemental herbicides in cereals, causing excessive ecological damage. Boutin *et al.* (2014) reported that drift from crop fields into adjacent non-target habitats is the most likely scenario for exposing non-target plants to herbicides. Between 5% (commonly) and 25% (occasionally) of the applied herbicide dose is expected to reach the vegetation in field margins and boundaries (e.g. hedgerows, woodlots, etc.) A total of 35 species (34% of total species) were found with marked herbicide effects including epinasty, leaf mottling, withering, yellowing, leaf and stem twisting, necrosis and bud malformations. The two herbicides viz., atrazine and tribenuron-methyl application by 3 years changed the species composition, reduced the number of plant species and the relative frequencies of some plants, and significantly reduced the Margalef species richness index and Shannon's diversity index of the plant community in the fallow field (Yue Qi *et al*., 2020).

iv. **Effect of herbicides on animals***:* Herbicides affect animals directly or indirectly. Glyphosate caused high death levels in frogs. It has been reported that atrazine causes degradation of frog genetics. Herbicide application is reported to lead to a decrease in the bird population. Exposure of chicken eggs to 2,4-D reduced incubation time and has been reported to cause feminization and infertility in pheasant chicks.

v. **Effect of herbicides on soil:** Herbicides are retained by soils in different degrees, depending on the interaction between the features of the soil and herbicides. The most important soil feature is organic matter content. As the organic matter content increases, the adsorption of herbicides also increases. Whenever the size of soil colloids was smaller, they adsorbed herbicides more. The active persistence period of different herbicides in soil varies from 2 months to 24 months as shown in the table below, indicating the potential damage they can cause.

Chemicals	Active persistence period
Acetochlor	3-12 months
Alachlor	1.5-3 months
Atrazine	4-18 months
Bromacil	9-18 months
Cholorxuron	3-6 months
Chlordbiamid	12-24 months
Dichlobenil	12-24 months
Isoxaben	6-12 months
Metsulfuron	2 -12 months
Oxadiazon and Terbacil	9-18 months
Trifluralin	5-10 months

Many herbicides can destroy microorganisms in the soil. On the other hand, microbial disruption can lead to the formation of more toxic and permanent metabolites. Although microbial soil complexes can adapt to changing environmental conditions, the application of herbicides has been reported to cause significant changes in populations. (Ustuner *et al.,* 2020) In some

instances, herbicide over-application has negatively impacted soil microbiota, affecting the dynamics of biogeochemical cycles and soil fertility likely due to loss of sensitive microbial populations providing specific ecological functions (M. Pileggi *et al.* 2020)

vi. **Effect of herbicides on the aquatic environment***:* Herbicides infiltrate the aquatic environment in many ways and cause harmful effects on living organisms. It has been reported that herbicides used in agricultural areas affect aquatic life. Approximately 1% of the applied herbicide is estimated to leak into the surrounding environment, and rain precipitation can increase this rate up to 3%. Aquatic plants provide about 80% of dissolved oxygen and are essential for the survival of organisms in the water. Herbicides have been observed to kill aquatic plants, thereby lowering O_2 levels and ultimately reducing fish numbers in the water. Atrazine and Alachlor have a serious effect on algae and diatoms, which are the main organisms in the food chain in the aquatic environment (Ustuner *et al.,* 2020).

The long-term use of thiobencarb caused imbalances in agricultural soils and in aquatic systems, mainly due to its toxicity in invertebrates, fish, and microorganisms, reducing their number and diversity. The world-wide use of the herbicide 2,4-D has also impacted groundwater on account of its high solubility (M. Pileggi *et al.* 2020).

As can be seen from this section, farmers efforts related to weed control emerge from the condemnation of 'all plants other than the crops on the farm' due to a lack of understanding of the important roles played by them. Their all-out efforts to control weeds using biocides like herbicides have serious consequences for the macro- and microfauna and flora in agricultural ecosystems, the wider environment like water bodies, etc., and human health. There are easier and safer ways to manage the issue of weeds that do not create havoc. The next chapter informs the reader of these ways.

Common chickweed has very small white petaled flowers

Section 4

Agroecological management of weeds

4.1 Living with weeds: *a new paradigm*

As described in Section 2, the plants labelled as weeds play multiple important roles in cropping systems and benefit humans in various ways, and they negatively affect the yield of crops only under certain conditions. Weeds maintain the biological diversity of farming landscapes, providing food and shelter for a variety of animals. Insects, which pollinate crops, extensively use weeds as a source of nectar when crops are not in flower. Weeds also attract crop pests, and there is evidence that pest populations in some crops are much lower in 'weedy fields' than in 'weed-free' crops. As many of our primary crops have 'weedy-relatives', the genes present in weeds appear crucial for the future evolution of crops, particularly to confer 'hardiness' (the ability to tolerate variable environmental conditions). Some weed species contribute to aesthetic pleasure as part of 'wild nature', while others provide culinary delights for humans and are important as food sources for both vertebrate and invertebrate animals. Many weeds with medicinal values continue to be used either as traditional 'herbal' remedies or extracted for secondary metabolites. The colonising strengths of several species are being used in the remediation of water and terrestrial environments to scavenge soil pollutants. Globally, there is considerable interest in using the large biomass produced by these species as raw materials for countless household products, including bricks, paper, and furniture, and as future biofuels. Therefore, a new and bold paradigm of 'co-existing' or 'living with weeds' needs to be adopted, recognizing their intrinsic worth as part of biodiversity and their many possible uses as bio-resources. Such informed practices should lead to

1. Benefiting from the weeds as much as possible and
2. Minimising the losses from the weeds.

4.2 Engaging with the 'plants labelled as weeds'

4.2.1 Understanding the abilities of weeds that make them stronger or more problematic

The plants labelled as weeds, being very good colonisers, have many inherent abilities that offer them an edge over the cultivated crops. Some of these abilities are shared below:

- **Prolific seed production**: Weeds have the ability to self-pollinate and produce seeds under adverse environmental conditions and to produce an enormous quantity of seeds. For example, wild oats produce 250 seeds per plant and wild Amaranthus produce 11 million seeds.
- **Fast recovery of seed bank**: Even though seeds in the soil are reduced by 95% due to germination and mortality, the seed bank can often recover in a single year.
- **Viability of seeds for a longer period:** Seeds remain viable for longer periods without losing their viability; For example, Annual meadow grass (*Poa annua*) and Scarlet pimpernel (*Anagallis arvensis*) remains viable for about 8 years; Creeping thistle (*Cirsium arvense*) for 20 years, and Field bindweed (*Convolvulus arvensis*) for about 50 years.
- **High ability to survive and propagate under varied environments**:
  - ✓ Weeds often germinate under a variety of conditions, including adverse soil-moisture conditions, and some portions of the population remain dormant.
  - ✓ Have a short period of plant growth, generally grow faster, and produce seed earlier than most crops growing in association.

- ✓ Tolerate a wide range of environmental conditions.
- ✓ Have tremendous capacity to disperse from one place to another through wind, water, animals, and humans.
    - Often, weed seeds mimic crop seeds due to their size and get transported from one place to another along with them. E.g., Seeds of *Argemone mexicana* resemble with mustard seeds, *Avena fatua* seeds resembles cultivated oat seeds (presentation by Vinod B Shimpale)

- **High ability to absorb nutrients:** Application of fertiliser may benefit weeds to a greater extent than crops because nutrient absorption is faster and higher in weeds than in crop plants (Balasubramanian and Palaniappan, 2004).
- **High ability to use water**: Weeds have a high ability to use water and therefore are serious competitors to crops for water.
- **Allelopathic effect:** Some of the weeds have allelopathic effects on other weeds and crops. E.g.: *Parthenium*

4.2.2 The reasons for the increase in issues associated with weeds

- Increase in monocropping or less diverse cropping practices
- Inadequate efforts to ensure crop rotation
- Shortage of labour
- Breaking down of the practice of exchange labour for timely weeding in the village communities
- Social mobility, inadequate availability of family labour, and less willingness to do manual labour
- The erosion of indigenous knowledge systems related to weed management among the farmers

Besides the above, farmers are made to see plants other than crops on the farm, aka weeds, as major enemies by the herbicide industry.

4.2.3 Know your weeds

It is important for the farmers and the field workers to know the major weeds on the farms in their area so that they can act appropriately. They need to make efforts to identify the weeds, the time of their occurrence (seasonal or seen throughout the year), what triggers their emergence and growth, and how they benefit or affect the prevailing crops during their visits to farms on various occasions. If some of the weeds are observed to cause significant damage, then further observations on their life cycle and actions to be taken to prevent their seed setting have to be made. Farmers, especially elder farmers and women farmers, have rich knowledge of the plants on their farms and their uses as indicated by Tamil old saying. Efforts to learn from elders regarding weeds and the transmission of knowledge from one generation to another, particularly with a focus on women, need to be facilitated. CSOs can organise on-farm participatory rural appraisal (PRA) sessions for this purpose during the crop cycle as part of the farm field school or other training sessions, so that farmers can collectively learn and share their experiences and insights. More interactions among the farmers on what works and what does not work in the utilisation of commonly available weeds and managing problematic weeds need to be facilitated. A few farm field schools to try out different management measures can also be organised. For identification of weeds, the following documents can be used:

1. Naidu, V.S.G.R. 2012, Hand Book on Weed Identification, Directorate of Weed Science Research, Jabalpur, India Pp 354.
2. Local names of weeds, Edited by Gogoi A.K., Yaduraju, N.T., Dubey, R.P. and Mishra, J.S. 2003

PRA exercises can be organised to learn about the weeds in the farm
Photo credit: Centre for Sustainable Agriculture

More on how the farmers need to approach weeds in their farm can be learnt from the following short videos:

Weed Management In Organic Farming – Part 1 | खरपतवार प्रभंधन | HINDI/हिंदी | 2020 (youtube.com)

Weed Management In Organic Farming – Part 2 | खरपतवार प्रभंधन | HINDI/हिंदी | 2021 (youtube.com)

4.2.4 Specific management measures

4.2.4.1 Utilising the weeds

The plants labelled as weeds can be seen as bioresources instead of as a menace. In the section below, some of the major uses of weeds that the farmers and development agencies can explore are discussed.

a. Composting

The general view is that if compost is made using weed plants, it will lead to the dispersion of weed seeds in the main field. But compost from weeds can be made in a perfectly safe way, and such compost may be rich in nutrients. The secret is hot composting, i.e. ensuring the compost gets hot enough to kill any seeds and roots. Turn the compost pile regularly and frequently to make sure everything in the pile gets into the hot zone in the centre. The weeds need to be harvested before flowering. For example, *Parthenium hysetreoforus,* commonly known as carrot grass, is considered a menace to farm lands. But good quality compost can be made from this abundantly occurring biomass of *Parthenium*. See picture below for more details.

Box 2: Making compost from Carron grass (*Parthenium*) plants

It is always recommended to collect the Parthenium biomass before flowering for making compost either by NADEP or pit method. But it is not practically possible to collect only flowerless plants because all the stages of parthenium are available at any time due to non-dormancy of seeds, which may germinate on the availability of water. Following procedure (Sujatha, *et al.*, 2021) can be adopted for making compost from parthenium:

Collection of fresh weeds before flowering and chopping in to small pieces

↓

Stacking of weeds and application of jeevamrutham

↓

Preparation of jeevamrutham

(Take 2kg cow dung, 1litre cow urine, 100g pulse flour, 100g. jaggerry, 5 hand full of virgin soil and mix thoroughly and make up to 20 litre with water and allow to ferment for 3 days)

↓

Stack the weedsup to 1.5 m height in a trapezium model

↓

Turning

Alternate turning up to 10 days (5 turning). Once in three days turning up to 25 days (5 turning). Once in five days turning up to 50 days (5 turning)

↓

Watering if necessary

↓

Maintain the heap up to 75 days

Sieving of compost: After removal of compost from pit, we may find some stems which give impression that Parthenium plants have not been decomposed yet. But actually, it is well decomposed. Spread this compost in the shady place to dry it. Pieces of Parthenium stems are seen in the compost, beat them with sticks. Sieve the compost with 2x2 cm size mesh.

Dosage: Basal- 2.5 – 3 tons/ha. In vegetable crops apply 4-5 tons/ha.

b. Using as fodder and feed

Although the presence of weeds in and around the cultivated fields has never been deemed desirable, these can significantly contribute to the production of quality organic feed for cattle and small ruminants. The nutritional profile of weeds determines the feasibility and scope of their inclusion in ruminant's feed.

Dry matter digestibility has a direct relationship with the quality of forage. Different weeds such as Barnyard grass (*Echinochloa crusgalli*), Jerusalem artichoke (*Helianthus tuberosus*), Lambsquarters (*Chenopodium album*), Dandelion (*Taraxacum officinale*), Yellow foxtail (*Setaria glauca*), Perennial sowthistle (*Sonchus arvensis*), and Canada thistle (*C. arvense*) had in-vitro dry matter digestibility equal to alfalfa (*Medicago sativa*). In addition, Common ragweed (*Ambrosia artemisiifolia*) and Redroot pigweed (*Amaranthus retroflexus*) had even greater in-vitro dry matter digestibility compared to alfalfa, as shown in the table below.

Weeds	DMD (%)	Forage crops	DMD (%)
Canada thistle (*Cirsium arvense*)	68–74	Alfalfa (*Medicago sativa*)	64–75
Dandelion (*Taraxacum officinale*)	78–84	Sorghum (*Sorghum bicolor*)	59–61
Sowthistle (*Sonchus arvensis*)	76–82	Maize (*Zea mays*)	63–68
Swamp smartweed/knotweed/tanwed (*Polygonum amphibium*)	54–62	Oat (*Avena sativa*)	60–63
Quack grass (*Elymus repens*)	58–68	Barley (*Hordeum vulgare*)	59–64
Brome grass (*Bromus tectorum*)	66–76	Pearl millet (*Cenchrus americanus*)	58–60
Curly dock (*Rumex crispus*)	50–58	Cowpea (*Vigna unguiculata*)	68–76
Jerusalem artichoke (*Helianthus tuberosus*)	81–86	Soybean (*Glycine max*)	70–76
		Cluster bean (*Cyamopsis tetragonoloba*)	70–79

Crude protein (CP) is the most important nutritional quality attribute, having a direct impact on milk production. Testing of 102 weed species belonging to *Poacea*, *Asteraceae*, *Fabaceae,* and *Euphorbiaceae* families commonly found in central Mexico revealed that only 25 had a balanced nutritional profile. CP content of weeds depend on growth stage, as matured weeds recorded less protein compared to harvestings done at the pre-bloom stage. Asthma plant (*Euphorbia hirta (Amman pacharisi (Tamil)*) recorded 16.7% protein content, Tick weed or Asian spider-flower (*Cleome viscosa, Nai kadugu (Tamil)*) with 14.7% followed it, while yellow nutsedge or nut grass (*Cyperus esculentus*) and button weed (*Diodia scandens*) contained 9.8 and 7.7% CP, respectively. Bluegrass (*Poa annua*) was found to have over 14%, which is higher than maize, sorghum, and oat, while Common purslane (*Portulaca oleracea*) (8%) was also suggested to be an equally good weed as far as CP content is concerned. Another study suggested that weeds including Bush sunflower (*Simsia amplexicaulis*), Creeping false holly (*Jaltomata procumbens*), and Mosquito flower weed (*Lopezia racemosa*) contained CP in the range of 6.5–16.9% and could be used solely or as supplementary feed mixed with maize straw to feed dairy cattle. Mixtures of weeds (*Commelinaceae* + *Amaranthaceae*) recorded crude protein twice as much as most of the roughages. Another study reported that Bush sunflower (*Simsia amplexicaulis*) weed supplemented with maize straw-based animal diets resulted in higher protein content and successfully met the dietary needs of dairy animals. Similarly, Climbing dayflower (*Commelina diffusa* L.) recorded an appreciably higher protein content (17.7%), which is comparable to commonly used forage crops. In addition, its rumen degradability of protein was recorded at over 72%, making it forage with balanced nutrition.

Mineral constituents of weeds: Minerals in appropriate quantity are essential for dairy animals to be utilised in various metabolic processes for boosting immunity levels against diseases and reproductive health. The asthma plant (*Eurphobia hirta*) was recommended to be included in animal feed for having reasonably higher concentrations of major minerals, including calcium (Ca) (13.6%), magnesium (Mg) (3.0%), and potassium (K) (2.5%), along with many trace elements such as iron (Fe) (0.7%), copper (Cu) (0.1%), and manganese (Mn) (0.1%). Common chicory (*Cichorium intybus*) was also suggested as a forage weed for having a comparable mineral composition, including Ca (6%), Mg (2%), Fe (0.5%), and Cu (0.06%). In addition, pink sorrel (*Oxalis debilis, Perum puliyarai (Tamil)*) was found to be poor on the animal nutrition scale for being deficient in Ca (4%), Mg (2.3%), Fe (2.4), and Zinc (Zn) (0.15) compared to other forage weeds. Very limited information has been reported so far regarding the mineral constituents of weeds, which limit their utilisation as a feed source for ruminants. Mineral composition of some of the weeds rich in Ca, Mg and Zn are given below.

Weeds	Ca	Mg	Zn
Wild oat (*Avena fatua*)	1.8	1.10	0.06
Burr clover (*Medicago polymorpha*)	10.2	2.42	0.14
Morning glory (*Ipomoea purpurea*)	9.0	0.63	2.99
Yellow duck (*Rumex crispus*)	4.7	2.70	0.20
Cheese weed (*Malva parviflora*)	19.3	1.22	4.59
Wood sorrel (*Oxalis decaphyllai*)	5.1	1.43	2.76

Various weeds used as animal feed includes (Pawan Kumar, 2022):

- Wild jujube (*Ziziphus numularia*)
- Amaranth (*Amaranthus species*)
- False Amaranth (*Digera arvensis*)
- Lambsquarters (*Chenopodium album*)
- Onion weed (*Asphodelus tenufolius*)
- Scarlet pimpernel (*Anagalis arvensis*)
- Bermuda grass (*Cynodon dactylon*)
- Red spiderling *(Boerhaavia diffusa)*
- Crown flower (*Calotropis gigantica*)
- Asian pigeonwings (*Clitoria ternetea*)
- Yellow Pea (*Lathyrus aphac)*
- Wild Jute (*Corchorus olitorius*)
- Field bindweed (*Convolvulus arvensis*)
- Wild Oat (*Avena fatua*)
- Creeping Launaea (*Launaea asplenifolia*)

See Plate 6 to get to know some of these useful weeds.

Plate 6: Weeds which are potential fodder- *a boon for integrated farming*

Common Ragweed
Ambrosia artemisiifolia

Curly dock
Rumex crispus

Asian spider flower
Cleome viscosa

Bush sunflower
Simsia amplexicaulis

Climbing dayflower
Commelina diffusa

Amman pacharisi
Euphorbia hirta

Common chicory
Cichorium intybus

Pink sorrel
Oxalis debilis

Cheese weed
Malva parviflora

Morning glory
Ipomoea purpurea

c. Utilisation of weeds to generate energy

Weeds can be used to generate energy through biomass gasification. Gasification is the conversion of biomass into a combustible gas. Locally known as *Besaram*, Ipomoea is found in abundance near water bodies. One hectare yields approximately 160 tons of green biomass, which is equivalent to 64 tons of useful feedstock for gasifier. *Parthenium hysterophorus* L. and *Cannabis sativa* L. have been employed for the production of biofuels (biogas, biodiesel, and biochar) through nano-catalytic gasification by employing Co and Ni as nano catalysts. During gasification of *Cannabis sativa* L., we have extracted the 53.33% of oil, 34.66% of biochar and 12% gas whereas in the case of *Parthenium hysterophorus* L. 44% oil, 38.36% biochar and 17.66% of gas was measured (Nadeem Tahir *et al.*, 2020).

4.2.4.2: Managing the weeds

In the science of agroecology, the focus is on how to "manage" weeds, rather than "control" them or "destroy" them, so that we can minimise the damage caused by weeds and maximise the benefits from the weeds. Farmers and development agencies need to look into the indigenous knowledge systems in vogue currently and in the past related to managing weeds in an area to learn the place- and context-specific interventions and build on that. There are two basic principles of weed management viz. a) avoiding or limiting the germination of weeds on the farm and b) removing or regulating the growth once it has emerged. Some of these measures are described below.

a. Avoidance

1. **Limiting the size of the weed seed bank or propagules**

   Preventing weed seeds from arriving in one's field is an important weed control strategy in no-herbicide arable crop systems. It involves the following tasks:

   - The basic source of seeds coming into the farm is farmyard manure. In most cases, not enough care is taken to make it fully composted. Well-made compost kills most of the weed seeds due to the high temperatures during the composting process. Processing animal dung through anaerobic digestion also helps in killing the weed seeds.
   - Weed seed also enters through irrigation water, winds, animals, and implements. All care should be taken to avoid such an entry.
   - Cleaning and sorting farm-saved seeds to avoid re-contaminating fields with seeds collected during the previous harvest.
   - Cleaning farm equipment, and combine harvesters to prevent accidental field contamination.
   - If the field is irrigated, pre-sowing irrigation followed by shallow cultivation is an age-old practice to kill viable weed seeds before sowing the main crop, thereby not allowing them to compete with the crop.
   - For highly infested plots, newly bought pieces of land, or at the beginning of the season, deep ploughing also helps to control obnoxious weeds like Purple nut sedge (*Cyperus rotundus), Halfa grass (Dabhado* (Hindi) *Desmostachya bipinnata),* and Bermuda grass (*Cynodon dactylon)*.
   - Preventing weeds from going to seed within fields by cutting the weeds before flowering.
   - Regularly cutting or shredding vegetation along field edges to prevent nearby weeds from going to seed and contaminating the field.

2. **Light and germination/ Night tillage**

Many buried weed species develop a light dependent stimulus for germination. This led to the concept of photocontrol, (excluding light during tillage), as a potential way to reduce weed seed germination. Light-excluded tillage has generally caused a greater reduction in the number of dicots emerging, with less impact on grasses. Emergence of small seeded broadleaf weed species such as lambs quarters, pigweeds, and wild mustard were reduced with night tillage, but there was no effect on large seeded broadleaf species like velvetleaf (E. Johnson, 2002).

Night-time tillage and sowing (syn. photocontrol of weeds, soil cultivation in darkness) can reduce the germination and subsequent density of light-sensitive weeds by excluding the short light flash during soil disturbance (P Juroszek *et al.*, 2017).

3. **Tillage**

Tillage is the process of mechanically manipulating soil with tools and implements to create perfect conditions for seed germination, seedling establishment, and crop development. The tillage strategy affects soil moisture and temperature, which might alter weed germination conditions. It is the most effective and cost-efficient weed management strategy. Weed management can be accomplished before planting by ploughing and during the crop period through cultivating and harrowing.

a. **Minimum tillage:** Minimum tillage is aimed at reducing tillage to the minimum necessary for ensuring a good seedbed, rapid germination, a satisfactory stand, and favourable growing conditions. While deep and frequent tillage has its advantages, it also helps to bring more dominant weed seeds and rhizomes to the surface. Store fresh weed seeds deep in the soil for future use.

b. **Summer fallowing:** Summer tillage, often known as off-season tillage, is one of the most successful cultural strategies for controlling perennial weed populations in crop cultivation. During the months of April, May, and June, farmers take up ploughing and expose their fields to the sun in order to reduce weeds, roots, rhizomes, and tubers of shallow-rooted perennials such as Bermuda grass and nut sedge.

4. **Crop and cultivar selection**

Certain crop cultivars are known to be better competitors with weeds than others. For example, white bean (*Phaseolus vulgaris L.*) cultivars differ in their ability to compete with weeds. Tomato (*Lycopersicon esculentum L.*) cultivars have considerable tolerance to dodder (*Cuscuta sp.*), a severe parasitic weed in many parts of the world. Other aspects that need to be given attention are:

- Larger or more rapidly growing cultivars (large seeds, broad leaves, good branching, and height with good yields) outcompete weeds.
- Depending on the cultivar & season, early planting before weed emergence or late sowing after maturation of weeds are options.

5. **Crop row spacing and population density**

These parameters can be used as a tool for weed management. For example, narrower row spacing and higher density significantly reduce the biomass of late-emerging weeds in corn. Close planting of crops reduces “weeds” ability to compete- e.g., Tomato and Beans. Row & grid sowing makes weed identification and weeding much easier; North-South orientation captures most light (Sruti and Soumik, 2018).

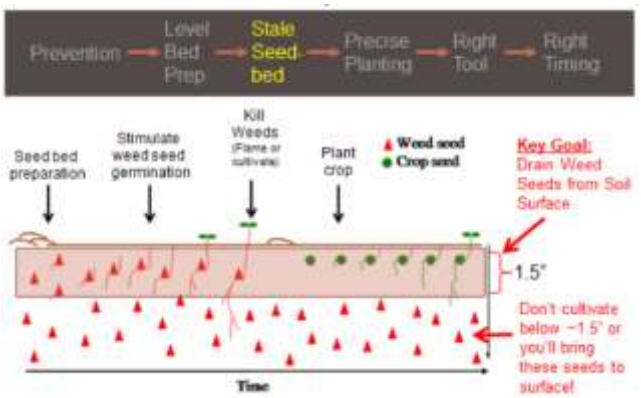
6. Stale seedbed preparation

This weed management strategy consists of preparing a fine seedbed, allowing weeds to germinate (relying on rainfall or irrigation for necessary soil moisture), and directly removing weed seedlings via light cultivation. There are three 'golden rules' that underpin stale seedbeds.

1. Only 85-95% of seeds are dormant at any given time, but of the 5-15% that are non-dormant, most germinate quickly.
2. Tillage is the most effective means of getting weed seeds to germinate.
3. Most weeds can or will only emerge from the top five centimetres (2") of soil.

How to prepare a stale seedbed:

1. The area should be smooth and ready to plant.
2. Irrigate the area or wait for rain sufficient to germinate weeds.
3. About 7 to 10 days after the rain or irrigation, perform shallow tillage with a rake, or hoe to kill the weeds.
4. Again, irrigate or wait for rain sufficient to germinate weeds.
5. About 7 to 10 days after the rain, perform shallow tillage with a rake or hoe to kill the weeds.
6. The area is now ready for planting (Senthilkumar *et al*., 2019).



Cross sectional view of stale seed bed preparation indicating weed control
Credit: Sam Hitchcock Tilton and Hans Bishop

7. Crop rotation

Crop rotation is an important part of the weed management plan in a farm. Crop rotation involves alternating different crops in a systematic sequence on the same land. It is an important strategy for developing a sound, long-term weed control program. Monoculture, that is, growing the same crop in the same field year after year, results in a buildup of weed species that are adapted to the growing conditions of the crop. When diverse crops are used in a rotation, weed germination and growth cycles are disrupted by variations in cultural practices associated with each crop (tillage, planting dates, crop competition, etc.).

In crop rotation, growing of non-host plants for weed management will reduce the problem of crop associated and parasitic weeds seed in the soil by reducing viability that will result in negligible crop competition. Crop rotation is effective in controlling of crop associated and crop bound weeds such as *Avena fatua* in wheat and *Cuscuta* in lucerne. Wheat-pea and gram break the Avena in wheat and Lucerne-grain crop rotation control *Cuscuta*. The obnoxious weeds like *Cyperus rotundus* can be controlled effectively by including low land rice in crop rotation. In certain parts of India, crop rotation using marigold (*Tagetes* spp.) during rainy season, instead of the usual crop, is found effective in reducing *Parthenium* infestation in cultivated areas. Crop rotation with legumes or other trap crops helps to germinate Striga seeds but makes Striga not to form haustoria (Lokesh Kumar *et al*., 2017).

8. **Relay cropping**

Relay cropping involves sowing the next crop when the current crop is close to the end of its crop cycle. Due to this, crops have a head start when compared to the weeds and are not affected by them. More details on the effect of relay cropping on weed are showed below.

Potential of relay cropping in reducing weed infestation (Mohsin Tanveer *et al*., 2016)

Relay intercrops	Sole crop	Weed type	Weed control
Legume crops	Winter wheat	Spring germinating annual weeds	35.2%
Sesbania sesban L. and *Cajanus cajan* L.	Sorghum	*Striga hermonthica*	62.1%
Canola and sunflower	Wheat	Spring germinating annual weeds	34.5%

Relay intercropping of legumes proved to be an effective solution to control weeds before and after the wheat harvest, provided suitable legumes species are chosen. Suitable legumes reduced the weed biomass up to the 90% during the intercropping and up to 94% in the following spring. According to the performance of legumes, *Medicago sativa*, *Trifolium repens* and *Medicago lupulina* had the most suitable characteristics for relay intercropping with durum wheat at the Ravenna site, in a highly productive region whereas *Medicago sativa*, *Hedysarum coronarium* and *Trifolium subterraneum* performed better in the low-input system near Pisa (Federico *et al.,* 2022).

b. Not allowing them to reach the problem level

1. **Baby weeding:** This practice involves weeding 10-15 days after the sowing or planting of any crop, when the weeds are very small, by using bullock-drawn implements, hand weeding, or cycle weeder. This will reduce the weed pressure for the emerging crops and eventually control weed seed production.

2. **Mulching:** Applying mulch after planting can offer some benefits in many cropping systems. Mulches reduce weed competition by limiting light penetration and altering soil moisture and temperature cycles.

    a. **Living mulch:** Living mulches are cover crops sown previously or at the same time as the main crop and maintained as a living ground cover throughout the growing season. If the living mulch is perennial, it may be possible to maintain it without the need for reseeding every year. Living mulches can decrease nutrient leaching, especially of nitrates, along with the absorption of carbon and nitrogen, provide efficient control of soil erosion, build up organic matter for better soil structure, and provide a habitat for beneficial insects.

    Annual or short-term perennial **cover crops** can be used in place of a fallow period to reduce soil erosion and maintain soil fertility while competing with weeds for resources such as light, water, and nutrients. Cover crops that develop rapidly and form a dense canopy can keep sunlight from newly emerging weeds and outcompete them. Cover crops can also provide organic mulch or living mulch to further suppress weeds. Cover crops suppress weeds by occupying their ecological niche and competing for resources, while their soil surface residues inhibit weeds through physical, biotic, and allelopathic interactions. The cover crop species can inhibit weed seed germination through the deposition of allelochemical compounds, which may be secreted both from living plants and decaying cover crop residues. Those species can be grown in rotation at times when crops are not being grown or simultaneously during part or all of the commercial growing season. Cover crops enhance soil quality and carbon sequestration,

and increase microbial, vegetal and animal biodiversity. However, the great benefits of cover crops as weed mitigators are usually associated with high cover crop biomass or rapid soil cover. Promotion of Pre-Monsoon Dry Sowing (PMDS) on a large scale in Andhra Pradesh indicated the scope for covering the land for a major part of the year by the crops and suppressing the weeds in the process.

Cover crop and intercropping

Intercropping involves growing a suitable crop between rows of the main crop. **Mixed cropping** involves growing a combination of associated crops, which are sown in a mixed manner without following rows. Most of the agricultural regions of India have context-specific traditional intercropping practices that have evolved over the years and reflect the local soil, weather, and socio-economic factors. Intercrops are able to suppress weeds. *Baranaja* cropping systems followed in Uttarakhand and traditional rainfed cotton systems involving six or more crops in Tirumangalam taluk in Tamil Nadu are some of the examples. Inter-cropping and mixed cropping are practiced in many production systems around the world because they allow for more efficient use of natural resources like light, water, and nutrients. They involve the planting of numerous species with differing growth and development modes. These variations may provide opportunities for weed management because inter/mixed crops can deplete resources that would otherwise be available to weeds and hence suppress weed growth. As a greater portion of the land area is covered by crops in intercropping or mixed cropping, there will be fewer weeds. Fast-growing crops like greengram (mung) and blackgram under intercropping cover the maximum land area and suppress weed growth. The weed suppression ability of the intercropping system depends on some factors like selection of crop, genotypes used, plant population, the ratio of crops considered in the intercropping and spatial arrangement, fertility, and soil moisture.

Crops with strong weed-suppressing ability can be used as cover crops, smother crops and green manure crops by altering cultural practices and by designing new cropping systems to aid sustainable weed management.

b. **Mulch with organic matter:** Organic mulches include many materials that can be produced on-farm, such as hay, straw, grass mulch, crop residues, and livestock or poultry bedding. Other materials, such as leaves, composted municipal waste, bark, and wood chips, may be available from off-farm sources.

c. **Newspaper mulching:** Newspaper mulching helps to control weeds. The thickness of the newspaper mulch should be around one to two cm and the edges should be fastened with materials like pebbles, gravel, etc. The application of newspaper mulch should be avoided on a windy day. Newspaper is a cheap, abundant, and useful mulch. And it's safe because newspapers nowadays do

not have lead (as was the case earlier), and the amount of hydrocarbons in coloured inks is insignificant.

Unlike some landscape fabrics and weed barriers, newspaper breaks down completely, so you don't have to extricate it in five years when it's shredded and roots are tangled in it. How quickly a layer of newspaper mulch breaks down varies greatly depending on several factors. The rate is faster if the soil is rich in microorganisms, if your region is damp or you water often, or if temperatures are warm but not hot. Experiment to find what works best in your garden. As a starting point, if you live in a warm, damp climate, make your layer about five sheets thick.

3. **Periodically cut the weeds in orchards**: The way to manage weeds in orchards is to periodically cut the weeds (before they flower) and mulch them at least 3-4 inches thick on the soil under crops. Without any sunlight falling on the weed seeds buried in the soil, fresh germination is effectively checked. Correspondingly, crop growth gets better while weed growth declines. In just 2-3 years, there should be no need for any weeding at all. Until then, the farmer is better advised to cut and mulch the weeds.

   The cutting of weed growth above the land surface–without disturbing the roots–and laying it on the earth as 'mulch' benefits the soil in numerous ways. With mulching, there is less erosion of soil by wind or rain, less compaction, less evaporation, and less need for irrigation. Soil aeration is higher. So are moisture absorption and insulation from heat and cold. The mulch also supplies food for the earthworms and microorganisms to provide nutrient-rich compost for the crops. Moreover, since the roots of the weeds are left in the earth, these continue to bind the soil and aid its organic life in a similar manner as the mulch on the surface. For when the dead roots get weathered, they too serve as food for the soil-dwelling creatures.

   It is also important that the cutting and mulching operation be done before the weeds have flowered and become pollinated. If the farmer is too late and the mulch contains pollinated weed seeds, a new generation of the same weeds will re-emerge strongly in the mulched areas.

4. **Water management:** The type of irrigation system and its timing can influence weed populations and their management. Weed seed germination is influenced both by soil moisture and temperature. Therefore, a change in soil moisture regimes can affect weed emergence patterns and population dynamics within a cropping system. For example, weed emergence and growth were suppressed under sub-surface drip irrigation compared to sprinkler and furrow irrigation systems in semi-arid cropping systems because of the drier soil surface under the drip system. In drip irrigation, water is applied in the crop root zone, and hence weed growth is minimal.

   Flooding fields in Paddy severely affects the growth of "weeds" unadopted to anaerobic conditions. This can also be used to suppress "weeds" before and during crop production.

   In orchards, weed management may need to be adjusted according to the irrigation and planting systems. For example, if an orchard is planted in flat beds and irrigation water is placed in the tree rows, weed management frequency may need to be increased because of the high moisture and greater weed germination in the tree rows. Conversely, where trees are planted on raised beds, the frequency of weed control measures may be reduced because of the drier soil surface in the tree rows.

   The field experiment was conducted during kharif 2021 at Oilseeds Farm of Agricultural College and Research Institute, Coimbatore to study the effect of irrigation and weed management practices on nutrient removal by weeds and weed control efficiency in groundnut. The results revealed that irrigation provided through drip system recorded lower weed dry matter and showed a higher weed control efficiency followed by rain hose method and surface method of irrigation (Arpitha *et al*., 2021).

c. Suppressing the weeds

1. Manual weeding

As it's very labour intensive, reducing weed density in the early crop season in the field as much as possible will bring less work later on and should therefore be aimed at. There are different tools to dig, cut, and uproot the weeds manually- hand, and ox-drawn tools. Using the right tool can increase work efficiency significantly.

Hand-held implements

a. **Khurpi:** The khurpi, also known as a hand hoe, is the most commonly used hand tool for weeding. The tool is used in a squatting position. The khurpi consists of a sharp, straight-edged metallic blade with a tang embedded into a wooden handle. The cutting edge is hardened and sharpened. The tang is joined to the wooden handle with the help of rivets. The shape and design of the khurpi are region- or location specific depending on the soil and cultural practices. For operation, the khurpi is held in one hand and pushed into the soil for the removal of weeds or unwanted plants. The cutting or uprooting of the weed or undesired plant takes place due to the shear and impact action of the blade of the khurpi.

i) **Push-type khurpi:** The hand tool is fabricated from a mild steel rod or square bar, and the working end of the blade is flattened by forging operations. Local artisans and blacksmiths fabricate the tool. The khurpi is used in and around the Barpeta district of Assam. A wooden handle is provided for the operation of the tool. The tool is operated in a squatting position by pushing the blade into the soil.

ii) **Push-and-pull type khurpi:** The hand tool consists of a flattened curved blade with a tang and wooden handle. A steel ring in the handle secures the tang. The blade is made from mild steel flat, angle, or old leaf spring steel by forging. The tip area is flattened by hammering on an anvil and sharpened along the periphery. Both convex and concave edges of the tool are used for cutting weeds. The tool is operated by a push-pull action in the squatting position.

iii) **Weeding hook:** The weeding hook is a twin- edged, sickle shaped hand tool used for cutting tall weeds and for loosening the soil. It consists of a 'curved blade 'with a tang fitted to the wooden handle. The inner curved edge has a serration for cutting the weeds and acts like a sickle. The outer edge is plain and is flattened at the tip. The flattened tip is forged to a sharp edge for manipulation of the soil and acts like a khurpi/ hand hoe.

iv) **Manual weeder** (locally called Tuthlaw)**:** The hand tool consists of a triangular shaped blade with one of the vertices drawn to form a tang. The blade is forged from a mild steel flat section to shape. The tang is inserted in a wood handle at the curved end. The cutting edge of the blade is sharpened for easy penetration into the soil. The tang end is also used for dibbling seeds by replacing the handle. For operation, the tool is operated in a bent posture or in a squatting position by holding the handle and drawing the blade in the soil towards the operator. It can also be used by a striking action of the blade in the soil.

Manual weeders operated by humans

a. Hoes

i. **V-Blade hand hoe:** The V-blade hand hoe is a long-handled weeding tool for operation in between the crop rows. The hoe consists of a V-blade, an arm ferrule, and a wooden handle. The arms are welded to the ferrule. A wooden handle is inserted in the ferrule. The blade of the hoe is the important component, which enters the soil and performs the cutting and uprooting of weeds.

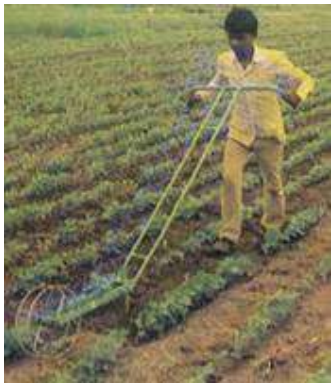
ii. **Three tined hand hoe:** The three-tined hand hoe, also known as grubber, is one of the widely used hoes for weeding and interculture in horticultural crops. It is a long-handled weeding tool and can be easily manoeuvred between the rows and around the plants. The tool essentially consists of three curved tines that are bent to appropriate shapes. The working blade tips are forged, flattened, and sharpened.

iii. **Wheel Hoe:** The wheel hoe is a widely accepted weeding tool for weeding and interculture in row crops. It is a long-handled tool operated by push and pull action. As the name implies, the general construction of a wheel hoe comprises a wheel assembly, a miniature tool frame, a set of replaceable tools, and a handle assembly.

iv. **Twin wheel hoe:** A twin wheel hoe consists of twin wheels, a frame, a V-blade with tyne, a U-clamp, a scraper and a handle. The cutting and uprooting of weeds in the field is done through the push- and pull action of the equipment. The equipment is operated at optimum conditions in the field for better output. Women workers liked the equipment.

b. Rice weeders: There are different types of weeders, especially those used in the System of Rice Intensification (SRI) for flooded fields, like Rotary weeder, Cono weeder, Mandawa weeder, etc. These not only help in removing weeds, but also in aeration, an increase in plant height, root proliferation, lower labour costs, the decomposition of organic matter, and increased productivity.

c) **Dryland weeder:** It is used for weeding in row crops to remove shallow-rooted weeds. It has been designed ergonomically for easy operation. It is useful in dryland and garden land crops and is ideal at a soil moisture content of 8 to 10%.



At the extreme end of the arm, a 120 mm diameter star wheel is fixed. A cutting blade is fitted to the arm 200mm to the back of the star wheel. The star wheel facilitates easy movement of the tool. The operating width of the blade is 120 mm. Ideal to remove shallow-rooted weeds. The workable moisture content has to be 8 to 10%.

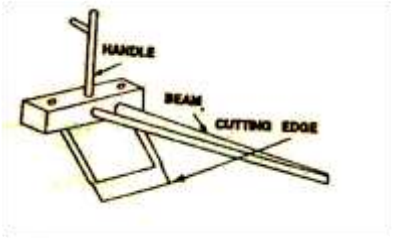
d. **Cycle weeder:** Cycle weeder or Cycle wheel hoe is used for weeding in drylands for upland crops like millets. In the front, a cycle wheel is attached with a weeder blade in the back. By moving forward and backward, the weeds are removed from the space between the crop rows.

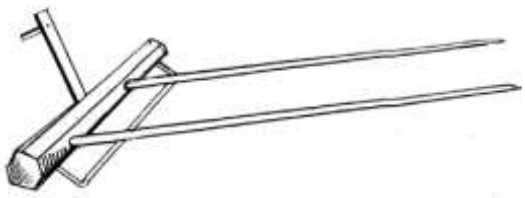
Bullock drawn weeders

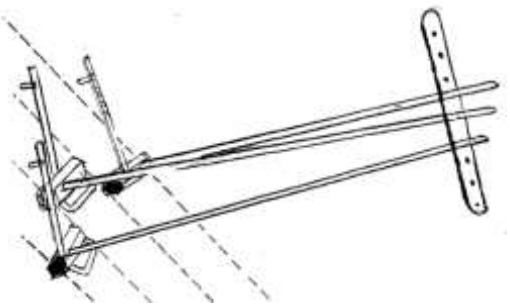
a. Harrows

i. Blade harrow:

These are different from conventional harrows. Blade harrows have no lines. Instead, there are horizontal blades that enter the soil and travel below the surface at a constant depth in the direction of the motion of the implement. These severe the surface layer from the soil below and leave it in its original position. But the separated layer is slightly disturbed. At the same time, the weeds in the fields are also cut under the surface of the soil. This eradicates all the weeds except those that have underground bulbs. The stubbles of previous crops and the weeds are left on the surface, imbedded in the soil, to serve as organic mulch.







The depth of penetration of the blade harrows into the soil is regulated by the distance between the blade and the yoke. When it is increased, the angle made by the blade with the land is increased, and the blade tends to go deep into the soil. Conversely, when the blade is nearer the

yoke, the implement takes less depth. There are some improved models of blade harrows whose depth of work is adjusted by modifying the angle of the s pole.

ii. Danties:

Danties are small size blade harrows. These are largely used for intercultivating line sown crops. The danties are 15 to 33 cm wide; these are suitable for crops with a spacing of 28 to 46 cm apart. Five or six danties are attached to a common yoke. These implements can cover about 0.4 hectares in a day of 8 hours. See the following video for an illustration of use of danties for weeding: Weeding in maize using ox

b. Bullock drawn kenny: This implement is used to create bunds in the row of standing cotton plants. In the process, the weeds between two cotton plants are removed and covered.

2. Mechanical weeding

Small scale mechanical weeders

a. Mini power weeder: This is very useful for mechanical control of weeds in crops grown in rows such as sugarcane, tapioca, cotton, tomato, and pulses whose row spacing is more than 45 cm.

Battery operated mini weeder by Toolsvilla company

Battery operated mini weeder by Agriezy

Many diesel/petrol powered and battery-powered prototypes of mini weeders are being marketed in India. Many of these models combine tilling and weeding, and some of them combine other functions as well. The width of coverage and depth of the power weeder can be adjusted based on

requirements. These mini weeders serve as one of the feasible options for farmers to manage weeds in the context of labour scarcity and rising wages.

b. **Brush cutter:** A brush cutter (also called a brush saw, clearing saw or gasoline goat) is a powered garden or agricultural tool used to trim weeds, small trees, and other foliage not accessible by a lawn mower or rotary mower. Various blades or trimmer heads can be attached to the machine for specific applications. Weeding is done by rotating a blade or wire at higher speeds parallel to the ground. It is best suitable for wider-row-spaced crops like pigeon pea, cotton, sugarcane, etc., and for orchard crops. In the recent past, electric bush cutters have also been available on the market.

Tractor drawn weeders

This helps in weeding and intercultural operations in between wider-row-spaced crops in larger plots. In the prototype shown below three number of sweep type blades are affixed to the ridger frame for accomplishing the weeding operation in between standing rows of crops. Three ridger bottom fitted behind the sweep blade, work on the loosened soil mass and aid in earthing up by forming ridges and furrows. Weeding efficiency is 61 per cent.

Another prototype, the multi-row rotary weeder, consists of a set of cutting blades, which penetrate into the soil, removing the weeds in the crop rows. The cutting blade has also been used as an inclined plane for elevating and converging the soil. The rotating blades are used to cut the weeds and pulverise the soil. Weeding efficiency is 71 per cent (http://eagri.org/eagri50/AGRO304/pdf/lec06.pdf).

3. Use of allelopathy for weed management

Several plant species produce chemical compounds that affect the germination, growth, and development of another plant species. These chemicals are termed allelochemicals and the process

allelopathy. Allelopathic crops include barley, rye, annual ryegrass, buckwheat, oats, sorghum, Sudan-sorghum hybrids, alfalfa, wheat, red clover, and sunflower. Suppression of weeds can be achieved by using rotational or companion crops with allelopathic potential, mulching or soil incorporation of plant residue(s) with allelopathic activity, and application of plant extracts. Both allelopathic influence(s) as well as physical effects of the plant cover (or residue) may influence weeds. The residue could also help conserve soil moisture, improve soil organic matter content, and reduce soil erosion. It is reported that sorghum, oat, wheat, and corn residues have an allelopathic effect on weed seed germination when they are used as mulching (Sruti and Soumik, 2018).

Examples of the application of plant extracts for weed management through allelopathy are given below:

- Foliar application of aqueous sunflower extract was found to suppress total weed dry weight by 33–53%.
- Aqueous extract (10%) of sorghum cultivars exhibited differential allelopathic effects, eliciting Purple nutsedge as a more susceptible test species than Horse purslane.
- A single spray of 5% sorghum water extract at 30 days after sowing (DAS) increased wheat yields by 14% and suppressed weed biomass by 20–40%.
- Pre-emergence application of sunflower water extract suppressed little seed canary grass density and dry weight by 50% and 65 %, respectively. Three foliar sprays of such extract as pre-emergence +25 +35 DAS suppressed the total weed biomass by 70 % in wheat fields (Cheema *al*, 2013)

4. Bioherbicides

Leaf extract of Crown flower (Calotropis) shows an inhibiting effect on seed germination, and if soil is treated with leaf extract of Calotropis before sowing, it can control weeds to an extent. Kassod tree (*Cassia siamea* (Caesalpiniaceae)) and Quick stick (*Gliricidia sepium* (Fabaceae)) have strong allelopathic potential against weeds which has been proven in studies. Few other weeds that contain natural essential oils are used for germination control. The main species in this category are Common mugwort (*Artemisia vulgaris* L. (Asteraceae)), Spear mint (*Mentha spicata* L. subsp. *spicata* (Lamiaceae)), Common basil (*Ocimum basilicum* L. (Lamiaceae)), Sage (*Salvia officinalis* L. (Lamiaceae)) and Mediterranean thyme (*Thymbra spicata* L. subsp. *spicata* (Lamiaceae)) (Sruti and Soumik 2018).

✓ **Bioherbicide preparation from** Crown flower (***Calotropis***)

Material required: Cattle urine-4 litres, Calotropis leaves – ½ kg, Salt – ½ kg, and Limestone- ½ kg

Preparation method: Mix ½ kg limestone and ½ kg sea salt in 4 litres of cattle urine. Then, with that mixture, add ½ kg chopped leaves of Calotropis. Keep the content for two days; after two days, squeeze two lemons into the solution.

Usage: For 10 litres of water, ½ to 1 litre solution is mixed to prepare the spray solution.

For more information, see the following videos:

https://www.youtube.com/watch?v=dyRFrrlZXFQ
https://www.youtube.com/watch?v=PQ5e3w-B2gg

✓ **Bioherbicide preparation from Century plant (Agave)**

Material required: 1) Cattle urine- 4 to 5 litres, 2) Agave leaves- 3-4, 3) Asafoetida- 40 to 50g and 4) Water-10 litres

Preparation: Mix chopped agave leaves with cattle urine and water; keep the solution for 48 hours; Then the solution is to be sieved and 40–50g of asafoetida is to be added.

Usage: With a 10 litres of water, ½ to 1 litre solution to be mixed to prepare the spray solution.

More details can be seen at:

https://www.youtube.com/watch?v=XwgeN7-ns3Y

✓ **Weedicide preparation from wood vinegar (Xinyou Liu *et al.*, 2021)**

Wood vinegar is the major organic compound found in wood pyrolysis liquid. Wood vinegar primarily contains water and also consists of various organic compounds, such as acids, alcohols, aldehydes, carbohydrates, esters, nitrides, ketones, and phenols, depending on the feedstock. Wood vinegar has a phytotoxic effect and could be potentially used as a naturally derived herbicide for weed control. Vinegar works as a non-selective, post-emergence, contact herbicide, causing rapid desiccation of plant tissues following application as the result of damage to cell membranes. Low concentrations of wood vinegar could effectively inhibit weed seed germination. Although wood vinegar has an inhibitory effect on germinating seeds, it may rapidly dissipate in the soil and therefore does not have residual activity for weed control. At high doses, wood vinegar can induce phytotoxicity on plants, serving as a potential herbicide. Aguirre et al. (2020a) reported that when sprayed at a high concentration of 50–100 % by weight, wood vinegar derived from the pyrolysis of tree pruning wastes effectively controlled brome foxtail (*Bromus madritensis* L.) and yellow mustard (*Sinapis alba* L.).

Wood vinegar application on Nitrophilus plant communities showed a greater than 70% decrease in biomass at 7 days after application. After 42 days, vinegar treated plots had four times less biomass than the control plots (Juan et al., 2020; Lie Chu et al., 2022; Rick Burnette, 2010).

Box 3: Wood vinegar production steps:

1. Arrange dry wood in the 200-litre drum kiln (see related article), close, and cover every hole with clay before burning. Stop feeding the fire when the smoke exiting the flue is very thick and white.
2. Approximately 30 minutes to 1 hour after having stopped feeding fuel into the kiln, if the smoke is yellowish and acrid, close off most of the outer vent.
3. Extend a hollow green bamboo pole (far end elevated to 45º) from the flue pipe. Wood vinegar can be collected with containers fastened underneath one to two holes, approximately 2 cm (3/4 in.) wide, drilled into the bamboo pole roughly 30 cm (11.8 in.) from the connection with the flue pipe.
4. If wood is burned for 12 to 15 hours (or less, depending on the type and size of wood) in a 200-litre oil drum kiln, it should produce 2 to 7 litres of raw wood vinegar. Leave the raw wood vinegar sealed in a bottle for approximately three months to allow sediments to settle.

5. Weeding with organisms

A biological control agent may be a virus, bacterium, fungi, nematode, or living insect, fish, bird, and other animal, existing naturally or released in large number for immediate effect. The natural enemies of weeds like insects, pathogens, etc, that regulate the weed's population in its homeland, may be introduced in the weed invaded territory to reduce and stabilize target plant density at sub-economic levels. A microorganism as biological control agent in general has a narrow target range and a very

specific mode of action. They have relatively critical application times and with have limited field persistence and a short shelf life, which present no residue problems. They are safer to humans and the environment than the conventional pesticide (Menaria, 2007). More details on natural enemies introduced in India to control weeds are given below.

Sl. No.	Exotic natural enemies (Order: Family) imported in India	Source country/year of introduction and weed plant	Current status/Reference
1	*Dactylopius ceylonicus* (Hemiptera: Dactylopiidae)	Brazil, 1795, prickly pear	It readily established on pear, *Opuntia vulgaris* (its natural host) in North and Central India and resulted spectacular suppression and excellent control or prickly pear.
2	*Dactylopius opuntiae* (Hemiptera: Dactylopiidae)	USA via Sri Lanka via Australia, 1926; prickly pear	Caused spectacular suppression of *Opuntia stricta* and related *O. elatior*
3	*Zygogramma bicolorata* (Coleoptera; Chrysomelidae)	From Mexico, 1983; against *Parthenium hysterophorus*	Released for control of Parthenium; established by natural spread and by concentrated efforts of Directorate of Weed Research (Jabalpur); established well in many states of India
4	*Neochetina bruchi* (Coleoptera: Curculionidae)	Argentina via USA, 1982/1983; against water hyacinth	Well distributed and established on *water hyacinth;* spread to different parts of the country; doing good control of weed along with *Neochetina eichhorniae*
5	*Neochetina eichhorniae* (Coleoptera: Curculionidae)	Argentina via USA, 1983 agaisnt water hyacinth	Well distributed and established throughout India in different water bodies. It is successful in stagnated ponds and lakes but not effective in running water like river
6	*Epinotia lantanae* (Lepidoptera: Tortricidae)	Mexico, unintentional Accidental introduction in 1919 on *Lantana*	Established on Lantana camara in several places; partially effective
7	*Lantanophaga pusillidactyla* (Lepidoptera: Pterophoridae)	Mexico, unintentional Accidental introduction, 1919 against *Lantana*	Established on Lantana but not effective
8	*Cyrtobagous salviniae* (Coleoptera: Curculionidae)	Brazil via Australia, 1982/1983; against *Salvinia molesta*	Initially released in Bengaluru; later released at Kuttanad (Kerala), well established, did excellent control
9	*Ctenopharyngodon idella* (Pisces: Cyprinidae)	China via Hong Kong & Japan, 1959/1962; against submerged aquatic weeds	Introduced to control submerged aquatic weeds such as *Vallisneria spp*. and *Hydrilla verticillata* in fishponds; established in different parts of the country; very effective
10	*Cecidochares Connexa* Diptera: Tephritidae)	South America via Indonesia, 2003 against *Chromolaena odorata*	Established at Bengaluru (Karnataka), Thrissur (Kerala); also released at Jagdalpur (Chhattisgarh); partially successful
11	*Phytomyza orobanchia* (Diptera: Agromyzidae)	Yugoslavia, 1982; against broom rape *Orobanche sp*	Recovered occasionally; Partially established

12	*Dactylopius confuses* (Hemiptera: Dactylopiidae)	South America via South Africa, 1836; against prickly pear	Introduced but not recovered on *Opuntia vulharis*

Source: Sushilkumar and Puja Ray, 2018

6. Management measures for problematic weeds

1. Parthenium (*Parthenium hysterophorus*)

Parthenium hysterophorus is commonly called carrot grass, bitter weed, star weed, white top, wild feverfew, and congress grass. The concept of ` one year seeding, seven years weeding' is true for Parthenium because it produces about 5000-10000 seeds per plant, which are viable even at the immature stage. It is a prolific seed producer, with seeds having a long storage life and can quickly disperse through the wind.

Management practices

- **Cultural management practices**

  a. Hand pulling: This practice is recommended once the weed emerges from the soil. If the area of spread is high, a serious hand pulling campaign is needed to control it.

  b. Crop rotation: In infested cultivated land, a normal crop is rotated with marigold during rains.

  c. Allelopathic effect: The weed can be suppressed by Cassia sericea. Its plant leachates have kaolines, which accumulate in the soil and interfere with the weed.

  d. Composting Parthenium: The weed reaches 50% of seed setting during flowering. The weed left as such in the same area acts as a seed bank because of its higher seed production capacity and extended dormancy period. Therefore, composting is recommended, as the seeds lose their viability due to the higher temperature during composting.

  e. Mulching: Mulching has a smothering effect on weeds by restricting photosynthesis. It also conserves moisture, lowers surface temperature, fertilizes the soil, protects it from the rainy season and improves the soil quality.

- **Biological method**

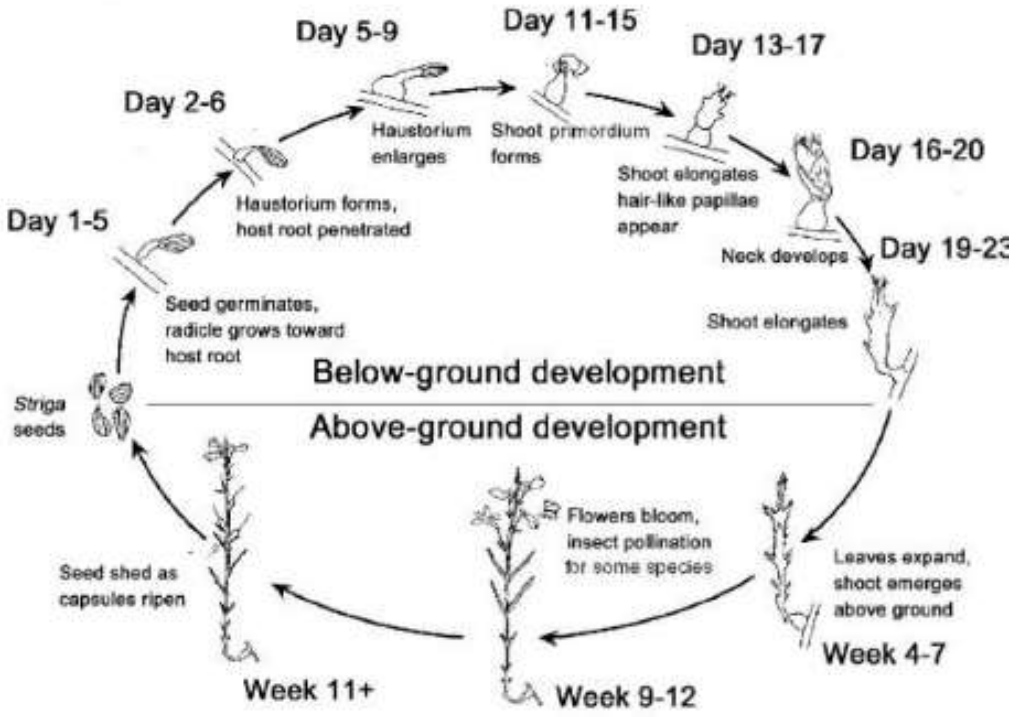
  a. *Zygogramma bicolorata*, a leaf eating beetle, was identified as a biocontrol agent that controls Parthenium weed by feeding on the foliage. Recently, the rust pathogen *Puccinnia abrupta var parthenicola* was identified, which is capable of controlling this weed.

- **Salt solution for control**

  Spraying of common cooking salt solution at 15-20% concentration before flowering will effectively control the weed. Rocksalt can also be used as mentioned below.
  For a 10 litre solution, mix 2 kg of rock salt and dissolve completely. This solution needs to be sprayed adequately over the parthenium weed in both the juvenile and adult stages of the plant. All plant parts will be destroyed within 2 days. For a one-acre area to prepare a 20% rock salt solution, 300 litres of water and 60 kg of rock salt are required. The plant will not recolonize until the salt content is present in the soil, and will regrow once it is reduced (Pazhanisamy, 2021; Rashmi and Logamoorthy, 2022).

2. *Striga* /Witch weed (*Striga asiatica*)

Striga, commonly known as Witch weed, is a genus of parasitic plants that occurs naturally in parts of Africa, Asia, and Australia. Although most species of *Striga* are not pathogens that affect agriculture, some species have devastating effects on crops. Three species cause the most damage: *Striga asiatica*, *Striga gesnerioides*, and *Striga hermonthica*. Witchweed parasitizes maize, millet, sorghum, sugarcane, rice, legumes, and a range of weedy grasses. It is capable of significantly reducing yields and in some cases, wiping out the entire crop. Host plant symptoms, such as stunting, wilting, and chlorosis, are similar to those seen from severe drought damage, nutrient deficiency, and vascular disease. The figure below describes the life cycle of *Striga* on above and below ground.



Life cycle of Striga

Management practices

- **Cultural management practices**

  a. Trap cropping and the sowing of false hosts such as coriander, cowpea, groundnut, sesame, and cotton to stimulate suicidal germination were reported to be an effective way of depleting the seed bank.

  b. Combining trap crops and nitrogen fertilisers was also reported to significantly decrease the *Striga* seed bank.

  c. Cover cropping showed *Striga* suppression directly through mulching, induction of suicidal germination, or its shading effect.

d. Intercropping of cereals with legumes or a trap crop such as *Desmodium spp*. (Push–Pull) reduced *Striga* emergence by improving soil fertility, organic matter, and soil moisture content and releasing allelochemicals, such as C-glycosylflavonoids, isoflavanones, isoschaftoside, phenolics, 3,4-dihydroxybenzoic acid, which might impact *Striga* germination, growth, or development.

- **Biological management**

a. Soil microbes like plant growth-promoting bacteria (PGPR), the employment of AM fungi, and some bacterial strains caused a considerable reduction in *Striga* germination, attachment, and emergence.

b. Myco-herbicides developed from the fungus *Fusarium oxysporum* showed *Striga* inhibition by reducing its attachment to cereals and decreasing seed bank in infested soils.

3. Bermuda grass (*Cynodon dactylon*)

Cynodon dactylon is commonly known as Bermuda grass. It is a major tropical grass found in all tropical and subtropical areas. It is highly tolerant to drought and heavy grazing and, therefore, extremely valuable for pasture. It is also used for cut-and-carry, hay, and deferred feed.

- **Utilization:** Bermuda grass has an outstanding spreading ability, the stolons being able to grow more than 7.5 cm/day.

a. **Pasture and cut-and-carry systems:** Cutting and grazing height should be about 5-10 cm in order to maintain a good stand density. To maintain quality, grazing pressure should be high with short rotations under rotational grazing or controlled with a low sward height under set-stocking management to avoid excess pre-grazing herbage mass and lowered digestibility. Cattle should be allowed to graze the upper 2/3 of the stand, as this part is much leafier and has a higher nutritive value.

b. **Hay and haylage:** Bermuda grass makes good quality hay and haylage. As a fine-stemmed leafy species, Bermuda grass cures quickly. It can be tightly packed in bales and maintain good nutritive value during storage.

Management Practices

- **Cultural management practices**

a. Raking to remove rhizomes and stolons will also help.

b. Mulch can be used in a variety of ways to manage bermudagrass. Black polyethylene applied over bermudagrass to prevent sunlight from reaching the plant can effectively control established plants.

c. Clear plastic mulching (solarization) is effective for the eradication of bermudagrass plants and seed if it is applied during periods of high solar radiation.

d. Niger and cowpea are highly competitive smother crops for perennial grasses and sedges like *Cynodon*. (Raj *et al.,* 2018)

4. **Purple nutsedge** (*Cyperus rotundus* L.)

Cyperus rotundus L., is commonly known as Purple nutsedge. It is native of India and pernicious perennial weed in 52 crops in more than 90 tropical and sub-tropical countries.

Management practices

- **Cultural management practices**

  a. Deep tillage without planking during the summer months is useful to control *Cyperus* by exposing the perennating structures- tubers, bulb, rhizomes, corms, and cormlets,- to hot sun. Once they get desiccated or dried up to a great extent, they should be raked by forked hoes/onion hoes or harrowed and collected into piles; then they are removed from the field.

  b. Line sowing and intercropping facilitate better *Cyperus* management in crop fields.

  c. A live mulch- a forage/fodder intercrop (e.g., cowpea, sorghum, maize), or a green manuring crop like Sesbania or mungbean- in between the rows of a main crop may be quite useful to manage *Cyperus*. An old saying in Tamil mentions that cultivating horsegram can help in the suppression of *Cyperus*.

  d. Niger and cowpea are highly competitive smother crops for perennial grasses and sedges (Cyperus). The effect is higher if the crop is broadcast. A competitive low-growing and easily destroyed cover crop during fallow or between crop rows can be grown to replace *Cyperus* in the crop fields.

  e. Among several crop husbandry practices adopted, wheat straw incorporation during summer resulted in maximum suppression of *Cyperus rotundus* followed by soil solarization in soybean under soybean-wheat and soybean- broccoli cropping system (Raj *et al*., 2018)

- **Biological method:**

  a. Ghorai et al. (2005) collected a pathogen from infected, C. rotundus plants from farmers' field at Kairapur, District 24 Parganas (N) and from CRIJAF main farm. The pathogen was identified as *Fusarium oxysporum* (Schlect) Snyder & Hansen. About two weeks after application of isolated fungus solution to *Cyperus*, the infection started. Initially the central leaf whorl of the sedges started yellowing, followed by wilting and they finally died. The pathogen was found to be more virulent on young seedlings emerging from tubers compared to older ones. Almost entire population were died within 40 days of inoculation.

- **Sorghum allelopathy for managing Purple nutsedge (*Cyperus rotundus* L.) and *Cynodon dactylon:***

  a. Weed growth could be suppressed by growing sorghum for two consecutive seasons because the sorghum residues present on the soil surface release different allelochemicals that suppress weed germination and development.

  b. It was also observed that sorghum root residues, incorporated with soil, suppressed the growth (dry weight) of purple nutsedge by 28 to 92% (Cheema, 1998).

  c. Matos *et al*., 2021 evaluated the bioherbicidal potential of sorghum carried out on *Cyperus rotundus* L. young seedlings with four types of sorghum extract: root extraction in alcohol, leaf extraction in alcohol, root extraction in water and leaf extraction in water, and five concentrations (0%, 20%, 40%, 80% and 100%). The results demonstrated that sorghum leaf

extract had a significant impact on *C. rotundus* by interfering in plant growth attributes. The alcohol and aqueous extract showed significant growth retardation in *C. rotundus*, while leaf had more promising effects than roots

5. **Lantana** (*Lantana camara*)

Lantana camara is a thorny multi-stem perennial shrub with an average height of 2 m (6 ft). The leaves of Lantana camara have a strong aroma. Its flowers are small, multi-coloured, stalked, and dense in flat-topped clusters, with a corolla having a narrow tube with four short spreading lobes.

- **Utilisation**

a. Lantana camara parts are being used effectively in making furniture, which is cheaper than cane and equally sturdy.

b. Lantana along with mud is used to make the walls of their houses as well as chicken coops.

c. Lantana oil is used externally for leprosy and scabies.

d. Lantana camara twigs and stems serve as useful fuel for cooking and heating in many regions of India.

e. Lantana camara, having 75.03% hollocellulose, 18.21% lignin, and 2.31% silica, can be a good potential source of raw material for papermaking.

Management practices

- **Cultural management practices**

a. Hand pulling, slashing or chopping of the stems, burning, and manual grubbing resulted in substantial removal of the root system.

b. The cut rootstock method is the new management strategy for control of lantana. It will be done by manually uprooting the weed and cutting its roots underneath the ground by an edge of 6-7 inches. It involves cutting the main tap root of the Lantana plant beneath the 'coppicing zone' (transition zone between stem base and rootstock).

- **Biological method**

a. Biological organisms that control Lantana camara include *Ophiomyia lantanae* (fruit-mining fly), *Calycomyza lantanae* (agromyzid seedfly), *Teleonemia elata* (leaf-sucking bug), and *Teleonemia scrupulosa* (leaf sucking bug); but they mostly failed as *Lantana camara* has several varieties or forms, that complicates the introduction and establishment of exotic insects.

For more information on salient experiences related to non-chemical weed management, readers can listen to the following webinar: **Weedicide-Free Farming: Science, Practices and Policies** https://www.facebook.com/AshaKisanSwaraj/videos/661253874826336/

Conclusions

As Harlan (1992) observed, "...*Weeds have been constant and intimate companions of man throughout his history and could tell us a lot more about man, where he has been, and what he has done, if only we knew more about them*...". The colonising species, disparaged as 'damned weeds', were here on earth before us, and they will be here after us. They are simply an essential part of the earth's rich biological diversity, just as much as we humans are. Wherever or whenever a natural disturbance occurs or when humans disturb a habitat, colonising plants will be among the first to make use of the opportunity of available space and resources. They will always shadow humans.

In the contest with other plants, those with colonising attributes will always win. This ecological emphasis has been downplayed in a large number of publications because the focus during the past 100 years or so has been so much on weed control due to their negative impacts on agricultural production. *Weeds are not the culprits*; *they are just a symptom of the real cause*, which is ecologically destructive land use practices by humans, including land clearing, monoculture cropping, overgrazing, and introductions of species for short-term profit. If weeds are to be better managed, land management practices must improve, and more broadly, all natural resources must be better managed. In natural systems, or man-made ecosystems, colonising plants serve valuable ecological functions, and these need wider and deeper recognition. Humans should focus their attention on exemplifying the complex biological interrelationships colonising plants have with other biota and the environment, such as providing resources for wildlife, slowing erosion, building soil, and generally enriching biological diversity through genetic exchanges. The future of humankind will surely depend on how well we manage our relationships with nature, and particularly with plants, our primary producers of food. It is a responsibility to manage weeds effectively and efficiently whilst appreciating their intrinsic worth and potential as bioresources (Chandrasena, 2014).

Most of the research on weeds has focused on addressing the drawbacks of weeds and advocating for weed control. Much extensive work was carried out in sustainable management of weeds by classical and modern approaches to weed management, whereas very little attentive work has been carried out in the field of weed importance. It is time to change the mindset of controlling weeds and to recognise the biological aspects of weeds in a way forward. Utilisation of different weeds for biodiversity, soil conservation, and other positive roles of weeds will help in sustainable agriculture.

Farmers need to learn about the weeds in their farm environment, their characteristics, their interactions with the prevailing cropping systems, and the scope for utilisation for various purposes to develop an informed context specific management plan. This may turn out to be an exciting journey of discovering the intricate relationships of humans with their immediate agroecosystems, how our elders and earlier generations understood them and capitalised on them for everyday life, and how we can creatively build on these to develop functional and context-specific ways of managing weeds after accounting for the prevailing socio-economic realities like dwindling family labour, declining collective agricultural operations, high labour costs, labour scarcity, etc. They may understand that some of the plants that are labelled as weeds are very useful and have to be welcomed as part of the cropping systems rather than eradication. As shown in Section 4, there are many effective, ecologically suitable, and time-tested ways of handling various weeds developed by farming communities and scientific establishments. Farmers can use these as their toolkit for developing a set of practices suitable for their farm and agroecosystems. They need to be supported in this journey by Civil Society Organisations and agricultural institutions. Encouragement and support are needed for widespread adoption of cropping system practices by farmers that avoids weed and ensure that weeds are not reaching damaging levels. Similarly, support is needed for the widespread adoption of simple manual bullock-drawn and small-scale machine-operated weed management tools that reduce drudgery, are cost-efficient, and accommodate crop diversity at the plot level. Further research is needed to develop such suitable technologies.

A concerted effort to educate farmers and other agriculture stakeholders on the 'living with weeds approach' and how they can practically apply the same in their area. Investment in initiatives that revalorise the plants labelled as weeds, like recipe contests on uncultivated greens, workshops on the preparation and use of ethno-veterinary medicines in the villages, etc., are needed. More research is needed on useful attributes of weeds, including nutritional analysis, crop-seed associations, nitrogen fixing ability, etc.

Chichory- a small weed with lavender coloured flower

Resources

The readers can refer to the following references for further learning on plants labelled as weeds:

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Equipment for Weeding and Inter-cultivation Suitable for Manipur Condition, KRISHI VIGYAN KENDRA, IMPHAL WEST, ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat, Manipur – 795004. E-mail: kvkimphalwest@gmail.com.

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